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Narrow and Wide Opener Effects on Soil Disturbance and Fertilizer Placement

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Abstract The objective of this experiment was to compare the narrow and wide types of fertilizer tine and toxic effect of fertilizer on seed decreases. This experiment was undertaken using a direct drill, Precision Seeding System (PSS), made in South Australia that consists of a front fertilizer tine and a rear (seed) tine fitted with presswheel, all made into a single module. The fertilizer tine was designed to work deeper than the seeding tine and uses a presswheel to press the soil over the seed and fertilizer. Tests were conducted at forward speeds 8 kh/h and depths of operation considered were 75, 100, and 125 mm. According to research results, Precision Seedling System (PSS) reduced fertilizer toxicity, lower soil disturbance reduces weed germination and improved plant growth. And the combined dual tine and presswheel module, the fertilizer tine and height of seeding tine above presswheel significantly affected the measured parameters of fertilizer spread and position, fertilizer scatter and position. When the press wheel is not used, the fertilizer is released deeper (depth: 73 mm), the presswheel compresses the soil and reduces the depth of the fertilizer (depth: 41 mm). When working depth increases, toxic effect of fertilizer on seed decreases.

Keywords Soil Disturbance, Fertilizer

1. Introduction

New tillage and planting tools causing low soil disturbance and minimizing vegetation deterioration are desired in the conservation tillage technology development [1]. Australian conservation tillage and planting practices, also known as no-till farming, generally depend on narrow tools to open the soil and place seeds and fertiliser in furrows, which are often followed by press-wheels to pack soil over the seeds and improve seed germination rate [2]. These openers can forn excesss soil disturbance and soil throw out of the furrow, thus reducing the quality of no-till farming [3]. Specific effects of soil throw are reported such as increasing the depth of soil cover on adjacent furrows [4], greater stimulation of weed seed germination [5] and enhancing seedbed soil moisture loss [6-7]. In southern and western Australian no-till farming systems, pre-emergence herbicides are often sprayed onto the soil surface just prior to sowing, and are mechanically incorporated by the sowing operation for improved early weed control efficacy [8]. This technique of herbicide 'Incorporation By Sowing' is often referred to as IBS. Excessive lateral soil throw at seeding can result in herbicide-contaminated soil being thrown onto adjacent seed rows [4], and impeding crop establishment [7].

This work will examine a no-tillage drill, Precision Seedling System (PSS), made in South Australia that consists of a front fertilizer tine and a rear (seed) tine fitted with presswheel, all made into a single module. The front tine was designed to work deeper than the seed tine and press the soil over the seed using a presswheel.

The purpose of this work was to examine how the key furrow openers affects the furrow width, depth, soil ridge height and soil throw width associated with opener type, fertilizer depth and presswheel.

2. Materyal and Methods

2.1. Description precision seedling systems

Precision Seeding System (PSS) seeding module was used for the tests. It consisted of a front (fertilizer) tine, parallelogram, rear (seed) tine and presswheel, as shown in (Figure-1). It was made by Horwood Bagshaw Company.

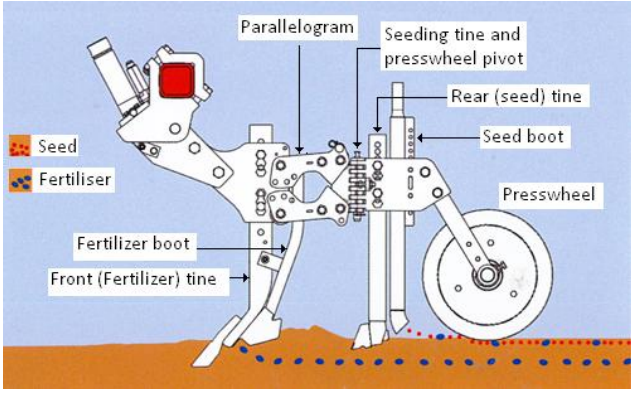
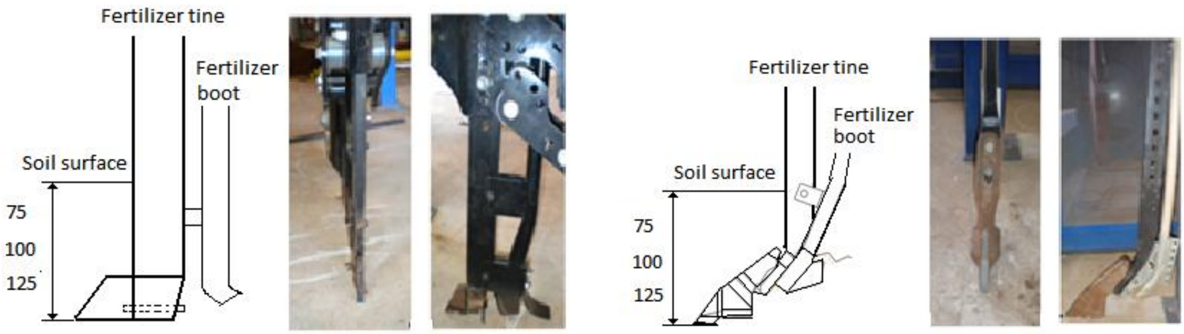


Figure 1: Precision Seedling Systems (PSS)

2.1.1. The front (fertilizer) tine

The front tine of the module was designed to dig and place fertilizer deeper than the rear (seed) tine. The fertilizer tine can be fitted with a range of soil openers [9-10]. In this study a narrow (15 mm) and a wide inverted T opener (65 mm) were compared (Figure-2). For the experiment the front tine was set to operate at depths of 75 mm, 100 mm and 125 below the original ground level.



a-Narrow tine b-Wide tine

Figure 2: Two style of fertilizer tine narrow (a) and wide (b)

2.1.2. The rear (seed) tine

The rear section of the parallelogram is fitted to, and pivots on, the front section of the parallelogram. Generally, seed should be placed approximately 12 mm-37 mm below the soil surface. The setting of the seeding boot relative to the seeding tine point and presswheel controls the depth of seed placement. The rear tine was evaluated using a range of height settings of the seed boot, seed opener relative to the base of the presswheel to evaluate if it could achieve vertical separation with the seed and be above the fertilizer so as to separate the placement of the seed and fertilizer and hence minimize fertilizer toxicity [11].

2.1.3. The presswheel

The presswheel was designed to press the soil over the seeds and act as a depth setting mechanism for the sowing tine. In this study the presswheel used was of semi-pneumatic construction and 55 mm wedge design. It was selected as previous tests [10], showed it to provide the fastest emergence [9]. The presswheel had an outside diameter of 380 mm. The presswheel was set up for the experiment to run in-line with the seeding tine [11].

2.2. The Seed Placement Test Facility

This experiment was conducted using the University of South Australia's seed placement soil bin test facility. The indoor facility was developed to provide a controlled environment to evaluate seeder related factors influencing distribution and depth of seed in the soil.

2.2.1. Test carriage

The test carriage had a length of 4.7 m and a width of 1.3 m. With a weight of 1 tonne, the test carriage can accelerate up to 16 km/h in 3.8 m prior to reaching the soil bin and stop in 2.0 m after leaving the soil bin. Two conveyor chains are used to drive the carriage back and forth. The seeding module was mounted in a height adjustable frame 1.1 m wide x 2.4 mm long. A sketch of the equipment is shown in Figure-3.

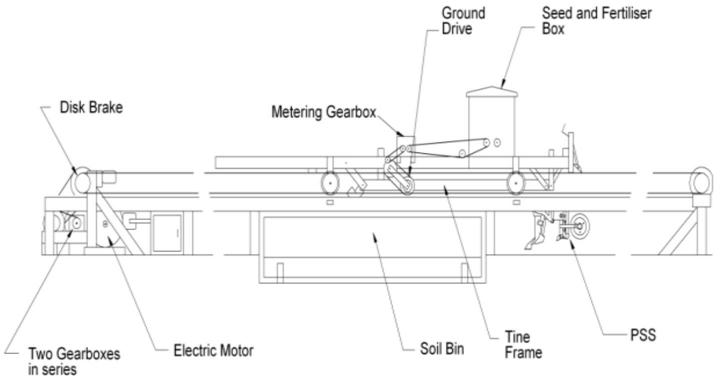


Figure 3: Soil bin seed placement test rig

2.2.2. Soil bins

The soil was composed of 16.10% clay, 11.80% silt and 72.10% sand. It was classified as a sandy-loam soil [12]. Soil moisture of 10.5% at the time of sowing was used. The average bulk density for the depth of 0 to 100 mm was 1.4 g/cm^3. Average soil penetration resistance was 1.4 MPa in the depth range of 0–50 mm, 1.5 MPa in the depth range of 50–100 mm, 1.6 MPa in the depth range of 100–150 mm [11].

The facility holds four soil bins. Each soil bin is 1.5 m wide and 3 m long and can be indexed and locked into place beneath the test carriage rails. The central 2 m length of the bin (steady state seeding) was used for seed and soil profile recording purposes. Removable plastic covers were fitted to the soil bins to provide an enclosed environment that conserves the moisture in the soil and provided protection from vermin [11].

2.3. Seed locations and soil profile development

The system developed at the University of South Australia uses a manual excavation method to find the seed. The soil was excavated after germination was completed by spoon and the location of each of the the seeds recorded. A three dimensional digitizer with a moveable pointer within a fixed reference frame was used to record the individual seed locations and soil profile. The measuring frame made of aluminum was constructed to locate accurately on the test carriage rails to provide an accurate and repeatable measurement reference [11].

2.4. Determining Soil Profile, Seed and Fertilizer Location

The performance of the seeding module for its various settings was compared in terms of furrow profile, seed and fertilizer location. Seed and fertilizer location was defined as the average lateral seed, fertilizer position from the centre of the fertilizer tine, lateral seed, fertilizer spread, average vertical seed and fertilizer position from the original soil level and the vertical seed and fertilizer spread, as shown in Figure-4, [9-11].

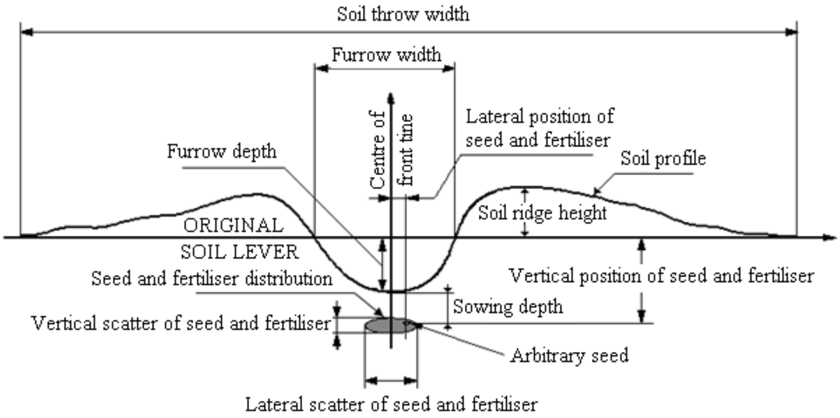


Figure 4: Definition of measurements and dimensions referred to in seed and fertilizer placement analysis [9].

2.5. Experimental Design

Each soil bin was partitioned into two blocks along the length of the bin. Each block was 2 m long by 750 mm wide and contained one row of seeding. For the experiment, a total of 36 plots were arranged in a randomized complete block design. Three replications were undertaken. The experiment varied the fertilizer opener between a narrow and a wide inverted T opener. The experiment varied the seeding parameters (a and b shown in Figure 6) with the parameters used being the seeding opener position above the base of the presswheel, a=30 mm, and the height of the seed boot discharge above the tip of the seeding opener, b=10 mm and no presswheel. The speed of tillage for the all tests was 8 km/h. The working depth of the front fertilizer tine was 75 mm, 100 mm and 125 mm (Figure 2). The seeding rate along the row was set at 100 seeds/m.

Analysis of variance was determined using the MSTAT statistical package to examine the effects of treatments [13]. Duncan's multiple range tests were used to identify significantly different means within dependent variables at P≤ 0.05.

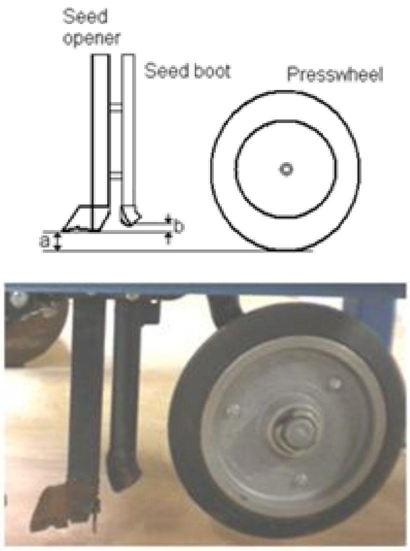


Figure 5: Position of seed opener, seed boot and presswheel

3. Result and Discussion

3.1. Effect of fertilizer unit on soil profile parameters

The average of the 3 replications of the furrow profiles created by only the leading tine (seeding tine and presswheel removed) is shown in Figure-6 for the travel speeds of 8 km/h. This figure shows the locations of all of the fertilizer from the 3 replications.

The analysis of variance presented that there were significant differences in furrow width, depth, soil ridge height and soil throw width associated with opener type, fertilizer depth and presswheel (Table-1-2-3 and 4). Manuwa, [14] found that as the tool moved through the soil in the soil bin, the soil was disturbed as it was cut and thrown to the sides of the tool. The width of the tool strongly influenced the soil disturbance parameters as they all increased as the working depth increased but less proportionately. This was also similar to the findings reported by [15]. Narrow opener width (with flat lift wings where present), at lower rake angles, set to operate at shallower depths, and fitted onto narrow, forward leaning shank tines should be targeted for minimum soil throw [16].

Table 1: Effect of opener on fertilizer soil profile parameters

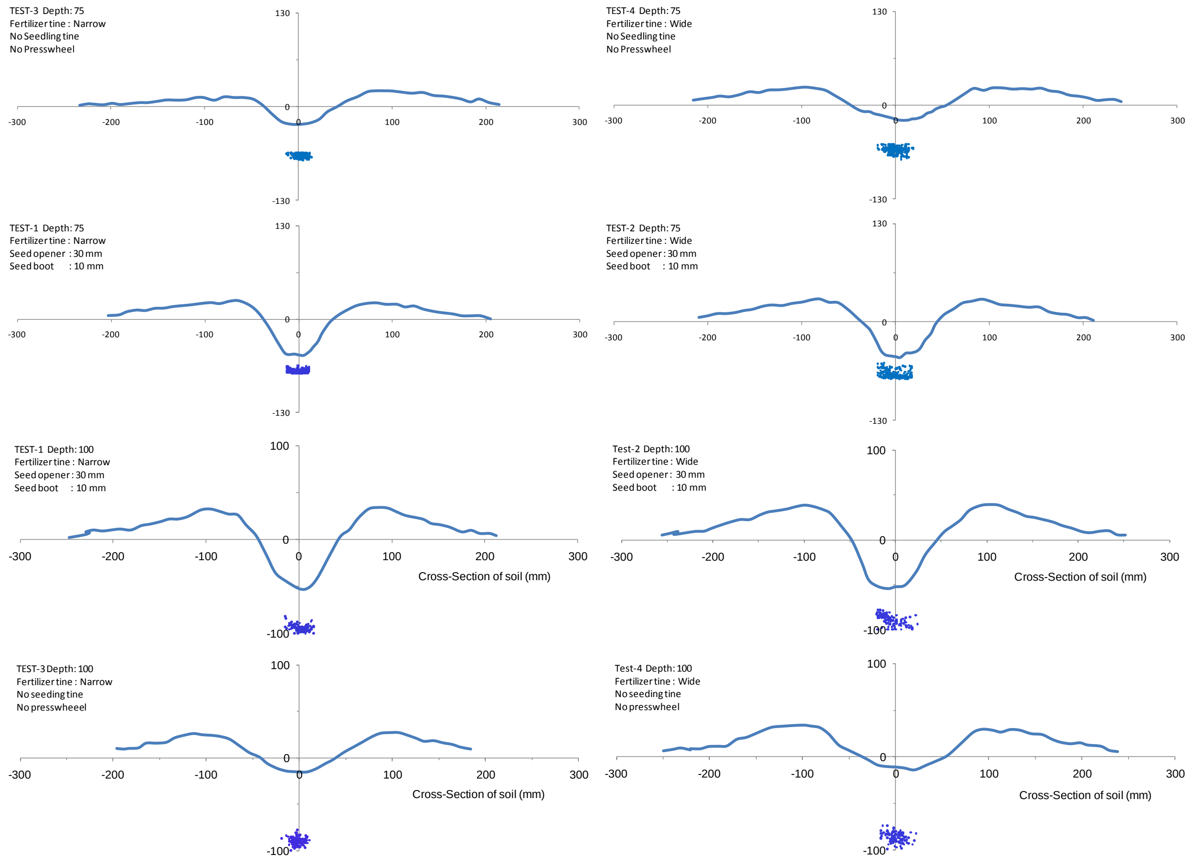
Furrow parameters	Narrow	Wide	F_{cal}
Mean furrow width (mm)	85	96	43.76**
Mean furrow depth (mm)	40	37	6.53*
Mean soil ridge height (mm)	32	35	24.96**
Mean soil throw width (mm)	448	472	76.73**

*Significant (P<0.05), **Highly significant (P<0.01) and ^{ns}= non-significant

Table 2: Effect of presswheel on fertilizer parameters

Furrow parameters	a=30 b=10	No PW	F_{cal}
Mean furrow width (mm)	92	88	4.76*
Mean furrow depth (mm)	56	20	1002.43**
Mean soil ridge height (mm)	36	32	14.92**
Mean soil throw width (mm)	450	470	49.16**

* Significant (P<0.05), **Highly significant (P<0.01) and ^{ns}= non-significant



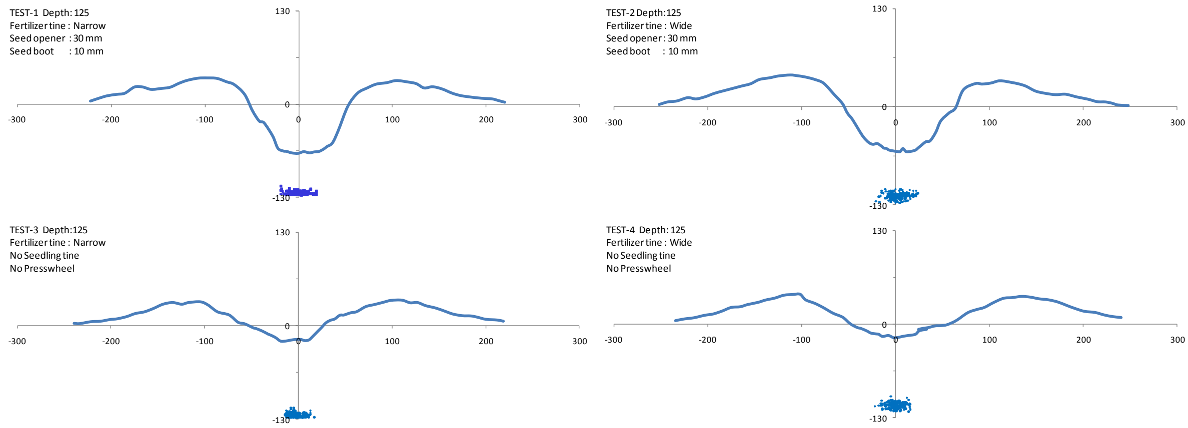


Figure 6: Effect of fertilizer unit on soil profile and fertilizer placement

Table 3: Effect of fertilizer depth on parameters

Furrow parameters	**75 mm**	**100 mm**	**125 mm**	**S_{-x}**	**F_{cal}**
Mean furrow width (mm)	85^{b}	87^{b}	100^{a}	1.498	32.10**
Mean furrow depth (mm)	36^{b}	36^{b}	43^{a}	2.870	16.46**
Mean soil ridge height (mm)	28^{c}	35^{b}	40^{a}	2.739	42.69**
Mean soil throw width (mm)	432^{c}	485^{a}	462^{b}	7.104	121.05**

Unlike letters in column denote significant differences (P<0.05), * Significant (P<0.05), **Highly significant (P<0.01) and ns= non-significant

Table 4: Effect of factors on soil profile parameters

Opener	**Fertilizer Depth**	**Seeding unit position**	**Furrow width (mm)**	**Furrow depth (mm)**	**Soil ridge height (mm)**	**Soil throw width (mm)**
Narrow	75	a=30 b=10	75^{e}	52	29	407^{f}
		No PW	81^{de}	24	23	440^{e}
	100	a=30 b=10	84^{de}	53	35	453^{de}
		No PW	79^{de}	18	28	483^{b}
	125	a=30 b=10	107^{b}	69	38	441^{e}
		No PW	83^{de}	23	37	460^{cd}
Wide	75	a=30 b=10	77^{e}	47	33	420^{f}
		No PW	106^{b}	21	27	461^{cd}
	100	a=30 b=10	95^{c}	55	41	506^{a}
		No PW	89^{cd}	17	36	499^{a}
	125	a=30 b=10	117^{a}	61	43	471^{bc}
		No PW	94^{c}	19	43	474^{bc}
		Duncun S_{-x}	2.996	----	----	4.844
		F_{cal}	4.85*	0.59^{ns}	0.03^{ns}	5.48*

Unlike letters in column denote significant differences (P<0.05), * Significant (P<0.05), **Highly significant (P<0.01) and ns= non-significant

3.5. Effect of fertilizer opener on fertilizer placement parameters

The type of opener, fertilizer depth and presswheel indicated a significant effect on the lateral and vertical fertilizer scatter and vertical fertilizer position, but none a significant statistical effect on lateral fertilizer passion (Table-5-6-7 ve 8) and all parameters variance analysis was given Table-9. When the presswheel is not used, the fertilizer is released deeper (depth: 73 mm), the presswheel compresses the soil and reduces the depth of the fertilizer (depth: 41 mm).

Table 5: Effect of opener on fertilizer parameters

Fertilizer placement Parameters	Narrow	Wide	F_{cal}
Mean lateral fertilizer position (mm)	-0.2	-0.3	0.007^{ns}
Mean vertical fertilizer position (mm)	95	89	201.98**
Lateral fertilizer scatter (mm)	28	37	84.28**
Vertical fertilizer scatter (mm)	13	19	106.79**
Mean depth of fertilizer (mm)	58	56	36.91**

* Significant (P<0.05), **Highly significant (P<0.01) and ^{ns}= non-significant

Table 6: Effect of presswheel on fertilizer parameters

Fertilizer placement parameters	a=30 b=10	No PW	F_{cal}
Mean lateral fertilizer position (mm)	-0.2	-0.3	0.06^{ns}
Mean vertical fertilizer position (mm)	94	91	97.19**
Lateral fertilizer scatter (mm)	34	31	10.32**
Vertical fertilizer scatter (mm)	16	17	6.67*
Mean depth of fertilizer (mm)	41	73	9484.74**

* Significant (P<0.05), **Highly significant (P<0.01) and ^{ns}= non-significant

Table 7: Effect of fertilizer depth on fertilizer placement parameters

Fertilizer placement parameters	75 mm	100 mm	125 mm	S_{-x}	F_{cal}
Mean lateral fertilizer position (mm)	0.2	-1.0	0.1	-----	0.07^{ns}
Mean vertical fertilizer position (mm)	68^{c}	90^{b}	120^{a}	1.102	4839.75**
Lateral fertilizer scatter (mm)	28^{b}	35^{b}	$3^{3}a$	0.838	19.36**
Vertical fertilizer scatter (mm)	14^{b}	22^{a}	13^{b}	0.521	85.16**
Mean depth of fertilizer (mm)	34^{c}	58^{b}	79^{a}	0.277	6501.39**

Unlike letters in column denote significant differences (P<0.05), * Significant (P<0.05), **Highly significant (P<0.01) and ns= non-significant

Table 8: Effect of factors on fertilizer placement

Opener	Sowing depth	Seeding unit position	Lateral fertilizer position (mm)	Vertical fertilizer position (mm)	Lateral fertilizer scatter (mm)	Vertical fertilizer scatter (mm)	Mean fertilizer depth (mm)
Narrow	75	a=30 b=10	-1.3^{bcd}	72^{g}	22	9	23^{i}
		No PW	2.3^{ab}	68^{h}	23	9	44^{f}
	100	a=30 b=10	2.3^{ab}	95^{d}	31	18	44^{f}
		No PW	-2.3^{cd}	90^{e}	30	22	75^{c}
	125	a=30 b=10	0.0^{abc}	124^{a}	35	10	58^{e}
		No PW	2.3^{cd}	124^{a}	25	10	103^{a}
Wide	75	a=30 b=10	-0.3^{abc}	69^{h}	33	17	26^{h}
		No PW	0.0^{abc}	62^{i}	34	18	43^{f}
	100	a=30 b=10	-4.3^{d}	89^{e}	41	21	38^{g}
		No PW	0.3^{abc}	86^{f}	38	25	74^{c}
	125	a=30 b=10	2.7^{a}	118^{b}	41	17	59^{d}
		No PW	0.0^{abc}	112^{c}	33	17	95^{b}
		Duncun S_{-x}	1.154	0.751	----	----	0.554
		F_{cal}	8.23**	6.21*	0.45^{ns}	0.11^{ns}	48.58**

Unlike letters in column denote significant differences (P<0.05), * Significant, ** Highly significant and ns= non-significant

Table 9: Analysis of variance table of parameters of fertilizer placement

Properties	Source	Degrees of freedom	Sum of squares	Mean square	F value
Lateral scatter	Replication	2	35.722	17.861	2.11ns
	Opener	1	711.111	711.111	84.28**
	Depth	2	326.722	163.361	19.36**
	Opener x depth	2	20.389	10.194	1.20ns
	Seed Unit Position (SUP)	1	87.111	87.111	10.32**
	OpenerxSUP	1	0.111	0.111	0.01ns
	DepthxSUP	2	159.389	79.694	9.44**
	OpenerxdepthxSUP	2	7.722	3.861	0.45ns
	Error	22	185.611	8.437	
Vertical scatter	Replication	2	46.222	23.111	7.08**
	Opener	1	348.444	348.444	106.79**
	Depth	2	555.722	277.861	85.16**
	Opener x depth	2	49.389	24.694	7.56**
	Seed Unit Position (SUP)	1	21.778	21.778	6.67*
	OpenerxSUP	1	0.111	0.111	0.03ns
	DepthxSUP	2	27.056	13.528	4.14*
	OpenerxdepthxSUP	2	0.722	0.361	0.11ns
	Error	22	71.778	3.263	
Lateral position	Replication	2	104.167	52.083	13.04**
	Opener	1	0.028	0.028	0.007ns
	Depth	2	10.167	5.083	1.27ns
	Opener x depth	2	32.056	16.028	4.01*
	Seed Unit Position (SUP)	1	0.250	0.250	0.06ns
	OpenerxSUP	1	8.028	8.028	2.01ns
	DepthxSUP	2	30.500	15.250	3.81*
	OpenerxdepthxSUP	2	65.722	32.861	8.23**
	Error	22	87.833	3.992	
Vertical Position	Replication	2	16.056	8.028	4.73*
	Opener	1	342.250	342.250	201.98**
	Depth	2	16401.389	8200.694	4839.75**
	Opener x depth	2	36.500	18.250	10.77**
	Seed Unit Position (SUP)	1	164.694	164.694	97.19**
	OpenerxSUP	1	10.028	10.028	5.91*
	DepthxSUP	2	12.389	6.194	3.65*
	OpenerxdepthxSUP	2	21.056	10.528	6.21*
	Error	22	37.278	1.694	

The depth of fertilizer foot was found to be an important parameter on seed and fertilizer depth (Table-10). According to the results obtained; when operated at a depth of 100 mm, the depth difference between the seed and fertilizer increases (Table-11). Thus, it reduces the toxic effect of fertilizer on the seed.

Table 10: Effect of opener on fertilizer depth

Fertilizer placement Parameters	Narrow	Wide	F_{cal}
Mean depth of seed (mm)	41	38	9.42**+
Mean depth of fertilizer (mm)	58	56	36.91**
Difference between seed and fertilizer	17	18	

* Significant (P<0.05), **Highly significant (P<0.01) and ^{ns}= non-significant

+ This result was found by Bayhan and Fielke, 2018

Table 11: Effect of depth of opener on working depth

Fertilizer placement Parameters	75	100	125
Mean depth of seed (mm)	28	32	59
Mean depth of fertilizer (mm)	34	58	79
Difference between seed and fertilizer	06	26	20

4. Conclusion and Comments

According to research results, Precision Seedling System (PSS) increased water infiltration, utilization of sub-soil moisture reserves for earlier germination, reduced fertilizer toxicity, lower soil disturbance reduces weed germination and improved plant growth. And the combined dual tine and presswheel module, the fertilizer tine and height of seeding tine above presswheel significantly affected the measured parameters of furrow width, furrow depth, soil throw height, soil throw width, and fertilizer spread and position, fertilizer scatter and position. The narrow foot reduces the toxic effect of the fertilizer, leaving the manure deeper. When working depth increases, toxic effect of fertilizer on seed decreases. At a working depth of 100 mm, the fertilizer has virtually no toxic effect on the seed (differences between seed and fertilizer is 26 mm).

Acknowledgments

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