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DEVELOPMENT OF SEED DRILL MACHINE TO CULTIVATE RICE GRAINS IN HILLS BETWEEN FURROWS

Asaad DERBALA[1], Adel ELMETWALLI[1], El-Amine ARIF[2], Hany HASHEM[2], Mohamed I. EL-DIDAMONY*[1]

[1]Tanta University, Faculty of Agriculture, Agriculture Engineering Department, Tanta 31527, Egypt, Emails: asaadderbala@yahoo.com, agri.mid@gmail.com
[2]Agricultural Engineering Research Institute (AEnRI), Agricultural Research Center (ARC), Giza 12611, Egypt, Email: hh_atef@yahoo.com

Corresponding author: hh_atef@yahoo.com, hanyatef_152392@agr.tanta.edu.eg

Abstract

Rice is one of the strategic crops in Egypt and the world. Therefore, the main objective of the research was to modify and develop the seed drill to suit the cultivation of rice and add the digger to make a path for the cultivation area to direct the irrigation water. The modification and development were done in the workshop of the Rice Mechanization Center (RMC) in Kafr El-Sheikh Governorate, and field experiments were carried out on the rice variety "Sakha Super 300" with the planting seasons 2021 and 2022. The field experiments were carried out using the modified hill seed drill under four different planting forward speeds, namely, 2.55, 4.01, 6.11, and 8.38 km/h.; three different hills spacing between within the row, namely, 12.5, 15.5 and 17.5 cm; and three different cell volumes of feeding rollers namely, 354, 428 and 509 mm^3 with a fixed depth of 6 mm. The results showed that when the forward speed of cultivation increased, the field capacity increased and power requirements, and a decrement percentage in field efficiency and energy consumption at any given load for modified hill drill. The minimum values of grain yield (3.45, 3.41, and 2.94 Mg/fed) were obtained at planting forward speed of 8.38 km/h., for grain cell volume of 354 mm^3 under 12.5, 15, 17.5 cm hill spacing, respectively. However, the maximum values of grain yield (4.79, 4.74, and 4.34 Mg/fed) were obtained at planting forward speed 2.55 km/h., and grain cell volume of 509 mm3 under 12.5, 15, and 17.5 cm hill spacing, respectively.

Key words: *direct-seeded rice, rice grain hill drill, hill spacing, planting rice in furrow*

INTRODUCTION

More than half of the population in Egypt depends on rice (Oryza sativa L.), making it one of the most significant crops in that country. An imputed value of 1.186235 million feddan of Egypt's rice areas are cultivated, yielding 4.84 million metric tonnes annually [7]. Mechanized rice planting methods can be divided into two categories: direct seeding and transplanting [1]. Direct-seeded rice DSR is an alternative cultivation technique to conventionally transplanted rice. It does not require seedlings due to sow seeds directly in the field and eliminating the need for nursery raising and its related processes [24]. DSR can generally be divided into dry-DSR (sowing dry seeds in dry soil), wet-DSR (sowing pre-germinated seeds in moist soil), and water-seeding (sowing dry or pre-germinated seeds in standing water) [15].

As direct seeding of rice crops has a shorter development period than traditional transplanting, it establishes rice fields more quickly and requires roughly 25% less work overall, reduces the need for energy, reduces the need for water (by 35–40%), matures the plant sooner (7–10 days), improves the efficiency with which fertilizer is used, and increases yields by 10% at low production costs [3, 16]. Therefore, compared to puddled transplanted rice, direct-seeded rice (DSR) with optimum management methods provided a comparable or greater yield with an overall net benefit up to 4,400–5,000 Rs/ha while utilizing 30–50 % less irrigation water (CTPR) [9]. For high-value rice harvests, mechanical transplanting may be more practical but is more expensive to utilise than direct seeding [26]. As the primary goal of sowing operations is to plant seeds in rows at the required depth and spacing between seeds, cover the seeds with soil, and provide sufficient compaction over the seeds. The sowing machine is therefore a tool that aids in planting seed in the appropriate location, helping the farmer save time and money [14].

Precision hill seeding and drill seeding give an alternative measure to current problems such as large amounts of seeds, high missed hill percentages, and uneven seedling taking in the process of machine transplanting rice [24]. Precision direct seeding technology has emerged as the direction for developing mechanized rice planting for both rows and hills released the seeds at a fixed spacing, not in a flowing stream with a uniform spacing between plants within a row and contributes to crop productivity and field efficiency by making sure that the precise number of seeds is planted [26, 21, 22]. Rice seeds are uniformly distributed in the population thanks to mechanized precision hills direct seeding, which also improves aeration and light transmission, prevents damage to the root system, results in well-developed individual roots, more productive tillers, a high ear-forming rate, and increases yield. Furthermore, the hill direct-seeded rice had much greater productivity than the drill direct-seeded rice, which might be attributed to a higher proportion of efficient tillers [5, 27].

Because there was less rivalry among the plants for scarce resources like light, water, and nutrients, there was more output as a result of uniform seed dispersion in the soil. Many elements, including the seed metering mechanism, tube-delivered seed, furrow opening design, physical features of the seed, and soil conditions, influence how seeds are distributed in the soil [10]. One of the most crucial factors that leads to an appropriate plant population and enhances crop quality and production is uniformity of longitudinal seed deposition [20]. Improving seed distribution uniformity during the sowing process contributes to the proximity of the plant growing area per seed relative to each other, resulting in an increase in yield [19]. The coefficient of variation (C.V.%) of longitudinal scattering increased from 10.2 to 12.2, and from 13 to 13.4%, with increasing planting speeds from 0.64 to 0.89 and 1.19 to 1.42 m/sec [8].

Increasing sowing forward speed from 6.8 to 11.17 km/h resulted in fuel consumption figures falling from 7.164 to 5.360 L/ha, having a substantial impact on seeding rate, fuel consumption, and effective field capacity [11, 13]. When the machine's forward speed is between 2.8 and 3.2 km/h, the sowing depth pass percentage is at least 75%, the qualifying row spacing rate is at least 80%, the rate pass row spacing rate is at least 90%, and the quantity of seeds per hill is at least 75%, all of these conditions are met [25]. In comparison to other sowing speeds, the 11.43 km/h speed had a higher effective field capacity of 1.08 ha/h, a lower fuel consumption per unit area of 8.11 l/ha, a lower total operating cost per unit area of 13,594 ID/ha (10.875 US$/ha), and a lower energy requirement of 29.40 kW/ha. The slip percentage was also within acceptable bounds at 10.98%. The first sowing depth of 3 cm outperformed other sowing depths by recording lower slippage percentage (4.64%), higher effective field capacity (0.87 ha/h), higher field efficiency (71.72%), lower fuel consumption per unit area (8.38 L/ha), lower operating costs for machinery units (16,721 ID/ha; 13.376 US$/ha), and lower energy consumption [12].

The main objective of the study is to find alternatives to the traditional methods of rice cultivation that consume large amounts of water and seeds. As Egypt and the world tend to save water due to the global water problems and seek to use optimal methods for agriculture that require less water needs and give high productivity. Therefore, the seeding machine was developed to suit the cultivation of rice, in addition to adding a digger that works on digging lines and paths to direct irrigation water.

MATERIALS AND METHODS

Experimental work

The machine was manufactured and developed in the central workshop of the Rice Mechanization Center (RMC) in Mait El Diba in Kafr El-Sheikh affiliated to the Agricultural Engineering Research Institute (AERI), Agricultural Research Center (ARC) in Giza, and field experiments were conducted at (RMC) farm. During 2021 and 2022 growing seasons using rice grain variety of "Sakha Super 300" to study the factors affecting on the sowing accuracy and uniformity of modified hill drill in a "clayey soil" according to the soil mechanical analysis of the experimental field in "Soil, Water and Environment Research Institute" as shown in Table (1).

Table 1. Soil mechanical analysis of the experimental field

Clay %	Slit %	(Clay + Slit) %	Sand %	Caco$_3$ %	Organic matter %	Soil type
53.32	17.63	70.95	29.05	1.3	1.71	Clay

Source: Soil, Water and Environment Research Institute.

The seed drill machine before developed

The seed drill machine was of the type (Tye), USA made, it consists of a main frame, grain hopper, metering device, furrow openers, grain tubes, drill wheels and transmission gearbox, as shown in Table (2). It was originally designed for cultivation on flat ground.

Table 2. Specification of the seed drill machine (Tye) before development.

Items		Seed drill
Dimensions	Length. mm	1,500
	Width, mm	3,000
	Height, mm	1,400
	Row spacing, mm	150
	No. of rows	20
	Operating width, mm	3,000
	Total mass, kg	560
Seed hopper capacity, kg		350
Feeding type		Fluted wheel
Grain tubes		Smooth
Furrow opener		Hoe type
Covering device		U-shaped knife
Marker		Knife
Tractor power used, kW		45
Coupling method		3-point direct coupling
Transmission system		Chain
Number of wheels		2

Source: Authors' calculation.

Main frame: The main frame of the seed drill (Tey-type) made from welded square and rectangular hollow iron tubes.

Grain hopper: the grain hopper of the seed drill is made of galvanized sheets 15 mm thick, 3,000 mm long, 400 mm wide, and 550 mm high, and the sides of the seed hopper, at a height of 120 mm from the bottom of the hopper, were at an inclination of 54° with a suitable cover. 20 circular holes in the bottom of the hopper, with a diameter of 70 mm, allow seeds to exit into the feeding system.

Metering device: the metering device of the seed drill was consisted of a plain flanged disc that interfered with an internally fluted feed wheel. The seeding rate can be controlled by the exposed length of the internally fluted feed wheel by moving. The seed maximum flow rate occurs when the fluted wheel covers the entire width of the gate, the flow rate also varies with the rotational speed of the fluted wheel as shown in Photo 1.

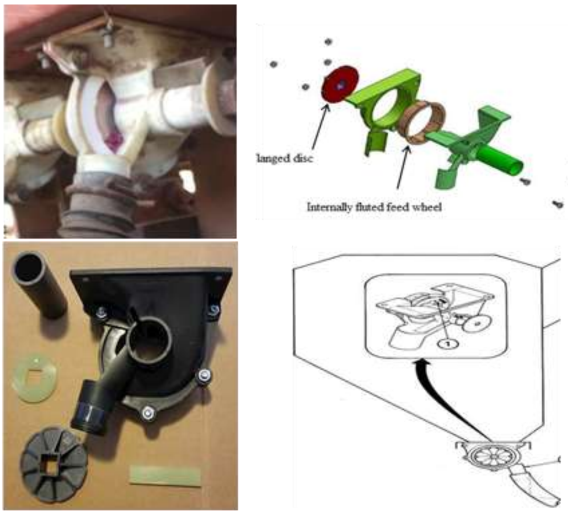

Photo 1. Metering device of the seed drill before developed.
Source: Authors' own illustration.

Grain tubes: the seed tube has a smooth inner surface and a 25 mm diameter. It is attached to the end pipe of the seed delivery funnel in the bottom of the hopper that receive grains from metering device and transport them to the furrow.

Furrow openers: hoe type, they open a furrow on the soil surface with the required depth into which the grain will be planted.

Transmission gearbox: the power is transmitted to the feeding system from the ground wheel by two chains and three sprockets, the first with 54 teeth attached to the ground wheel, the second with 21 teeth in a double row attached to an intermediate shaft fitted in front below the main frame, and the third with 21 teeth attached to the feeding shaft.

Drill wheels: two wheels (with a diameter of 710 mm, a circumference of 2,250 mm, and a width of 177.8 mm) were fitted on the main axle of the seed drill with suitable attachments. The ground wheels are used to transmit power to operate grain feeding mechanism.

The seed drill machine after developed

The modified hill drill used in this study mainly consists of a main frame, seed hopper, metering (feeding device) transmission gearbox, seed tubes, furrow openers, seed covering device, additional attached bed ridgers, and markers. The main technical specifications of the modified hill drill are shown in Table 3. While, the side view, Elev. Charts and photo of the modified hill seed drill are shown in Fig. 1 and Photo 2.

Table 3. Main specifications of the modified hill drill

Items		Modified hill drill
Dimensions, mm	Length	1,350
	Width	2,700
	Height	1,400
	Operating width	240
	Row spacing	15
	No. of rows	12
	Ridgers spacing	26
	No. of ridgers	3
	Total mass, kg	500
Seed hopper capacity, kg		280
Feeding mechanism		regular roller with 5 cells on the circumference
Grain tubes		Smooth
Furrow opener		Shoe type
Coupling method		3 Point direct coupling
Transmission system		Chain
Number of wheels		2

Source: Authors' calculation.

Grain hopper: the grain hopper of the modified hill drill made of a galvanized sheet 15 mm thick, 2,400 cm long, 400 cm wide, and 550 mm high, and the sides of the seed hopper were modified at an inclination of 41° to ensure free flow of seeds inside the hopper, with a suitable cover.

A 12 rectangular holes were created at equal distances in the bottom of the hopper, with a length of 72 mm and a width of 40 mm, to setup the modified feeding rollers inside the hopper with a height of 15 mm.

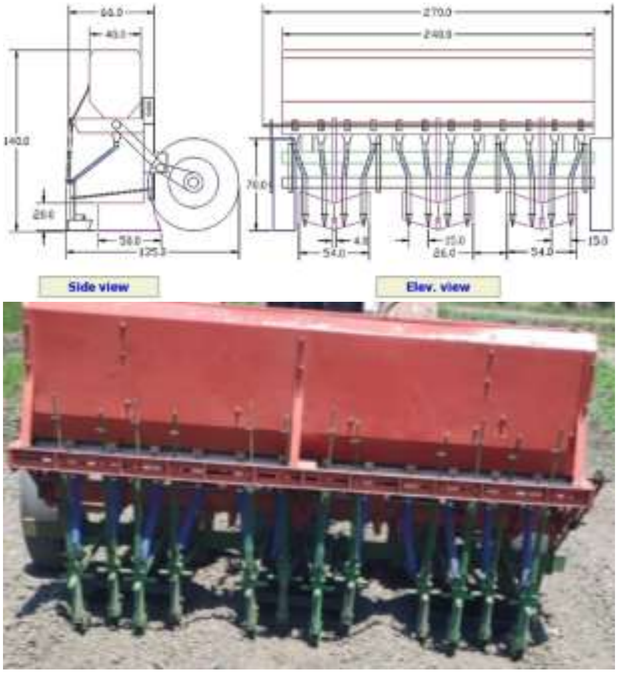

Fig. 1 and Photo 2. Side view and Elev. of the modified hill drill
Source: Authors' own illustration.

Metering device: the metering device after a modification consists of a regular roller with 5 cells on the circumference of the feeding roller, which is fabricated from Artillon Teflon material with a square inner hole (16 × 16 mm) and outer diameters of 79.6 mm, and a thickness of 38.5 mm as shown in Photo 3.

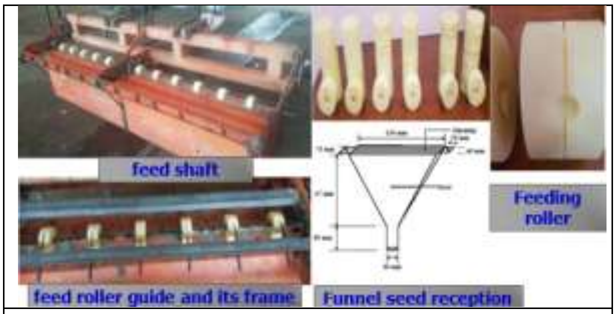

Photo. 3. Metering device after modification.
Source: Authors' own illustration.

Photo. 4. Additional soil bed ridgers
Source: Authors' own illustration.

The grain cells have a fixed depth of 6 mm with different volumes (diameters) of 354 mm^3 (10 mm φ), 428 mm^3 (11 mm φ), and 509 mm^3 (12 mm φ), respectively. The feeding rollers are installed on the feeding shaft at the internal bottom of the grain hopper. When the shaft rotated, the cells filled with rice grain and dropped them into the grain receiving funnel, which is installed on a frame at the external bottom of the grain hopper. Then rice grain enter the grain tubes and fall by the gravity force into a furrow, which has been opened by a furrow opener share as shown in Photo 4.

***Additive bed ridgers*:** an additional three soil bed ridgers were fixed on the modified hill drill frame in front of the furrow openers for making bed ridges in same time of direct sowing using the modified hill drill. The ridger penetration angle and distance between ridger were 5° and 260 mm, respectively as shown in photo (3).

***Transmission gearbox*:** The ground wheels are used to transmit power to operate grain feeding mechanism of the modified hill drill through an intermediate shaft fitted in front below the main frame and then to the feeding mechanism shaft via 4 sprockets and 2 chains of drive transmission with speed ratios of (1:2.6, 1:3, and 1:3.6) to change the hill spacing within rows of modified hill drill.

Power unit

A Yanmar tractor 500DT (50 HP (37 kW) 4WD) was used to mount the modified hill drill on its three-hitch point device during the laboratory/field calibration and field experiment.

Scope of variables

To realize the purpose of this study, a series of field experiments were carried out using the modified hill seed drill under the following different study variables:

(a)***Sowing forward speeds:*** The performance of the modified hill seed drill was tested under four different sowing forward speeds, namely, 0.71, 1.11, 1.7, and 2.33 m/s (2.55, 4.01, 6.11, and 8.38 km/h).

(b)***Intra-row hill distances:*** The performance test of the modified hill seed drill was carried out using three different distances between hills within the row, namely, 12.5, 15.5 and 17.5 cm.

(c) ***Feeding cell volume:*** Three different cell volumes of feeding rollers for the modified hill drill were used, namely, 354 mm^3 (10 mm φ), 428 mm^3 (11 mm φ), and 509 mm^3 (12 mm φ), with a fixed depth of 6 mm.

Measurements

Physical and mechanical properties of rice grains

The measurements of physical and mechanical properties of rice grain variety (Sakha super 300) at the laboratory of Rice Mechanization Center (RMC). The obtained results were tabulated in Table 4.

Table 4. Physical and mechanical properties of rice grain variety (Sakha super 300)

Rice grain Sakha super 300	Rep.	Max.	Min.	Av.	SD	CV.
Moisture content, %	5	13.5	12.8	12.9	0.2	1.55
Length, (mm)	100	7.97	6.62	7.32	0.26	3.55
Width, (mm)	100	3.62	2.92	3.3	0.15	4.55
Thickness, (mm)	100	2.39	1.78	2.12	0.11	5.19
Volume, (mm^3)	10	33.51	21.34	28.15	2.58	9.17
Arithmetic mean diameter, mm.	100	4.53	3.87	4.24	0.13	3.07
Geometric mean diameter, mm.	100	3.93	3.39	3.71	0.11	2.96
Sephericity, %.	100	54.38	46.97	50.71	1.44	2.84
Wight of 1000 seeds, (g)	100	26.35	25.85	26.18	0.25	0.97
True density, (kg/m^{-3})	10	1104	1096	1100	3.22	0.29
Bulk density, (kg/m^{-3})	10	597	592	594	3.54	0.60
Porosity, (%)	10	46.2	45.9	46	0.15	0.33
Angle of repose, (o)	5	30.94	28.42	29.3	0.96	3.28
Shape index,	100	3.11	2.49	2.77	0.12	4.33
Aspect ratio, %	100	50.22	38.69	45.09	2.36	5.23
Surface are, mm^2	100	48.58	36.14	43.26	2.66	6.15
Equivalent diameter, mm	100	3.55	3.21	3.41	0.07	2.05
Friction coefficient of iron, (m)	5	0.32	0.31	0.32	0.01	2.86

Source: Authors' calculation.

Laboratory and field calibration: rice grain damage was calculated and related to the grain discharge.

Seed damage: the percentage of rice grain damage was calculated and related to the grain discharge according to equation (1).

$$\text{Rice grain damage, \%} = \frac{M1 - M2}{\mathit{Total\ weight\ of\ the\ rice\ grain\ sample}} \times 100 \quad \text{...(1)}$$

where:

M1= Mass of rice grain damaged in the sample, which are manually separated from each rice main sample before it passed through the feeding system.

M2= Mass of rice grain damaged in the sample, after passing through the feeding system.

Rice grain germination: One thousand grains of rice grains were germinated to give the germination ratio before passing through the feeder. The actual germination ratio of the rice grains after passing through the feeding system was calculated after a sample of 100 seeds was germinated and replicated three times before planting.

Emergence percentage: **t**he number of plants per three meters of the row was counted for the four speeds (2.55, 4.01, 6.11, and 8.38 km/h) to determine the emergence percentage according to the following formula 2:

$$\textbf{Emergence percentage} = \frac{\text{Average No.of plant per sq.m}}{\text{Average No.of delivered grains per sq.m}} \quad \text{.........(2)}$$

Modified hill drill performance measurements

Tractor wheel slippage: the slippage percentage of tractor wheels was calculated according to Awady [2], using the following equation 3:

$$\text{Slippage, \%} = \frac{d_1 - d_2}{d_1} \times 100 \quad \text{.........(3)}$$

where:

d_1= Distance of 10 forward revolutions without load, m.

d_2= Distance of 10 forward revolutions with load, m.

Effective field Capacity and field efficiency: the theoretical field capacity (T.F.C.) was calculated using the formula 4:

$$\text{Theoretical field capacity, T.F.C.} \left(\frac{\text{fed}}{\text{h}}\right) = \frac{\text{Machine width (m)} \times \text{Speed (km/h)}}{4.2} \quad \text{.........(4)}$$

The effective field capacity (E.F.C.) at different operating speeds was estimated according to Srivastava et al [17], as follows:

$$\text{Effective field capacity, E.F.C.} \left(\frac{\text{fed}}{\text{h}}\right) = \frac{1}{\text{Total effective time (h) per feddan}} \quad \text{.........(5)}$$

While The field efficiency (η_f) was calculated using the following formula 6:

$$\text{Field efficiency, } \eta_{f\,(\%)} = \frac{\text{E.F.C.}}{\text{T.F.C.}} \times 100 \quad \text{.........(6)}$$

where:

T.F.C. = theoretical field capacity, fed/h

E.F.C. = effective field capacity, fed/h.

Power consumption and energy requirements: power consumption (EP) was determined for the modified hill seed drill according to Embaby [6], using the following equation 7:

$$\text{EP} = \left(F_c \times \frac{1}{60 \times 60}\right) \rho_f \times \text{L.C.V.} \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36}\ \text{(kW)} \quad \text{.........(7)}$$

where:

F_c = Fuel consumption, l/h.

ρ_f = Diesel fuel density (0.85 kg/l).

L.C.V. = Lower calorific value of diesel fuel (10,000 kcal/kg).

427 = Thermo-mechanical equivalent, kg.m/kcal.

η_{th} = Thermal efficiency of diesel engine, (40%).

η_m = Mechanical efficiency of diesel engine, (80%).

Estimation of the energy required for sowing rice crop was carried out using the following equation 8:

$$\text{Energy requirements (kW.h/fed.)} = \frac{\text{Power requirement (kW)}}{\text{Effective field efficiency (fed/h)}} \quad \text{.........(8)}$$

Sown grain scattering and uniformity.

The longitudinal scatterings and distribution uniformity of the sown grains (3 weeks after planting) were calculated for each treatment under study according to Steel and Torrie [18], also, the plant distribution was analyzed to determined coefficient of variation (CV) and to calculate the coefficient of uniformity of plants spacing using the following equations:

$$\text{Scattering} = \sqrt{\frac{\text{Sum of square of variance of seed scattering from its mean}}{\text{No. of hills}}} \quad \text{.........(9)}$$

$$\text{Coefficient of uniformity(\%)} = (1-\text{CV}) \text{ X100} \quad \text{.........(10)}$$

$$CV,\% = \frac{\text{SD of plant spacing}}{\text{Recommended plant spacing}} \times 100$$

....(11)

$$SD=\sqrt{\frac{(\text{Plant spacing - Recommended plant spacing})^2}{n}}$$

....(12)

where:
CV= coefficient of variation
SD = Standard deviation.

The coefficient of variation under 10% is considered excellent and with value under 20 % is generally considered acceptable for most field applications as reported by Coates [4].

Plant density: **t**he number of plants per hill and No. of plants/m^2 was measured as plant density after three weeks from sowing date for each treatment under study. For this measure, a wooden frame with the dimensions of 0.5 x 2 m was randomly placed in different areas for each treatment to determine the plant density.

Shape of soil surface profile: the changes in soil surface roughness before sowing effect, the bottom surface of the bed and the shape of the bed ridges top (and sides) after direct sowing rice grains using modified hill drill under different planting forward speeds with attached additional ridgers for making bed ridges were measured randomly by profile-meter according to the standard method of *ASAE*, [23] using a straight wood piece marked at 5 cm intervals and supported in both terminals on a constant height supports. A scale was used to measure the head at all points height of the soil surface profile. The mean and standard deviation for all points height of the soil surface profile were calculated to find the changes of the profile shape.

Crop yield and its components measurements

The crop yield and its components measurements were taken into consideration in this study. The grain and straw yields, in addition to the yield components such as number of productive tillers, panicle length, number of panicles per plant, number of grains per panicle, 1,000-grains weight and harvest index for each treatment under study.

RESULTS AND DISCUSSIONS

Laboratory and field calibration tests

During the laboratory and field calibration tests of modified hill drill, the visible mechanical damage; the germination ratio; No. of grain per hill, No. of grain per m^2, and calibrated seeding rate was determined and calculated under study variables of grain cell volume, hill spacing and planting forward speed.

Rice grain visible damage: the visible mechanical damage occurred in rice grains due to moving parts of metering device were measured and the values of obtained results were shown in Fig. 2.

These results indicated that, the visible mechanical damage was clearly observed in rice grain samples under calibration variables. An increase of grain cell volume or hill spacing decreased the obtained values of visible damage at any given level of planting forward speed. However, an increase in planting forward speed increased the visible mechanical damage at any given grain cell volume and hill spacing.

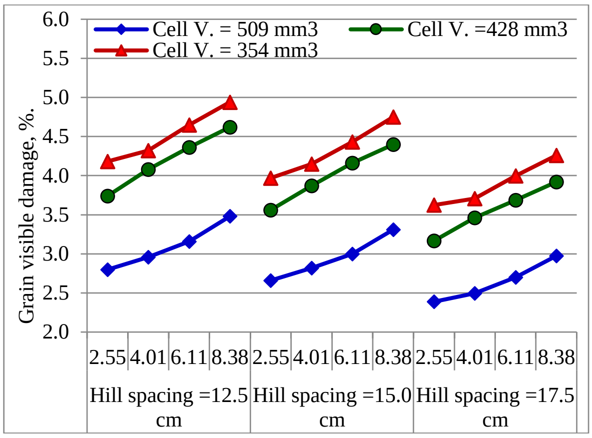

Fig. 2. Grains visible damage during field calibration of the modified seed hill drill under different levels of grain cell volumes, hill spacings and planting forward speeds.
Source: Authors' own results.

These results may be due to decreasing the velocity of moving parts for metering mechanism which decrease the chance grain damage. The highest value of visible rice grain damage of 4.94, 4.75, 4.26 % were obtained at the highest planting forward speed of 8.38 km/h, and lowest grain cell volume of 354 mm^3 under hill spacing of 12.5, 15, and 17.5 cm, respectively. However, the lowest value of visible rice grain damage of 2.8, 2.66, and 2.39 % were obtained at the lowest planting forward speed of 2.55km/h, and the highest grain cell volume of 509 mm^3 under hill spacing of 12.5, 15, and 17.5 cm, respectively.

Germination ratio: the results of germination ratio for rice grain samples obtained during laboratory and field calibration of the modified hill drill under different levels of grain cell volume, hill spacing and planting forward speed compared with same rice grain variety before putting in the modified seed hill drill hopper are illustrated in Fig. 3.

In general, the results indicated that an increasing in cell volume and hill spacing increased the obtained values of germination ratio. However, any increase in planting forward speed decreased the obtained values of germination ratio. Meanwhile, the value of germination ratio for rice grain before using it in hill drill hoper were higher than that obtained under any given calibration variables. These results may be due the visible mechanical damage values occurred for rice grain putted in the modified hill drill hopper for field calibration. Also, it could be mentioned that germination ratio was negatively affected by grain cell volume and hill spacing and positively affected by planting forward speed.

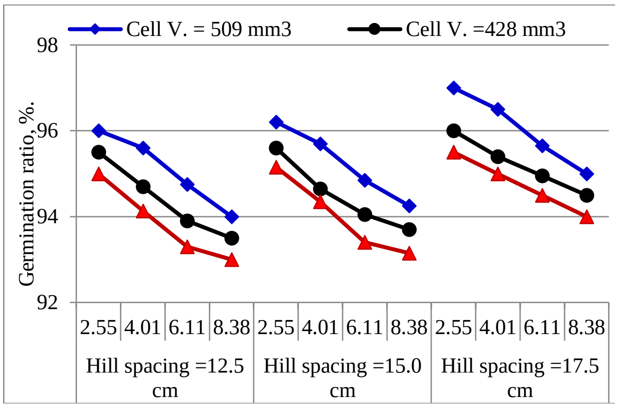

Fig. 3. Germination ratio for rice grains during field calibration of the modified seed hill drill under different levels of grain cell volumes, hill spacings and planting forward speeds.
Source: Authors' own results.

The recorded values of germination ratio of used rice grains in calibration process cleared that using the highest cell volume of 509 mm^3 gave the highest value of germination ratio of 96.0, 96.2 and, 97.0% at 2.55 km/h planting speed, under hill spacing 12.5, 15, 17.5 cm, respectively compared with 93.0, 93.15, and 94.0% when using the lowest cell volume of 354 mm^3 at 8.38 km/h planting forward speed, under hill spacing of 12.5, 15, and17.5 cm, respectively.

Calibrated seeding rate: the obtained results No. of grain per hill, No. of grain per m^2, and calibrated seeding rate listed in Table (5) indicated that, the different level of grain cell volume 354, 428, 509 mm^3 gave about 3-4, 4-6, and 7-9 grain per hill (cell), respectively. However, the count number of grains/m^2 was increased from 96 to 370 and the calibrated seeding rate (kg/fed.) was increased from 10.87 to 41.69 kg/fed. When calibrated the modified hill drill under 509 mm^3 cell volume, 12.5cm hill spacing and 2.55 km/h planting forward speed instead of 354 mm^3 cell volume, 17.5cm hill spacing and 8.38 km/h planting forward speed. Also, the obtained results in Table 5 cleared that, the values of number of grains/hill and seeding rate kg/fed., were increased by any increase in given levels of grain cell volume and planting forward speed under study and decreased with any increase in given levels of hill spacing under study.

Table 5. No. of grains per m^2 and seeding rate during field calibration of the modified seed hill drill under different levels of grain cell volumes, hill spacings and planting forward speeds

Hill Spacings, cm	Speed, km/h	Grain cell volume, mm^3								
		354		428		509		354	428	509
		grains /hill	grains /m^2	grains /hill	grains /m^2	grains /hill	grains /m^2	Seeding rate; kg/fed		
12.5	2.55	4.15	181	5.38	234	8.49	370	20.37	26.40	41.69
	4.01	3.95	173	5.17	227	8.22	360	19.52	25.54	40.62
	6.11	3.61	160	4.48	198	7.35	326	18.03	22.34	36.71
	8.38	2.87	129	3.64	163	6.27	281	14.50	18.40	31.69
15.0	2.55	4.15	151	5.55	201	8.72	316	16.98	22.70	35.66
	4.01	3.92	143	5.33	195	8.43	308	16.15	21.93	34.70
	6.11	3.61	133	4.53	167	7.38	272	15.02	18.85	30.68
	8.38	2.87	107	3.64	136	6.43	240	12.08	15.33	27.09
17.5	2.55	4.18	130	5.51	171	8.71	271	14.67	19.32	30.54
	4.01	4.01	126	5.21	163	8.29	260	14.15	18.39	29.25
	6.11	3.64	115	4.51	143	7.53	238	12.98	16.08	26.84
	8.38	3.01	96	3.74	120	6.42	205	10.87	13.49	23.15

Source: Authors' own results.

Sowing accuracy and plant density

The emergence percentage, the longitudinal scatterings and distribution uniformity of the sown grains and planting density (plant/m^2) for sown rice plants using modified hill drill under study variables of grain cell volume, hill spacing and planting forward speed were counted at 3 weeks after planting and soil irrigated.

Emergence percentage: the recorded values of emergence percentage of rice grain after planting in the field, it could be cleared that, the emergence percentage values were taken the similar trend for germination ratio among the different levels of grain cell volume, hill spacing and planting forward speed under study as shown in Fig. 4.

The planting forward speed and grain cell volume was found to be highly significant effect on the emergence percentage of rice grains after planting in the soil than that effect of hill spacing.

The highest values of emergence percentage of 83.51, 83.43, and 84.87% were obtained when using the highest grain cell volume of 509 mm^3 at 2.55 km/h planting forward speed and 12.5, 15.5, 17.5 cm hill spacing, respectively. However, the lowest values of emergence percentage of 76.94, 77.35, and 77.75 % were obtained when using the lowest grain cell volume of 354 mm^3 at 8.38 km/h planting forward speed and 12.5, 15.5, and 17.5 cm, hill spacing, respectively.

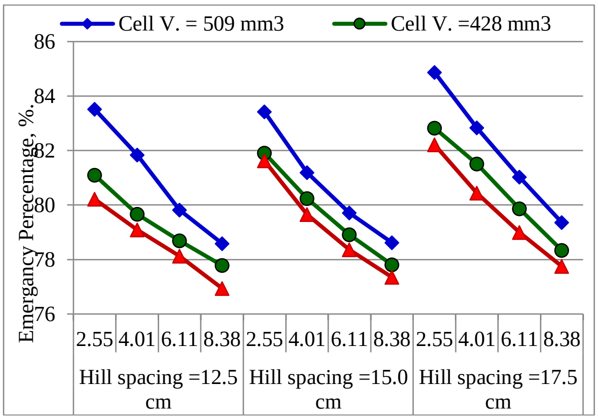

Fig. 4. Emergence percentage for rice grains during field calibration of the modified seed hill drill under different levels of grain cell volumes, hill spacings and planting forward speeds
Source: Authors' own results.

Longitudinal scattering: the distance between successive hills (plants) in each row was measured to calculate the longitudinal scattering (distribution) within the row under the different levels of grain cell volume, hill spacing and planting forward speed. Also, the coefficient of variation (C.V.) for the longitudinal scattering and the coefficient of distribution uniformity were calculated and the obtained results were illustrated in Fig. 5 and 6.

These results indicated that, there are a negative correlation for the effect of grain cell volume and hill spacing on the variation coefficient (C.V.) of longitudinal scattering values under any given level of planting forward speed and a positive correlation for the effect of planting forward speed on the variation coefficient (C.V.) values of longitudinal scattering under any given level of grain cell volume and hill spacing. Increasing the grain cell volume from 354 to 509 mm^3 decreased the variation coefficient (C.V.) of the longitudinal scattering values from 17.8 to 12; from 13.45 to 10.25; and from 12.48 to 8.59% when operating the modified hill drill at planting speed of 2.55 km/h under hill spacing 12.5, 15.0, 17.5 cm, respectively.

However, increasing the hill spacing from 12.5 to 17.5 cm decreased the coefficient of variation (C.V.) of the longitudinal scattering values, from 17.18 to 12.48; from 14.34 to 10.30; and from 12 to 8.59 % when operating the modified hill drill at planting forward speed of 2.55 km/h under different grain cell volume of 354, 428, and 509 mm^3, respectively.

Meanwhile, increasing the panting forward speed from 2.55 to 8.38 km/h results in an increase in the coefficient of variation of the longitudinal scattering from 12.48 to 20.35; from 10.3 to 18.52, and from 8.59 to 16.89 % at hill spacing of 17.5 cm under levels of grain cell volume, 354, 428, and 509 mm^3, respectively.

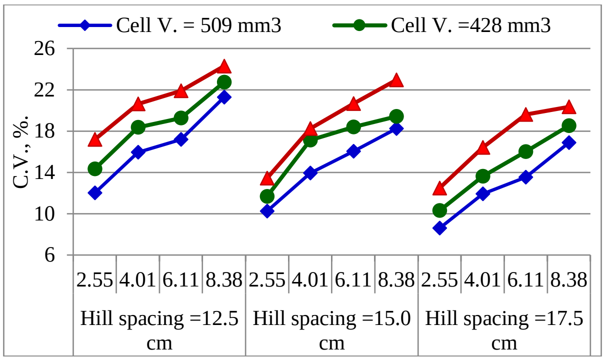

Fig. 5. Coefficient of variation (C.V.) of grain longitudinal scattering during evaluation of modified hill drill under different grain cell volumes, hill spacings and planting forward speeds
Source: Authors' own results.

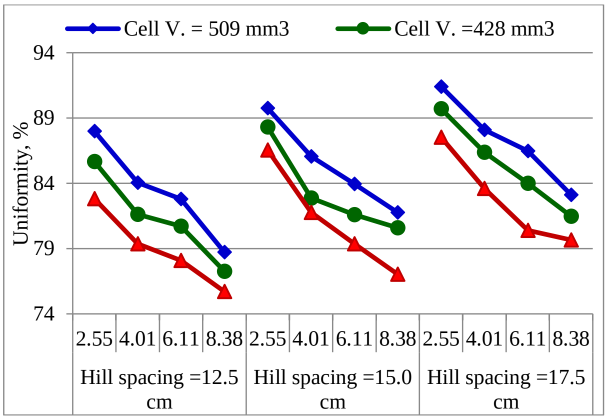

Fig. 6. Coefficient of plant distribution uniformity of modified hill drill under different grain cell volumes, hill spacings and planting forward speeds
Source: Authors' own results.

Also, from the results illustrated in Fig. 6 which shown the coefficient of plant distribution uniformity when using modified hill drill under different study variables, it could be stated that increasing the coefficient of plant distribution uniformity by increasing cell volume and hill spacings and by decreasing the planting forward speed. The highest value of uniformity of 87.52, 89.7, and 91.41% under cell grain volume 354, 428, and 509 mm^3, respectively at forward speed of 2.55 km/h, and 17.5 cm hill spacing. While the lowest value of uniformity of 75.7, 77.26, and 78.72 % under grain cell volume 354, 428, and 509 mm^3, respectively at forward speed of 8.38 km/h, and 12.5 cm hill spacing.

Planting density: regarding to the obtained results of planting density (plant/m^2) for sown rice plants using modified hill drill under study variables of grain cell volume, hill spacing and planting forward speed were counted at 21 days after soil irrigated and recorded in Table 6.

The recorded data indicated that, there is positive correlation between number of plant/m^2 and study parameters. Increasing cell volume increased the number of plant/m^2 at any given levels of planting forward speed and hill spacing under study. However, increasing planting forward speed and hill spacing decreased the number of plant/m^2 at any given levels of grain cell volume under study. The obtained results may be referred to the significant effect of study parameters on the visible mechanical damage, germination ratio and emergency percentage. The maximum values of plants/m^2 (309, 264, and 230) were obtained when using largest cell volume of 509 mm^3 at 2.55 km/h planting forward speed under hill spacing of 12.5, 15, 17.5 cm, respectively. While the minimum values of plants/m^2 (99, 84, and 75) were recorded when using the smallest level of grain cell volume (354 mm^3) at the highest level of planting forward speed (8.38 km/h) under hill spacing of 12.5, 15, and 17.5 cm, respectively.

Table 6. No. of plants/m^2 of rice crop after sowing using modified hill drill under grain cell volumes, hill spacings and planting forward speeds

Hill Spacings, cm	Planting Speed, km/h	Cell Volume 354mm^3	Cell Volume 428 mm^3	Cell Volume 509 mm^3
12.5	2.55	145	190	309
	4.01	137	181	295
	6.11	125	156	260
	8.38	99	127	221
15.0	2.55	123	165	264
	4.01	114	156	250
	6.11	105	132	217
	8.38	84	107	189
17.5	2.55	107	142	230
	4.01	101	133	215
	6.11	91	114	193
	8.38	75	94	163

Source: Authors' own results.

Modified hill drill evaluation performance

The evaluation performance of modified hill drill includes tractor slip ratio; effective field capacity and efficiency; power requirements and energy consumed were carried out during direct sowing rice grains under different planting forward speeds with normal (without making bed ridges) and full loads (for making bed ridges with attached additional ridgers) of modified hill drill.

Slip ratio: measuring values of the slip ratio for the tractor used to mount modified hill drill during evaluated it under the study variables of grain cell volume, hill spacing and planting forward speed, were plotted in Fig. 7. The obtained results of tractor slip ratio cleared that, an increase in planting forward speed, increased the values of tractor slip ratio. The average values of the tractor slip ratio were 3.13, 3.25, 4.25, and 6 % under the planting forward speed of 2.55, 4.01, 6.11, and 8.38 km/h, respectively during normal load of modified hill without attached bed ridgers compared with 5.75, 6.00, 7.25 and 8.75 % for full load of modified hill drill (with attached additional bed ridgers) under the same mentioned previous planting forward speed of normal load.

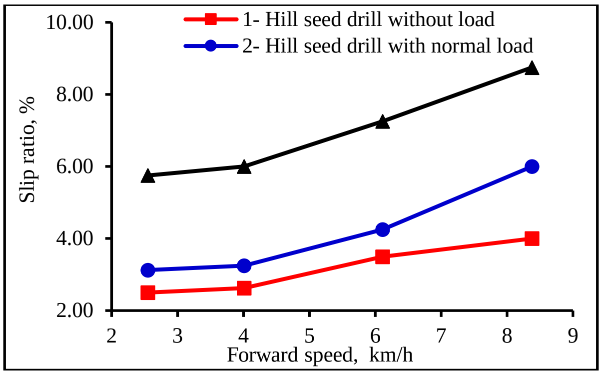

Fig. 7. Tractor slip ratio during evaluation of modified hill drill under different loads and planting forward speeds
Source: Authors' own results.

Effective field capacity and efficiency: the obtained results of the effective field capacity and efficiency for the modified hill drill under study variables illustrated in Fig. 8. From these results it could be cleared that, an increase in planting forward speed results in an increase in effective field capacity and a decrease in field efficiency at any given load for modified hill drill. Using attached additional ridgers for making bed ridges (full load) tends to decrease in the obtained values of affective field capacity and field efficiency at any given planting foreword speed. These results may be due to increase tractor wheel slip ratio with increasing hill drill load. The values of effective field capacity of 1.26, 1.82, 2.65, and 3.53 fed./h were obtained when using modified hill drill with normal load at 2.55, 4.01, 6.11, and 8.38 km/h planting forward speeds, respectively compared with 1.20, 1.75, 2.58, and 3.44 fed./h when using modified hill drill with full load under the same pervious forward speed, respectively. Meanwhile, the field efficiency values of 83.31, 79.42, 75.85, and 73.80% were obtained for using modified hill drill under normal load compared with 79.36, 76.42, 73.9, and 71.88 % for using modified hill drill under full load at 2.55, 4.01, 6.11, and 8.38 km/h planting forward speeds, respectively.

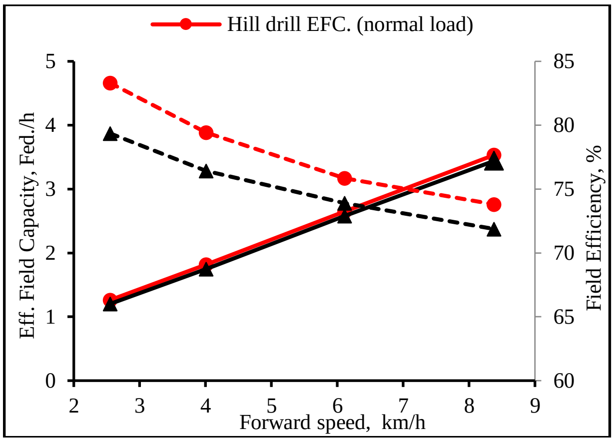

Fig. 8. Effective field capacity and field efficiency under different planting forward speeds and normal/full loads of modified hill drill
Source: Authors' own results.

Power requirements and energy consumption: the obtained values of power requirements and energy consumed under different planting forward speed and normal or full loads of modified hill drill were illustrated in Fig. 9.

With respect of the obtained results for power requirement and energy consumption due to use the modified hill drill for planting rice grains, it could be concluded that increasing planting forward speed results in an increment percentage in power requirements, and a decrement percentage in energy consumption for any given modified hill drill load used in the study. These results may be due to increasing fuel consumption with any increase of planting forward speed and modified hill drill load.

The maximum values power requirements were 14.56 and 17.16 kW for using modified hill drill at 8.38 km/h planting forward speed with normal and full load of modified hill drill, respectively.

While the minimum values of 9.61 and 10.98 kW were obtained for using modified hill drill under planting forward speed of 2.55 km/h with normal and full load, respectively.

Also, from the results of energy consumption shown in Fig. (9), it could be observed that, an increase of planting forward speed decreases the values of energy consumption at any given load of hill drill due to increasing effective field capacity with increasing planting forward speed.

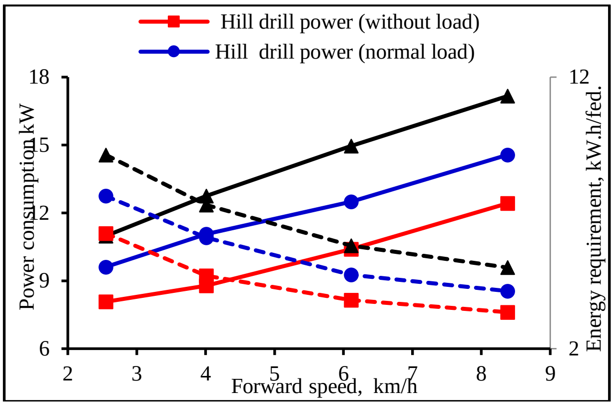

Fig. 9. Power requirements and energy consumed under different planting forward speeds and normal/full loads of modified hill drill
Source: Authors' own results.

The highest values of energy consumption of 7.62 and 9.14 kW.h/fed. Were obtained at 2.55 km/h planting forward speed with normal and full load of modified hill drill. While the lowest value of 4.12 and 4.99 kW.h/fed were obtained at planting speed of 8.38 km/h with normal and full load of modified hill drill, respectively.

Height of the ridge profile and cross-section area: According to the results obtained using the modified hill drill shown in Fig. 10, the effect of forward speed on the height of the ridge profile is as follows: the highest value of the height of the ridge profile is 12.5 cm obtained at forward speed 2.55 km/h; the lowest value of the height of the ridge is 10.1 cm at forward speed 8.38 km/h during sowing. It was observed that when increasing forward speed from 2.55 to 8.38 km/h, the highest value of the ridge profile decreased by 19.2% during sowing.

Ridge profile height after 30 days of soil irrigation (sowing) with 5 days interval irrigation: the effect of 5 days interval irrigation on ridge profile height is a decrease in the height of the ridge from 12.5 to 11.8, from 11.03 to 10.4, from 10.3 to 9.6, and from 10.10 to 9.2 cm, at forward speeds of 2.55, 4.01, 6.11, and 8.38 km/h, respectively, after 30 days of soil irrigation.

Ridge cross-section shows the same trend, where cross-section area decreased from 0.0281 to 0.0227 when forward speed increased from 2.55 to 8.38 km/h.

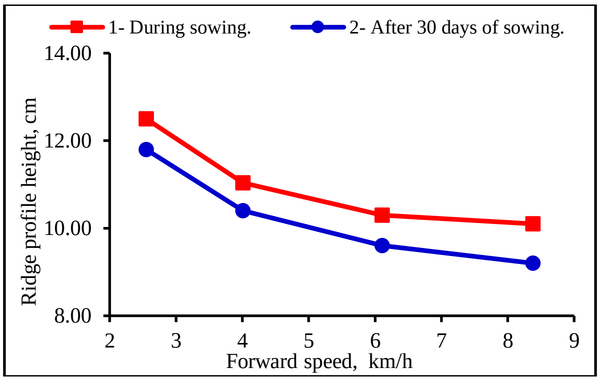

Fig. 10. Effect of forward speed on the ridge profile height, during sowing, and after 30 days of sowing
Source: Authors' own results.

Rice yield and its components:

The obtained results of yield and yield components of rice crop sown using modified hill drill under different grain cell volumes, hill spacing and planting forward speeds were listed in Table 7 and shown in Fig. 11.

The yield components including No. of grains/panicle, filled grain percentage (ripping ratio, %), 1,000 grains weight (g), straw yield (ton/fed.), harvest index (%) were taken into consideration as effective indicators for total grain yield of rice and straw under study variable. In general, the rice grain yield and straw yield values were found to be in a positive correlation with increasing grain cell volume levels and a negative correlation with increasing hill spacing and planting forward speed. The grain yield values ranged from 2.94 ton/fed., under 354 mm^3 cell volume, 17.5 (cm), hill spacing and 8.38 km/h, planting forward speed, to 4.79 ton/fed., under 509 mm^3 cell volume, 12.5 hill spacing and 2.55 km/h planting forward speed. The minimum values of grain yield (3.45, 3.30, and 2.94 ton/fed.) were obtained at planting forward speed of 8.38 km/h for grain cell volume of 354mm^3 under 12.5, 15, 17.5 cm hill spacing respectively. However, the maximum values of grain yield (4.79, 4.74, and 4.34 ton/fed.) were obtained at planting forward speed 2.55 km/h and grain cell volume of 509 mm^3 under 12.5, 15, and 17.5 cm hill spacing, respectively.

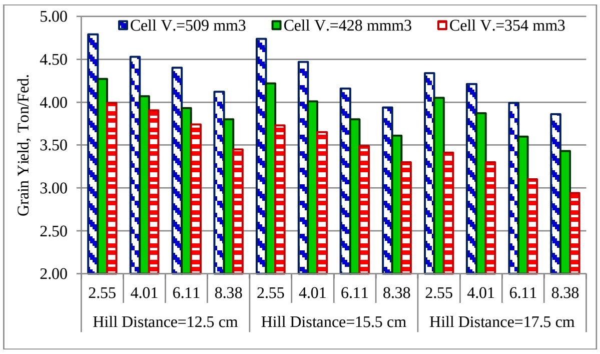

Fig. 11. Grain yield of rice crop sown using modified hill drill under different grain cell volumes, hill spacing and planting forward speeds
Source: Authors' own results.

Table 7. Grain yield and yield components of rice crop sown using modified hill drill under different grain cell volumes, hill spacing and planting forward speeds

Hill Spacings, cm		12.5			15.5			17.5		
Measuring Items	Planting Speed, km/h.	Cell Volume, mm^3								
		354	428	509	354	428	509	354	428	509
No. of Grain/Panicle	2.55	173	201	215	172	183	201	156	179	194
	4.01	161	190	208	150	173	198	145	162	183
	6.11	153	175	191	139	163	190	129	152	170
	8.38	141	170	185	133	156	182	121	143	166
1000 Grain Weight, (g).	2.55	25.53	25.22	24.92	25.57	25.39	25.13	25.59	25.47	25.19
	4.01	25.61	25.34	25.13	25.62	25.54	25.27	25.71	25.56	25.41
	6.11	25.69	25.46	25.26	25.73	25.59	25.38	25.78	25.62	25.45
	8.38	25.83	25.66	25.54	25.91	25.77	25.53	25.91	25.77	25.53
Filled Percentage (%)	2.55	96.74	95.31	93.12	97.19	96.39	93.66	97.37	96.43	95.28
	4.01	96.75	95.40	93.30	97.22	96.43	93.98	97.44	96.50	95.44
	6.11	96.89	95.89	94.05	97.43	96.52	94.66	97.82	96.90	95.70
	8.38	97.39	96.35	94.94	97.75	96.63	95.20	98.24	97.21	96.26
Grain Yield. (ton/fed.)	2.55	3.99	4.27	4.79	3.73	4.22	4.74	3.41	4.05	4.34
	4.01	3.91	4.07	4.53	3.65	4.01	4.47	3.30	3.87	4.21
	6.11	3.74	3.93	4.40	3.49	3.80	4.16	3.10	3.60	3.99
	8.38	3.45	3.80	4.12	3.30	3.61	3.94	2.94	3.43	3.86
Straw Yield. (ton/fed.)	2.55	5.10	5.82	6.78	4.55	5.29	6.47	4.04	4.80	5.88
	4.01	4.84	5.43	6.41	4.28	5.26	6.31	3.97	4.63	5.62
	6.11	4.76	5.26	6.27	4.21	5.23	6.25	3.94	4.37	5.24
	8.38	4.66	5.16	6.21	4.18	5.15	5.93	3.92	4.32	4.93
Harvest Index, (%)	2.55	43.88	42.30	41.39	45.03	44.37	42.30	45.77	45.78	42.46
	4.01	44.66	42.83	41.39	46.02	43.27	41.47	45.36	45.54	42.82
	6.11	43.98	42.76	41.22	45.34	42.07	39.97	44.04	45.14	43.22
	8.38	42.53	42.39	39.89	44.11	41.20	39.93	42.84	44.28	43.89

Source: Authors' own results.

Meanwhile, the obtained results of yield components such as straw yield, No. of grain/panicle and 1,000 grains weight were giving the same trend of grain yield under different study parameters.
However, the yield components of filled grain % results in an inverse trend compared to grain yield.in other words, increasing the level of planting forward speed and grain cell volume and hill spacing results in an increase in filled grain % as shown in Table 7.

CONCLUSIONS

Based on this research, the following conclusions were drawn:
-An increase of grain cell volume or hill spacing decreased the obtained values of visible damage at any given level of planting forward speed. However, an increase in planting forward speed increased the visible mechanical damage at any given grain cell volume and hill spacing.
-An increasing in cell volume and hill spacing increased the obtained values of germination ratio and emergence percentage. However, any increase in planting forward speed decreased the obtained values of germination ratio and emergence percentage.
-Increasing the coefficient of plant distribution uniformity by increasing cell volume and hill spacings and by decreasing the planting forward speed.
-Increasing planting forward speed results in an increment percentage in effective field capacity and power requirements, and a decrement percentage in field efficiency and energy consumption at any given load for modified hill drill.
-The minimum values of grain yield (3.45, 3.41, and 2.94 ton/fed.) were obtained at planting forward speed of 8.38 km/h for grain cell volume of 354mm^3 under 12.5, 15, 17.5 cm hill spacing respectively. However, the maximum values of grain yield (4.79, 4.74, and 4.34 ton/fed.) were obtained at planting forward speed 2.55 km/h and grain cell volume of 509 mm3 under 12.5, 15, and 17.5 cm hill spacing, respectively.

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