Stages in the development of an animal drawn zero tillage seeder for small grains [1]

P C Wall [2], L Zambrana [3], P Gamez [3], B Sims [4], R. San Martin [5], C. Calle [6] and J. Rodríguez [7]

Summary

Multiple row seeders adequate for direct (zero tillage) seeding of small grain cereals using animal traction have not been commercially available in South America. Given the probable benefits to small farmers (3-4 ha of land) in the inter-Andean valleys of Bolivia from the use of zero tillage, an inter-institutional project was initiated to design, construct and test seeders for these conditions. A three-row seeder has been produced that has undergone several cycles of participatory evaluation and modification. The seeder gives higher plant stands, results in considerable savings in time compared to the traditional system of seeding into tilled land, and has a lower draught requirement than the traditional wooden plough. Farmer interest is high, mainly because of the time saving the use of the seeder represents, and the first commercial models have now been produced and sold. Small farmers (owning up to 50 ha of land) in the Bolivian lowlands are also interested in the seeders given their problems in obtaining seeding services on time. This paper describes the evolution of the seeder from the initial model to the present one.

Introduction

The small-holder farmers of the inter-Andean valleys of Bolivia possess, on average, 3-4 ha of land, use animal traction for land preparation and manage mixed crop-livestock systems. Wheat is a major crop, especially in the drier and more degraded areas. Farmer surveys have shown that the major limitations to wheat productivity are moisture stress, soil erosion and degradation (Wall *et al*., 1995).

Land preparation generally consists of ploughing twice, the second pass at 90^{o} to the first, using two oxen and a wooden (ard type) plough. Where wheat is to be seeded, the seed is broadcast on the surface and incorporated with another pass of the wooden plough. This process is costly and time-consuming, taking in total 12 days per hectare, and forcing the farmer and the oxen to walk 100 km for each hectare prepared and seeded. The intensive land preparation also results in organic matter decomposition and soil structural breakdown, and leaves the land exposed to rain and wind, resulting in widespread land degradation.

In the Bolivian lowlands land has been distributed to colonizers from the highlands. These farmers own up to 50 ha, and typically crop between 10 and 40 ha of these. The interrelated problems of moisture stress and soil degradation are the most important limitations to crop production in the lowlands. Although water erosion is not a serious problem on the plains, wind erosion is important due to the high wind intensity. The small farmers of the lowlands typically use tractor power, prepare the land with disc implements and use mechanical seeders, often contracting service providers for these activities.

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[1] Poster paper presented at the International Workshop on "Modernizing Agriculture: Visions and Technologies for Animal Traction and Conservation Agriculture". Jinja, Uganda. May 19-25, 2002.

[2] Natural Resources Group, CIMMYT, Apdo. Postal 6-641, 06600, Mexico, DF, Mexico. P.Wall@cgiar.org
[3] PROMETA/CIFEMA, Casilla 831, Cochabamba, Bolivia. cifema@pino.cbb.entelnet.bo
[4] Silsoe Research Institute, Wrest Park, Silsoe, Bedford, MK45 4HS, UK. brian.sims@bbsrc.ac.uk
[5] PROTRIGO, Casilla 3299, Cochabamba, Bolivia. protrigo@supernet.com.bo
[6] PROTRIGO, Casilla 971, Sucre, Bolivia. protrigs@mara.scr.entelnet.bo
[7] ANAPO, Casilla 2305, Santa Cruz, Bolivia. anapo@cotas.com.bo

Zero tillage is successful in increasing moisture use efficiency, reducing soil erosion and reverting soil degradation in the mechanised agriculture of the plains of the Southern Cone of South America (Derpsch, 1999). Over the past ten years zero tillage agriculture has expanded rapidly in the Bolivian lowlands, primarily on large farms, and occupied approximately 50% of the area of annual crops in 2001 (ANAPO, personal communication). Consequently, the Bolivian national wheat programme (PROTRIGO), together with CIMMYT, has been working on adapting this form of conservation agriculture to the conditions of the small farmers of both the (inter-Andean) valleys and the (lowland) plains.

System limitations to the adoption of zero tillage in the valleys were identified as a) lack of adequate zero tillage seeders adapted to animal traction on the local market; b) farmer's use of crop residues for animal feed; and c) hand harvesting of cereals, and threshing outside the field, resulting in all crop residues being removed from the field. This paper describes the work conducted to overcome the first of these limitations, and the spill-over effect of this work in the lowlands, where the major limitation to the adoption of zero tillage on small farms is the large size and cost of adequate machinery on the local market.

In initial trials, single row animal drawn direct seeders from Brazil were used, but these machines, although they resulted in good crop establishment without tillage, were principally designed for seeding maize and beans, and proved cumbersome and slow for seeding small-grain cereals. Multi-row seeders for seeding small-grains using animal traction were not available in South America.

In 1998, the PROMETA/CIFEMA project, CIMMYT and, PROTRIGO, embarked on a project to develop a 3-row small grain seeder for seeding small-grain cereals without previous tillage using animal traction. The first prototype was developed in the 1998/1999 season and tried in farmers' fields in the 1999/2000 crop season. Since the first prototype, two cycles of participatory evaluation and modification have resulted in the latest model that is currently being produced commercially and being evaluated by field technicians and farmers.

Objectives

The objectives of the project were to design, construct and evaluate a small-grain seeder for animal traction that could seed in untilled conditions with up to 4 t/ha of dry crop residues on the surface.

Given that the seeder is designed for use by small farmers with scarce resources, the project aimed to produce a seeder that is:

- As light as possible to facilitate transport and reduce draught requirements.
- Easy for the farmer to manage alone when seeding behind a pair of oxen.
- Moderately priced to enable adoption and rapid diffusion.
- Easy to maintain and repair.

Seeder Design

The First Model

The seeder was constructed using three separate seed boxes, one for each row. Seed was distributed and metered by vertical rotors with peripheral seed cells, whose depth could be altered for different seed sizes and sowing rates by adjusting an internal screw. The seeding mechanism was mounted on a metal frame supported on two wheels. The frame could be raised or lowered with respect to the wheels to allow two positions: one for transport with the seed-furrow openers above the wheels, and one for seeding with the openers below the wheels. An adjustable stop limiting the height to which the ground wheels could be raised, enabled seeding depth adjustment. The seeding mechanism was driven from one of the ground wheels, using a 1:1 ratio. Fore and aft levelling of the seeder was achieved by adjusting the angle of attachment of the draw-pole using two U-bolts.

In order to reduce the weight of the machine, chisel openers were used, as opposed to disc openers that would require more weight (vertical force) for penetration. Freely rotating metal wheels with exterior spokes (straw wheels) were attached alongside each chisel to hold the straw and reduce its' accumulation on the chisel. Trials using the machine with sharp-crested or slightly convex chisels, with or without the straw-wheels, and with or without press-wheels behind the chisels, showed that the highest plant populations were achieved with the crested chisels, together with both the straw wheels and press wheels (Callisaya, 1999). However, as only the convex chisel points were readily available on the local market, these were finally used on production models.

Between-row spacing on the seeder can be adjusted from 20 to 35 cm. Experience has shown that under zero tillage conditions, the 20 cm row spacing is best, even though this makes seeding slower as less area is covered with one pass of the drill.

The draught force required by the seeder is only 450 $\pm$ 6 Newtons (N) compared to 760 $\pm$ 20 N required by a traditional wooden plough under the same conditions. Wheel slippage, measured under zero tillage conditions with straw ground cover was only 1% (Callisaya, 1999).

Despite the positive results of initial tests, participatory evaluations with farmers and technicians in farmers' fields showed several shortcomings of the seeder. The principal problem was the accumulation of straw on the chisels and the inadequacy of the straw wheels to control this. The straw wheels also tended to make a lot of noise, frightening the draught animals. Other problems encountered were the difficulty of maintaining wheel contact with the ground in uneven surface conditions, resulting in stoppage of the seed metering mechanism and unseeded areas, and some minor structural problems.

The Second Model

In order to overcome the problems encountered with the first prototype, the straw wheels were removed and replaced with discs in front of each chisel opener to cut the straw. The centre disc, which is fluted for reduced slippage, drives the seed-metering mechanism. The outer cutting discs are plain. Thus the wheels are used only for transport and depth control, overcoming the problem of unseeded areas when stones or harder soil raise the machine slightly.

Ten machines with vertical seed rotors were tested with farmers in the 2000/2001 summer cropping season in the inter-Andean valleys of Bolivia. In trials and demonstration plots seeded with the animal drawn seeder, average stands were 246 $\pm$ 37 plants/m^2, whereas in the check plots using the normal farmers' technology, the average stand was 166 $\pm$ 39 plants/ m^2. This latter value is representative of farmer's fields: a monitoring study of 73 farmers' fields in the drier 1999/2000 season showed an average plant stand in farmers fields to be 136 $\pm$ 41 plants/m^2 (PROTRIGO, 2002).

Farmer evaluation, however, concentrated more on the savings in time for land preparation and seeding that the seeder permitted, rather than plant stand. Using the seeder with 20 cm between rows without any prior tillage results in the farmer and oxen walking 17 km to seed one hectare, compared to the normal 100 km with the traditional land preparation and seeding method. Furthermore a hectare can be sown in 10 hours (two working days for a team of oxen) compared with 12 days for conventional sowing. This saving in time and effort, and the possibility of using the oxen to seed a greater area in the season, has provoked widespread farmer interest.

The problems found with this model included some structural problems, associated especially with the leg supports. Due to the torque involved in turning, these twisted slightly, impeding the raising and lowering of the machine. Farmers also found the machine difficult to turn at field ends: oxen do not describe a half-circle when turning but rather shuffle sideways. On turning, the draw-pole of the seeder pressed against the leg of the inside animal, causing it severe discomfort. Also, farmers required more versatility in terms of crops that could be seeded than the machine with the vertical rotors allowed. These were also difficult to change, limiting the acceptability of the seeder. The addition of the cutting discs greatly improved straw handling ability, but due to the additional weight requirement for their penetration, extra weight (generally large stones) needed to be added to the seeder in harder soils or drier conditions. Finally the seed delivery tube on the centre chisel, set back from the others to improve straw handling, was at too low an angle to allow free seed flow.

The Present Seeder

The major modifications on this model were an increase in the general robustness and mechanical simplicity of the seeder. The leg supports have been strengthened, and the problems associated with seed delivery to the centre chisel resolved. The major design difference is the replacement of the vertical rotor seed distributors with a horizontally rotating seed-plate system which is slightly more expensive, but far more versatile with respect to seeding different amounts and types of seed.

A horizontally articulated draw-bar connector eases turning at field ends, and overcomes discomfort to the draught animals, and a frame has been added above the cutting discs to permit the easy addition of weights to the front of the machine.

Fifteen of these seeders have been produced and distributed to extension agents working with farmer groups. Initial results have been excellent, but further testing of the drill is required.

As yet there have been few purchases of the seeder. We postulate that although this is influenced by the price of the machine ($US 330 for a production model of the vertical seed-rotor model and US$ 350 for the horizontal seed plate model), the major factor is farmer risk aversion, and that further demonstration over several seasons will result in widespread farmer adoption.

Use in Conventionally Tilled Situations

Although the seeder was designed originally for direct seeding, it may also be used under tilled conditions. For this application the outer (plain) cutting discs are removed and the central fluted disc is replaced with a strake-wheel to gain sufficient traction to drive the seeding mechanism. Wings may be attached to the chisels to form ridges, with seed deposited at the base of the furrow between them. This configuration offers advantages for water accumulation in tilled soils, but suffers from excessive seedling depth if heavy rains destroy the ridges before crop emergence. The best row and ridge spacing when the wings are attached is 30cm. Under optimal conditions this is not a limitation to crop yield, but in poor soils where crop growth and development is not enough to cover the inter-row area, the wider spacing is detrimental to yield.

Lowlands

In the lowlands farmers have also shown interest in using this equipment. This was surprising as currently they use only tractor power. However these small farmers say their interest is due to restricted credit availability for machinery purchase, the relatively large size of equipment available on the local market (the smallest tractor readily available is a 80hp (60 kW) model, and the smallest no-till seeder is 3m wide), and the difficulty they encounter in obtaining service equipment during the optimum seeding dates. With a total outlay of approximately US$ 1000, a farmer may purchase a horse or a team of oxen, a seeder and a sprayer, enabling him to seed about 10 ha during the optimum crop seeding periods.

The Oilseed and Wheat Producers Association (ANAPO), together with CIMMYT, has conducted several field days and demonstrations using the animal-drawn seeders described in this paper. Currently some farmers are purchasing and training draught animals, and it is expected that seeder purchases will follow. However, given their greater field size than their counterparts in the valleys, farmers in the lowlands are interested in larger seeders with the capacity to seed five rows of wheat, three rows of soyabeans or two rows of maize. Although this will increase the cost and weight of the seeder, the traction force required should still be within the working range of the draught animals.

Acknowledgement

This publication results from research projects funded by the European Union Food Security Support Project (PASA) in Bolivia, the United States Agency for International Development Bolivia (USAID) PL-480 Title III Program in Bolivia, and the United Kingdom Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of these donors.

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Figure 1. Conformation of the seeder for direct seeding using the horizontal plate seed metering system, and equipped with the articulated draw-pole connector.