Supplementary Material

1. Test-bench Setups

1.1. Fixed-frame test bench with conveyer belt

The test bench has a motor which allows moving a conveyer belt at variable speeds, independently a second axle that is used to drive any implement mounted on a fixed frame. In Figure 1 a schematic of the test bench is shown and a picture of the bench in action. The equipment is built specifically to evaluation different metering systems and enables spatial analysis of the distribution patterns.

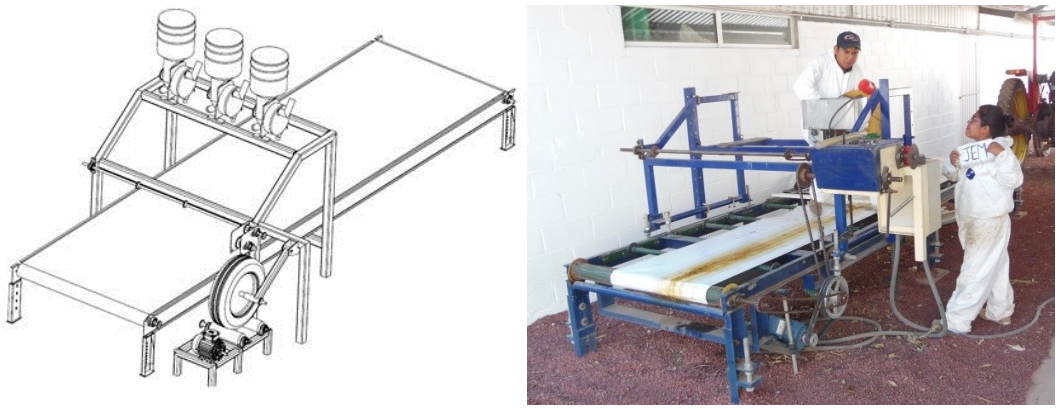

Figure 1. Schematic representation of the fixed-frame test-bench (left) and the test bench in action during the seed meter evaluations (right)

1.2. Inclination and vibration test-bench

A second experimental set up was used for the final part of the seed meter evaluation, available at the facilities of CENEMA-INIFAP (Centro Nacional de Estandarización de Maquinaria Agrícola). This test bench is built to comply with the Mexican norm NMX-O-168-SCFI-2009 for the testing of agricultural machinery, mechanical and pneumatic seeders in particular (Figure 2). This setup allows entire machine frame to be attached to a driving axle with redactor engine and the bridge structure can simulate working on sloped land by lifting the while frame up from one side. Additionally, it is equipped with a shell-shaped cam shaft that allows evaluating the effect of added vibration on the entire machine (Figure 3).

Figure 2. Bridge set up at CENEMA with steps for adding an angle to the structure (left) and a set of 3 seed meters mounted on a fixed frame during the trails with 1) the supporting bridge, 2) the mounted frame, 3) the vibration cam shaft and 4) the chain transmission (right)

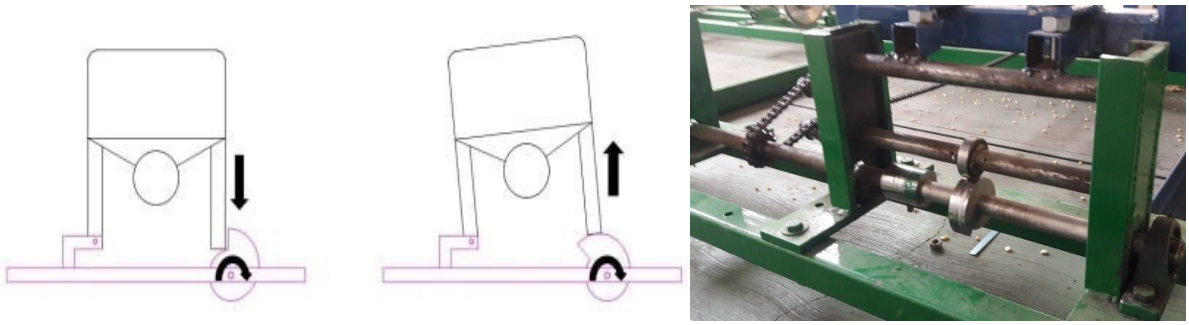

Figure 3. Schematic of the vibration generation mechanism of the test-bench (left) and detailed view of the shell-shaped cam shaft (right)

2. Description of various types of seed meters used in the experiment

2.1. National Agro Industries Inclined Plate

This seed meter is manufactured by National Agro Industries, an Indian agricultural equipment manufacturer located in Ludhiana, Punjab, and is usually produced as a modular nit mounted on a frame, holding a different number of units depending on the machine size1. The seed meter (Figure 4) is one with a metering plate that operates at an adjustable inclination angle. The plate itself has 24 seed cells and its diameter spans 170 mm. The seed bin or container has a volume of 3.8 l and presents a divider that controls the seed flow towards the plate. Above, the seed plate is topped with a brush that serves as a seed ejector when these reach the cavity leading to the seeding tube.

[1] The manufacturer offer a variety of agricultural equipment – using the same metering setup on different seeders

Both plate and spinning base are made in plastic, the individual seed containers are made of steel sheet with the following dimensions: 0.7 m length, 0.35 m width and 0.26 m height. The width is measured at the position of the divider plate.

Figure 4. The National Agro Industries inclined plate seed meter - A) a modular setup of 3 inclined plate seed meter units, B) 24-cell seed plate

2.2. BARI 24-cell Inclined Plate

Similar to the previous one, this seed meter consists of an inclined plate with 24 seed cells and 170 mm diameter but is fabricated in aluminum. The seed meter finds its original in the Bangladeshi Agricultural Research Institute (BARI - www.bari.gov.bd) and is the standard option for their two-wheel tractor zero-till drill seeder (Hossen et al., 2013). Here, two seed meter units are mounted on a single frame (Figure 5). The seed container is equally built out of steel sheet, with a capacity of 4.5 l and with overall dimensions of 0.5 m x 0.33m x 0.22 m in length, width and height respectively. Also, here a central divider is present, only here with a central gate that allows adjusting the size of the opening that feeds seed to the actual metering plate.

Figure 5. The BARI 24-cell inclined plate seed meter - A) Seed meter unit with container and central divider gate, B) aluminum 24-cell seed plate

2.3. Sembradoras TIMS Inclined Plate

The Mexican version of the common inclined plate seed meter unit comes as a single unit made up of 3 semi-individual seed meter modules (Figure 6). The plate has again 24 seed cell and a diameter of 170 mm. The capacity of one single seed section is around 9.5 l and the setup with 3 meter unties measures 0.95 m x 0.27 m x 0.22 m for length, width and height respectively. The seed plate is made out of aluminum and the seed container is built out of stainless steel.

Figure 6. Sembradoras TIMS inclined plate seed meter - A) Single seed unit with 3 seed sections, B) aluminum 24-cell seed plate

2.4. BARI 9-cell Inclined Plate

Another Bangladeshi inclined plate seed meter system, but a smaller rendition - the aluminum plate holds only 9 seed cavities and plate diameter is restricted to 115 mm. The standard frame holds two identical seed meter units with the containers made out of steel sheets. Each container has a volume of 3.5 l, with a length of 0.45 m and 0.21 m and 0.20 m width and height respectively (Figure 7).

Figure 7. The BARI -9-cell inclined plate seed meter - A) Frame with two seed meter units, B) aluminum seed plate

2.5. VMP-12 Vertical Plate

This seed meter system uses a vertical metering plate with 12 seed cells in the shape of small buckets or spoon-like holes to transport the seed from the lower part in the seed container towards the opening leading to the seeding tube. The plate has is a plastic rendition with a diameter of 125 mm. As all presented Bangladeshi-style seed meter modules, two seed containers are combined on one fixed frame (Figure 8). This particular version can also be used for metering smaller grains, with a fluted roller system at the bottom of each seed container. The container capacity is quite large with a volume of 14 l (i.e. 7 l per section); the full frame dimensions are 0.7 m x 0.35 m x 0.3 m for length, width and height respectively.

Figure 8. VMP-12 vertical plate seed meter – A) Frame with two seed meter units, B) Plastic bucket or spoon-like vertical plate

2.6. Finger Vertical Plate (SRK)

This vertical plate seed meter system holds a plate of 150 mm diameter and as before 12 seed cavities. The metering system is of Chinese origin and the aluminum plate resembles a shuriken like star with tiny fingers that lift up the seed from the seed container. Further, the seed unit consists of a transplant plastic seed bin with a 9 l volume. The full unit dimensions are 0.28 m * 0.21 m * 0.5 m in length, width and height respectively (Figure 9). The unit features an additional mechanism that allows adjusting the position of the opening towards the seed tube where the seed drop, as shown in Figure 10, and has a built-in individual gear box that enables adjustment of rotation speed of each seed plate separately.

Figure 9. Finger vertical plate seed meter system - A) Seed unit with seed container and seed meter system, B) aluminum vertical seed plate

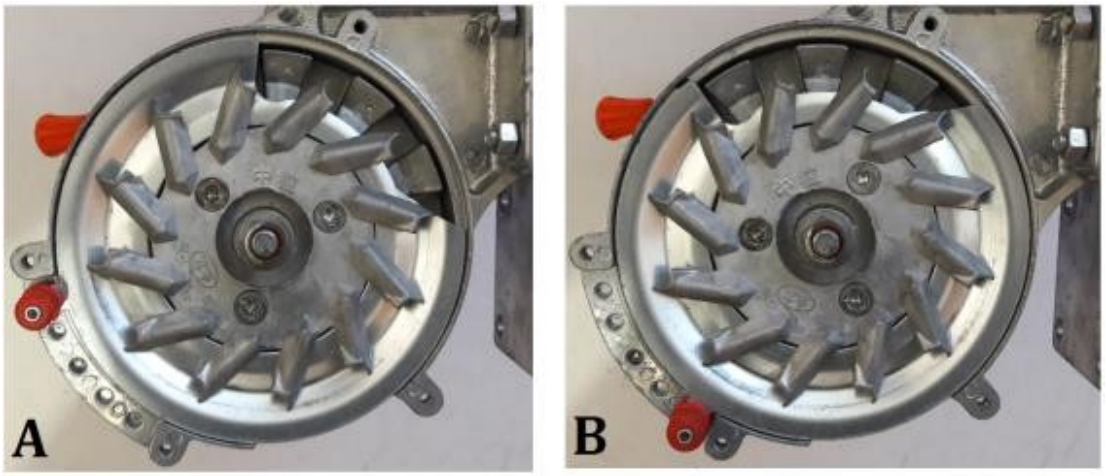

Figure 10. Close up of seed drop position adjustment mechanism of the finger Vertical seed meter system - A) Position 1, B) Position 2

2.7. Sembradoras del Bajio Horizontal Plate

Mexican agricultural machine manufacturer Sembradoras del Bajío (SDB) uses a horizontal plate metering system in their mechanical seeders. The seed meter unit drags the seed horizontally with the plate into an iron cast ejection chamber which pushes the seed out into the seeding tube opening (Figure 11). The metering unit comes with a variety of plastic seed plates for different sizes and

shapes. The plate diameter is 175 mm and the large seed container holds up to 16 l of volume. The complete seed meter unit has a height of 0.35 m and has an overall diameter of 0.26 m.

Figure 11. Sembradoras del Bajio horizontal Plate Seed meter system - A) Seed container, B) Horizontal plate and ejection chamber

2.8. Fitarelli Horizontal Plate

The Fitarelli seed meter system is another plastic horizontal plate meter, but from Brazilian make. Once more a series of different plates are offered to adjust for seed sizes and shape. The seed container capacity is of 10 l and has a height and diameter of 0.3 m and 0.26m respectively. The unit also presents an ejection chamber, but made in plastic making it a very light compared to the other meters.

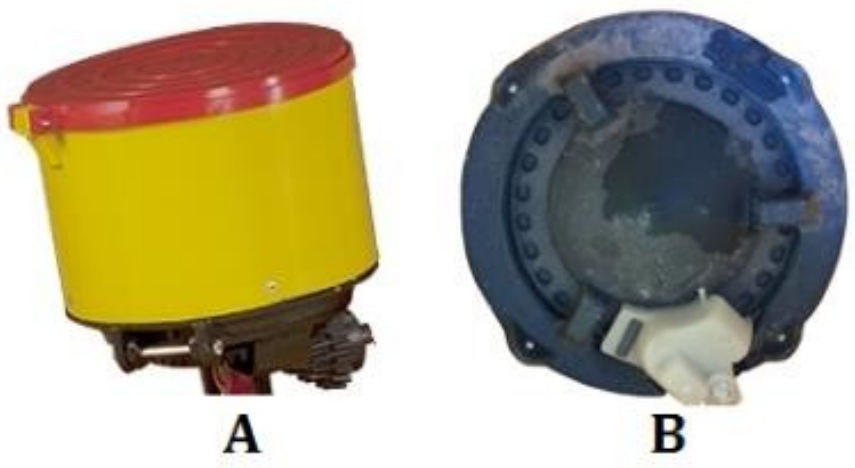

Figure 12. Fitarelli horizontal plate seed meter system - A) Seed Container, B) Horizontal seed plate and ejection chamber

2.9. 2BGF Sliding Fluted Roller

This Chinese seed meter consists of a fluted roller able to work with two different flute sizes by sliding in a left position for bigger seeds or right position for smaller seeds (Figure 13). The seed container is built out of stainless steel in 2 sections; one that allows seeding while the other is used for fertilizer application. Each hold a volume of 6 l and together measure 0.22m * 0.16 m *0.3 m in length, width and height respectively.

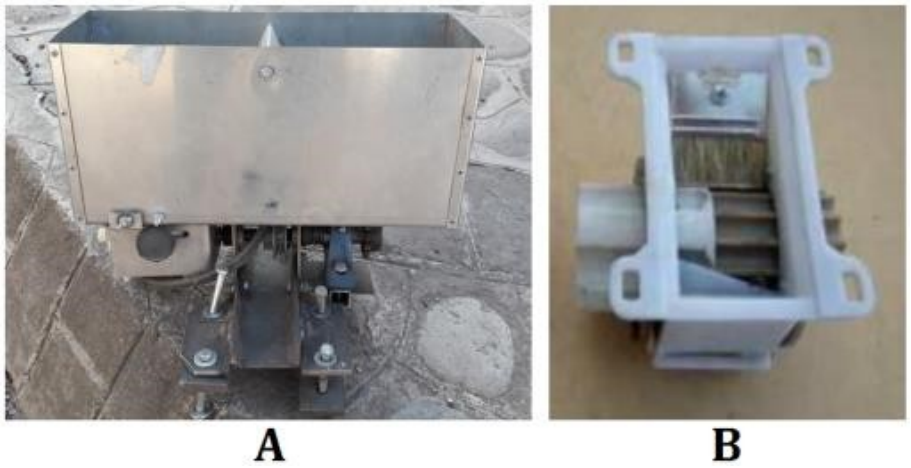

Figure 13. 2BGF sliding fluted roller seed meter system - A) Split seed and fertilizer container, B) Two-size fluted roller

2.10. Terradonis Celled Roller

Similar to the previous system, this seed meter of French origin also works with a roller system (Figure 14). However, in this case, a roller with fixed cells controls the seed selecting process. Separate roller with distinct seed cell sizes can be placed. The seed unit is almost completely made out of transparent plastic, making it easy to observe what is going on while operating. The seed container has a capacity of 11 l and measures 0.175 m * 0.15 m * 0.05 m in length, width and height respectively.

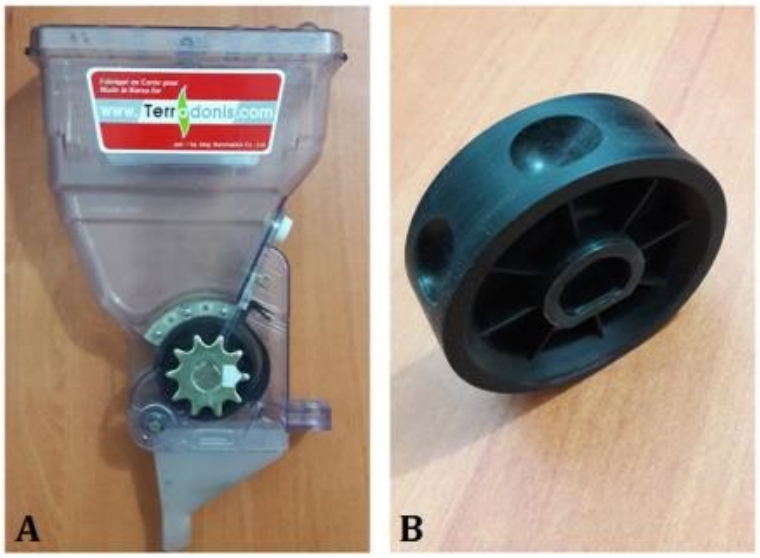

Figure 14. The Terradonis celled roller seed meter system - A) The complete seed meter unit, B) on of the provided celled rollers