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Research Article

EFFECT OF ENGINE SPEED HYDRAULIC LEVER POSITION GEAR TYPE ON PUNCH SPACING

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Abstract: Based on the seed to seed spacing within the row for maize crop the reduction mechanism was developed. Generally, recommend spacing for maize is 220 to 260 mm. The speed of the punch wheel was estimated based on the predetermined seed to seed distance of 240 mm for maize crop. To obtained the optimum spacing between consecutive punches, the gear reduction was selected in three stages. The first reduction stage occurred between engine to PTO shaft, second stage between PTO shaft to reduction gear box output shaft and third stage reduction gear box output shaft to punch wheel shaft. Engine speed was maintained at 1000, 1500 and 2000 rpm corresponding PTO speeds were noted and average reduction ratios were calculated at two PTO lever positions as 4.46 and 3.07 respectively. Reduction ratios from PTO shaft to gear box output shaft were obtained as 1.85 and 1.84 at two lever positions. The reduction ratios from gear box output shaft to punch wheel were obtained as 2.41 and 2.42. overall reduction ration from engine speed to Punch wheel shaft at two lever positions were obtained as 19.96 and 13.67. Tractor forward speed was measured in three gear positions by increasing the engine speed from 800 to 2400 rpm. In three gear positions the forward speed increases by increasing the engine speed. In a particular PTO lever position (P1) with the combination of gear selection three different punch spacing were obtained as 16, 24 and 53 cm respectively. In each combination (P1G1, P1G2 and P1G3) even though forward speed increases, there is no significant effect on punch spacings were obtained as 10, 16 and 35 cm respectively. In a particular PTO lever position (P2) with the combination of gear selection three different punch spacing are obtained. In each combination (P2G1, P2G2 and P2G3) even though forward speed increases, there is no significant effect on punch spacing.

Keywords: *Punch spacing, Reduction ratio*

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Introduction

Maize (*Zea mays* L.) is an important cereal food crop of the world with the highest production and productivity as compared to rice and wheat. It is the most versatile crop grown in more than 166 countries around the globe including tropical, sub-tropical and temperate regions from sea level to 3000 m MSL. The top producing states Andhra Pradesh, Karnataka and Maharashtra were recorded with a production rate of 4.2, 3.9 and 2.2 million tonnes respectively during the year 2015-16 [1].

In manual dibbling method, the seeds are sown in lines with a spacing of 22-25 cm between seeds in the rows which are 60 cm apart. By using the long bamboo stick initially make holes in the field generally by the male labour, after that female labour drop one or two seeds in the previously made holes. This is highly labour consuming practice and also the cost of operation is high compared to other practices.

In machine dibbling, an implement is used for making the holes in the field. These implements are available in different sizes depending on the power source. These implements are operated by medium size tractors as well as mini tractors also. After making the holes by the dibbler in the field the holes are filled with one or two seeds by manually. In this also the cost of operation is high but only little bit difference is that the time taken for making holes is less compared to manual dibbling. To maintain fixed punch spacing at PTO lever position 1 and 2 speed reduction unit from PTO to punch rod is taken major role.

Review of Literature

Nader and Rouhollah [2] studied different ways to improve planting common bean in different soils, Punch planting method was used and the effect of different openers and rice husk mulch as a new idea in punch planting was tested. Field tests were conducted in farm at Sharekord University. Common bean was planted to test the seedbed shape (bar, conical and grooved), sowing depth (6 and 9 cm) and the seedbed mulching (with husk and without it).

Akhtar *et al*. [3] indicated that the various types of innovations were done in seed sowing machine available for plantation. The machine for seed sowing was a key component of agriculture field. Cotton was a significant beneficial harvest and extensively traded commodity across the world.

Douglas *et al*. [4] developed a punch planter to sow maize seeds in no-tillage system, and also evaluated the performance of its seed metering and delivery systems. They made two punch wheels in a “V” turn, synchronized due to gearing and the vertical seed metering is positioned between the two different punch wheels. Laboratory testing has been conducted for evaluating the performance of seed metering system was assessed in relation to the punch wheel speed and the quantity of punches on the wheel. The planter was evaluated for its performance for four levels of forward speed of operation *viz*., 4, 6, 8 and 10 kmh^{-1} with three different quantity of punches *viz*., 6, 9 and 12 punches. They concluded that, the quality of feed index was 92.75 per cent for the forward speed of 4 kmh^{-1} with punches and miss index was reduced to 2.01 per cent. The multiple indexes have been reduced due to the forward speed of 10 kmh^{-1} with 12 punches.

Table-1 *Specifications and quantity of the materials used for fabrication of punch planter*

Name of the component	Material used	Size (mm)	Quantity (m)/Nos.
Three points hitch system	MS flat	50 x 12	2.64
Main frame	MS angular	50 x 6	4.98
	MS angular	37 x 6	3.57
	MS angular	25 x 6	2.14
	MS flat	50 x 6	1
	MS flat	50 x 8	0.5
	MS rod (circular)	19	0.3
Reduction gear box	Crown and pinion bevel gear (cast iron)	1.85 :1 (reduction ratio)	1 no.
Spur gear	Cast iron	19 teeth and 11.0 mm pitch	1 set
Chain	Cast iron	12.7 mm pitch	1067
Sprocket	Cast iron	13 teeth and 12.7 mm pitch	3 no.
Sprocket	Cast iron	36 teeth and 12.7 mm pitch	1 no.
Punch wheel assembly	MS circular plate	200 dia. X 20	6 no.
	MS rod (square)	25 x 25	0.8
	MS rod (square)	12.5 x 12.5	3
Shaft	MS rod (circular)	25	2.26

Jayan and Kumar [5] developed a mechanical dibber planter for planting selected seed namely maize, red gram, and cotton. The dibber planter consisted of six dibbers with size of 185 mm length and peg shaped, arranged radially on a dibber wheel, which actuates the seed metering mechanism and allows the seed to fall on the seed transfer cup and travel to the tip of the dibber. The position of the cam was fixed in such a way that seed control lever opened the dibber when it is about to penetrate the soil.

Ismail and Hanify [6] developed a punch planter for maize and evaluated for no-till conditions. They investigated the effect of oscillating tube mechanism on the seed's distribution with two oscillating radii of 90 and 120 mm and with two connecting rod length of 150 and 180 mm and determine the factors that realize the best operation condition. The planter was evaluated for its performance at four levels of forward speed of operation *viz*., 1.0, 1.4, 1.7 and 2.1 km h^{-1} and concluded that seed spacing increases with the increase of speed and oscillating tube radius. The seed miss index increased with the increase of speed and decreased with the increase of oscillating tube radius. The multiple indexes increased with the increase of speed and oscillating tube radius. The quality of feed index decreased with the increase of speed and oscillating tube radius. The optimum parameters were found at punch planter speed of 2.1 km h^{-1} and oscillating tube radius of 120 mm and connecting rod length of 180 mm.

Saburigermi *et al*. [7] developed a punch planter for conservation tillage systems and evaluated for its performance on three soil conditions (tilled, untilled with no residue, untilled with wheat residue) and at three levels of forward speeds of operation *viz*., 1.5, 3.0, 4.5 kmh^{-1}. Field test results showed that no significant difference between tilled and untilled stubble soil with the forward speed of 1.5 and 3.0 kmh^{-1} on feed index. Miss index increased and multiple indexes decreased by increasing the forward speed. They concluded that, the planter showed an acceptable performance in forward speed of 3.0 km h^{-1} on tilled and untilled stubble soil.

Materials and Methods

A mini tractor drawn prototype punching mechanism was developed based on the optimized values of machine and operational parameters obtained from the selected levels of variables. The prototype consists two major mechanisms which includes universal joint, three points hitch connections, main frame, reduction gear box, power transmission or power train, punch wheel assembly.

The mini tractor of Mitsubishi Shakthi MT 180D was used for this study. For fabrication of punching mechanism material used is shown in [Table-1].

Development of Punching Mechanism

The main objective of punching mechanism in the punch planter is to convert rotating motion of the PTO shaft into reciprocating motion of the punch rod. The punching mechanism consists following components.

1. Universal joint
2. Three points hitch connections assembly
3. Main frame
4. Reduction gear box
5. Spur gear transmission system
6. Chain and sprocket transmission system
7. Punch wheels
8. Punch rods

Universal joint

Triangular shaped telescopic pipe made up of hard carbon steel connected to the universal joint is used to transfer the rotary motion of the PTO shaft to the reduction gear box fitted on the main frame. The universal joint used for punch planter.

Three points hitch connections

Three points hitch assembly with four MS flats of (50 x 12 mm) size was fabricated and fixed to the main frame with the help of bolts and nuts to facilitate proper hitching of punch planter to the tractor. by using one top link and two lower links as shown in [Plate-1]. The overall length, width and height of the linkage are 51, 61 and 54 cm respectively.

Plate-1 Three points hitch connections on punch planter

Main frame

A rectangular frame of size 1220 mm x 1100 mm was fabricated by using MS flats and angular as mentioned sizes and quantities in [Table-2]. The overall dimensions of the main frame are shown in [Table-3].

The main frame supports the entire transmission system consists of reduction gear box with shaft, chain and sprockets, spur gear assembly, punch wheels with punch rods and seeding mechanism.

The reduction gear box was fixed to the main frame with the help of MS bolts and nuts. The output shaft of the gear box was supported by main frame through bearings. Two punch wheels along with punch rods are mounted on either side of the main shaft, which is attached to the main frame through bearings and fitted with nuts and bolts.

Table-2 *Material used for fabrication of main frame*

Material used	Specifications (mm)	Quantity(m)
MS angular	50 x 6	4.98
	37 x 6	3.57
	25 x 6	2.14
MS flat	50 x 6	1.00
	50 x 8	0.50

Table-3 *Overall dimensions of the main frame*

Particulars	Size
Length, mm	1220
Width, mm	1100
Height, mm	500

Reduction gear box

Commercially available crown and pinion bevel gear reduction gear box was used to reduce the speed of PTO shaft to the desired level at punch wheel with a reduction ratio of 1.85 : 1 between PTO and reduction gear box output shaft. . The specifications of the reduction gear box are shown in [Table-4].

Table-4 *Specifications of reduction gear box*

Parameter	Specification
Type	Crown and pinion bevel gear
Speed reduction ratio	1.85: 1
Input power, kW	11.45
Input speed ranges, rpm	600-900

Spur gear transmission system

The power from gear box output shaft is directly transmitted to the punch wheel in clock wise direction. But for proper punching with minimum soil disturbance in the field, the punch rod has to move along the direction of travel. Hence to obtain the rotation of punch wheel in clockwise direction, spur gear transmission system was incorporate in the transmission system between gear box output shaft and punch wheel. The spur gear arrangement was made to change the direction of the shaft only. Hence, the teeth on the both spur gear was maintained same. The specifications of spur gear transmission system are mentioned in [Table-5].

Table-5 *Specifications of spur gear transmission system*

Parameter	Specifications (mm / number)
Shafts Centre to centre distance	60.00
Number of teeth on driving sprocket	19.0
Number of teeth on driven sprocket	19.0
Pitch of the driving sprocket	11.00
Pitch of the driven sprocket	11.00

Plate-2 Final reduction transmission system (Chain and sprocket)

Chain and sprocket transmission system

The final speed reduction in the punch planter was obtained through chain and sprocket transmission system with gear reduction ratio of 2.74:1 between (driving shaft and driven shaft connected to punch wheel) the main shaft and punch wheel. Single roller chain ISO: 08B number was selected as per the design calculations. The major specifications are mentioned in [Table-6] and the single roller chain and sprocket system is shown in [Plate-2].

Table-6 *Specifications of chain and sprocket transmission system*

Component	Specifications (mm / number)
Shafts centre to centre distance	384.00
Number of teeth on driving sprocket	13.0
Number of teeth on driven sprocket	32.0
Pitch of the driving sprocket	12.7
Pitch of the driven sprocket	12.7
Number of links in the chain	84.0
Pitch of the chain	12.7
Between inner plates	7.75
Roller diameter	8.51
Chain width	17.00
Weight, kg m^{-1}	0.70
Length of the chain	1067
Power transmitted, kW	7.42
Average velocity of chain, m s^{-1}	0.83
Tension acting on the chain, N	8939.0
Breaking strength, N	18000.0

Punch wheel assembly

The punch wheel assembly consists of punch wheel and punch rod. Punch wheel was attached to the shaft with the help of bushes and bolts and nuts. The shaft was supported by two ball bearings. To obtain reciprocating motion to punch rod, punch wheel was fixed at a distance of 60 mm towards circumference from the centre. It consists two mild steel circular discs of 200 mm diameter and 10 mm thickness and a circular ring having 200 mm and 160 mm as outer and inner diameters. The punch rod 250 mm long of 25 x 25 mm square cross section was fixed at the circumference of the circular ring as shown in [Fig-1].

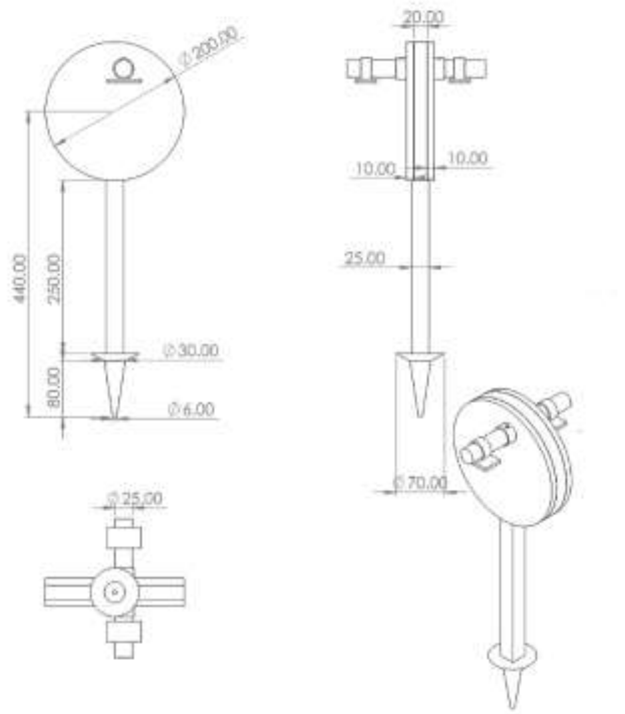

Fig-1 Punch Wheel assembly represented in Pro-E

Results and Discussion

Generally, the seed to seed spacing within the row for maize crop varies from 220 to 260 mm. The speed of the punch wheel was estimated based on the predetermined seed to seed distance of 240 mm for maize crop.

To obtained the optimum spacing between consecutive punches, the gear reduction was selected in three stages as shown below

First stage: Speed reduction from engine to PTO shaft

Second stage: Speed reduction from PTO shaft to reduction gear box output shaft

Third stage: Reduction gear box output shaft to punch wheel shaft

Reduction Ratio between Engine Speed and PTO Speed

Reduction ratio between Engine speed and PTO speed was measured to find out the final punch wheel speed to obtained recommended punch spacing. Engine speed increases from 1000 to 2000 rpm, the PTO speed also increased from 223 to 447 rpm respectively in lever position 1. In lever position 2 it was observed that the speed increased from 315 to 657 rpm with the increase of engine speed.

The average reduction ratios from engine speed to PTO speed for the selected PTO lever position 1 and 2 were tabulated in [Table-7].

Table-7 *Reduction ratios of engine speed to PTO speed at two lever positions*

Engine speed (rpm)	PTO speed (rpm)		Reduction Ratio	
	At lever position 1	At lever position 2	At lever position 1	At lever position 2
1000	223.00	315.00	4.48	3.17
1500	339.67	503.80	4.42	2.98
2000	447	657.17	4.47	3.04
Average Reduction ration			4.46	3.07

Reduction Ratio between PTO to Gear Box Output Shaft

In the same manner as mentioned above the reduction ratio between PTO speed to gear box output shaft for PTO lever position 1 and 2 are tabulated in [Table-8]. The average reduction ratios obtained from PTO shaft to gear box output shaft were 1.85 and 1.84 for PTO lever position 1 and 2 respectively.

Table-8 *Reduction ratios of PTO to gear box output shaft at two lever positions*

Reduction Ratio between Gear Box Output Shaft to Punch Wheel

In lever position 1, gear box output shaft speed increases from 120 to 244 rpm the punch wheel speed also increased from 48 to 104 rpm respectively. In this case reduction ratio was obtained 2.41.

In lever position 2, gear box output shaft speed increases from 174 to 358 rpm and the punch wheel speed also increased from 70 to 149 rpm respectively. In this case reduction ratio was obtained 2.42 as shown in [Table-9].

Table-9 *Reduction ratio of gear box output shaft to punch wheel*

Engine speed (rpm)	Gear box output shaft speed (rpm)		Punch wheel shaft speed(rpm)		Reduction ratio	
	At lever position 1	At lever position 2	At lever position 1	At lever position 2	At lever position 1	At lever position 2
1000	120.00	174.33	48.00	70.00	2.42	2.49
1500	183.00	266.67	74.33	112.00	2.46	2.38
2000	244.33	358.00	104.00	149.33	2.35	2.40
Average reduction ratio					2.41	2.42

Overall Reduction Ratios

The reduction ratios at two lever positions from engine to PTO are 4.46 and 3.07 for lever position 1 and 2 respectively. Fixed reduction ratios of 1.85 and 2.42 were obtained between PTO shaft to gear box and gear box output shaft to punch wheel shaft respectively. It shows that the overall reduction ratios from engine to punch wheel were 19.96 and 13.67 for PTO lever position 1 and 2 respectively. The reduction ratios at different stages are mentioned in [Table-10].

Table-10 Overall reduction ratios from engine speed to punch wheel speed at different stages

Type of reduction	Reduction ratio	
	At PTO lever position 1	At PTO lever position 2
Engine to PTO shaft	4.46	3.07
PTO shaft to Gear box output shaft	1.85	1.84
Gear box output shaft to Punch wheel shaft	2.42	2.42
Engine speed to Punch wheel shaft	19.96	13.67

Effect of Engine Speed on Forward Speed of Tractor

Tractor forward speed was measured in three gear positions by increasing the engine speed from 800 to 2400 rpm. In three gear positions the forward speed increases by increasing the engine speed. In PTO lever position 1 and gear position 1, the forward speed of the tractor increases from 0.35 to 0.98 kmh^{-1} by increasing the engine speed from 800 to 2400 rpm. In gear position 2 and 3 it was obtained as 0.80 to 1.53 kmh^{-1} and 1.69 to 3.28 kmh^{-1}.

In PTO lever position 2 and gear position 1, the forward speed of the tractor increases from 0.35 to 0.99 kmh^{-1} by increasing the engine speed from 800 to 2400 rpm. In gear position 2 and 3 it was obtained as 0.85 to 1.68 kmh^{-1} and 1.75 to 3.50 kmh^{-1}. It was observed that there is no effect of PTO lever position on forward speed of the tractor. The effect of engine speed on forward speed of the tractor is shown in [Fig-2 and 3].

The linear equations were developed between engine speed and forward speed of the tractor with R^2 value more than 0.95. The equations in different gear and PTO lever positions are mentioned in [Table-11].

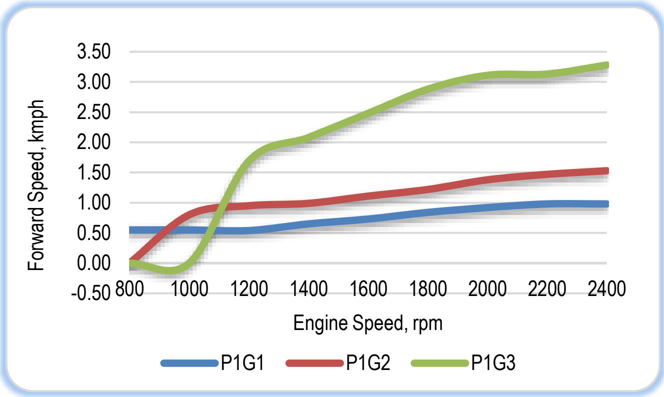

Fig-2 Effect of engine speed on forward speed of tractor in PTO lever position 1

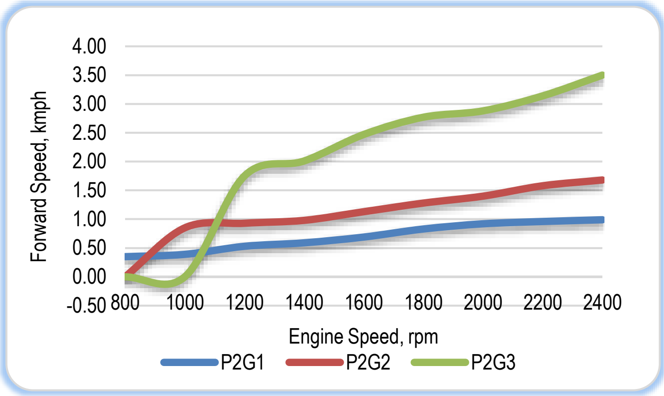

Fig-3 Effect of engine speed on forward speed of tractor in PTO lever position 2

Table-11 *Linear equations in between engine speed and forward speed of tractor*

Lever position	Gear position	Linear equation	R-square value
P1	G1	y = 0.267x + 1.057	0.927
	G2	y = 0.107x + 0.592	0.988
	G3	y = 0.087x + 0.272	0.97
P2	G1	y = 0.282x + 0.948	0.981
	G2	y = 0.124x + 0.543	0.983
	G3	y = 0.088x + 0.253	0.979

Effect of Gear and PTO Lever Selection on Punch Spacing

The average punch spacing of 10, 16, 24, 35, 53 cm was obtained in different gear and PTO lever positions as mentioned in [Table-12]. Punch spacing was not changed in particular gear and PTO lever position. The punch spacing was obtained in PTO lever position 1 and varying gear positions 1, 2 and 3 were 16, 24 and 53 cm respectively and punch spacing was obtained in PTO lever position 2 and varying gear positions 1, 2 and 3 were 10, 16 and 35 cm respectively as shown in [Fig-4].

In particular gear and PTO lever position, forward speed of the tractor increases with increasing engine speed, but there is no effect on punch spacing. The required punch spacing can be obtained by selecting the gear and PTO lever. The minimum and maximum forward speed of the tractor was obtained 0.35 and 3.28 km h^{-1}.

Table-12 *Punch spacing in different gear and PTO lever position*

Punch Spacing (cm)	Lever and gear selection	Forward speed (km h^{-1})
10	P2G1	0.35 - 1.00
16	P1G1	0.35 -0.98
	P2G2	0.85 - 1.68
24	P1G2	0.8 - 1.71
35	P2G3	1.75 - 3.50
53	P1G3	1.69 - 3.28

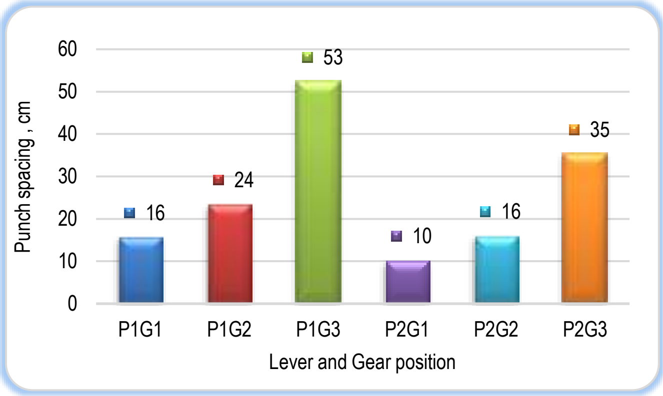

Fig-4 Punch spacing at different gear and lever positions

Effect of Forward Speed on Punch Spacing

PTO Lever Position 1 and Three Gear Combinations

Different forward speeds of the tractor obtained by increasing the engine speed from 800 to 2400 rpm in a particular gear. Maximum forward speed of 3.28 kmh^{-1} obtained in gear 3 (G3) followed by 1.53 kmp^{-1} and 0.98 kmh^{-1} in gear 2 and gear1respectively as shown in [Table-13]. PTO lever position will not effect the forward speed of the tractor but effects the punch spacing.

In a particular PTO lever position (P1) with the combination of gear selection three different punch spacing are obtained. In each combination (P1G1, P1G2 and P1G3) even though forward speed increases, there is no significant effect on punch spacing.

Table-13 *Punch spacing at different forward speed of the tractor in PTO position 1*

Lever and gear position	Forward speed (km h^{-1})	Punch spacing (cm)
P1G1	0.35	15.10
	0.39	15.10
	0.54	15.40
	0.65	15.80
	0.73	16.30
	0.84	16.30
	0.92	16.80
	0.98	16.50
	0.98	15.30
P1G2	0.8	24.00
	0.95	24.00
	0.99	24.10
	1.11	23.80
	1.22	23.20
	1.38	23.20
	1.58	23.10
	1.71	23.52
P1G3	1.69	53.60
	2.08	53.60
	2.48	52.20
	2.88	52.60
	3.11	51.80
	3.13	51.20
	3.28	52.50

PTO Lever Position 2 and Three Gear Combinations

Different forwards of the tractor obtained by increasing the engine speed from 800 to 2400 rpm in each gear selection Maximum forward speed of 3.50 kmh^{-1} obtained in gear 3 (G3) followed by 1.68 kmp^{-1} and 0.99 kmh^{-1} in gear 2 and gear1respectively as shown in [Table-14]. PTO lever position will not effect the forward speed of the tractor but effects the punch spacing. In a particular PTO lever position (P2) with the combination of gear selection three different punch spacing are obtained. In each combination (P2G1, P2G2 and P2G3) even though forward speed increases, there is no significant effect on punch spacing.

Table-14 *Punch spacing at different forward speed of the tractor in PTO position 2*

Lever and gear position	Forward speed (km h^{-1})	Punch spacing (cm)
P2G1	0.35	10.82
	0.39	10.60
	0.53	10.54
	0.59	10.40
	0.69	10.40
	0.83	10.10
	0.92	10.30
	0.96	10.10
	0.99	9.90
P2G2	0.85	16.20
	0.93	16.06
	0.98	16.10
	1.13	16.06
	1.28	16.20
	1.40	16.24
	1.58	16.24
	1.68	16.10
P2G3	1.75	35.64
	2.01	35.68
	2.47	35.40
	2.77	35.70
	2.88	34.90
	3.14	35.30
	3.5	35.40

Conclusion

Different forward speeds of the tractor obtained by increasing the engine speed from 800 to 2400 rpm in a particular gear. Maximum forward speed of 3.28 kmh^{-1} obtained in gear 3 (G3) followed by 1.53 kmp^{-1} and 0.98 kmh^{-1} in gear 2 and gear1respectively. There was no significant effect of PTO lever position on forward speed of the tractor but significant on punch spacing. In a particular PTO lever position (P1) with the combination of three gear selection different punch spacings are obtained. In each combination *i.e.* P1G1, P1G2 and P1G3 even though forward speed increases, there was no significant effect on punch spacing. Maximum forward speed of 3.50 kmh^{-1} obtained in gear 3 (G3) followed by 1.68 kmp^{-1} and 0.99 kmh^{-1} in gear 2 and gear1 respectively. There was no significant effect of PTO lever position on forward speed of the tractor but significant on punch spacing. In a particular PTO lever position (P2) with the combination of three gear selection different punch spacing are obtained. In each combination *i.e.* P2G1, P2G2 and P2G3 even though forward speed increases, there was no significant effect on punch spacing.

Application of research

1. To obtain different punch spacings by selecting different gears and hydraulic lever positions
2. After punching in the field with required spacing, seeds or seedlings can be dropped in the punches
3. This can be converted semi-automatic Transplanter
4. For this can attach seeding mechanism for automatic punch planter

Research Category: Agricultural Engineering

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Research project name or number: Research station study

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: College of Agricultural Engineering, Bapatla, 522101

Cultivar / Variety / Breed name: Maize (*Zea mays* L.)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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