Development and performance evaluation of manual/bullock operated multicrop planter for hilly region

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Abstract: In hills, sowing of various crops is generally performed manually by broadcasting of seeds, and that not only consume higher seed rate but also cause uneven distribution of seed at improper depth and moisture, poor germination, unhealthy plants and ultimately lower the yield. To overcome these problems, a single row manual/bullock multicrop planter was designed and developed for line sowing of wheat, maize, soybean, lentil, pea, mustard, millet etc. for hilly small fields. The power and pull requirements were 74.6 W and 12 kgf, respectively. The machine has a nylon made cell type seed metering mechanism with 4 types of cells of different sizes on a roller, and also has a fluted roller for fertilizer metering. Shovel type and Inverted T-type furrow openers can be used as the need. Two persons are required to operate the machine manually by one using handle and one with bullocks. The effective field capacity was observed 0.0378, 0.05, 0.058 and 0.056 ha h^{-1} in wheat, lentil, mustard and pea, respectively. The cost of operation was observed 42% less in multicrop planter with 21%-33% increase in yield as compared to traditional broadcasting method.

Keywords: multicrop planter, line sowing, broadcasting, hills

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1 Introduction

Mechanization of agricultural operations in plains has played a vital role in efficient and timely field operations, but mechanization almost untouched in hilly areas. Most of the farmlands in the mountains are in small and undulating terraces. Manual and bullock power is predominantly used on farms (Singh and Vatsa, 2007). The bullocks available with the farmers are smaller in size and less in power than plain areas. Farm equipment for the hill region must suit the terrain. Machines designed for plains are not suitable in the hills due to topography and size of land holdings. Due to lack of a proper sowing device, the adoption of line sowing is almost negligible in hill farming. The farmers are still using traditional method of sowing i.e. manual broadcasting of seeds by hands. Abd El-Lattief (2014) claimed that sowing methods played an important role in the placement of seed at proper depth and stand establishment of the growing crop which ultimately affects crop growth and productivity. Wheat, paddy, maize, millets, pulses, pea, lentil, mustard, horsegram are the crops grown in hills of Uttarakhand. Broadcasting of seeds is normally adopted for sowing of various crops, which not only consumes more man-power but also affects the crop stand, resulting in poor yield (Singh, 2014). Line sowing is the most efficient means of sowing the crops and most ideal for crop management (Devnani, 1989). Studies in India have shown that a yield increase of 10% to 12% obtained in wheat and maize can be achieved with the use of seed-cum fertilizer drill and planters.

A number of manual/bullock/power tiller operated seed drills/planter have been developed in the country for small fields Singh and Bhardwaj (1985), Gupta et al. (1999) and Vatsa et al. (2000) claimed, but some of them

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are heavy for use in hills and when sowing different crops they have to change the seed metering devices that is not easy at the farmers level and waste time.

Considering these points, efforts was made to develop a lightweight, simple and compact multicrop planter matching for the hilly existing farming situations. As farmers in hills are generally resource poor, so the higher production cost is a matter of concern. Further, hills generally receive very high rainfall and soil is prone to different kind of degradation. Under such situation, sowing under zero-till condition can be a suitable answer to reduce the degradation process. Therefore, during the multicrop planter development, the priority of the machine should be used for both ploughed and un-ploughed (no-till) conditions and also had the provision to place the fertilizers at the proper place. Considering these facts, a lightweight, single row multicrop planter was developed at ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora (Uttarakhand) which not only enables the placement of seeds of different crops and fertilizer at desired rate and at proper soil depths, but also considerably reduces the cost of cultivation.

2 Materials and methods

2.1 Design considerations

The basic design considerations in the development of the multicrop planter were:

1) It should be operated manually with two or three persons or with a pair of bullock.

2) It should be light in weight so that it can be transported easily from one terrace to another by a single person.

3) The machine should be economical i.e. within the purchasing capacity of small and marginal farmers.

4) It should be able to sow the major crop of hills viz. wheat, maize, soybean, millet, pea, lentil, paddy etc.

5) It should be able to work under ploughed and unploughed conditions (No-till), meter the seed and fertilizer with required seed rate.

6) It should be easy in operation and maintenance.

7) It should be easily fabricated by local manufacturers.

2.2 Constructional details

Prototype of manual/bullock multicrop planter was developed at ICAR-VPKAS, Almora (Uttarakhand) India with technical specifications given in Table 1. The machine consisted of a main frame, ground wheels, seed and fertilizer hoppers, seed and fertilizer metering system, furrow opener, power transmission system and hitch (Figure 1).

Table 1 Technical specification of the multi-crop planter

Particular	Value
Overall dimensions Length × width × height (mm)	530×580×810
No. of row	Single
Type of furrow opener	Shovel & Inverted T
Power source	Manual/bullock
Ground wheel diameter, mm	260
Seed metering mechanism	Cell type roller made of plastic
Type of cell on roller	4
Roller diameter & length, mm	64 & 100
Fertilizer metering system	Fluted roller made of Aluminium
Power transmission to metering device	From ground wheel through sprocket and chain arrangement
Depth of sowing	Adjustable up to 80 mm
Estimated cost of machine, Rs	2,500/-

Figure 1 Developed prototype of multicrop planter

A cell type multicrop seed metering roller having four different type/size of cell made of plastic was used to avoid changing of roller for a particular crop. The length and diameter of the roller was 100 mm and 64 mm. The roller was mounted on a shaft of 19 mm diameter and it rotates in housing, filled with seeds on the back side which is attached to the main seed hopper. A brush type cut-off device is provided above the roller in the middle for regulating the flow of seed to cells (Figure 2) which delivers seeds to the seed tube attached with the roller housing towards lower front side. The four different type and size of cells on the roller is given in Table 2. A particular cell size available on the roller was used for a particular crop as per the seed size and seed rate. The fluted roller made of aluminium was used for fertilizer metering mounted on 16 mm shaft. The seed and fertilizer rate was calibrated using combination of gears (one drive and two driven gears). The numbers of teeth on drive gear and driven gears were 22 and 18. The range of seed rate achieved was also calculated by inter changing the drive and driven gears.

Table 2 Detailed specifications of cell type seed metering roller

Type of cell on the roller	Number of cells	Cell Dimensions		
		Length/diameter, mm	Width, mm	Depth, mm
Rectangular	14	15.4	9.6	2.8
Circular	22	4.0	-	2.4
Circular	10	11.9	-	5.6
Circular	14	9.65	-	5.2

Figure 2 Cell type seed metering roller used in the planter

The furrow opener of a sowing device is the final modifier of soil environment in a seedbed. Hence, it is one of the most important components of a seed cum fertilizer drill. Shovel type furrow opener was used in the multicrop planter. To operate the planter under no-till conditions, an inverted "T" type furrow opener was fabricated and used in the planter. There have been many experiments that investigated design factor mostly focus on optimum rake angle (Gebersenbet and Johnson, 1992; Mathur and Pandey, 1992; Damora and Pandey, 1995). The summary of all above research indicated that the vertical and horizontal forces can be increased, by increasing rake angle and the minimum pulling resistance occurred at 25°. The furrow opener is made up of 5 mm thick mild steel plate. For hardening the soil cutting edge of furrow opener, arc welding and grinding was done.

The ground wheels acts as power transmission wheels for seed and fertilizer metering were made of mild steel MS flat of size 30 × 5 mm. As lands are stony in hills, so for uniform power transmission to central shaft, pegs of 60 mm on ground wheels were provided.

While designing the handle, the ergonomic aspect was taken into consideration. The position of the handle could be adjusted according to height of the operator using two-point linkage system. For bullocks, handle could be replaced by beam of about 3000 mm.

2.3 Field evaluation

Field trials were conducted at the Hawalbagh farm of the Institute on a sandy clay loam soil and at the farmers' field to evaluate the manual multicrop planter for sowing of wheat, pea, lentil and mustard. Machine performance parameters like effective field capacity, field efficiency, speed of operation, depth of sowing and labour requirements were determined as per the standard procedure and compared with the conventional practice. For comparing the performance of the multicrop planter with the traditional method of sowing at the farmers' field, a minimum plot size of 10 × 8 m^2 was taken with three replications for both the methods. The machine was also tested for wheat sowing under no-till conditions at Hawalbagh farm with three replications and compared with traditional method.

2.4 Cost analysis

A cost analysis was made based on the procedure given in the IS Code (Indian Standard Institution, 1979). The useful life of multicrop planter was assumed to be 8 years and the annual use was assumed to be 100 h.

3 Results and discussion

The field performance of the developed multicrop planter was conducted at farmers' field and at Hawalbagh Farm of the Institute for sowing of wheat, lentil, pea and mustard in spring 2012.

3.1 Field performance of multicrop planter for wheat sowing

The performance result of the multicrop planter for sowing of wheat is given in Table 3. The improved wheat variety of the Institute VL-892 was used in the experiment. The sowing date was November 23 and

December 16. The planter was operated manually in the field by two persons having age 32 and 55 years. One person was used to pull the planter and another rear person was used just to guide the planter by holding the rear handle. The wheat was sown under rain-fed and irrigated conditions and that was compared with the conventional method (Figure 3). The cost of operation was 42% higher in conventional system and yield of wheat was observed 30%-33% higher in multi-crop planter in both rain fed and irrigated conditions than the broadcasting method. This was due to proper placement of seed at proper depth in moist zone.

Table 3 Performance results of manual multicrop planter for sowing of wheat

Parameters	Multicrop planter		Broadcasting
	Rain-fed	Irrigated	
Moisture content, %	9.0	20.0	10.0
Speed of operation, km h^{-1}	2.5	2.5	-
Germination, % After 10 days	32	75	18
After 20 days	73	80	80
Effective tiller m^{-2}	285	346	263
Effective field capacity, ha h^{-1}	0.039	0.04	0.16* & 0.025**
Labour required, man-h ha^{-1}	50 -53	50	6.25 & 40
Cost of operation, Rs ha^{-1}	1000-1060	1000	1725
Yield, kg ha^{-1}	1770-1910	2100	1400

Note: *Broadcasting of seeds and **Mixing of seeds by ploughing.

Figure 3 Planter in operation at farmers' field

3.2 Performance of multicrop planter under zero-till conditions

The results of testing of machine for wheat sowing under zero-till conditions are given in Table 4. The previous crop was paddy and average stubble height was 65 mm in the field. The zero-till multi-crop planter was compared with the conventional practice of wheat sowing i.e. ploughing the soil + broadcasting of seeds + mixing of seeds. The power tiller was used for ploughing and mixing of seeds. The multi-crop planter was operated in paddy harvested field for wheat sowing (Figure 4) at 23% soil moisture content. The better germination was observed in the field sown under zero-till condition and also the high effective tillers per square meter than the conventional practice. The cost of operation was 63% less in zero-till than conventional practice of tilling the soil and yield was also observed 16% higher.

Table 4 Results of multi-crop planter for wheat sowing under zero-till conditions

Parameters	Multicrop planter (Zero-tillage)	Broadcasting method (conventional practice)
Location/Name of village	Institute farm	Institute Farm
Name of crop sown	Wheat	Wheat
Variety	VL-953	VL-953
Date of sowing	28.11.2012	28.11.2012
Moisture content, %	23	20
Speed of operation, km h^{-1}	2.1	-
Width of operation, cm	20-21	-
Row to row distance, cm	20-21	-
Germination, % after 10 days	46	40
Germination, % after 20 days	95	84
Effective tiller m^{-2}	509	385
Effective field capacity, ha h^{-1}	0.031	0.042P* + 0.16B**+ 0.05M***
Labour required, man-h ha^{-1}	64	24 P+ 6.25B+ 20M
Cost of operation, Rs ha^{-1}	1280	1800+125+1500=3425
Yield, kg ha^{-1}	6569.65 (16%)	5652.87

Note: P*=Ploughing the soil, B**=Broadcasting and M***= Mixing of seeds.

Figure 4 Multi-crop planter in operation under zero-till condition and crop stand in field

3.3 Performance of multicrop planter for sowing of lentil, mustard and pea

The multi-crop planter was also used for sowing of lentil, mustard and pea at the Institute farm and at farmers' field (Table 5). The actual seed rate observed with planter was 26, 7 and 80 kg ha^{-1} in case of lentil, mustard and pea, respectively. The labour required during sowing was 34-42 man-h ha^{-1} and cost of operation was Rs 680-840 ha^{-1}. The planter was appreciated by the farmers due to its easy operation, better placement of seed and fertilizer in line and at proper depth.

Table 5 Performance result of multicrop planter for sowing of lentil, mustard and pea

Parameters	Multi-crop planter			
Location/Name of village	Odiyari	Institute farm	Institute farm	Institute farm
Variety	Lentil (VL-126)	Lentil (VL-126)	Mustard (VLT-3)	Pea
Moisture content, %	8.0-8.5	18.0	15	16
Speed of operation, km h^{-1}	2.5-2.6	2.6	2.6	2.5
Width of operation, cm	25-27	25-26	30	30
Actual seed rate used, kg ha^{-1}	26	26	7	80
Row to row distance, cm	25-27	25-26	30	30
Plant to plant distance, cm	4-5	4-5	8	7
Germination, % after 10 days	20-45	50	80	60
Germination, % after 20 days	80-95	96	90	74
Effective field capacity, ha h^{-1}	0.048-0.05	0.052	0.058	0.056
Labour required, man-h ha^{-1}	40-42	38	34	36
Cost of operation, Rs ha^{-1}	800-840	760	680	720

3.4 Total cost of manufactured prototype

The manufactured cost of prototype developed was calculated based on the prevailing markets rate of the raw materials used for fabrication of the machine during the year 2012-13 viz. angle iron, pipe, metering roller, fluted roller, rod, flat etc. and man-power used for fabrication. The approximate cost of the machine was Indian Rs.2500/-.

3.5 Power and pull measurements

According to Campbell et al. (1990) equation that Sharma and Jain (2008) had claimed, the power of useful work done by human being is given by formula Equation (1).

$$HP = 0.35 - 0.092 \log t \quad (1)$$

where, t = time in minute.

For 3-4 h continuous work to operate the planter, the power developed by the operator would be 0.10-0.13 hp say 0.11 hp.

$$HP = Draft \text{ (kgf)} \times Speed \text{ (m s}^{-1}\text{)}/ 75 \quad (2)$$

Let the operating speed of the machine be 0.7 m s^{-1} i.e. about 2.5 km h^{-1}.

$$Draft \text{ (kgf)} = (HP \times 75)/Speed \text{ (m s}^{-1}\text{)} =$$
$$0.11 \times 75/0.7 = 11.78 \text{ say 12 kgf} \quad (3)$$

Hence, force developed by an average human worker was = 12 kgf.

4 Conclusions

The light weight multi-crop planter was developed and tested very appropriate in hills for sowing of major crops of the regions without changing the metering rollers as it resulted in saving about 42%-63% cost of operation and increasing 21%-33% in yield over traditional methods.

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