Seed and Fertilizer Separation under Till-Planting System

By

M.T. Afify   R.L. Kushwaha   W.G. Milne

Agricultural & Bioresource Engineering Department
University of Saskatchewan
57 Campus Drive, Saskatoon, SK S7N 5A9

Z. A. El-Haddad   M.Y. El-Ansary

Department of Agricultural Engineering
College of Agriculture at Moshtohor
Zagazig University (Benha Branch)
Egypt

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Abstract

Three prototypes of till-planting unit were developed with which tilling strips, application of fertilizer with separation below the seed, and seeding was accomplished simultaneously. Therefore, the number of field operations required was decreased. The separation between seed and fertilizer was determined for till-planting units in an indoor soil bin facility at three speeds, three depths, three levels of soil compaction, and three levels of soil moisture content. Field tests were also conducted at three speeds and three depths. Results of the soil bin tests indicated that the most favorable condition in terms of high vertical separation between seed and fertilizer occurred with unit two at medium level of soil moisture, low level of soil compaction, 100 mm depth, 3-5 km/h speed of operation. However, in the field tests, the best results were obtained at 125 mm depth and at 3 km/h speed with unit two.

Introduction

Several advantages could be achieved with placing fertilizer below the seed. These advantages were: i) possible delay of fertilizer reaction with the soil due to the diminished fertilizer-soil contact. ii) deeper placement of nutrients into soil where moisture is less limiting to uptake. iii) forced plant uptake of nitrogen causing a more acid conditions at the root surface (Murphy, 1983). One of the potential features of any furrow opener's performance is its ability to deposit seed at proper depth and perhaps apply the fertilizer with separation from the seed. Although, the manufactures of planting machines have contributed numerous designs of no-tillage furrow openers, there are few of these openers which provide effective seed and fertilizer separation by distance or directions. Also, the major considerations for fertilizer placement away from the seed include possible toxicity of the fertilizer to the seed and seedlings, and increased yield responses of the growing plants to the placed fertilizer (Baker et al., 1996). Since dry soil tended to result in more fertilizer damage to seed than when the soil was moist, it is beneficial to place fertilizer with separation from the seed under dry conditions (Collis-George and Lloyd, 1979).

In till-planting system, little research has been done to investigate the position of fertilizer relative to the seed (Wittmus et al., 1971; Peterson et al., 1978; Hyde et al., 1979; and Parsons et al., 1982). Results of these studies indicated that vertical separation of seed and fertilizer is required and the separation between them should be at least 50 mm. Therefore, the overall objectives of this study were:

- To develop design criteria for a single-unit till-planting system for use in dryland row crop production under Egyptian conditions.
- To evaluate the effect of design parameters of three till-planting units in relation to seed and fertilizer separation.
- To compare the ability of three till-planting units to add the fertilizer with separation from the seed under soil bin and field conditions.

Literature Review

Results of several studies in no-tillage systems indicated some advantages to placing fertilizer with separation from the seed. Payton et al. (1985) stated there was evidence of better competition of the crop against weeds with the fertilizer placed below the seed. They also added that fertilizer placed below the seed was advantageous for winter wheat planted on barley residue. Spring wheat plots, with fertilizer placed below the seed, showed a visible decrease in wild oat populations. Baker and Afzal (1986) studied the effect of fertilizer placement and soil moisture status on germination by using a cross-slot opener. They found that vertical separation and fertilizer mixed with seed both caused germination and seedling damage when soil became dry, but was equivalent to other treatments in the moist soil. Hyde et al. (1987) reported attempts to separate seed and fertilizer vertically with the same opener by modifying a hoe opener such that it deflected soil back over the fertilizer before the seed was placed. They added that the deflecting action was dependent on forward speed and soil moisture conditions. Kaspar et al. (1991) found that fertilizer placement altered root distribution, but did not effect in the total root length and weight produced by corn plants. Subsurface placement of fertilizer may be preferable to surface broadcasting because root proliferation near subsurface fertilizer would be less susceptible to soil drying than roots near the surface. Walker (1983) stated that the optimum location for fertilizer placement with corn is not necessarily the optimum for wheat and barley. He added that soil type, soil moisture available at planting, the fertilizer formulation, and salt index are the primary factors determining how much fertilizer can be safely banded with the seed at planting. No-tillage wheat yields from horizontal fertilizer separation with a cross-slot opener and vertical separation with modified a hoe opener showed that there is no difference in yield between two different fertilizer separations (Saxton and Baker, 1990). However, in the same conditions, the cross slot opener resulted in 13% increase in wheat yield compared to double disc opener. Harapiak (1984) found that placement of the fertilizer below the seed (nitrogen, phosphate, and sulfur) is advantageous over other application techniques.

Materials & Methods

Till-planting units

Three prototypes of a single till-planting unit system were designed and assembled using standard parts.

Unit one: This unit consisted of the following parts: i) Two smooth rolling coulters, 460 mm diameter, (Fig.1.) were assembled at 150 mm spacing and steered in the direction of travel. ii) A twisted double point 100 mm wide shovel share (Fig.2a.) was mounted on a heavy-duty tillage shank. A granular fertilizer tube was fabricated and mounted to the shovel point to add fertilizer at the bottom of the shovel point (Fig. 2d.). iii) A packer wheel with flat blades (Fig. 3a.) was connected at the mid-point of the shovel point and was located 150 mm behind. The wheel was 200 mm wide, 280 mm diameter with 15 flat blades (25 by 100 mm) extending from the circumference of packer wheel in six rows (Fig. 3c.). iv) A double disk furrow opener with closing system was used to place and cover the seed and also pack the furrow (Fig. 4a.).

Unit two: This unit was similar to unit one except for the following differences:

- In place of twisted shovel, a 100 mm wide sweep (Fig. 2b.) was used.
- A packer wheel with round blades was used instead of a packer wheel with flat blades. The round blade was a 25 mm in diameter and 100 mm length (Fig. 3b.).
- A Barton angle disk opener with closing system was used instead of a double disc opener (Fig. 4b.).

Unit three: This unit was similar to unit two except for the following differences:

- Instead of double rolling coulters, a single rolling coulter was used.
- In place of a sweep, a 100 mm wide wing share (Fig. 2c.) was used.
- A packer wheel without blades was used instead of a packer wheel with round blades.
- A hoe opener with closing system was used instead of a Barton angle disk opener (Fig. 4c.).

Soil bin experimental procedure

Tests were conducted in an indoor soil bin facility of the Department of Agricultural and Bioresource Engineering, University of Saskatchewan. The three till-planting units were tested with the following parameters:

- Three speeds of operation (3, 5, and 8 km/h)
- Three depths of operation (50, 75, and 100 mm)
- Three levels of soil moisture content (10, 15, and 20%)
- Three levels of soil compaction (low, medium, and high)

Soil in the bin is composed of 47% sand, 24% silt, and 29% clay. The bin is 1.75 m wide, and 12.2 m long with 0.3 m depth. Tools tested were supported on a movable carriage.

Travel speed of the tool was controlled with a variable speed drive electric motor connected to the soil bin carriage. A pneumatic delivery system with a variable transformer placed on the carriage was used to meter seed and fertilizer. The soil was prepared by using the soil processing units. The soil was first rototilled and gradually brought to the desired moisture content by spraying water. Then, the soil was leveled and packed. A sheep-foot packer was used to pack subsoil followed by a smooth roller to pack the surface soil. Different compaction levels were obtained by varying the number of compacting passes. Immediately, after each run was performed, the depth of seed and fertilizer were determined by taking three readings from each row along the soil bin, then the vertical separation between seed and fertilizer was calculated. The seeding depth was adjusted to 30, 40, and 50 mm for 50, 75, and 100 mm operating depth respectively. Fertilizer was placed at the bottom of the furrow. Therefore, the expected separation between seed and fertilizer would have been 20, 35, and 50 mm for 50, 75, and 100 mm operating depth respectively.

Field experimental procedure

A field experiment was carried out with three till-planting units at three speeds and three depths with three crops. The speeds were 3, 5, and 8 km/h. The depths were 75, 100, and 125 mm. The field soil was a clay soil, having 45% clay, 30.7% silt, and 24.3% sand. The land is located at the University Farm, Arable Acreage Animal Science Central, Saskatoon, SK. The experimental area was previously cultivated for a canola crop with a limited amount of crop residue. A split-split-plot experimental design with three replicates was used. An area of about 1.1-hectare was divided into 243 plots. Therefore the area of each plot becomes 45 m^2 with 30 m length and 1.5 m width. All till-planting units were calibrated to add the fertilizer (16N-20P-15S) at the rate of 55 kg/ha. Depth of the seed and fertilizer were measured three times for each plot, then the vertical separation between seed and fertilizer was calculated. Fertilizer was placed at the bottom of the furrow and the seeding depth was adjusted to 40, 50, and 60 mm for 75, 100, and 125 mm operating depth respectively. Therefore, the expected separation between seed and fertilizer would have been 35, 50, and 65 mm for 75, 100, and 125 mm operating depths respectively.

Results & Discussion

Soil bin experiment

Initial soil compaction

Figure 5 presents the distribution of soil compaction level from 50 to 150 mm depth for the soil bin before till-planting units tests. The value for each depth is the average of 143 measurements. There were steady increases in soil compaction with depth at different levels of soil moisture content. As expected, the highest values of soil compaction were obtained at a low level of soil moisture content. When the soil moisture content increased from 10 to 20%, the soil compaction decreased by 58 %, 17%, and 14% at 50, 100 and 150 mm depths respectively.

A statistical relation between cone index and depth of penetration was derived at three levels of soil moisture content as follow:

$$CI = a_0 + a_1 d$$

Where:

CI = cone index, (kPa),

d = depth of penetration, (mm) and
a_0 and a_1 = constants, depends on soil moisture content**.**

Effect of the speed of operation

Figure 6 shows the vertical separation between seed and fertilizer with the speed of operation at various levels of soil compaction and at low level of soil moisture. The vertical separation between seed and fertilizer decreased by 15%, 14%, and 18% as the speed increased from 3 to 8 km/h for unit one, unit two, and unit three respectively. This may be attributed to the following reasons:

- The increase in the area of soil disturbance by increasing the speed for all units at various levels of soil compaction (data not shown).
- The increase in soil dispersion at high speed might cause the depth of seed selection accuracy to decrease with an increase in the speed of operation for all units.

The highest values of the vertical separation between seed and fertilizer were obtained with unit two. However, the moderate and lowest values of the vertical separation between seed and fertilizer were obtained with unit one and unit three respectively. These results may have been due to the following reasons:

- The sweep share spreads soil sideways less than with shovel and wing shares.
- A packer wheel with blades provided more soil cover between seed and fertilizer compared with the packer wheel without blades.

The change in soil compaction from low to medium did not produce any appreciable change in the vertical separation between seed and fertilizer for all units. However, when the level of soil compaction increased from medium to high, the vertical separation between seed and fertilizer decreased by 18%, 14%, and 13% for unit one, unit two, and unit three respectively. At a low level of soil compaction, unit two resulted in the highest values of the vertical separation between seed and fertilizer followed by unit one and unit three respectively. However, at medium and high levels of soil compaction, there were no appreciable differences in the vertical separation between seed and fertilizer among unit one and unit two. This may have been caused by the increase in the area of soil disturbance for unit one and unit three at low compaction by almost 26% compared with unit two. However, at medium and high levels of soil compaction, the area of soil disturbance for unit three increased by 21% compared to unit two.

Results of the vertical separation between seed and fertilizer at medium and high soil moisture presented similar trends at low soil moisture except for the following differences:

- The change in soil moisture from 10% to 15% produced an increase in the vertical separation between seed and fertilizer by 11%, 12%, and 9% for unit one, unit two, and unit three respectively.
- The vertical separation between seed and fertilizer decreased by 10%, 6%, and 15% when the soil moisture increased from 15% to 20% for unit one, unit two, and unit three respectively.
- At a medium level of soil moisture, there was no appreciable difference in the vertical separation between seed and fertilizer among three till-planting units at different levels of soil compaction.

- At a high level of soil moisture, the vertical separation between seed and fertilizer decreased by 26%, 23%, and 25% as the soil compaction increased from low to high for unit one, unit two, and unit three respectively.

Field experiment

Figure 7 presents the average values of the vertical separation between seed and fertilizer with the speed of operation at different depths. Similar to the results of soil bin tests, the vertical separation between seed and fertilizer decreased with increase in the speed of operation for all units. At low depth, unit two resulted in the highest values of the vertical separation between seed and fertilizer followed by unit one and unit three respectively.

In comparison among three units at different speeds, there was no appreciable change in the vertical separation between seed and fertilizer among unit one and unit two. However, the vertical separation between seed and fertilizer for unit three decreased by 17%, 15%, and 21% compared to unit two at 3, 5, and 8 km/h speeds respectively.

Results of the vertical separation between seed and fertilizer at 100 and 125 mm depth of operations showed similar trends as 75 mm depth except for the following differences:

- The increase in the depth from 75 to 100 caused an increase in the vertical separation between seed and fertilizer by 18%, 22%, and 16% for unit one, unit two, and unit three respectively. This result may have been due to the increase in the expected vertical separation between seed and fertilizer from 35 mm to 50 mm as the depth increased.
- Although the expected vertical separation between seed and fertilizer increased by the same proportion (15mm) as the depth increased from 100 to 125mm, the actual vertical separation between seed and fertilizer increased by 35% for all units when the depth increased from 100 to 125 mm. This may be attributed to the average value of the area of soil disturbance with all units did not increase by more than 7% when the depth increased. However, the increase in the depth from 75 to 100 mm caused an increase in the area of soil disturbance by 19%, 17%, and 16% for unit one, unit two, and unit three respectively.

Comparison of data

Figure 8 shows a relation between the vertical separation of seed and fertilizer from field and from soil bin tests for three till-planting units. Soil bin data was taken at 15% moisture content, 100 mm depth, different speeds, and 1769 kPa Cone Index. However, the field data was taken at 22% moisture content, 100 mm depth, different speeds, and 1687 kPa Cone Index. The field results are in agreement with the soil bin results and the correlation between them is 91%.

Statistical analysis

Analysis of variance was conducted using the MINITAB statistical package under soil bin and field conditions. In the soil bin tests (Table 1), the analysis of variance was performed for vertical separation between seed and fertilizer in relation to soil moisture, soil compaction, speed, and depth with three till-planting units. It was also conducted in the field with respect to speed and depth with three replicates (Table 2). Results in the soil bin tests indicated that the highest values of the vertical separation between seed and fertilizer were obtained with unit one or unit two at 3 km/h speed, 100 mm depth, 15% moisture content, and at medium level of soil compaction. However, in field tests, the best results were obtained with unit two at 3 km/h speed and 125 mm depth.

Conclusions

Based on the results from soil bin and field experiments, the following conclusions could be stated.

- The sweep share contributed to better seed and fertilizer separation by spreading less soil sideways.
- The packer wheel with blades resulted in the highest values of the vertical separation between seed and fertilizer by providing more soil cover between seed and fertilizer.
- Unit two, which was preceded with double rolling coulters to limit the cultivation area, gave the highest values of the vertical separation between seed and fertilizer compared to unit one and unit three.
- All till-planting units resulted in good accuracy of placing the fertilizer away from the seed at 15% moisture content and a low level of soil compaction in the soil bin tests.
- Excellent separation between seed and fertilizer was achieved with 100 and 125 mm depth at 3km/h speed for soil bin and field tests respectively.

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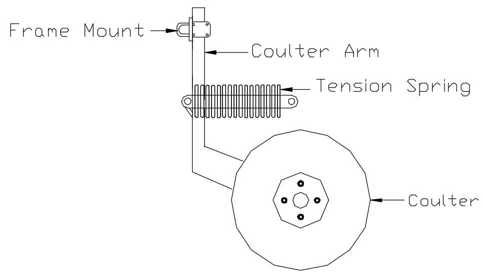

Figure 1. Schematic diagram of rolling coulter.

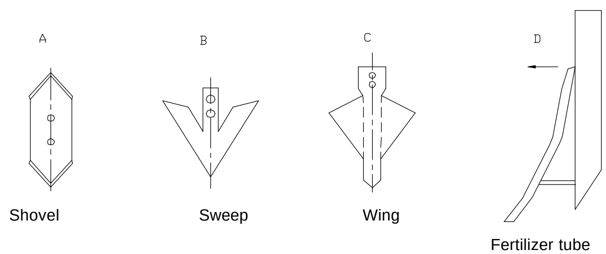

Figure 2. Schematic diagrams of share forms and fertilizer tube.

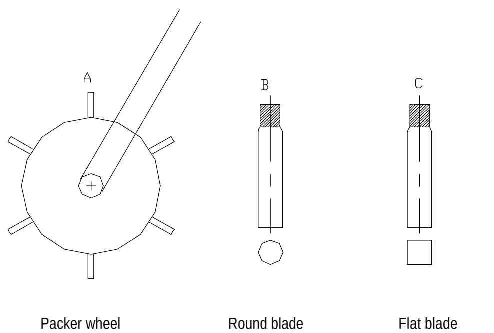

Figure 3. Schematic diagrams of packer wheel and blade forms.

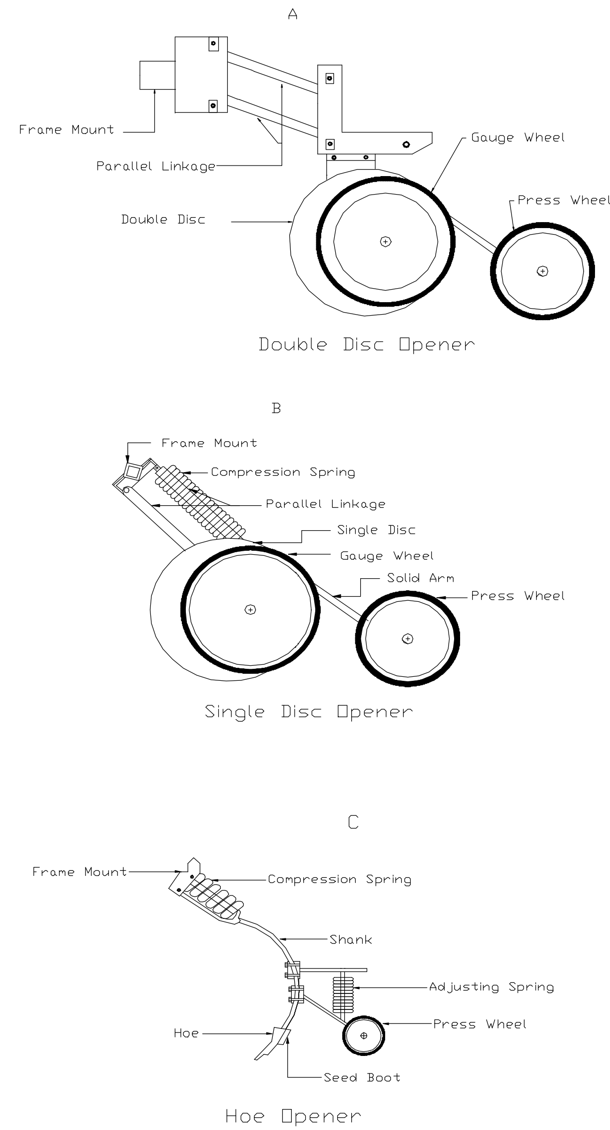

Figure 4. Schematic diagrams of furrow opener forms

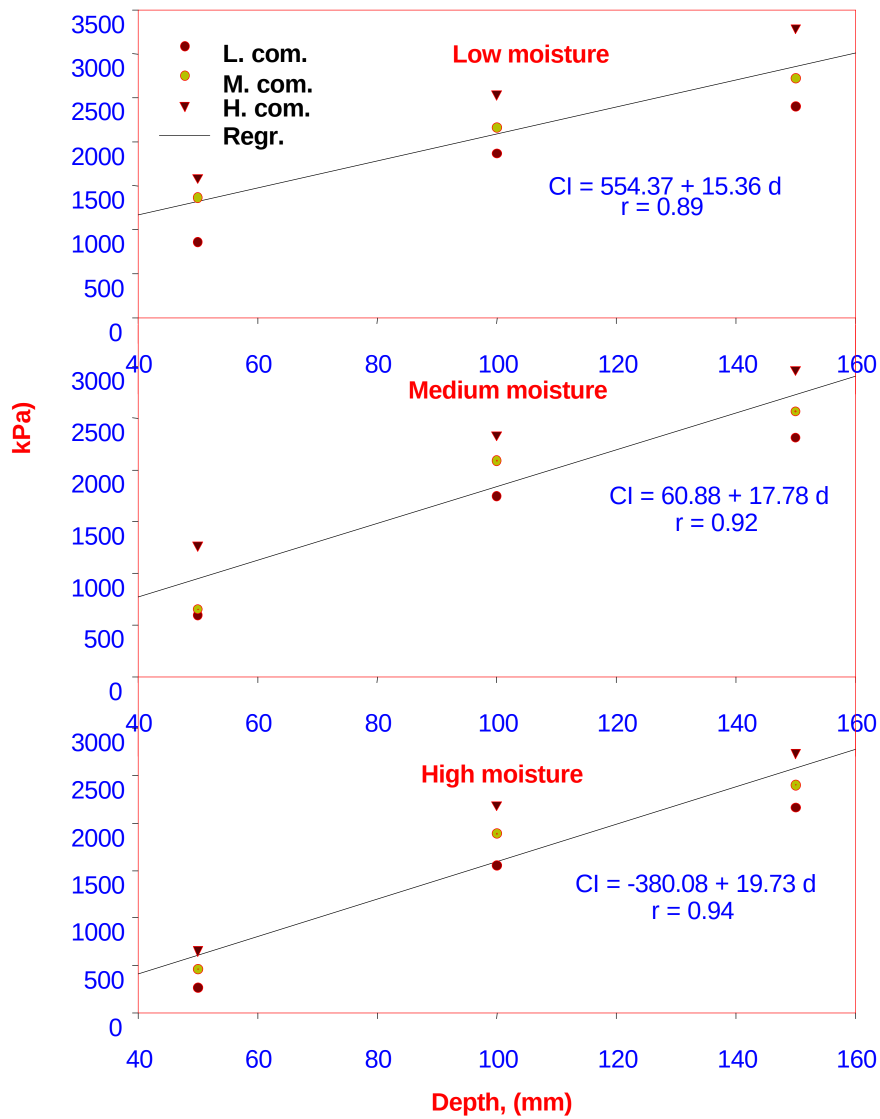

Figure 5. Distribution of soil compaction with the depth of penetration at three levels of soil moisture content before till-planting units tests.

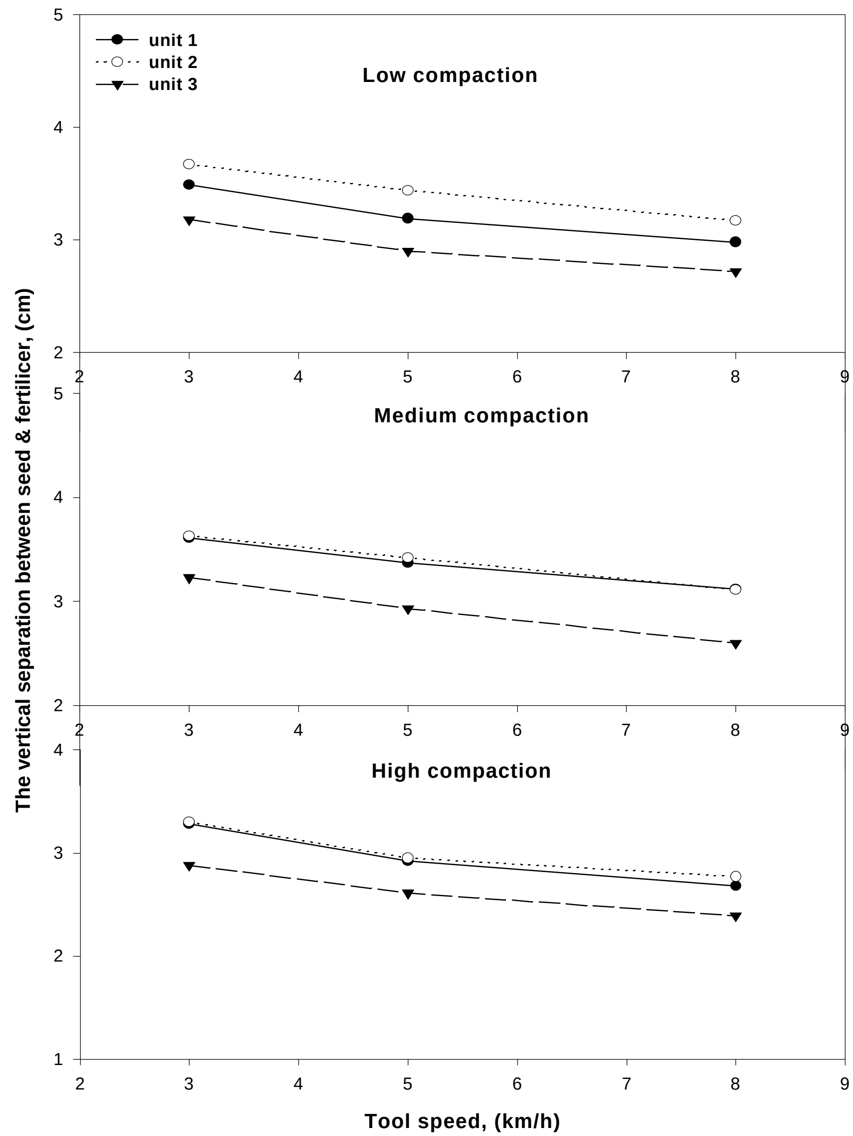

Figure 6. The vertical separation between seed and fertilizer with the speed of operation for three till-planting units at various levels of soil compaction and low level of soil moisture.

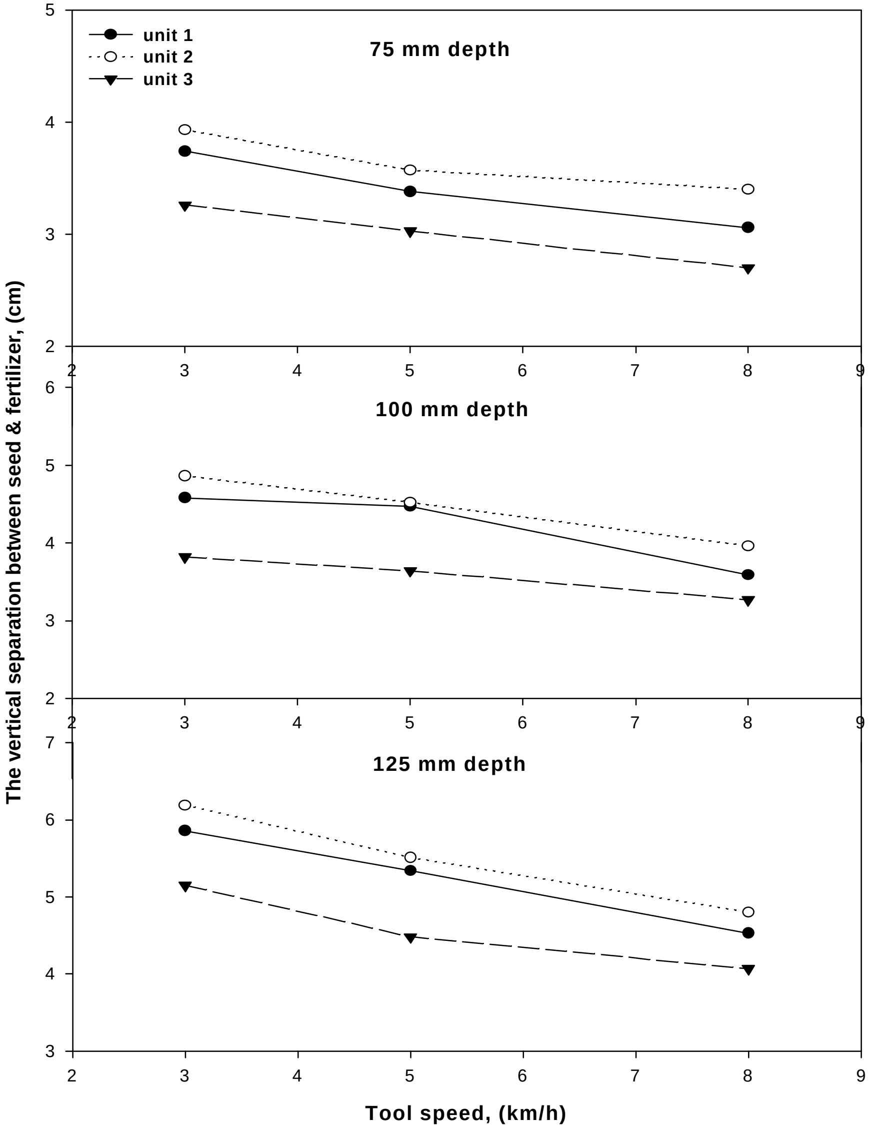

Figure 7. The vertical separation between seed and fertilizer with the speed of operation for three till-planting units at different depths under field condition.

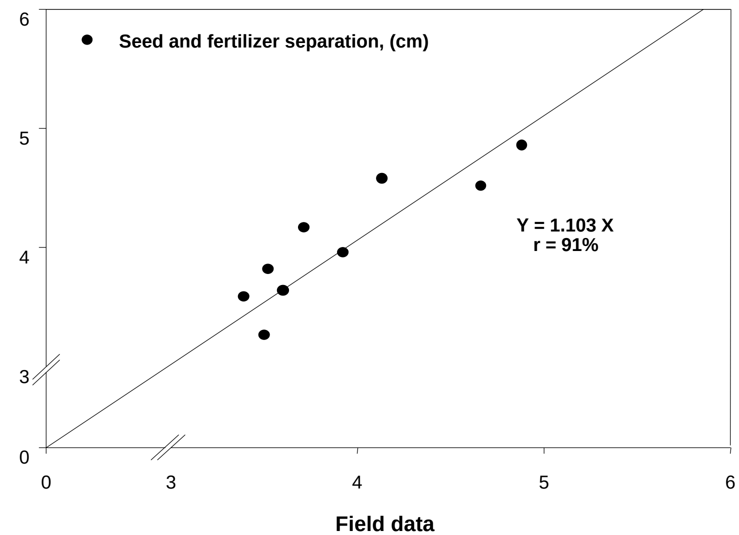

Figure 8. Relative the vertical separation between seed and fertilizer for three till-planting units at 100 mm depth and different speeds.

Table 1. Analysis of variance for the vertical separation between seed and fertilizer of till-planting units under soil bin conditions.

ANOVA TABLE

Source	DF	SS	MS	F	P
U	2	9.21062	4.60531	527.71	0.000**
M	2	1.10787	0.55393	63.47	0.000**
C	2	6.50172	3.25086	372.51	0.000**
S	2	11.26271	5.63136	645.29	0.000**
D	2	23.47585	11.73793	1345.03	0.000**
U*M	4	0.39256	0.09814	11.25	0.000**
U*C	4	0.37665	0.09416	10.79	0.000**
U*S	4	0.01056	0.00264	0.30	0.875-
U*D	4	0.56966	0.14242	16.32	0.000**
M*C	4	6.26178	1.56545	179.38	0.000**
M*S	4	0.03073	0.00768	0.88	0.483-
M*D	4	0.05082	0.01270	1.46	0.230-
C*S	4	0.09283	0.02321	2.66	0.044*
C*D	4	0.48257	0.12064	13.82	0.000**
S*D	4	0.21844	0.05461	6.26	0.000**
U*M*C	8	3.48093	0.43512	49.86	0.000**
U*M*S	8	0.04643	0.00580	0.67	0.719-
U*M*D	8	0.11541	0.01443	1.65	0.135-
U*C*S	8	0.11421	0.01428	1.64	0.140-
U*C*D	8	0.24345	0.03043	3.49	0.003**
U*S*D	8	0.30267	0.03783	4.34	0.001**
M*C*S	8	0.06221	0.00778	0.89	0.531-
M*C*D	8	0.22991	0.02874	3.29	0.004**
M*S*D	8	0.14114	0.01764	2.02	0.064-
C*S*D	8	0.35553	0.04444	5.09	0.000**
U*M*C*S	16	0.21850	0.01366	1.56	0.116-
U*M*C*D	16	0.13651	0.00853	0.98	0.495-
U*C*S*D	16	0.28483	0.01780	2.04	0.029*
M*C*S*D	16	0.02206	0.00138	0.16	1.000-
Error	48	0.41889	0.00873		
Total	242	66.21803			

- None significant

* Significant at 5% level of confidence

** High significant at 1% level of confidence

MEAN VALUES

Units	S&F	Mois.	S&F	Comp.	S&F	Speed	S&F	Depth	S&F
1	3.19[a]	0.10	3.03[a]	1	3.21[a]	3	3.38[a]	50	2.67[c]
2	3.29[a]	0.15	3.20[a]	2	3.24[a]	5	3.09[b]	75	3.26[b]
3	2.84[b]	0.20	3.09[a]	3	2.87[b]	8	2.85[c]	100	3.40[a]

LSD (0.05)= 0.27
Means within the same column followed by the same letter are not significant.

Table 2. Analysis of variance for the vertical separation between seed and fertilizer of till-planting units under field conditions.

ANOVA TABLE

Source	DF	SS	MS	F	P
U	2	9.8926	4.9463	47.71	0.000**
S	2	10.6335	5.3168	51.28	0.000**
R	2	0.3002	0.1501	1.45	0.264-
D	2	45.0515	22.5257	217.26	0.000**
U*S	4	0.3653	0.0913	0.88	0.497-
U*R	4	0.1374	0.0344	0.33	0.853-
U*D	4	1.0290	0.2572	2.48	0.086-
S*R	4	0.3461	0.0865	0.83	0.523-
S*D	4	1.1649	0.2912	2.81	0.041*
R*D	4	0.2430	0.0608	0.59	0.677-
U*S*R	8	1.1872	0.1484	1.43	0.257-
U*S*D	8	0.6308	0.0789	0.76	0.641-
U*R*D	8	0.9058	0.1132	1.09	0.417-
S*R*D	8	1.0257	0.1282	1.24	0.340-
Error	16	1.6589	0.1037		
Total	80	74.5718			

- None significant

* Significant at 5% level of confidence

** High significant at 1% level of confidence

MEAN VALUES

Units	S&F	Speed	S&F	Depth	S&F
1	4.21[a]	3	4.57[a]	75	3.26[c]
2	4.53[a]	5	4.18[a]	100	4.08[b]
3	3.69[b]	8	3.68[b]	125	5.09[a]

LSD (0.05) = 0.46
Means within the same column followed by the same letter are not significant.