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Development and Evaluate a Small Planter to Suit Planting Maize

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Abstract: One of the main reasons for the development of the planter is the lack of small machines for planting areas of less than an acre. Therefore, this planter was developed , which is planting two rows of maize, and it was tested for planting three varieties of maize Triple (Hybrid 310, Hybrid 352) and Single Hybrid 168 .The evaluation of developed planter is carried out through the terms of three forward speed (1.8, 2.7, and 3.5 km/h) and three speeds for grain metering device (6, 9, 11.6 rpm) equivalent to (3.8, 5.7, 7.3 m/min) for disc with an inclined circular cell shape. The results showed that the ideal forward speed is about 2.7 km/h giving the actual field capacity of 0.24 ha/h, the field efficiency of 63%, the power of 11.61 kW, the specific energy requirements of 49.36 kW.h/ha , the operating cost of 29.97 $/ha . The maize grains emergence (86.6, 93.1, 91.04%) , the grain longitudinal scattering (26.93, 25.7, 24 cm), the missing hills (13.4,6.9,8.96 %), the double plants (3.8, 6.73, 9.13%) , the production cost (3.25,2.41,1.75 $/ton) and the maize yield (9.21, 12.45, 17.17 ton/ha) for Hybrid 310, Hybrid 352 and Hybrid 168 , respectively at 2.7 km/h. Statistical analysis of the results showed that different letters under the same factor are significantly different at $p \leq 0.05$ as determined through the LSD test.

Keywords: Maize, mechanical, planter, metering device, power.

1. Introduction:

Maize (Zea mays) is the main cereal crop worldwide to its importance for human, animal, and poultry feed as in dry feed industry by up to 70 %, on bread ingredients by 20 %, as interference in some industries, such as obtaining glucose, fructose, and oil. It constitutes a staple food in many regions of the world. In addition to that, maize represents the third-largest crop after rice and wheat, **(Ministry of Agriculture-Egypt, 2021)**. In Egypt, the maize cultivated area is about 935778 ha which produces annually 7.3 million tons of maize grains approximately **(FAO, 2018).** Due to higher yield potential, short growing period, high value for food, forage and feed for livestock, poultry and a cheaper source of raw material for agro- based industry, it is increasingly gaining an important position in the cropping system **(Saif et al., 2003).** The most uniform seed distribution is usually obtained with combinations of seed size, cell size, and cell speed that gives about 100 % average cell fill, they also showed that the cell diameter or length should be about 10 % greater than the maximum seed dimension and the cell depth should be about equal to the average seed diameter or thickness. The percentage of damaged seeds increases as the cell speed is increased. Damage is also greater if the cells are too large. Damage can be minimized by making the cutoff device flexible and gentle or by employing designs in which individual seeds are lifted out the seed mass so that no cutoff is needed, as with an inclined plate, pneumatic, and vacuum type metering units **(Kepner et al., 1978).** The seed emergence percentage decreased by increasing planting forward speeds from 2.2 to 6.4 km/h with all mechanical planting methods used **(El Awady et al., 2004).** The maize is a plant with single productivity; therefore plant density determines yield significantly. Optimal plant density can be affected by the genetic properties and vegetation time of the given hybrid, just as by the conditions of the production area, by the crop yield and the extent of water and nutrient supply **(Peter and Mihaly, 2013).** The knowledge of some physical and mechanical properties of seeds is an important tool for designing agricultural machines and equipment for planting, harvesting, processing, packaging and storage. Some of the properties determined include size, geometric mean diameter, surface area, bulk volume, bulk density, true density, porosity, sphericity, angle of repose, coefficient of friction, rupture force and rupture energy **(Soyoye et al.,2018).**Seed metering mechanism is the core functional component of any planter. A new seed metering mechanism was developed for round seeds with the cell design termed 'Anjul' aimed to eliminate seed damage and obtain better seed singulation of seeds while metering. There was no visible damage to the seed by the planter. A comparison of X-Ray photographs of metered seeds with normal seeds was done for assessing seed damage. No crack or breakage in the metered seed happened **(Kumar et al., 2018).** With the development of precision farming technology, precision farming has become one of the most important means in the cultivation of certain crops such as corn, cotton and sugar beet, as precision farming enables to save a large amount of seeds, reduce labor and increase productivity **(Wang et al.,2020).** Mechanical properties of corn grains are of key importance in a design of processing machines whose energy demand depends on these properties **(Kruszelnicka, 2021).** Precision seeding requires that the corn drill drop seeds into the soil by specific in-row spacing while it's travelling speed fluctuate due to unevenness of the field ground. Presents a low-cost precision seeding control system for a conventional corn drill with mechanical metering devices of finger-pickup type. A median filtering method was implemented in the control system to process measurements from a rotary encoder in order to acquire stable values of the corn drill travelling speed. The metering unit was driven by an electric motor controlled by the metering ECU according to the actual travelling speed and the desired in-row spacing in real-time **(Yin et al., 2018).** Shoe and modified shoe-type furrow openers were tested and compared with three inverted-T furrow openers with rake angles of 75°, 65° and 55°. The newly designed inverted-T furrow openers were narrower than the shoe-type openers; they also had longer, hollow shanks and provided better options for adjustment to achieve the desired seeding depth and line spacing. Compared to shoe-type openers, better seeding depth, uniformity and higher degree of seed coverage were recorded with use of the inverted-T furrow opener with a 65° rake angle. This resulted in better seed coverage in the furrow, a higher emergence rate index, and the highest emergence percentage of maize and mung bean. Findings can be generalized to small holder production systems on loam and clay loam soils **(Hoque et al., 2021).** The hopper in seed drill may be trapezoidal, rectangular or oval. The capacity of the hopper also varies, depending upon the size of the machine. Making the hopper trapezoidal in shape help to insure a free flow of seed **(Kual and Egbo, 1985)**. By increasing planting forward speed both longitudinal and transverse scattering increased **(Metwalli et al., 1998).** Seed size had an important effect on the accuracy of seed spacing, seed rate and damage. Increasing cell speed generally reduced cell fill, increased seed damage and seed spacing along the row **(Korayem, 1986).** The percentage of seeds dropped per meter along the furrow decreased by about 20 % for the different crops by increasing operating speed. Also, lateral and longitudinal deviation of seeds along the row increased by increasing operating speed and decreasing seed size (Moussa, 1999). Performance of available planter on different parameter has been studied which shows tractor operated planter gives better result. Study also focus on their limitations of cost and source of power supply. There is scope of seed metering mechanism on developed tractor drawn planter which will changeable by other crop of metering plate. By attaching different varities of metering plate we can use multicrop planter for sowing of different crops **(Sahu et al., 2017).**The aim of this study is to development a small planter for planting maize in hills which suitable for small areas to save workers, grains, power, specific energy requirements and cost.

2. MATERIALS AND METHODS

Experiment was carried out to develop and evaluate a small planter to accommodate the planting of maize in hills and planting the Hybrids maize grains in the field at Shobra Sora village, Diarb Negm City, Sharkia province, Egypt during the season 2020 / 2021.

2.1 MATERIALS:

Developed planter: A planter dimensions 845 mm in length, 1056 mm in width and 665 mm in height planted in row provided with two tubes transfer grains from the hopper across a feeding device to the ground. Distance between planting tubes rows is about 70 cm and distance between grains in the same row 25cm. The planter was manufactured from low cost iron bars and galvanized steel sheet local material to overcome the problems of high power and high cost requirements under the use of imported machines and to develop local planter suitable for small holdings. The elevation, plan and side view of the planter is shown in **Figures (1- 3).**

Tractor: Kubota model with water cooled, four stroke diesel engine, and power of 22.07 kW.
Tested crop: Three varieties of maize were used one type of white maize (Triple Hybrid 310) and two varities of yellow maize (Triple Hybrid 352, Single Hybrid 168). Characteristics of the maize hybrids are provided in Table 1.

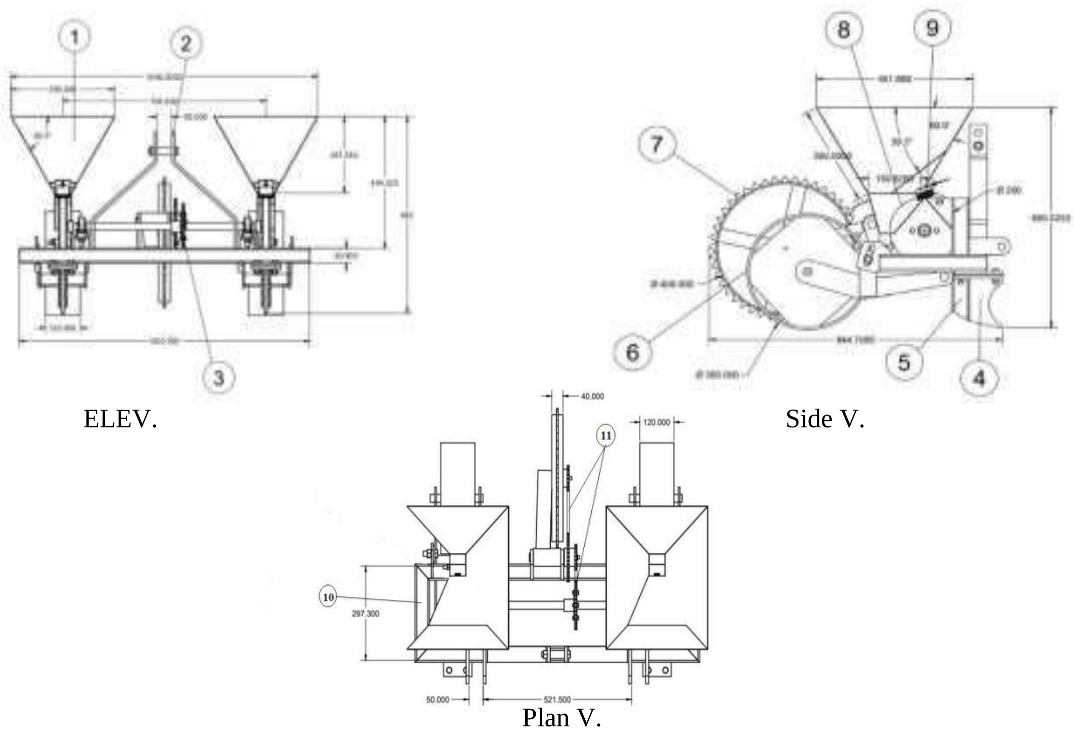
Table 1. Characteristics of the maize hybrids.

Characteristics	Hybrid 310 (white)				Hybrid 352 (yellow)				Hybrid 168 (yellow)			
	Min.	Max.	Mean	SD.	Min.	Max.	Mean	SD.	Min.	Max.	Mean	SD.
Length, mm	9.25	13.03	11.62	0.90	10.65	13.62	12.11	0.83	9.14	11.58	10.02	0.62
Width, mm	7.87	11.3	9.28	0.781	6.42	9.43	7.74	0.68	6.8	9.29	8.29	0.65
Thickness, mm	3.67	5.8	4.33	0.521	3.7	6.68	4.52	0.78	3.52	7.25	4.81	1.03
Volume, mm^3	208.17	301.79	260.99	31.66	148.22	301.34	242.94	51.19	154.15	317.45	207.96	41.40
Mass of 100(M_{100}), g	24	25	24.46	0.32	20	21.8	20.97	0.62	21	22.5	21.6	5.48
Bulk density, g/cm^3	0.77	1	0.862	0.073	0.75	1.06	0.92	0.080	0.667	0.900	0.775	0.059
True density, g/cm^3	1.29	1.96	1.68	0.24	1.29	2.04	1.6	0.24	1.05	1.50	1.28	0.115
Repose angle, degree	20.96	29.49	24.58	2.71	20.38	29.19	24.88	2.97	20.65	32.62	25.90	4.47

The developed planter consists of seven main parts:

1. Frame: Main frame of the planter was constructed from iron bars with dimensions of the frame are 1000 mm length, 297 mm width and 35 mm thickness. The planter units are mounted on a main frame which is attached to three-point hitch of the tractor. The metering wheel was connected at the frame. It is transmitted the motion to the grain metering device with a proportion to the planter forward speed.

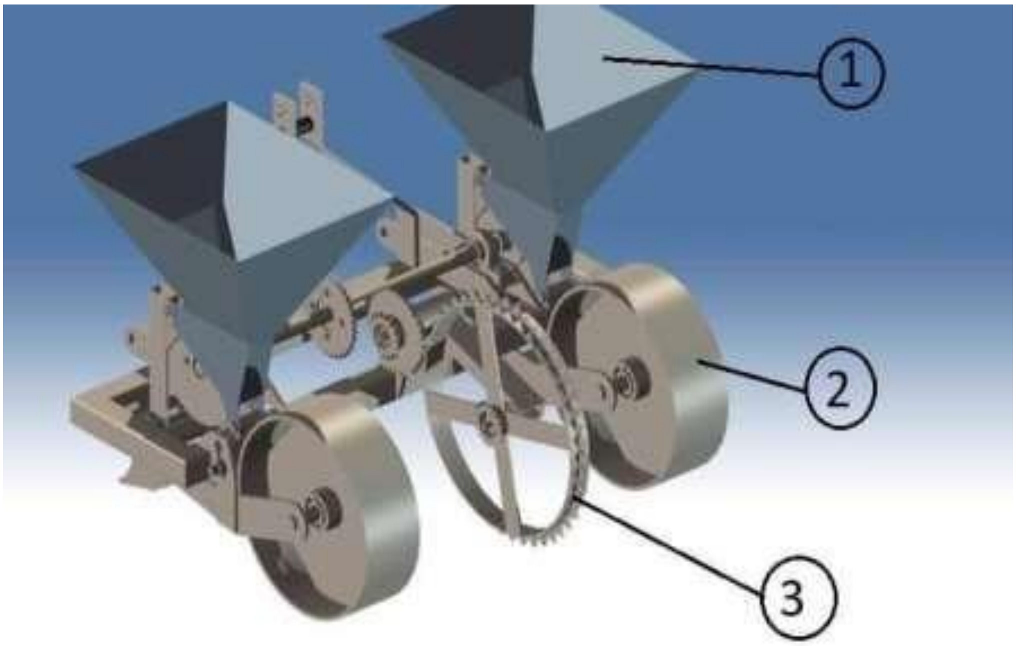
2. Grains hopper: The grain hopper was made from galvanized steel with a trapezoidal shape. The overall dimensions of the grain hopper are 36 cm length, 45 cm width and 26 cm height. The bottom of the hopper had an inclination angle of 32° with the horizontal plan.



Overall dimensions in mm.

No.	Part name	No.	Part name	No.	Part name
1	Grain hopper	5	Grain tube	9	Brush
2	Hitching points	6	Covering wheel	10	Frame
3	Transmission system	7	Metering wheel	11	Chains
4	Furrow opener	8	Grain metering device		

Figure 1. Three views of the developed maize planter.



No.	Part name
1	Grain hopper
2	Covering wheel
3	Metering wheel

Figure 2. Isometric for the developed maize planter.

3 . Grain metering device and brush: The grain metering device takes a feed from the bottom of the grain hopper to fall behind furrow opener. When the wheel of the metering turn, it transmits the motion to the grain metering devices, then fill cells with grains to fall behind the furrow opener. The diameter of grain metering device is 20 cm. The grain metering device made from Teflon. There is one grain metering device with an inclined circular cell shape is shown in **(Figure 4).**
An inclined circular cell shape has 13 mm length, 9 mm diameter and 8 mm depth. Grain metering device contains 20 hollow cells in the outer surround. Three speeds were used for grain metering device (6, 9, 11.6 rpm).

Figure 3. The developed maize planter mounted on the tractor.

Brush is plastic piece in the grain hopper, which forbid more than one grain enter the cell, where brush is directly above the grain metering device, and a tendency with a nail of the grain hopper makes it easy to jaw and install.
4. Metering wheel: The motion was transmitted to the metering device from metering wheel by chain and sprockets. Metering wheel with diameter of 40 cm and width of 4 cm was set in the center of the developed planter.

5. Transmission system: Sprockets and chains were used as a transmission system. The transmission system of the planter is used to transmit power from a large metering wheel mounted in the middle of the previous sprocket of planter frame. The sprocket of 18 teeth on metering wheel was connected with sprocket of 36 teeth on the frame by chain. The other sprocket is on the frame with 18 teeth on the same shaft of the previous sprocket was connected with sprocket of 36 teeth on the metering-device shaft with another chain. So, the transmission ratio between metering wheel and metering device shaft was 4:1. The metering device has 20 cells and the diameter of metering wheel is 40 cm. So, the grain spacing in the same row is about 25 cm.

6. Furrow openers: Shoe-type openers are intended for work on leveled well tilled soils. In terms of construction, these shoes are distinguished by the angle of entrance into the soil. The openers consist of a narrow casing opener tip, with a sharp knife set at an obtuse angle to the horizontal for formation of furrow.

7. Covering device: The covering device should press the soil firmly around the grains, cover them to the proper depth and yet leave the soil directly above the row loose enough to promote easy emergence. So, a press-wheel with diameter of 35 cm and width of 12 cm was set in the developed planter as a covering device.

Figure 4. Inclined with circular shape

Instruments:

Electric Balance: The grains were weighed using a sensitive electronic balance with an accuracy of 0.1 gram. The balance JL – Jewelry Light is characterized by the accuracy and quality with small sizes.

Stop watch: A stop watch was used to estimate the time requirements of different operations. The accuracy of stop watch 0.01 sec.

Graduated cylinder: Graduated cylinder was used to measure the fuel consumption for each operation.

Digital caliper with Vernier: Dimensions of grains were determined by digital caliper reading up to 15 cm with accuracy 0.05 mm. A digital caliper manufactured from hardened stainless steel was made in China.

2.2 METHODS:

The performance of the developed planter was studied under the following variables:
1. Three forward speeds: 1.8, 2.7 and 3.5 km/h,
2. Three speeds for grain metering device with an inclined circular cell shape: 6, 9, 11.6 rpm equivalent to 3.8, 5.7, 7.3 m/min, respectively.
3. Three of maize varieties of maize were used (one type of white maize (Triple Hybrid 310) and two varities of yellow maize (Triple Hybrid 352, Single Hybrid 168).

The soil was plowed twice by chisel plough and leveled by land lever. The experiments were done in a 4200 m^2 in the village of shobra sora and the number of experimental pieces was 27 pieces.

Measurements

The grain physical and mechanical properties were measured using the following equations**:**

Volume: It is determined as the procedure of **Vursavus and Ozguven, (2004)** as follows:

$$V = \frac{\pi}{6} \; L \,.\, W \,.\, T \qquad (1)$$

Where: L, W and T are length, width and thickness in mm, respectively.

Bulk density is specified according to **Davies, (2009)** as follows:

$$\rho_b = \frac{M_s}{V} \qquad (2)$$

Where ρ_b is the bulk density of grains, g/cm^3, M_s is the mass of grains, g.

True density is specified according to **Davies, (2009)** as follows:

$$\rho_s = \frac{M}{V_t} \qquad (3)$$

Where ρ_s is the true density of the individual grain, g/cm^3, M is the mass of the individual grain, g, V_t is the volume of the individual grain, cm^3.

Repose angle (α) : cylindrical tube of 50 mm height and 30 mm diameter was set on a clean surface and filled with grain samples was estimated. By steadily lifting and removing the cylinder, maize grain samples took on a cone shape. The cone's radius and height were measured. The angle of repose (α) was estimated using the formula of **Yildirim and Tarhan, (2016)** as follows:

$$\alpha = \tan^{-1}\left(\frac{L}{R}\right) \qquad (4)$$

Where L is the height of cone, mm, R is the radius of cone, mm.

Some field measurements:

Emergency: The emergency ratio was determined after three weeks from planting in a one-meter square by the following equation:
E = (Number of plants/m^2) / (Theoretical number of plants /m^2) ×100 (5)

Longitudinal scattering: The distance between 20 hills in the row for all treatments was measured. The longitudinal scattering of grain placements was determined statistically by the standard deviation of the measured distances according to **Steel and Torrie (1980).**

$$\sigma = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} \quad (6)$$

$$C.V. = (\sigma/\bar{x}) \times 100 \quad (7)$$

Where:

σ : Standard deviation $\bar{x}$: The average distance, cm

n : Number of readings x: Distance between hills on row, cm

C.V.: Coefficient of variation in row from average distance, %

The coefficient of variation under 10% is considered excellent and with value less than 20 % is generally considered acceptable for most field applications as reported by **Coates (1992).**

Transverse scattering: The transverse scattering was calculated by the same method mentioned with longitudinal scattering but around the centerline of row **Metwalli et al., (1998).**

Missing hills percentage:
The theoretical adjusted hill numbers in 5 m long distance in the same row were estimated and the actual were accounted and the missing hill numbers were found in the same distance. The percentage of the missing hills was given by **Helmy et al., (2005)** using the following equation:
Missing hills, % = (No. of missing hills / No. of theoretical hills) × 100

Percentage of hills has double plants: The percentages of hills have double plants were calculated according to **Helmy et al., (2005)** by using the following equation;
Percentage of hills has double plants = (No. of hills have double plants/m)/ (No of theoretical hills/m) ×100

Theoretical field capacity: It was determined using the following formula:

$$Pth = S \times W / 10000 \quad (10)$$

Where:
Pth: Theoretical field capacity of the planter, ha/h.
S: Forward speed, m/h. W: Rated width, m.

Actual field capacity: It was determined by using the following formula:

$$Pact = (60 / Tu + Ti) \quad (11)$$

Where:
Pact: The actual field capacity of the planter, ha/h
Tu: The utilized time per ha, min. Ti: The summation of time lost per ha, min.

Field efficiency: It was calculated using the following formula:

$$\zeta = (Pact / Pth) \times 100 \quad (12)$$

Fuel consumption: Volumetric fuel consumption per unit time was determined by measuring the volume of the consumed fuel. It was calculated as the following:

$$VFC = V/t \quad (13)$$

Where: VFC = The volumetric fuel consumption rate, l/h;
V = The volume of consumed fuel, l; t = The duration of the experiment, h.

Power: The following formula was used to estimate Power (P) as provided by **Hunt (1983):**

$$P = (FC/c) \times (\eta_{th}/100) \times HV \quad (14)$$

where P = Required power, kW FC = Fuel consumption, kg/h
ηth = The thermal efficiency, % c = Constant, 3600.
HV = The fuel heating value, kJ/kg

Specific energy requirements: It was calculated using the following formula

$$\text{Specific energy requirements} = \frac{\text{Required power (kW)}}{\text{Actual field capacity(ha / h)}}, \text{kW. h / ha} \quad (15)$$

Cost analysis: It was determined using the following equation **(El Awady 1978):**

$$C = \frac{p}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (1.2\ W.S.F) + \frac{m}{144} \quad (16)$$

Where:-

C = Hourly cost, $/h.
P = Price of planter, $.
h = Yearly working hours, h/year.
a = Life expectancy of the planter, h.
i = Interest rate/year, %
F = Fuel price, $/l.
t = Taxes, over heads ratio, %
r = Repairs and maintenance ratio, %
m = Monthly average wage, $
1.2 = Factor accounting for lubrications.
W = Engine power, kW.
S = Specific fuel consumption, l/kW.h.
144 = The monthly average working hours, h

The operational cost was determined using the following equation:

$$\text{Operating cost} = \frac{\text{Planter cost}}{\text{Actual field capacity}} \text{ , \$ /ha} \quad (17)$$

$$\text{Production cost} = \frac{\text{Operating cost}}{\text{Grain yield}} \text{ , \$ /ton} \quad (18)$$

Distance between grains in the same row: The distance between grains in the same row was calculated according to **(Kepner et al., 1978):** by using the following equation;

$$ds = \frac{\pi \times D}{I \times Nc} \quad (19)$$

Where:-

ds = The intra distance between seeds in the row, cm
D = The diameter of the driver ground wheel, cm
I = Speed ratio (from drive wheel shaft to metering shaft)
Nc = No. of cells on the circumference of metering device

3. RESULTS AND DISCUSSIONS

The performance of developed planter was discussed through the following criteria by using one shape of grain metering device (an inclined circular shape).

3.1 Germination ratio: The three varities of maize grains Hybrids Triple 310 (White), Triple 352 (Yellow), Single 168 (Yellow) are characterized by high germination ratio where (98.8, 98, and 97.7 %), respectively, as shown in (**Figure 5)**.

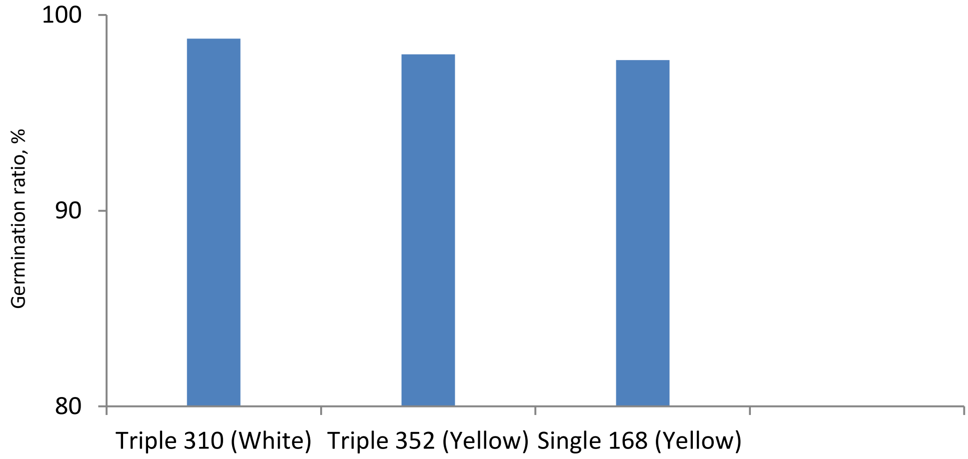


Figure 5. Germination ratio for three varities.

3.2 Theoretical and actual field capacity:

The effect of forward speed on theoretical, actual field capacity and field efficiency as shown in **(Figure 6)**. The lowest theoretical field capacity of 0.25 ha/h. was obtained with forward speed of 1.8 km/h. While the highest theoretical field capacity of 0.49 ha/h. was obtained with forward speed of 3.5 km/h. The minimum actual field capacity of 0.18 h/ha was obtained with forward speed of 1.8 km/h. While the maximum actual field capacity of 0.28 h/ha was obtained with forward speed of 3.5 km/h. The minimum field efficiency of 57 % was obtained with forward speed of 3.5 km/h. While the maximum field efficiency of 72 % was obtained with forward speed of 1.8 km/h. Field efficiency decreased by increasing forward speed, due to the portion of lost time to turn and repair was a big time for planting operation in the fast speeds.

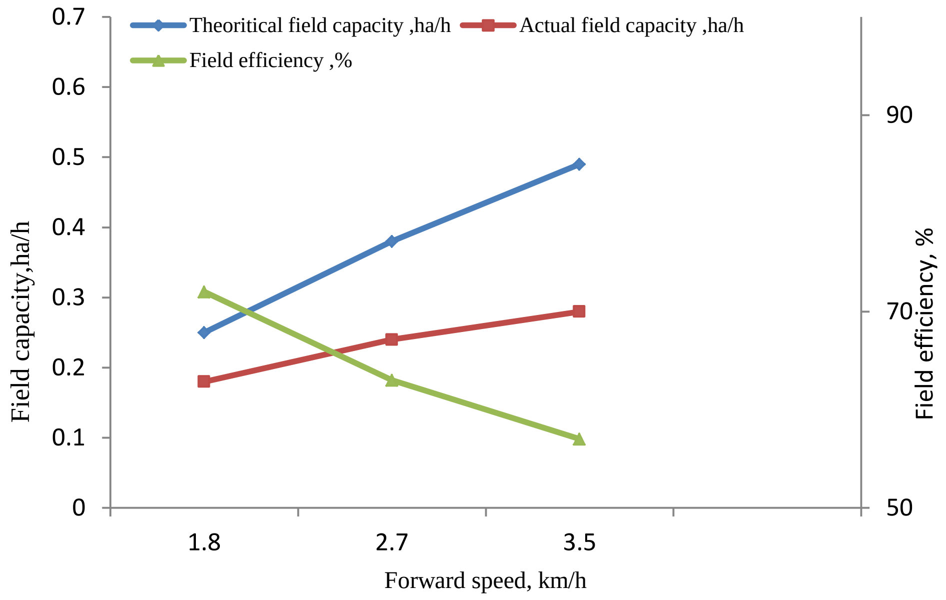


Figure 6. Effect of forward speed on theoretical, actual field capacity and field efficiency.

3.3 Grains emergence:

The effect of forward speed on maize grains emergence as shown in **(Figure 7)**. Data obtained show that increasing forward speed from1.8 to 3.5 km/h, measured for three varities of maize grains Hybrids Triple 310 (White), Triple 352 (Yellow), Single 168 (Yellow) decreased grains emergence from 90.82 to 81.27 %, from 95 to 90.25 % and from 95 to 89.06 %, respectively. These results agree with **El Shal and Awny, (2019),** reported that by increasing forward speed the emergence ratio decreased.

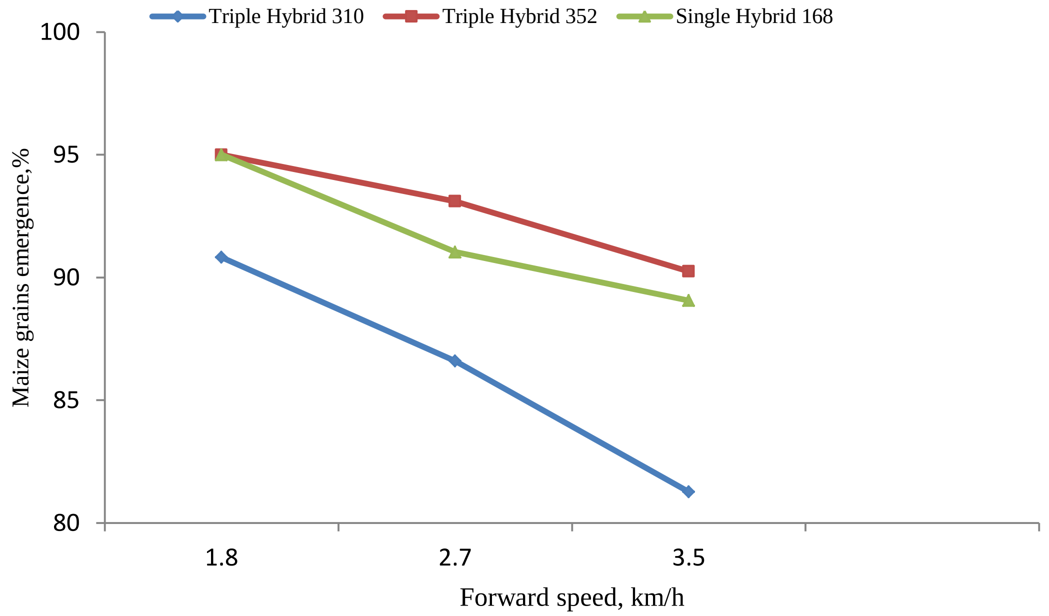


Figure 7. Effect of forward speed on maize grains emergence.

3.4 Longitudinal scattering and transverse scattering :

It noticed that increasing the forward speed of developed planter from 1.8 to 3.5 km/h increased the grain scattering for three varities of maize grains Hybrids Triple 310 (White), Triple 352 (Yellow), Single 168 (Yellow) from 25.14 to 30.49 cm, from 24 to 29.1 cm and from 21 to 26 cm, respectively as shown in **Figure 8.** There is no significant transverse scattering observed. These results agree with **Liu et al., (2017),** who stated that the coefficient of variation of seed spacing increased with the increase of travel speed.

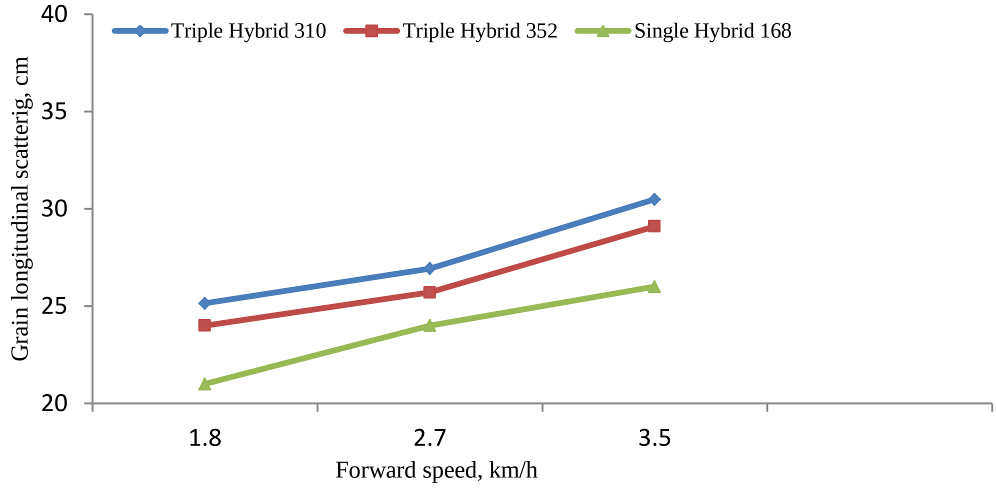


Figure 8. Effect of forward speed on grain longitudinal scattering.

3.5 Power and specific energy requirements:

It is noticed that increasing the forward speed of developed planter from1.8 to 3.5 km/h increased the required power from 9.776 to 13.748 kW. On the other hand, the specific energy requirements decreased from 54.12 to 49.60 kW.h/ha. As increasing the forward speed of the developed planter from 1.8 to 2.7 km/h, specific energy requirements decreased from 54.12 to 49.36 kW.h/ha. As increasing forward speed from 2.7 to 3.5km/h. specific energy requirements increased from 49.36 to 49.60 kW.h/ha, as shown in **Figure 9**. From mentioned results, it is recommended to use speed 2.7 km/h cause of the lowest specific energy requirements at this speed.

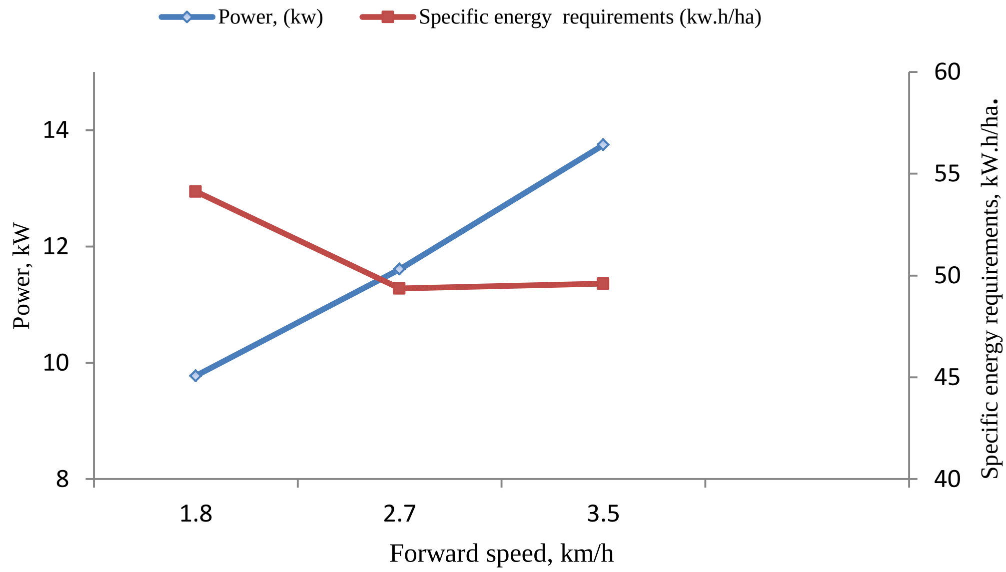


Figure 9. Effect of forward speed on power and specific energy requirements.

3.6 Missing hills and double plants index:

The effect of forward speed on missing hills for three varities of maize grains Hybrids Triple 310 (White), Triple 352 (Yellow), Single 168 (Yellow), as shown in **Figure 10.** Data showed that increasing forward speed from 1.8 to 3.5 km/h., the missing hills percent increased from 9.18 to 18.73 and from 5 to 9.75 and from 5 to 10.94 %, respectively. These results agree with **Yang et al. (2015),** found that missing-seeding index and precision index become worse with the increase of forward speed. **Figure 11.** show by increasing forward speed from 1.8 to 3.5 km/h., the double plants percent decreased from (7.21 to 1.92), (10.09 to 4.33) and (15.38 to 6.25) %, respectively.

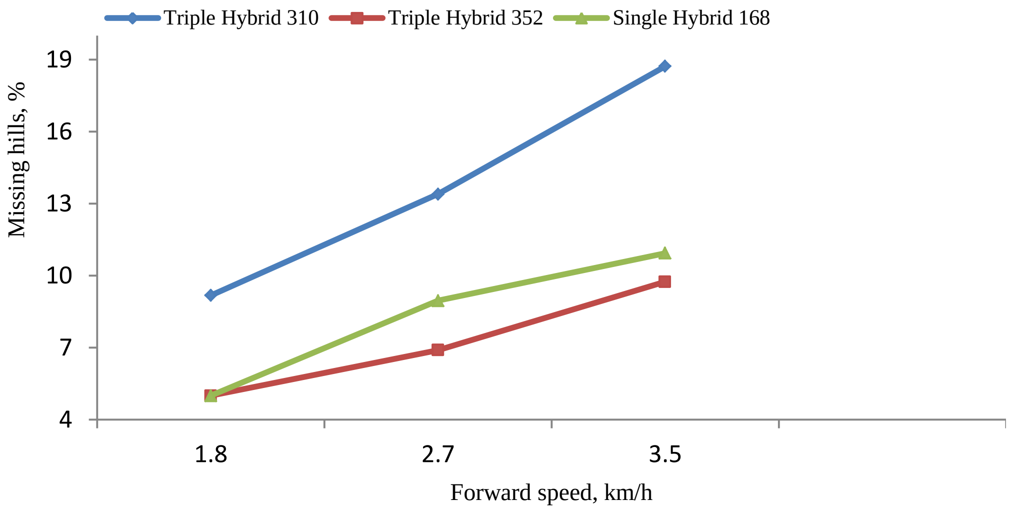


Figure 10. Effect of forward speed on missing hills.

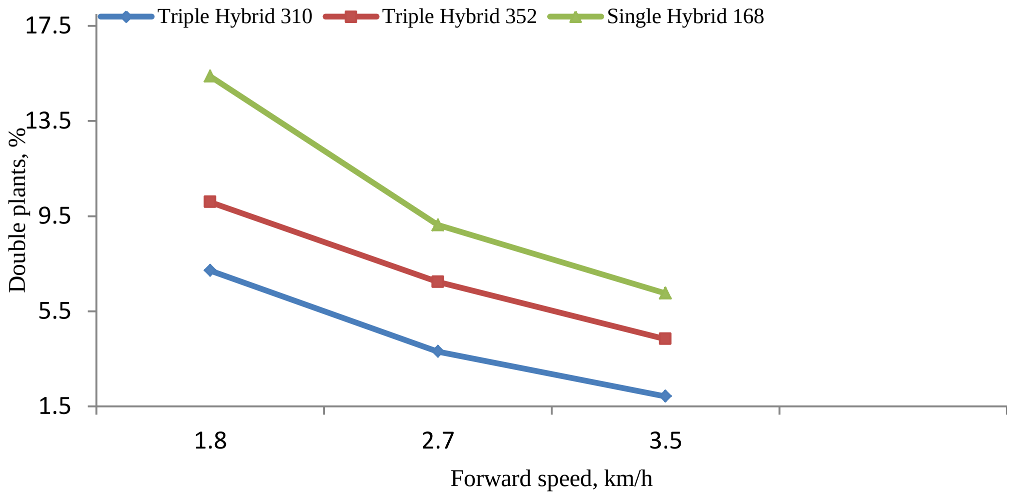


Figure 11. Effect of forward speed on double plants.

3.7 Crop yield:

The effect of forward speed on maize yield. The maize yield decreased with increasing forward speed. Data obtained show that increasing forward speed from 1.8 to 3.5 km/h, measured for three varities of maize grains hybrids Triple 310 (White), Triple 352 (Yellow), Single 168 (Yellow), decreased maize yield from 10.21 to 7.93 ton/ha, from 13.24 to 10.38 ton/ha and from 18.24 to 13.71 ton/ha, respectively as shown in **Figure 12**.

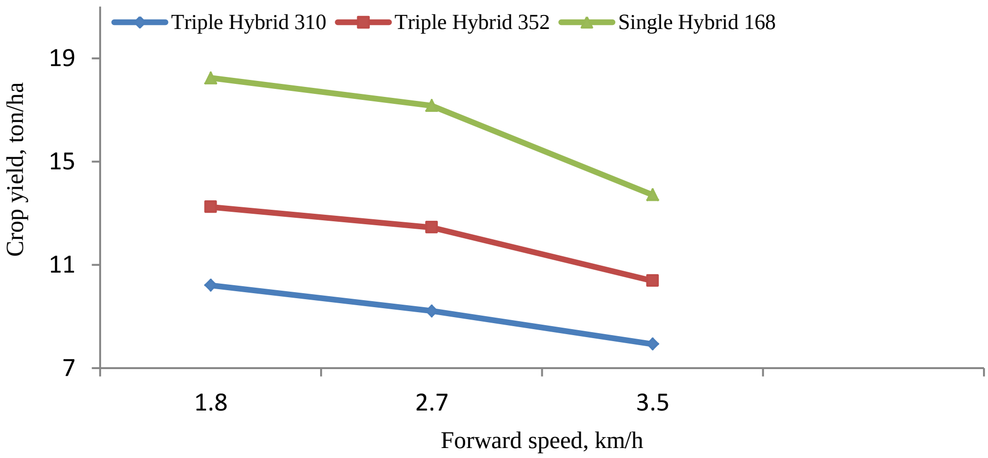


Figure 12. Effect of forward speed on crop yield.

3.8 Operating and production cost:

It is remarked that increasing the forward speed of developed planter from 1.8 to 3.5 km/h decreased the operating cost from 37.32 to 26.72 $/ha. That is due to the increase in actual field capacity as increasing the forward speed as shown in **Figure 13**. The obtained data in **Figure 14.** viewed that increasing the forward speed of developed planter from 1.8 to 2.7 km/h decreased the production cost from (3.65 to 3.25), (2.82 to 2.41) and (2.05 to 1.75) $/ton. while increasing forward speed from 2.7 to 3.5 km/h, the production cost increased from (3.25 to 3.37), (2.41 to 2.57) and (1.75 to 1.95) $/ton for maize grains Hybrids Triple 310 (White), Triple 352 (Yellow), Single 168 (Yellow), respectively.

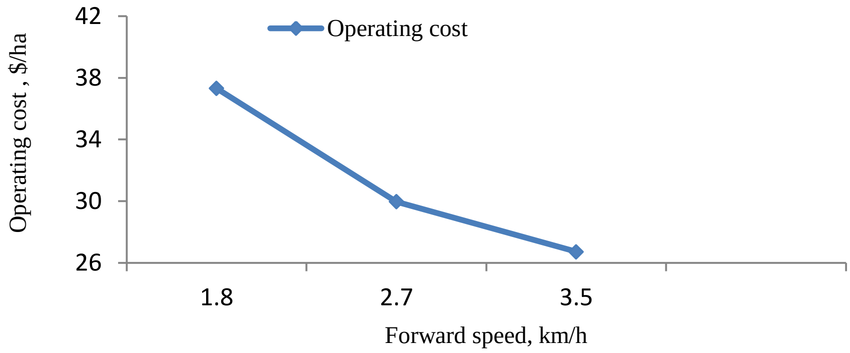


Figure 13. Effect of forward speed on operating cost.

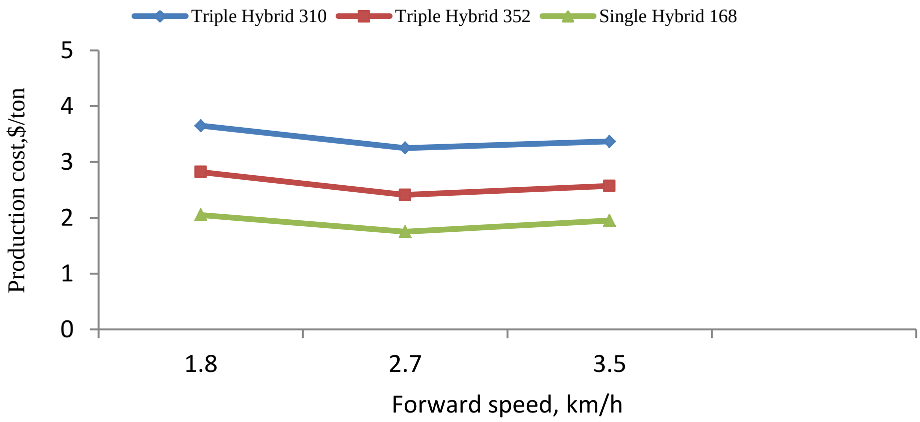


Figure 14. Effect of forward speed on production cost.

Test results
LSD all-pairwise comparisons test are presented in (Tables 2 - 4) for some variables in the field.

Table 2. LSD all-pairwise comparisons test of triple 310 (White) for varities

Forward speed	1.8 km/h	2.7 km/h	3.5 km/h
Parameter	**Triple 310 (White)**	**Triple 310 (White)**	**Triple 310 (White)**
Emergence ratio (%)	90.8 b	85.8b	92.8 b
Missing hills (%)	9 a	13.4 a	18.7 a
Plant spacing (cm)	25.1 a	26.9 a	30.4 a
Double plants (%)	7.2 b	3.8 b	4.7 a
Production cost ($/ton)	3.65 a	3.25c	3.37 b
Maize yield(ton/ha)	10.21g	9.21h	7.93i

From Table 2 found that the speeds (1.8, 2.7, 3.5 km/h) are suitable with emergence ratio, missing hills and plant spacing, while the speed of 2.7 km/h is ideal speed with double plants then results with other speeds 3.5 and 1.8 km/h, respectively the most appropriate is 1.8 km/h with crop yield then 2.7 and 3.5km/h, respectively and the most appropriate speed is 2.7 km/h with production cost then 3.5 and 1.8 km/h.

Table 3. LSD all-pairwise comparisons test of triple 352 (Yellow) for varities

Forward speed	1.8 km/h	2.7 km/h	3.5 km/h
Parameter	**Triple 352 (Yellow)**	**Triple 352 (Yellow)**	**Triple 352 (Yellow)**
Emergence ratio (%)	95.0a	93.1 a	90.2 a
Missing hills (%)	5 b	6.9 c	9.7 c
Plant spacing (cm)	24.0 b	25.6 b	29.1 b
Double plants (%)	8.9 b	5.9 b	3.5 a
Production cost ($/ton)	2.82d	2.41f	2.57e
Maize yield(ton/ha)	13.24d	12.45e	10.38f

From Table 3 found that the speeds (1.8, 2.7, 3.5 km/h) are suitable with emergence ratio and plant spacing, while the speed of 1.8km/h is ideal speed with missing hills then results with other speeds 2.7 and 3.5km/h, respectively and the most appropriate is 3.5 km/h with double plants then results with other speeds 2.7 and 1.8km/h, respectively, the most appropriate speed is 2.7km/h with production cost then the speeds 3.5 and 1.8km/h , respectively. The most appropriate speed is 1.8km/h with crop yield then the speeds 2.7 and 3.5 km/h.

Table 4. LSD all-pairwise comparisons test of single 168 (Yellow) for varities

Forward speed	1.8 km/h	2.7 km/h	3.5 km/h
Parameter	**Single 168 (Yellow)**	**Single 168 (Yellow)**	**Single 168 (Yellow)**
Emergence ratio (%)	95.0 a	91.0 a	89.0 a
Missing hills (%)	5 b	8.9 b	10.9 b
Plant spacing (cm)	21.0 c	24.0 c	26.0 c
Double plants (%)	15.3 a	9.1 a	8.4 a
Production cost ($/ton)	2.05g	1.75h	1.95g
Maize yield(ton/ha)	18.24 a	17.17 b	13.71 c

From Table 4 found that the speeds (1.8, 2.7, 3.5 km/h) are suitable with emergence ratio, missing hills, plant spacing and double plants, while the speed of 1.8 km/h is ideal speed with crop yield then the speeds 2.7 and 3.5 km/h, respectively and the speeds (1.8, 3.5 km/h) are not suitable with production cost but the speed of 2.7km/h is suitable.

4. CONCLUSION

Developed a small planter to accommodate planting maize in hills and evaluate the performance under some variables. This developed planter is one of the main reasons for its design, the lack of a planter for planting maize in small areas, this planter is used in areas less than an acre and is highly efficient. The results recommended using the forward speed of 2.7 km/h giving the actual field capacity of 0.24 ha/h, the field efficiency of 63%, the power of 11.61 kW, the specific energy requirements of 49.36 kW.h/ha, the operating cost of 29.97 $/ha, the production cost (3.25, 2.41, 1.75 $/ton) and the maize yield (9.21, 12.45, 17.17 ton/ha) for Hybrid 310, Hybrid 352 and Hybrid 168, respectively.

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