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Research Article

Design and Testing of Power Tiller Driven 2-Rows Reduced Tillage Maize Planter

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A B S T R A C T

The indigenous methods adopted for planting maize are not only labor intensive, but also time consuming and expensive. Inadequate plant density and delayed planting are the major yield limiting factors in maize. The Minimum and Zero tillage technologies had been successfully adopted to sort out above problems in the maize production. In this study, a reduced maize planter was designed based on design survey, fabricated, modified and its performance was tested under both laboratory and field conditions using 12 hp power tiller in the workshop of research fields of the station. The design of planter consists of two cylindrical seed hoppers of 0.5 ha. capacity, an inclined (14 degree) cell plate type seed metering device having cell no.=24 and cell dia.=9mm, a pair of seed tube, a pair of adjustable furrow opener (hoe type) and a handle which engage or disengage the bevel gear (gear teeth ratio=10:16, final transmission ratio=3:10). Power transmission occur through axial of power tiller with the help of chain and sprocket which further transmitted to metering device by bevel gears. The cost of fabrication of planter was NRs 23000/-. The planter can be operated both in tilled and no-tilled conditions of fields with singulation and no breakage of graded seed with plant to plant spacing=25 cm (adjustable), row to row spacing =60 cm(adjustable) and depth of planting =3-5 cm. The seed rate was about 20 kg/ha. and the germination was 98 %. The actual field capacity was 0.18 ha. /hr. at speed of 2 km/hr. and with field efficiency of 70% which save 40 % time compared to conventional method. The total cost of sowing (NRs 1725/ha) was found to be 77% cheaper than the traditional method of sowing (@ NRs 7500/ha).

Keywords: Design, Reduced Maize Planter, Inclined Cell Plate Type Metering Mechanism, Field Capacity, Economic

Maize (Zea. Mays L.) is an major and second most important crop after rice in Nepal, and has diversified use; fits well with the current choice of cropping pattern opted by the Nepalese farmers.[1] In 2022, the total area under maize was 9,79,776 ha with the production of 29,97,733 MT and productivity of 2.99 MT/ha. Maize crop alone contributes about 26.96% of total cereal production.[2] Maize is emerging as an industrial crop in the accessible areas of Nepal as a corn oil, livestock feed ingredients, glucose, corn flakes etc. The main maize growing area is the terai and hilly region of the Nepal. There is great demand of maize as food for people living in the hilly area for feed and fodder. Therefore, the existing production of maize has to be increased to meet the demand of the country. This goal can be achieved by mechanized farming with the use of modern agricultural farm tools and implements.

Traditional maize growing practices are resource consuming and labor intensive. High inputs and labor costs have been the burden for hybrid maize growing farmers. Repeated tillage, poor crop establishment, lower resources use efficiency, lower yields and low net return are the major constraints of maize-based crop production system. In terai region, farmers grow maize after rice and wheat and area of hybrid maize are growing exponentially.[4] They have less time of sowing and there is great scarcity of labour during the peak time of sowing.

The tillage operation in conventional agriculture is time consuming and costly process where operation required up-to one-third of total cost. Conservation tillage is major technique to withstand and increase soil fertility and crop productivity.[5] Minimum tillage and zero tillage are popularly accepted resource conservation technologies in different parts of the world. Minimum tillage and zero tillage can save substantial amount of time, irruption, momentary cost in crop production.[5,7] In Nepal, the agricultural mechanization has very slow pace, and most of the farmers are continuing the traditional methods of farming which are labor incentive, costly, and time consuming. The average land holding per family across Nepal is found to be less than 0.8 hectare. Due to low investment capacity and lack of infrastructure and market opportunities, majority of farmers in Nepal are adopting traditional technology in their production systems.[8] Therefore, cheap and small size machines are more suitable for promoting mechanization. Maize is the second major crop after rice in Nepal, and its demand is increasing day by day.[9] There is urgent need for the mechanization of maize farming systems in Nepal.

The main objective of this study was to develop the power tiller driven reduced tillage maize planter. In the present study, the seed metering system of Chinese seed drill was replaced by developed metering system for maize seed and its performance was evaluated.

Hence, seeing the present scenario of country, mechanization in maize plantation is necessary, so that economy of country can be boosted as well as living standard of farmers. Thus, the designed and modified reduced tillage maize planter will definitely addresses the genuine above maize cultivation in Nepal and will reduce the cost of operation and will increase yield of maize crops.

Materials and Methods

Description of the Power Tiller

The power tiller, two-wheel tractor with attached rotavator, was used as power source for maize planting in this study. The power tiller was made in China (trade mark: Dongfeng), and its rated power was 12-15 hp. The engine, used in power tiller, contained one cylinder and operated by diesel. The forward speed can be maintained in the range of 1.54 to 16.83 km/hr., and reverse speed can be maintained in the range of 1.20 to 4.18 km/hr.

Design Description, Analysis, And Fabrication of Maize Planter

The overall production of maize was not satisfactory with the conventional methods adopted in past two decades. The resource conservation technology (Minimum and Zero tillage) had been successfully adopted in the maize production. A need was felt to develop the reduced tillage maize, for the adoption of conservation technology in maize for small and medium holdings farmers.

The design and development of a power tiller based reduced tillage maize planter, carried out at the workshop of Agriculture Implement Research Station, Ranighat, Birgunj was adopted to develop an existing seed-drill for maize planting under reduced tillage with power tiller as the power source. The machine was developed in attempt to create multiple use of the Chinese developed power tiller in combination of reduced tillage wheat drill that has been becoming popular among the farmers in terai and inner terai.

The preliminary design survey for design considerations of proposed prototype was conducted in various places viz. Phatepur Village Development Committee, Bara District; Purwanchal Campus, Dharan; National Agricultural Engineering Research Center, Khumaltar, Lalitpur and National Maize Research Program, Rampur, Chitwan. which includes detail information about all types of maize planters used previously (Specially design aspects), their advantages and disadvantages and about constraints in sowing of maize. The following design assumptions was followed best on survey and the machine was designed and fabricated in the workshop of Agriculture Implement Research Station, Ranighat, Birgunj with the help of a prototype brought from the workshop of Institute of Engineering, Purwanchal Campus, Dharan.

1. The maize planter is specially designed for planting the maize in Rice-Wheat Cropping System.
2. The machine is designed for medium textural soil of terai region.
3. Row to Row and Plant to Plant distance is maintained by fixing the distance between the seed tubes and providing cell-feed seed delivering system.
4. Wheel speed of power tiller=2km/hr.
5. Capacity of hopper = 0.5ha.
6. Driving power is tapped from power tiller wheel by the help of chain and sprocket.
7. Plant to Plant distance = 29.83 cm = 30cm, and Row to Row distance = 60 cm (Adjustable).
8. Total coverage width of planter=1.2m
9. Cell type metering mechanism, No. of cells in cell plate=24, diameter of cell=9 mm (For hybrid maize)
10. Type of gear= bevel gear, Gear teeth ratio 10:16, Final Transmission ratio=3:10

The required materials such as MS Sheet, MS Shaft, MS Bar, Angle iron, bearings, bearing blocks, chain, sprocket, welding rods etc. was brought from the local market. Some cast iron plates were moulded outside in the foundry. The machine was designed and fabricated basically for planting maize with minimum energy and re-compaction of seed bed. The main shaft of maize planter was used same as Chinese seed drill. The main parts designed were drive arrangements, seed box (hopper) and cell-feed metering device.

The design and development of the machine was limited to develop attachment, seeding mechanism and drive arrangements in existing power tiller reduced tillage drill. One set of 2-rows Maize planter was fabricated. The cost of fabrication of prototype was found to be NRs. 23000/-. (calculated on 2012) which is given in Table 1. The calculated cost is reasonable that can be easily afforded by a medium class farmer.

Table 1.Cost of Fabrication of 2-Rows Power Tiller-Driven Reduced Maize Planter (calculated on 2012)

S. No.	Particulars	Size (mm)	Nos	Weight (Kg)	Rate (NRs/kg)	Total Cost (NRs)
1.	Frame Angle	3×40×2820	1	5.310	125	664
2	Angle	2×25×300	8	1.880	125	235
3	MS bar	3×40×145	5	0.680	125	85
4	MS bar	2×20×40	16	0.201	125	25
5	Clutch Stand Angle	3×30×100	4	0.565	125	70
6	Base Plate Supporting	3×30×160	8	1.809	125	226
7	Clutch Handle	2×20×580	1	0.182	125	22
8	Base Plate	ø 330×6	2	8.057	125	1007
7	Cell Plate I	ø200×4	2	1.973	125	246
8	Cell Plate II	ø 200×6	2	2.959	125	369
9	Bottom Hopper Ring	3×20×630	2	0.600	125	75
10	Upper Hopper Ring	3×20×1225	2	1.160	125	145
11	Support for Hopper	3×20×300	6	0.848	125	106
12	Hopper (MS Steel, 22 gaug)	22ga×1225×310	2	10	125	1250
13	MS Shaft	ø 25×970	1	3.738	125	467
14	Bevel Gear	10:16 Teeth	2	-	-	3550
15	Sprockets	45 Teeth	2	-	775/piece	1550
16	Chain	2m long	1	-	840/piece	840
17	Rivet	4×12.5	75	-	-	160
18	Clutch Ring	40×40	1	-	-	90
19	Nut- Bolt, Washers	-	-	0.200	125	56
20	Spring	ø 25×75	2	-	20/piece	40
21	MS Shaft Support	4×40×150	1	-	125	25
22	Bearing Bush	-	2	-	280/piece	560
23	Bearing Shaft	-	2	-	420/piece	840

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S. No.	Particulars	Size (mm)	Nos	Weight (Kg)	Rate (NRs/ kg)	Total Cost (NRs)
24	Bearings	-	4	-	300/piece	1200
25	Spring Stopper	ø 40×60	1	-	-	400
26	Sprocket Coupling	-	1	-	400/piece	400
	Sub Total:					14557.00
27	Scrap (10%)	-	-	-	-	1455.70
28	Labour Cost (30%)	-	-	-	-	4367.13
29	Machine Cost (12%)	-	-	-	-	1746.85
30	Electricity Cost (4%)	-	-	-	-	582.28
31	Miscellenous (1%)	-	-	-	-	145.57
	Total			-	-	23000.00

Components of the Maize Planter

Main frame, cylindrical type seed hopper, inclined cell plate type seed metering device, seed tube, hoe-type furrow opener and lever for engaging and disengaging bevel gear are the main components of maize planter. Details of components were given below.

Main Frame

All components of planter were fixed on the simple frame structure of maize planter and attached to top of rotary section of Chinese seed drill. Considering the weight and durability of planter, mild steel angle bar of 40 mm x 2820 mm and 3 mm thickness were used to give rigidity and strength to the planter required during operation.

Cylindrical Seed Hopper

Another most important component of the planter is seed hooper which hold the quantity of seed required for seeding of maize in a required field. The shape of hopper is combination of cylindrical and truncated cone as shown in the figure above the cell plate attached to the main frame of the planter with the help of nut and bolt. The most important function of seed hopper is to supply continuous flow of seed during operation of planter in the field. Placement of seed hopper i.e., angle of repose of the seed will help in continuous supply of seed for each cell in the cell plate of the planter. Considering the weight of seed hold by it, mild steel sheet metal of 22-gauge x 1225mm x 310mm was used for construction of seed hopper for the planter as shown in Figure 1.

Seed Metering Mechanism

Metering mechanism in any machine depend upon the seed rate across the required field during operation of any kinds of planter. Similarly, in this planter to control the seed rate and distance between seed to seed, an inclined (14 degree) cell plate type with numbers of cell were developed. So, according to size of seed and number of cells are punched on the surface of plate to meet the desired seed rate for field operation by the planter. In this design, the circular plate of diameter 200 mm with thickness of 4mm & 6 mm having cell diameter of 9 mm were design to collect the seed from seed hopper to convey to furrow opener through seed tube which is shown in Figure 2. For the operation of cell plate, it was connected to bevel gear so that cell plate can rotate to perform it works. The entire Seed Metering Mechanism is attached to a vertical shaft with gear. A gear mechanism was paired between the vertical shaft and a horizontal shaft to transfer wheel power to the seed metering mechanism without any difficulty in operation. Different cell plates having different no. of cells with different cell diameters were also fabricated for local to hybrid varieties.

Bevel Gear

The power transmission in maize planter plate was done by using bevel gears (Figure 3) so that metering mechanism can be able to drop seed of desired rate. The horizontal main shaft was used to

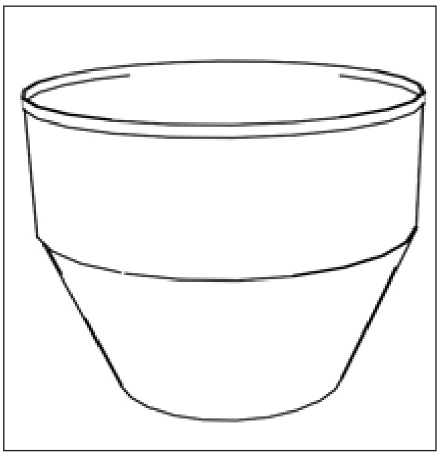

Figure 1.Seed hopper

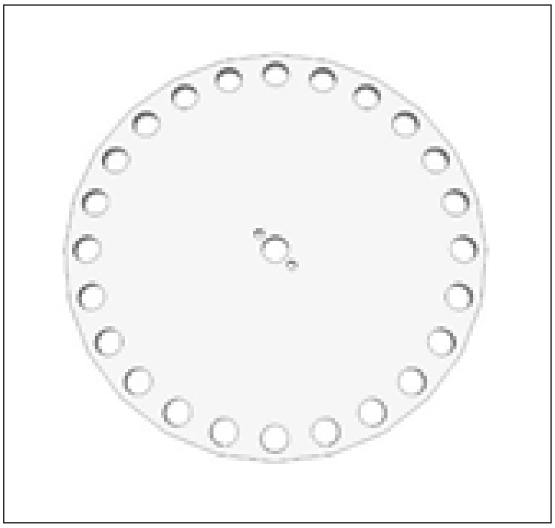

Figure 2. Cell Plate

transfer power tiller power to cell plate through set of bever gear which is attached with cell plate in order to perform operation.

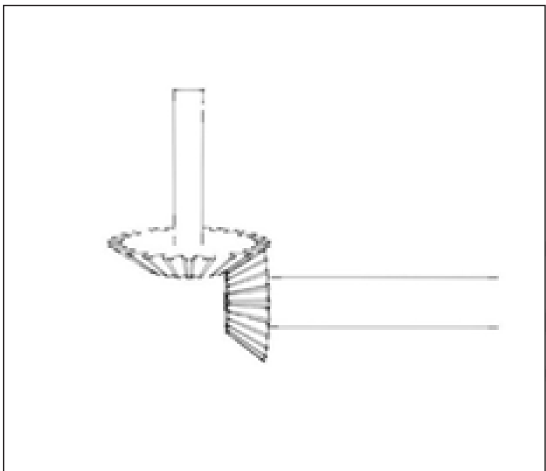

Figure 3. Bevel Gear

Bearing Selection

To keep the cost of planter minimum locally available 2 bearing were used based on the uses for smooth operation of planter. These two bearing were provided at the end of the frame to support the shaft which is used to run the metering unit of planter connected together with bevel gear.

Power Transmission System

The power transmission in maize planter was done by using chain and sprocket. The one and one sprockets were used on shaft of power tiller and another one on the shaft of planter with the help of chain. Material used for sprocket is steel with 45 teeth with Gear teeth ratio 10:16 and Final Transmission ratio=3:10.

Seed tube

A plastic tube was places just below the metering units to collect seed and discharge it directly into the furrow without any disturbance in continuously in a line. It is a plastic tube through which seeds were passed from the metering device to the soil. The length of tube depends upon the gap between cell and furrow opener. The attachment mechanism was such that its upper part was attached just below the cell plate opening and end part attached to furrow opener top as shown in Figure 4.

Inverted T-Type Furrow Opener

[10]found the inverted T- type furrow opener best for loamy soil among different types of openers viz., shoe type, inverted T-type and disc type as it tends to penetrate more easily than the disc opener. Inverted T-type furrow opener was used to open space for seed placement in the soil as shown in Figure 4. Seed drill furrow opener was used in this planter for furrow opener for seed placement. The used furrow opener suits the soil condition as well as adjustable to various variety of seed in both spacing and depth.

Lever

The lever in this planter was used to control the engaging and disengaging the metering parts with the shaft which is used to transfer the power from axel of power tiller (Figure 4). This lever provide option to the operator to the control the operation where to seed the maize and where to stop the planting during operation. The design of lever was made such a way that with any height of operator can handle without any difficulty. During operation operator has to engage the lever so that power transmission to cell plate is made possible otherwise no seed placement is seen into the soil during operation of planter. The material used for the lever was made from mild steel square pipe of 2mm x 20mm x 580mm.

Working Principle of Maize Planter

The metering device for seed was powered by axel of power tiller through chain and sprockets and the planter was attached with lower parts of Chinese seed drill. By changing gear ratio of this planter desired seed rate can be obtained which helps in showing different varieties of seed. Accordingly gap between plant to plant can also be adjusted by adjusting tyne as required by farmers. During operation, to control the wastage of seed, engaging and disengaging lever was provided which is used to control by operator.

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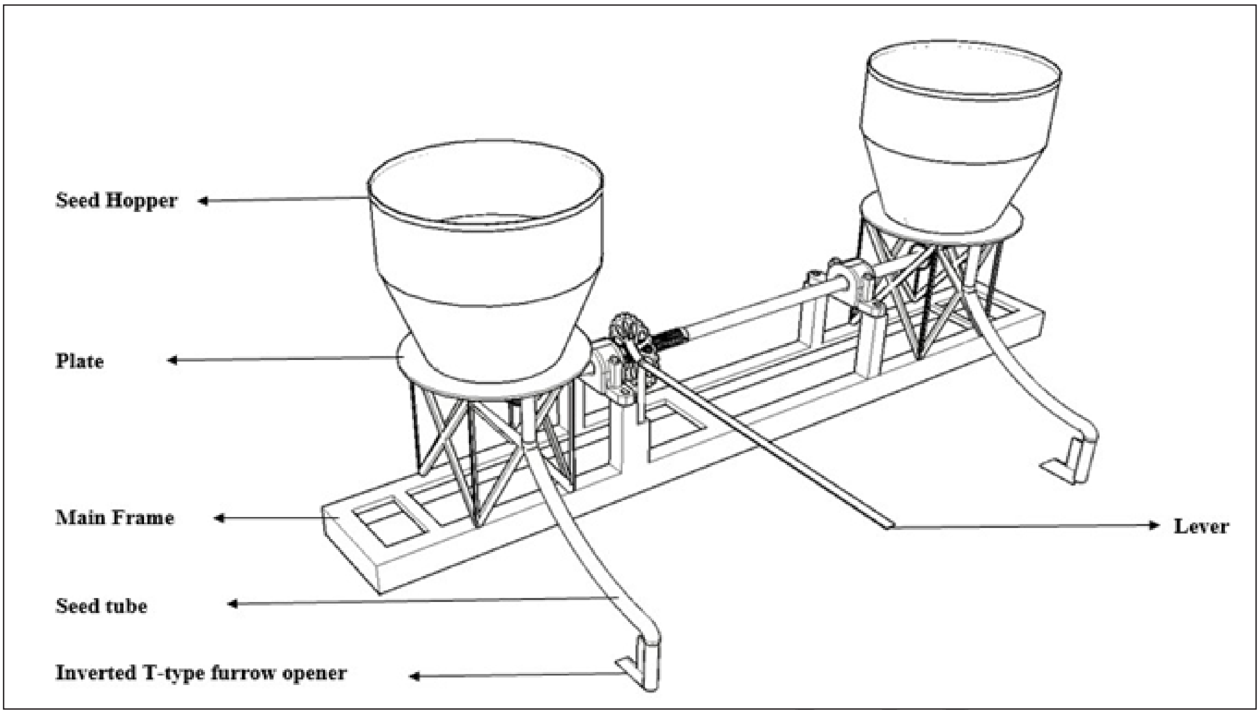

Figure 4.Power Tiller Driven 2-Rows Maize Planter

Performance Evaluation

The 2-rows maize planter designed and fabricated in F.Y. 2011/12 was tested to evaluate its performance in actual field condition. The on-station test and further modifications regarding constraints in test of fabricated prototype were completed. The laboratory and actual field tests were performed for two fiscal years in on-station viz.2012/13 and 2013/14. The economy of different planting methods as well as farmers feedback were calculated/ collected. The laboratory tests include calibration of the machine, uniformity of seed in distribution and spacing, seed breakage, seed rate, no. of seeds per hill whereas actual field test include soil type, initial moisture content, bulk density, plant population (germination percentage) and spacing, row to row distance, seed rate, speed of the operation, effective working width, wheel slip, theoretical/ actual field capacity, field efficiency, fuel consumption, yield and economic analysis.

The on-station test plots were laid down in Randomized Completely Block Design (RCBD) with 3 replications each. The following levels of treatment were performed under this experiment:

T1=Single Pass of rotary tillage in unploughed field and seeding at depth d1=3.0 cm.

T2=Single Pass of rotary tillage in unploughed field and seeding at depth d2=5.0 cm.

T3=Single Pass of rotary tillage in ploughed field and seeding at depth d1 =3.0 cm.

T4=Single Pass of rotary tillage in ploughed field and seeding at depth d2=5.0 cm.

T5=Conventional method of sowing (Farmer Practice)

The plot size was 2.5 m x 8m (20 m2). Prior to conducting the experiment, the laboratory test of the modified prototype was done on 9th march, 2014 regarding tilting, angle, calibration, seed spacing etc.in the workshop of Agriculture Implement Research Station, Ranighat, Birgunj. The herbicide (Glyphosate @ 10ml/lit.) was applied in the selected field one week before and land preparation, lay-out were conducted on 12th March, 2014. The soil samples were collected from three different locations of the test plots using augur up to depth of 100 mm for determination of type, texture, moisture content and dry bulk density. The hybrid maize variety P-3785 was sown using fabricated prototype on 13th March, 2014. The total fertilizer was applied @150:100:50: N2: P2O5: K2O kg/ha. in which basal dose was 75:100:50: N2: P2O5: K2O kg/ ha, and rest 75:0:0: N2: P2O5: K2O kg/ha. applied on top dress. A total of 4 flood irrigations were applied during crop season. Insecticide Furadan and Noorani 505 were used for control of stem borer and other insects. The crop was harvested on 30th June, 2014 and data on plant population, plant height, No. of cob, weight of cob, moisture content, yields were recorded which is given in Table 2 & 3.

Table 2.Grain Yield and Yield attributes of maize Arun-4 planted by power tiller driven 2-rows maize planter 2012/13.

Treatment	Plant population / ha	Number Of Cobs/ha.	1000 Kernel Weight, gm	Mean MC %	Grain yield (kg/ha) at 14%
TI	45556	53334	336.68	27.0	3764
T2	48889	53334	336.68	26.4	4526
T3	51111	52222	333.35	25.7	4073
T4	50000	52222	364.18	27.7	4605
T5	63889	70834	337.5	27.7	5321

Table 3.Grain Yield and Yield attributes of maize P-3785 planted by power tiller driven 2-rows maize planter 2013/14.

Treatment	Mean Population/ (ha.)	Mean No. of Cob/ (ha.)	Mean weight of cob (kg)	Mean of kernel (gm)	Mean MC %	Mean Yield(kg/ha)
TI	64445	68889	10.57	125	19	8852
T2	61111	71111	12.04	130	18	9643
T3	66667	66667	10.04	128	20	8692
T4	70000	81111	12.09	130	20	9997
T5	64445	66667	11.19	130	19	9399

Laboratory Testing

The planter was operated in the workshop of station for calibration of seed. The other laboratory tests were also performed. The machine was operated in 2nd low gear. The test codes and procedures described in RNAM Test Codes (for field capacity, calibration etc.) and Procedures for farm machineries were followed.

Calibration of Planter

The calibration of planter was done to acquire recommended seed rate. This process includes collection of seed in respective openers while travelling power tiller for a fixed distance. Then calculation was continued until and unless the planter was able match to seed rate through their openers. The planter will be ready for seeding, if recommended seed rate is obtained.

Actual Field Testing

The performance evaluation was done in actual field based on the following indicators/ parameters/ observations.

Plant Populations (Germination %) and Spacing

This planter will be able to plant 2-rows at 60 cm spacing in single operation. Plant to plant distance was found to be 20 cm through testing and germination was 98% with seed rate 20 kg per hectare. It can sow seed at depth of 3-5 cm accordingly available moisture in the soil for germination. There was decrease in germination percentage when using locally available seed as compared to hybrid seed and ways of plantation of seed in the field.

Speed of Operation

The speed of planter was calculated using formula travelled distance (measured by using tape) and divided by time taken (noted by using stop watch). Distance is measured in kilometre where time is measured in second.

Working Width of Operation

The product of no. of tyne and distance between two tyne will give working width of planter during operation.

Wheel Slip

Forward speed of drive wheel within fixed distance under no load (a_1) and under load (a_2) were measured. The calculation was done by using formula [11-13].

Wheel slip (%) = $(a_1 – a_2)/ a_2$ *100

Fuel Consumption

Fuel consumption was calculated as given below:[14]

FC= B/ T Where, B = Total fuel consumed (litres) and T = Total time taken (hours)

Total time of field operation (T) in seconds and area covered (A) in square meter was recorded. After completing the operation, the tractor was brought to the same levelled ground, positioned same as to refill the tank. Differences between the initial level of fuel to fill tank after operation will be the fuel consumed.

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Field Capacity and Field Efficiency

The effective field capacities and field efficiencies were calculated using equations:[15]

Effective field capacity (*EFC* ha. / hr.) = *Plot area* (ha)/*Total time required to cover the plot* (hr)

Field efficiency= (*time for actual operation/ total time taken*) *x* 100%

The measurement of the effective field capacity and field efficiency of the planter was done by continuous observation and timing of each activity and time losses for turning, filling of seed as well as adjustment if done during time of operation. Two persons were involved in the evaluation, one operated the planter while the second observed and recorded the time taken for the operation (time loss at field ends and time taken for the actual planting operation). The time taken was recorded using a digital stopwatch and the inter-row and seed width measured using a steel tape.

Results and Discussion

The design of planter consists of two cylindrical seed hoppers (Figure 5) of 0.5 ha. capacity, an inclined (14 degree) cell plate type seed metering device having cell no.=24 and cell dia.=9mm, a pair of seed tube, a pair of adjustable furrow opener (hoe type) and a handle which engage or disengage the bevel gear (gear teeth ratio=10:16, final transmission ratio=3:10). Power is transmitted from the axial of power tiller with help of chain and sprocket to the metering device through bevel gear mechanism. The cost of fabrication of planter was NRs 23000/- whose detail cost is given in Table 1. The planter can be operated both in tilled and no-tilled conditions of fields with singulation and no breakage of graded seed with plant to plant spacing=25 cm (adjustable), row to row spacing =60 cm(adjustable) and depth of planting =3-5 cm. The seed rate was about 20 kg/ha. and the germination was 98 %. The seed rate and germination were about 18.7 kg/ha. and 95 % respectively as reported by.[16] The seed rate could be adjusted by changing the cell plates with various nos. of cells. For various seed size and type of seeds, two types of cell plates, one for hybrid seed and another for local seed were developed. The distribution of seed was found to be uniform. The sowing depth adjustment can be done easily. The attachment and detachment of seed drill in power tiller was found to be easy. The seed breakage was found to be less than 3% at a speed of 1.25 to 2.0 km/hr. in initial year of testing (i.e. 2012/13) which could be the reason of slight decrease in maize yield (4.6 ton/ha.) as compared to traditional practices (5.3 ton/ha.). So, modification in the placement of cell plate was carried out in the fiscal year 2013/14. After modification in tilting angle of cell plate, the planter performed well in actual field condition which seemed to improved compared to last fiscal year. The tilting of cell plate (14 degree) of planter enhanced the seed breakage issue in fiscal year 2013/14. The uniformity in seed distribution and spacing was found to be improved compared to last year. The actual field capacity was 0.18 ha. /hr. at speed of 2 km/hr. and with field efficiency of 70% in clay loam soil having initial moisture 17.56 % and bulk density 1.17 gm/cc with 40% time saving than traditional method. The fixed cost and variable cost of planter were found to be NRs. 49.69/hr. and NRs. 269.08/ hr. respectively. The total cost of sowing was NRs 1725/ha, which was found to be 77% cheaper than the traditional method of sowing (@ NRs 7500/ha). The highest grain yield was recorded (9.9 ton/ha., hybrid variety- P-3785) in Single Pass of rotary tillage in ploughed field with 5 cm seeding depth whereas farmers' practice yielded 9.3 ton/ha. Thus, it can be concluded that the maize planter not only reduces the planting cost but also increases grain yield per unit area.[17] reported that productivity of agriculture crops can be increased through the use of reduced technology with minimum resource management.

Figure 5.Field Testing of 2-Rows Maize Planter at On-station

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The field efficiency was found to be 70 % with 30% slippage which can be increased if wheel slip is reduced. This shows a good and satisfactory performance within the range of values obtained for planting operation for medium textural soil of terai region. The machine performance output was satisfactory when compared with traditional planting. The forward speed of tractor was 2.0 km/ha. and the effective working width was 1.2 m. The fuel consumption was found to be 2.5 lt./hr.

Conclusion and Recommendation

The developed planter has demonstrated promising results in terms of performance and cost-effectiveness, making it a viable option for maize cultivation under both minimum and zero tillage conditions. The key findings from the tests and evaluations include:

The performance of the maize planter was found to be better under minimum tillage conditions than under zero tillage conditions.

The use of a reduced tillage planter could reduce maize planting costs by more than 77% compared to traditional methods used in Nepal.

The technology appears to be suitable for medium and small holding farmers and for medium textural soil of terai, inner terai, and flat hill regions.

These findings suggest that the developed planter has the potential to significantly improve the efficiency and profitability of maize cultivation in various agricultural settings. However, further research is needed to fully understand the commercialization potential of this technology. This includes conducting more in-depth studies on the long-term impacts of reduced tillage practices on soil health, crop yield, and overall farm sustainability. Additionally, it is crucial to explore the potential of this technology in different agricultural zones and regions to ensure its widespread adoption and success.

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