Effects of Soil Penetration Resistance on the Performance of Semi-mounted Potato Planter

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ABSTRACT--- ***This study is conducted to evaluate the performance of semi-mounted potato planter (two row with a cup), on an area of (50 x 8 m) in the farm of the College of Agricultural Studies-Sudan University of Science and Technology. The effects of three levels of soil penetration resistance (100-70kg/cm^2, 70-45kg/cm^2 and 45-25kg/cm^2) on the performance of potato planter was evaluated in terms of the seed to seed spacing, percentage of missing seed , depth of planting and field capacity. The results revealed that the increase in the soil penetration resistance induced a significant decrease in the depth of planting, Also There is no significant different between the two higher and medium levels of soil resistance (100-70kg/cm^2 and 70-45kg/cm^2), for seed to seed spacing, while there are a significant different in the lower level (24-45 kg/cm^2). In contrast the levels of soil resistance did not show significant differences in the percentage of missing seed At the recommended soil resistance the effective field capacity and field efficiency of the planter was about 0.20 ha/hr and 63%, respectively. The developed polynomial relations between the studied evaluations attribute soil penetration resistance can be used to predict the field attribute to implement for certain soil penetration resistance.***

Keywords--- Field Performance; Soil Penetration Resistance; Missing Seeds. Compaction, potato tubers.

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1. INTRODUCTION

Potato production in the Sudan is a relatively recent agricultural activity, starting in Khartoum (more than 70% of production), and later spreading to other parts of the country (Northern, River Nile, Kassala, and Gezira States), and it reached Jabel Marra in the far West. Potatoes importance has markedly increased due to expansion in urban centers, as a result of migration from rural areas, increase in population, a general awareness of the nutritional value of vegetables, besides others socio-economic changes that dictated some shifts from traditional meals in Sudanese houses (Tahani, 2000).Due to labor shortage at peak crop season extensive use of farm machinery is investable (Hunt, 2001). This resulted, in the recent years; in increase in the number of power tiller, threshing, husking and transporting. (Mari et al, 2002). At present more than 80% potato cultural practices, in China, are carried out with power tillers (Rashid, 2007).

Ryszard et al (2017) reported that subsoil compaction is universally known to have negative impacts on crop production. The outcome of sub-soiling in potato systems is variable. Alternative methods, such as controlled traffic and biological drilling, have potential to aid in remediating fields with subsoil compaction and minimizing future reoccurrence. These alternative methods need further research to identify points for optimization within potato systems and confounding conditions that may limit their potential as an effective tool for producers van Loon and Bouma (1978).

Potato planting in particular is a difficult and expensive task that requires careful handling of tubers. Bader (2002) evaluated three potato feeding systems (semi automatic chain, semi automatic tray and automatic cup) to determine the optimum operational requirements (in terms of planting depth and tuber orientation), and to select the most effective system. Automatic cup planter was found to be the best (Singh et al., 2005 Stalham et al (2007). Zheng, et al (2021) reviewed and paper summarized the research progress and application status of potato planters all over the world. Specifically, the seed-metering devices of potato planters are classified, and the characteristics of some typical commercial potato planters are discussed, to propose suggestions to promote the development of suitable potato planters that can meet the agronomic requirements of potato

Mari, (2002) studied planting mechanism of potato planter. He described the seed metering mechanism of the potato planter to be a cup type horizontal drive, and as the tractor moved forward the seed-metering device shall be rotated by a chain-sprocket arrangement through drive wheels. Then, three operators were required to operate the machine; one to drive the tractor and the other two, sitting on the frame, placed the seed potatoes in the seed metering cup by hand very quickly, if there were any missing. Just after the potato placement, a ridge is formed by the two consecutive mould-boards. The depth of placement of potato tubers is function of the soil penetration resistance. Such soil character is function of tillage implement used, degree of compaction created by number of machinery passage over the field, soil moisture status, and soil type. However, to operate the potato planter it essential to select the tillage machine and its mode of operation that can produce the optimum compaction level. This requires collecting information on the properties of the plow layer before tillage and makes it possible to choose an appropriate depth of tillage and intensity of soil crushing and to estimate the tillage quality. Soil compaction or its penetration resistance can be measured by cone pentrometer. Bulk density can be used as a proxy indicator of degree of soil compaction, and its penetration resistance. The relationships between the soil bulk density and the penetration resistance are described by complex nonlinear models (Atwell, 1993).

Getachew et al (2010) determined the effect of seed spacing on total yield and marketable yield of potato in Ethiopia. They found that the highest total number yield is obtained at seed spacing of 10 cm, whereas marketable tuber yield at seed spacing of 10 cm had the lowest value. Similarly et al (2012) reported that seed planted at seed spacing of 8 cm resulted in more potato yields than those seed planted at spacing from 15 to 91 cm, and the market value decreased due to increasing percent of small potatoes. Naturally, accuracy of seed spacing changes depending on the size and shape of cups. However, although many works were done on potato planters, studies on the effect of soil penetration resistance on seed spacing uniformity are limited. Edrris et al (2020) conducted a field study to assess the variability in three levels of soil compaction (low1.2-1.9 MPa, a medium 2.0-2.3 MPa and a high level of 2.4-2.9 MPa.), and to investigate their effects on the engineering properties of potato tubers in terms of tuber shape and key dimensions (length, width and thickness) and resistance to penetration, rupture and shear forces. Results revealed that there were no significant changes in the key tuber dimensions corresponding to the variability in soil compaction. However, inverse linear relationships were observed between soil compaction and the key tuber dimensions with (R^2) values of 77%, 97% and 96% for length, width and thickness, respectively. Similarly, the soil compaction was shown to have no effect on the tuber resistance to compression and shear force. In contrast, the tuber resistance to penetration was significantly affected by soil compaction ($p>F = 0.0012$). This result is confirmed by Huntenburg et al (2007) who studied the agronomic and physiological responses of potato subjected to soil compaction and/or drying. The study revealed that plants exposed to deficit irrigation produced more, smaller potatoes than their respective control. Thus, low soil water availability and/or compact soil caused these field-grown potatoes to restrict shoot growth.

The general objective of this study is to evaluating the performance of the semi automatic potato planter while the specific objective is to determine the effect of the soil penetration resistance on the seed to seed spacing, Percentage of missing seed, depth of planting and field capacity.

2. MATERIAL AND METHODS

2.1 Study Area:

The experiment was conducted on a selected area of (50 x 8 m) in the farm of the College of Agricultural Studies, Sudan University for Science and Technology (LAT: 15°40'N LONG: 32°32'E and ALT: 380M), the main daily temperature is 29.3°C. Average maximum temperature reaches 47.3°C in May while the minimum temperature is 5.5°C in February. The mean relative humidity is 28% and show some variation ranges from 16% in April to 45% in August. The average annual rainfall is about 147.5 mms, with most of the rain falling in June – October. The soil texture of the farm belongs to the Central Clay Plain of the Sudan that has been formed by alluvial deposit of the Nile primarily of basaltic origin, which is largely Vertisols.

2.2 Tools:

For the purpose of implementing the experiment in the field, the following tools and equipment were used:

1. Tractor with horsepower 120 Hp model is New Holland tractor, used to pull the planter,
2. Two row semi automatic planter, Model: RUMPTSTAD potato planter the RUMPTSTAD potato planter is a semi-mounted two row planter consisting of: cup, base frame, potato metering device, furrow openers, soil covering device, planter drive wheel and chain with sprocket for power transmission. The machine is mounted on a three point linkage of a tractor and two persons sitting on the machine feed the cups as shown in schematic diagram (Figure 1). The RUMPTSTAD potato planters perform three functions simultaneously. Making furrows, sowing seeds and making ridges and theplanter is easy to operate and maintain.
3. Soil penetrometer units, and other tools and implements which were used in the study include: small size potato seeds, ruler for measure depth of seed. seed uniformity, seed depth and missing seed, soil resistance.
4. Meter tape (50m),
5. Stop watch,

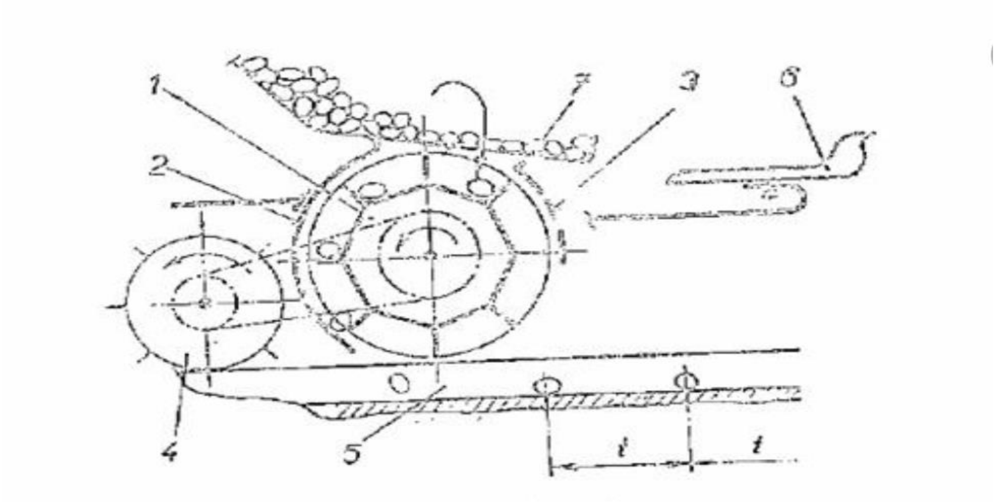

Figure (1) Schematic Diagram of the RUMPTSTAD Potato Planter

2.3 Experimental Design and the layout

The area selected was divided into three stations (25m for each) in the farm with Semi- automatic potato planter was evaluated on basis of

2.4 Calculation of technical parameters:

1. Seed to seed spacing (SS) and seed depth (SD): The Meter tape is used to measure the distance between each hole and the distance determined by the calibration procedure. These readings are recorded for each station.
2. Percentage of missing seed: Percentage of missing seed was determined by equation given below:

$$\boldsymbol{PMS = \frac{h_n}{h_t}}$$

Where:

PMS = Percentage of missing seed, h_n = number of null hole in 25 m space, and h_t = number of total hole in 25 m space.

3. Field capacity**:** Theoretical field capacity (TFC) was calculated as follows (Mari *et al.,* 2008).

$$TFC = \frac{W \times S}{c}$$

Where:

W = rated width of the planter (m), S = rated forward speed of machine (km/hr), and C = constant

The effective field capacity (EFC) of the potato planter is a function of the rated width of the planter, the percentage of the rated width actually utilized, the speed of travel, and the amount of field time lost during the operation. It is the actual average rate of coverage by the planter. Effective field capacity is usually expressed as hectare per hour. It is calculated by following formula (Kepner *et al.,* 1978):

$$EFC = \frac{T}{A}$$

Where:

T = total time for the planting operation, hr, and A = total area planted,

Field Efficiency (FE) (%) is the percentage of the ratio of effective field capacity and theoretical field capacity (Kepner et al., 1978).

$$FE = \frac{EFC}{TFC}$$

3. RESULTS AND DISCUSSIONS

Table 1 shows the samples of collected and calculated data (i.e., seeding distance, seeding depth, and seed count at each point). Each data is replicated three times and calculated at one point on each row based on method described by Choi et al. (2016).

Table 1: Sample of collected Data of experiment

Distance between seed (cm)			**Depth**		**N0. of missing seeds**		**soli rest**	std	
Point Num	**row 1**	**row2**	**row 1**	**row2**	**row 1**	**row2**	**(kg/cm^2)**	**row 1**	**row2**
1	43	60	3.5	3	1	1	22.2	10	25
2	45	43	0	4	0	1	27.6	6	10
3	0	0	2.1	3.7	1	1	22	100	100
4	70	0	2.7	3.4	1	1	45	46	100
5	74	47	0	0	0	0	35.8	54	2
6	0	0	3.7	0	2	0	25.2	100	100
7	55	75	0	3	0	1	42.4	15	56
8	0	0	3	0	1	0	24.2	100	100
9	43	70	2	2.7	1	1	30.8	10	46
10	60	60	3	0	1	0	26	25	25

3.1 Effects of Soil Penetration Resistance:

The average seed to seed spacing of potato and analysis of coefficient of variance at each soil penetration resistance (100-70kg/cm^2, 70-45kg/cm^2 and 45-25kg/cm^2) are shown in table2 and table3 respectively. Figure3 shows the measurement of seed spacing. Tables, (2 and 3) revealed that there is no significant difference between the high and medium levels of soil resistance (100-70kg/cm^2 and 70-45kg/cm^2) and at the same time, the average distance between the seeds to seeds in the two levels of soil resistance (49.4 cm) is appropriate and close to the distance required when calibration of the planter (48 cm). The soil resistance at the lower level (45-25kg/cm^2) has given significant differences (75.7 cm) when compared to the previous levels and the average distance is considered to be large and inappropriate (Getachew et al ,2010) These results are in agreement with Edrris et al , (2020).

Table 2: Average Seed to Seed Spacing

soil penetration resistance (kg/cm^2)	mean seed to seed spacing (cm)
100-70	50.8
70-45	47.9
45-25	75.7

Table 3: Analysis of Variance for Seed to Seed Spacing

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	304	152.19	0.09	0.9170
soil resistance	2	141	70.44	0.04	0.9607
Rows	1	2492	2491.67	1.42	0.2341
Error	570	1001247	1756.57		
Total	575	1004184			

*DF, degrees of freedom in the source, SS, sum of squares due to the source, MS, mean sum of squares due to the source, F, F-statistic, P, P-value

Table 4 shows the mean depth of planting which statistically analyzed by analysis of variance and depicted in table5. It is observed from table4 and table5, that the depth of planting is increasing with the decrease of soil penetration resistance. The planting depth varied firstly due to the variation of soil penetration resistance and uneven land surface and soil moisture content. This result is in line with that stated by **Huntenburg et al (2007)** who attributed such variations to be due to differences of soil moisture.

Table 4: Mean Depth of Planting

soil penetration resistance (kg/cm^2)	mean depth of planting(cm)
100-70	2.2
70-45	2.8
45-25	3.9

Table 5: Analysis of Variance Table for depth

Source	DF	SS	MS	F	P
Rep	2	16.88	8.43	2.30	0.1010
soil resistance	2	52.13	26.06	7.11	0.0009
Rows	1	15.18	15.17	4.14	0.0424
Error	570	2090.06	3.66		
Total	575	2174.25			

Table 6 and table 7 shows the impact of the three levels of soil penetration resistance on percentage of missing seeds. The results of the statistical analysis did not show significant differences in the percentage of missing seed in three levels of soil penetration resistance. (Table 6 and table 7). The relationship between the depth of the seeds and the highest level of soil penetration resistance is shown in Figure4. The figure indicate significant and strong association ($R^2 = 0.91$) between them. These results correspond to what is mentioned by **Kupiers, (1989)** when he used soil penetration resistance levels higher than 100 kg/cm^2.

Table 6: Percentage of missing seed

soil penetration resistance (kg/cm^2)	Percentage of missing seed (100%)
100-70	20
70-45	31
45-25	39

Table 7: Analysis of Variance Table for missing

Source	DF	SS	MS	F	P
Rep	2	0.385	0.19271	0.37	0.6887
soil resistance	2	0.948	0.47396	0.92	0.4000
Rows	1	4.516	4.51562	8.74	0.0032
Error	570	94.385	0.51647		
Total	575	00.234			

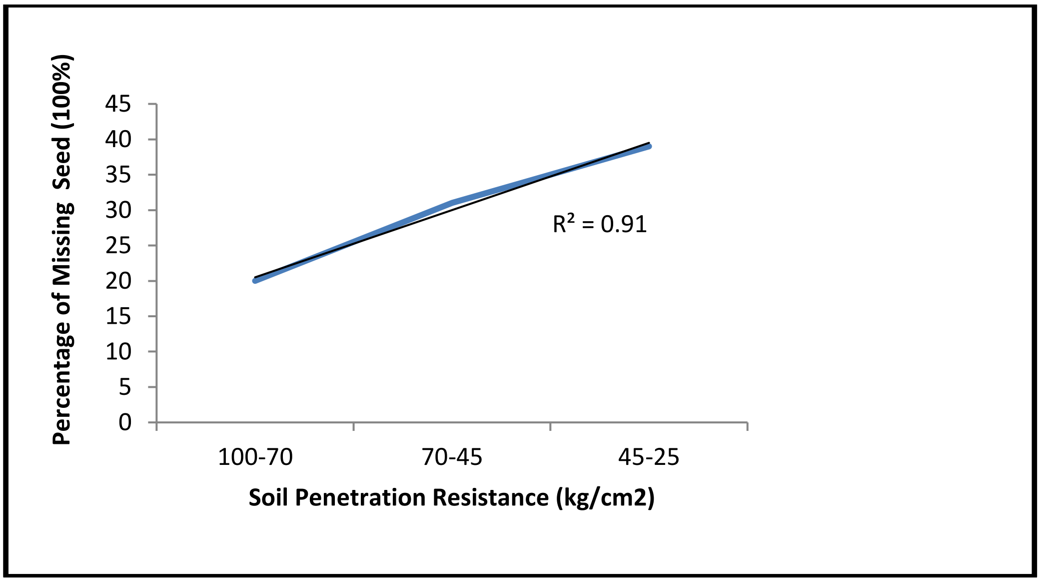

Figure3: Percentage of missing seed

The theoretical effective field capacity and field efficiency at different soil penetration resistance are shown in table8. The field efficiency was highest 63% at soil resistance (100-70 kg/cm^2). Though there was highest effective field capacity o.31 fed/hr at resistance (45-25 kg/cm^2), but efficiency was low due to the higher proportion of turning loss.

Table 8: The theoretical effective field capacity and field efficiency at different soil penetration resistance

soli resistance	seed distance(cm)	depth	missing seeds	field efficiency,%	Actual field capacity, fed/hr	heoratical field capacity, fed/l
100-70	50.8	2.2	20	63	0.2	0.3
70-45	47.9	2.8	31	50	0.3	0.6
45-25	75.7	3.9	39	44	0.37	0.7

The polynomial relations to describe variation of studied parameters (seed spacing (SS), seed depth (SD), missing seed (MS), field capacity (FC) and Field efficiency (FE)) with the different soil penetration can be described as given in Figure5 with the following regression relations:

a. The obtained regression equations were in the form of

$$f(x) = aSS^n + aSD^{n-1} + aMS^{n-2} + aFC^{n-3} + aFE^{n-4}$$

Where: a=----, n=----,

b. the change in seed spacing (SS), $f(SS) = 15.35x_2 + 44.33x$

c. seed depth (SD) , $f(SD) = 3.5x_2 + 68.23x$

d. missing seed (MS), $f(MS) = -1.5x_2 + 22.13x$

e. field capacity (FC) and $f(FC) = 0.25x_2 - 0.15x + 2.1$

f. Field efficiency (FE) , $f(FE) = -0.015x_2 + 0.145x + 0.07$

These relations are given to help the decision-maker to decide on the level of soil penetration resistance expected to attain by tillage machine if he decided to attain a certain set of agronomic evaluation attributes or a certain one (Figure4).

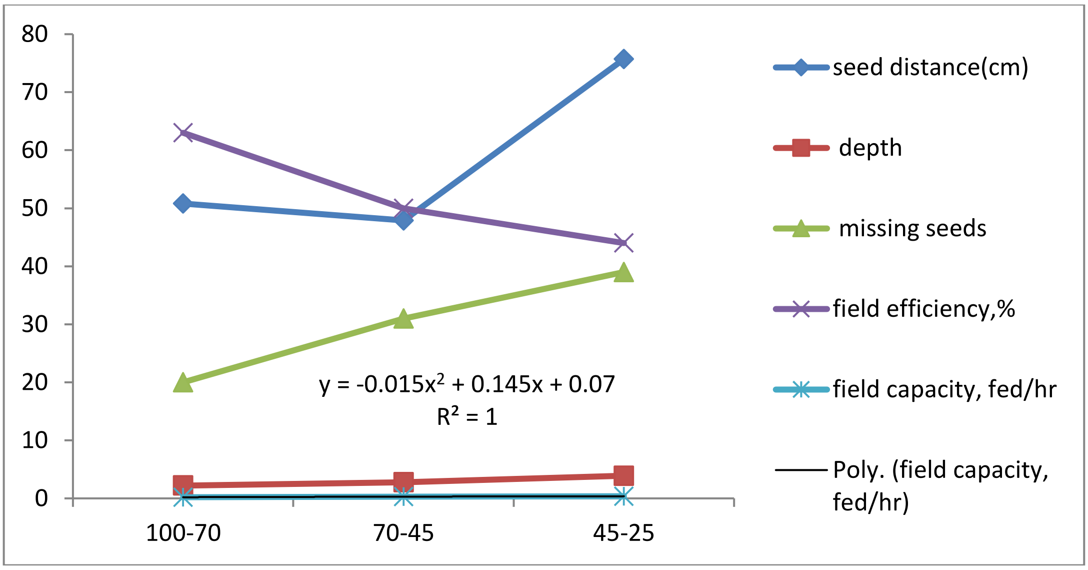

Figure 4: The polynomial relations between the studied parameters with the different soil penetration can

4. CONCLUSIONS

The planter gave average plant spacing of 48 51.1 cm, row spacing of 70 - 60 cm and depth of planting 2 – 3.4 cm of potato seeds. The results revealed that the increase in the soil penetration resistance induced a significant decrease in the depth of planting. The results shows that no significant different between the two levels of higher and medium soil resistance (100-70kg/cm^2 and 70-45kg/cm^2), for seed to seed spacing, while there are a significant different in the low penetration resistance level (24-45 kg/cm^2). The results of the statistical analysis did not show significant differences in the percentage of missing seed in three levels of soil penetration resistance. At the recommended soil resistance the effective field capacity and field efficiency of the planter was about 0.20 ha/hr and 63%, respectively. The developed polynomial relations between the studied evaluations attribute soil penetration resistance can be used to predict the field attribute to implement for certain soil penetration resistance

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