Design, Development and Evaluation of Manual-Cum-Bullock Operated Zero-Till Seed-Cum Fertilizer Drill for Hills

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Abstract

A double row manual-cum-bullock drawn seed-cum-fertilizer drill (Vivek seed-cum-fertilizer drill; cost INR 2000/=) suitable for sowing rice, wheat and lentil has been developed at Vivekananda Institute of Hill Agriculture, Almora, India. The machine was fabricated using locally available materials. It consists of an MS body, inverted T-type furrow opener with 25° rake angle, adjustable MS beams for man and bullock power, seed box with fluted feed metering device, fertilizer box with agitator, plastic delivery tube, and MS transportation-cum-power wheel. The weight of the seed-cum-fertilizer drill is 23 kg. It can be operated by two persons for sowing in a prepared seedbed and by a pair of bullocks in case of no-till sowing. The machine has the capacity to sow 0.025 to 0.04 ha/hr. Line sowing of wheat and lentil with zero-till seed-cum-fertilizer drill (power source: 2 men) resulted in saving of INR 5059 and INR 4206 respectively as compared to traditional practice (two passes of ploughing with indigenous plough + Manual clod crushing + Two pass of wooden plank + Manual broadcasting; Power source: 1 Man and 1 bullock pair). Energy savings in wheat and lentil sown with zero-till seed drill were 1,305.3 MJ/ha and 1,106.6 MJ/ha, respectively, as compared to the traditional method of broadcast sowing. Study of soil physical properties showed that soil water content at all the studied soil depths were higher in plots under line sowing without seedbed preparation (T_2) than those in plots under line sowing with seed bed preparation (T_1). The values of soil bulk density at harvest under T_2 were higher in 0-15 cm soil depth. Initial infiltration rates were greater in the plots under T_1 than those in T_2. However, the steady state infiltration rate and mean weight diameter (MWD) were higher in the plots under T_2 than those under T_1. The advantage of zero-tillage with animate (man + animal) power source could be realized by using zero-till seed cum fertilizer drill.

Introduction

Unlike in plains, the green revolution has little impact in hilly areas. The reasons could be difficult terrain with undulating topography with small and scattered land holdings on steep slopes and lack of mechanization. Mechanization of agricultural operations in plains has played a vital role in efficient field operations thereby reducing the production cost. Whereas, Indian hill farming is almost untouched as far as mechanization is concerned.

The productivity of major cereals in hills is much lower than the productivity of those crops observed in plains of Uttaranchal. This may be due to poor germination and population because of traditionally popular broadcast sowing in hills. Broadcast sowing not only requires more seed rate but also makes the intercultural operations cumbersome and labour intensive. Line sowing, where seeding is done at appropriate depth, gives 10-15 % more grain yields than broadcast sowing across the crops.

It has been estimated that about 15 % of the total energy available for the rural sector is used for agricultural production (Singh, 1997) of which about 20 % is consumed only in seedbed preparation (Anonymous, 1984). 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. Due to lack of a proper sowing device, the adoption of line sowing is almost negligible in hill farming. In hills, agriculture is performed on small zig zag terraces and farmers are resource poor. The bullocks available with the farmers are smaller in size and less in power than plain areas. Considering these points, efforts were made to develop a small compact and lightweight seed drill matching existing farming resources and situations. Farmers in hills are generally poor and the higher production cost (almost all the agricultural operations are done manually) is a matter of concern. Therefore, during the seed drill development, the priority was whether the machine should be dual purpose, i.e. suitable for both ploughed (power source: 2 men) and un-ploughed (power source: 1 man and two bullocks) conditions and also had the provision to place the fertilizers at the proper place.

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. The improvement of soils structure is important for controlling water erosion processes. Effect of cultivation of soils in structural degradation and decrease in soil organic matter (SOM) has been well documented. Oades (1993) stated that the repeated cultivation of soils, combined with limited SOM inputs, would eventually result in breakdown of aggregates leaving the soil vulnerable to erosion. Tillage incorporates organic matter in soil surface layers, which alters the distribution and may increase decomposition. In soils with low to medium clay content (sandy clay loam soil), loss of SOM can be minimized with the use of conservation tillage, which retains crop residues on the soil surface and minimizes soil disturbance. Zero-tillage practices modify soil physical properties including soil structure (Kay, 1990), dry bulk density (Wu et al., 1992), water distribution (Azooz et al., 1996), pore size distribution (Kay, 1990) and root distribution (Lal et al., 1989). Thus, conservation tillage results in improvement of storage and transmission of air along with water and solutes, which in turn may lead to improved crop performances.

Considering these facts, a light-weight, two-row seed-cum-fertilizer drill was designed and developed at this Institute, which not only enables the placement of seeds and fertilizer at proper soil depths but also considerably reduces the cost of cultivation.

Materials and Methods

Design of Various Components

In hills of Uttaranchal, the soils range from light textured sandy, sandy loam, loamy sand and loam in upland to medium textured silty clay loam in valley areas. Before the development of the present seed-cum-fertilizer drill (**Fig. 1**), a survey was conducted to find out the suitability of machine considering the local situations. Following points emerged during the process.

- The weight of seed drill should be limited to 25 kg, so that it can be easily carried by a single person,
- Preferably it could be operated, both manually and by bullocks, and
- It should be easy in operation and maintenance.

A zero-till seed-cum-fertilizer drill of 500 mm width and 1,640 mm length was developed at VP-KAS (ICAR) Research Farm, Hawalbagh, Almora. The technical details of the drill are given in **Table 1**. There are four assemblies in the machine, i.e. furrow opener, frame, seed-cum-fertilizer box and transportation-cum-power wheel. Physical attributes of the grains have major consideration on designing parameters. The theoretical basis of the design of different components is given in subsequent sections.

Frame

The Frame of the machine is made

Table 1 Technical details of the seed-cum-fertilizer-drill

Component	Description
Body	Mild steel body, 640 mm length and 500 mm width
Transportation cum power wheel	Mild steel, 490 mm diameter, 6 no of spokes and 25 mm lug height
Number of furrow opener	Two
Furrow to furrow spacing	Adjustable, 15 to 25 cm
Furrow opener	Inverted T type
Shank	Mild steel flat, 30 × 6 mm size and 300 mm length
Share	Mild steel, hardened by arc welding/griding
Fertilizer and seed box	Mild steel shaft of 1 mm thickness
Volume of seed box	0.0056 cu.m
Volume of fertilizer box	0.0056 cu.m
Weight of the seed drill	23 kg
Seed and fertilizer tube	Plastic tube of 30 mm diameter
Handle	Mild steel pipe of 25 mm diameter
Beam	Mild steel pipe of 45 mm diameter

of mild steel square box and MS angle having length and width of 210 and 180 mm, respectively. The front arm, on which the furrow openers are mounted, is made of MS square box (30 × 30 × 5 mm) to provide more strength whereas, other arms are made of MS angles (30 × 30 × 6 mm) to reduce the weight of the machine. In the front arm, circular holes (10 mm) at a regular intervals (2 cm) have been made for adjusting the spacing between furrow openers to suit the spacing requirement of different crops. In the same frame, seed box, fertilizer box, adjusting beam and adjustable guide arms are fitted. The size and type of the material of the frame has been selected on the basis of several test runs.

Furrow Opener Assembly

In the furrow opener assembly, the main components are shank, share, and seed and fertilizer pipes.

Design of Shank

An inverted T-type furrow opener is fitted at one end of the Shank and the other end of the shank is attached with frame by nuts and bolts. The thickness, width and length of the shank were decided on the basis of design given below:

The section modulus of the shank can be computed from the classical flexure formula (Seely et al., 1952 and Timoshenko et al., 1964) as given below

$f_b = M_b Y / I$ ....(1)

where,

f_b = Bending stress, kgf /cm^2

M_b = Bending moment, kgf-cm

Y = Distance from the neutral surface to the fiber where the stress is fb in cm

I = Moment of inertia for rectangular cross-section about the neutral axis in cm

From equation number (1)

Section modulus = I/Y = M_b/f_b = $b_b^2/6$ ....(2)

Mb = Dd L

where,

D_d = Design draft in kgf which should be kept 3 to 5 times of actual draft for safety point of view.

Actual draft = k_0 A

where,

k_0 = Soil resistance, kgf/cm^2

A = Cross-section area of furrow, cm^2

Therefore M_b = 5 k_0 A L ....(3)

From equation (2)

Here the length of shank (L) = 30 cm

Area of cross-section of furrow = 9.1 cm^2

f_b for mild steel rectangular cross-section = 1000 kgf/cm^2

It is assumed that b: d = 1:4 or d = 4b

b^3 = 0.36

b = 0.71 cm say 7 cm

Therefore d = 2.84 cm say 3 cm

Standard MS flat of size 30 × 6 mm was used for fabricating the shank of furrow opener

Design of Inverted T-type Furrow Opener

The furrow opener is fitted with multi hole shank with nuts and bolts.

The depth of cut can be adjusted by changing the hole order of the shank and rake angle of the furrow opener (**Fig. 2**). Generally the draft increases with increase in rake angle and the rate of increase in draft becomes greater with tynes of more than 500 rake angle. This phenomenon is extremely important for reducing the draft (Osman, 1964).

Siemens et al. (1965) analyzed and concluded experimentally that a furrow opener with 25° rake angle gave minimum draft. In this machine, provision has been made to change the rake angle ranging from 15 to 25° to suit different soil conditions. However, after several test runs under different soil conditions, it was found that the furrow opener with 25° rake angle provided optimal upward force, soil disturbance and draft. 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.

Fig. 1 VL seed-cum-fertilizer drill

Fig. 2 Furrow opener

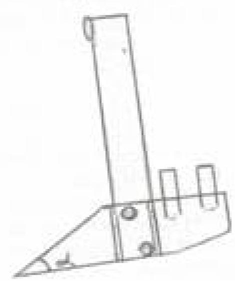

Table 2 Sowing method-wise time requirement, energy consumption and cost of sowing for Lentil crop

Treat.	Time, hr/ha	Man-hr/ha	Bullock pair-hr/ha	Energy consumption, Mj/ha	Sowing cost, INR/ha	Yield, q/ha
Wheat						
T_1	287.2	287.2	187.2	2,073.6	6,975	38.6
T_2	38.3	38.3	76.6	768.3	1,916	39.1
Lentil						
T_1	259.9	259.9	159.9	1,799.8	6,122	7.2
T_2	38.3	38.3	76.6	693.2	1,916	8.5

Labour charge = INR 80/day (8 working hour in a day)
Bullock pair charge = INR 144/day (8 working hour in a day)
1 Bullock hour = 8.07 MJ (Body weight less than 350 kg)
1 Man hour = 1.96 MJ

The inverted T-type furrow opener was selected because it caused less soil disturbance with less draft and firm furrow for better placement of seed and fertilizer.

Seed and Fertilizer Box

The size of seed box was decided on the basis of field size and seed rate of wheat crop. In general, the available working field size in hills is approximately 2 Nalies (0.04 ha), which requires 4 kg seed at 100 kg/ha. The seed box was made of mild steel sheet of 1.0 mm thickness. The top length and width of the seed-cum-fertilizer box is 320 mm and 260 mm, respectively, and partitioned with 1.0 mm MS sheet to have separate seed and fertilizer boxes. The bottom length and width of the box was 160 and 130 mm, respectively. According to RNAM recommendation, the orifice diameter for particle size of 5 mm should be 25.1 mm and bottom width of 25 mm on each side of the opening. The volumetric capacity of each of the seed and fertilizer box was 0.005 cu. m. The height and inclination of seed box was calculated as follows:

Average field size of Uttaranchal hill's field = 0.04 ha

Seed required for this area at 100 kg/ha = 0.04 × 100 = 4 kg

Bulk density of wheat grain (measured) = 0.79 g/cm^3

Volume of 4 kg seed = 5050 cm^3

Required volume of seed box with 10 % free board = 5555 cm^3 = 0.0056 m^3

Calculation of Height of Seed Box

Volume = $\frac{1}{2}[(L_t - L_b) \times B_t \times h + (B_t - B_b) \times L_b \times h + L_b \times B_b \times h] = 5555$

Or h = 21.36 cm, say 22 cm

Side slope angle of the seed box =

$$\cot^{-1}\frac{\text{Top width} - \text{Bottom width}}{\text{Height of the box}}$$

$= \cot^{-1} 0.25$

$= 75.96^\circ$, say 76°

The side wall of fertilizer box and seed box were kept 76° inclined, which was greater than the angle of repose of seed and fertilizer. The angle of repose in case of wheat ranges from 31.3 to 33.1° (IS: 6663-1972) and is approximately 28° for lentil.

Seed metering and fertilizer agitating device: For controlling the seed rate, fluted feed roller type metering device (**Fig. 3**) with adjustable opening is fitted in the seed box. This type of metering device is generally used for seed such as wheat, barley, paddy, oats, maize, sorghum. The exposed length of the fluted feed can be calculated as follows:

Volume of seed grain required in 1.0 m running length,

$V = 1/8\,[N_f \times \pi \times (D_f)^2 \times L_e]$

$L_e = 8V / (\pi N_f D_f^2)$

where,

L_e = Exposed length of fluted feed roller, cm

N_f = Number of flutes in fluted feed roller

V = Volume of seed grain required in 1 m running length, cm^3

D_f^2 = Diameter of semi circular flute, cm

The fertilizer box is equipped with agitator and orifice with adjustable opening. In this device, four flats of 25 × 25 mm size have been welded on an agitator shaft vertically just above the orifices of fertilizer box. Power for the agitator shaft is from the feed shaft with the help of chain and sprocket, which receives power from ground wheel. For controlling the fertilizer rate, a sliding shutter is fitted below each orifice of the fertilizer box. Plastic tubes of 30 mm diameter have been used for providing smooth seed and fertilizer flow from seed and fertilizer box to furrows.

Power-cum-transportation Wheel

In this seed-cum-fertilizer drill, the transportation wheels acts for power as well as depth control. Ground wheels or power wheels were made of mild steel MS flat of size 30 × 5 mm and round bar of size 10 mm diameter. Lands are stony in the hills, therefore, peg type ground wheels were provided for uniform power transmission to the central shaft, which, in turn, transmit power to seed metering device and fertilizer agitating device. For removing the requirement of an extra chain sprocket and central shaft for the ground wheel, the wheel size was increased to 490 mm (diameter) with 25 mm pegs. It also provided space for a furrow opener, seed tube and primary hopper as well as higher ground clearance.

During development of this seed-cum-fertilizer drill, main emphasis was given to make it lightweight so that it can easily be carried in hilly terrains. The total weight of this seed-cum-fertilizer drill was 23 kg. It could be operated by animate (man and animal both) power source. It was named the Vivek zero-till seed-cum-fertilizer drill.

The speed of power wheel, centre shaft and fluted roller was worked out as follows

Normal man speed = 2 km/h

Wheel diameter = 490 mm

$N = [V / \pi D] \times [(2 \times 1000) / 60] \times [1 / (3.14 \times 0.49)] = 22$ rpm

If we assume slippage = 6 %

Then N for fluted feed roller = 21 rpm

In hills, row to row spacing for lentil = 16 cm

Total running length of the furrow in one ha field = 62500 m

Distance covered by ground wheel in one rotation = $\pi d = 3.14 \times 49 = 1.54$ m

No. of rotations in 1 ha = 40584

Seed rate for wheat crop = 100 kg/ha

Seed of wheat required in one rotation = 2.46 g

Adjustable Beam

Adjustable beams have been provided to make it manual as well as bullock operated. For manual operation, the beam was made of 25 mm OD/22 mm ID MS pipe having total length of 1200 mm and a grip of same MS pipe having 370 mm length was welded on the beam perpendicularly. The beam is fitted with the frame with the help of two nuts and bolts. While designing the beam, the ergonomic aspect was taken into consideration. The position of the beam could be adjusted according to the height of the operator using two-point linkage system. For bullocks, beams could be replaced by 45 mm OD/42 mm ID MS pipe. The total length (3000 mm) of the beam was made using three MS pipes (length of each pipe = 1000 mm), which were joined with each other using nuts and bolts during operation.

Characterization of Physical Properties of Soil

Soil bulk density was measured by core sampler. Soil moisture content at different soil layers was determined by gravimetric method. Infiltration rate was determined by a double ring infiltrometer. Aggregate size distribution was determined by wet sieving method as described by Yoder (1936). Approximately a 50 g soil sample (2-4.75 mm) was immersed in water on a nest of sieves (2, 1, 0.5, 0.25 and 0.1mm) for 10 minutes before the start of wet-sieving action. The sieve nest was then clamped and transferred to the drum securely. The sieve assembly was oscillated up and down by a pulley arrangement for 20 min at a frequency of 30-35 cycles min-1 with a stroke length of 4 cm in salt free water inside the drum. The water stable aggregates retained on sieves were then backwashed into pre-weighed containers, oven dried at 50 0 C for 2 to 3 d, and weighed. The MWD was calculated taking into account the sand content in each aggregate size fraction, using the following relationship:

MWD (VanBavel, 1949) = $\Sigma xiyi$

Where, xi is the mean diameter of the soil aggregate size (mm) fractions and yi is the proportion of each aggregate size with respect to the total sample weight.

Field Evaluation

Seeding performance of this seed-cum-fertilizer drill was studied, on a sandy clay loam soil at the Experimental Farm (Hawalbagh) of VPKAS (ICAR), Almora. Both wheat and lentil was grown under rainfed condition. Soil characteristics in the plots where wheat was sown were 57.2 % sand, 20.1 % silt, 22.7 % clay, 0.95 % organic carbon, moisture content 16.12 % (d.b.) and 1.33 Mg/m3 bulk density and in the plots where lentil was sown had 58.5 % sand, 19.7 % silt, 21.8 % clay, 0.92 % organic carbon, moisture content 16 % (d.b.) and 1.34 Mg/m^3 bulk density. Time required for sowing, energy consumption and cost of sowing were calculated for each of the following treatments.

T_1 = Two passes of ploughing with indigenous plough + Manual broadcasting + One pass Manual clod crushing + Two passes of wooden plank + Line sowing by Vivek seed-cum-fertilizer drill (Power source: 1 man and 1 pair of bullocks).

T_2 = Line sowing with Vivek seed-cum-fertilizer drill with out seedbed preparation + One pass planking (power source: 2 men).

Result and Discussion

Time Requirement for Sowing Operation

The sowing of lentil crop, using newly developed seed-cum-fertilizer drill, was successfully carried out under zero-tillage condition. Time requirement (**Table 2**) for sowing operation was less by 650 % in zero-till condition sowing of wheat crop compared against the sowing in prepared seed bed. A similar trend was observed in lentil crop sowing.

Energy Requirement

Use of the above mentioned seed-cum-fertilizer drill resulted in considerable reduction in energy consumption for sowing of both crops. The consumption of energy for wheat sowing was 768.3 MJ/ha in the plots under T_2 treatment. This increased to 2,073.6 MJ/ha in the plots under T_1. A similar trend was observed in lentil crop sowing. In prepared seed bed sowing, energy requirement increased due to the involvement of extra energy in seed bed preparation (**Table 2**).

Cost of Sowing

The sowing cost of wheat and lentil crops by the traditional method comes to INR 6,975/ha and INR 6,122/ha. However, it was only INR 1,916/ha for zero-tillage (T_2) with the newly developed seed-cum-fertilizer drill for the both crops. Thus, line sowing with Vivek seed-cum-fertilizer drill not only saved time and energy but also considerably reduced the cost of sowing.

Crop Performance

The plant stand was up to the mark both under prepared seed bed and zero-tillage conditions. It was 38/m and 49/m row in ploughed plots and 42/m and 46/m in unploughed plots for wheat and lentil, respectively. Only 59.0 mm rainfall

Table 3 Soil bulk density and mean weight diameter (MWD) at harvest of wheat crop

Treat.	Soil bulk density, $Mg\ m^{-3}$					MWD, mm				
	0-15	15-30	30-45	Mean	S.D.	0-15	15-30	30-45	Mean	S.D.
Initial	1.33	1.35	1.39	1.36	0.02	1.12	1.01	0.94	1.02	0.07
T_1	1.33	1.36	1.39	1.36	0.03	1.09	0.99	0.94	1.01	0.09
T_2	1.35	1.36	1.40	1.37	0.02	1.13	1.03	0.95	1.04	0.09

Table 4 Soil bulk density and mean weight diameter (MWD) at harvest of lentil crop

Treat.	Soil bulk density, $Mg\ m^{-3}$					MWD, mm				
	0-15	15-30	30-45	Mean	S.D.	0-15	15-30	30-45	Mean	S.D.
Initial	1.34	1.36	1.40	1.37	0.03	1.10	1.02	0.92	1.01	0.09
T_1	1.33	1.36	1.39	1.36	0.03	1.08	1.02	0.91	1.01	0.08
T_2	1.37	1.37	1.40	1.38	0.02	1.12	1.03	0.91	1.01	0.097

was received during the entire crop season and, as a result, the grain yield was low. The grain yield of wheat and lentil crops under two situations did not differ significantly being 3860 kg/ha and 394 kg/ha in ploughed plots and 39.1 kg/ha and 383 kg/ha, respectively, in unploughed plots.

Soil Bulk Density

Treatments were imposed for 2 years. Results showed that, with increase in soil depths, bulk density values increased and the highest bulk density value (1.40 Mg m^{-3}) was observed at 30-45 cm soil depth (**Tables 3** and **4**). At harvest of wheat and lentil crops soil bulk density was higher in plots under T_2 at the soil surface (0-15 cm) compared with tilled T_1. There were no variation in soil bulk density values due to tillage management at the other two studied soil depths (15-30 and 30-45 cm soil layer). The higher value of soil bulk density under ZT at the surface soil layer might be due to non disturbance of soil matrix that resulted in less total porosity compared to tilled plots.

Mean Weight Diameter (MWD)

Aggregate stability is a soil quality indicator directly related to soil organic matter (SOM). The stability of soil surface aggregates relies on SOM, enabling them to withstand mechanical forces due to tillage implements. The results indicated a decline in MWD after plowing for both the crops in plots under T_1 treatment (**Tables 3** and **4**). After harvest of both wheat and lentil crops it was observed that plots under T_2 had higher MWD than that in the plots under T_1 in all the studied soil layers.

Soil Infiltration Rate

The initial rate of infiltration through the soil profile at harvest of both the crops were higher in the plots under T_1 than that observed in the plots under T_2. In comparison, the steady state infiltration rate in the ZT system (T_2) was slightly higher at harvest of the crop than that in the plots under T_1 (**Table 5**).

Soil Moisture Content

In plots under T_2, seedbed was not prepared before sowing and hence the sowing time moisture contents (average of 4 samples) for both the plots were considered the same. As we imposed two passes of plowing in the plots under T_1 before sowing of lentil on the same date in all the plots, soils under T_1 for both the crops contained different moisture content (**Tables 6** and **7**). Soils under T_2 contained more soil moisture than soils under T_1 at harvest of both the crops, irrespective of the date of sampling at 0-15 and 15-30 cm soil depths, suggesting significant rearrangement of pores near the soil surface (**Table 5**). In contrast, the differences in soil water contents were small at the 30-45 cm soil layer. The average soil moisture content of 11.57 % in plots under T_2 was greater than in the plots under T_1 (10.86 %) up to 45 cm depth of soil profile at 60 days after sowing of lentil. A similar trend was observed in the wheat growing season also. Greater water retention in the 0-15 cm soil depth under ZT than under conventional tillage (CT) was also observed in a silt loam and sandy loam soil by Azooz et al. (1996) in Canada.

Discussion

The developed seed-cum-fertilizer drill was compared with the performance of traditional method of sowing (in prepared seed bed) of wheat and lentil crops. For wheat sowing, the traditional method (T_1) covered only 0.028 ha area in a day (8 h duration) with a pair of bullocks and one labourer. But Vivek zero-till-ferti- seed drill with zero-tillage sowing (T_2) covered 0.21 ha in the same period of 8 hours with the same number of bullock and one additional labourer i.e., with 2 labourers (**Table 2**).

The developed seed-cum-fertilizer drill saved 1205.3 MJ/ha and INR 5059/ha in sowing wheat and fertilizer application over the traditional methods. A similar trend was found for lentil sowing. The use of the developed seed drill was really advantageous for the resource poor hill; farmers as it save time, energy and money and also more area covered under favorable climatic conditions to get higher yields and returns.

Trends in soil bulk density are gen-

Fig. 3 Fluted feed roller type metering device

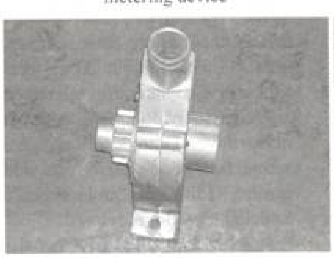

Fig. 4 Lentil crop sown by VL seed-cum-ferti drill

Table 5 Infiltration rate (cm min^{-1}) of soil at harvest of wheat and lentil crops

Time*, min	Wheat T_1	Wheat T_2	Lentil T_1	Lentil T_2
5	0.19	0.16	0.18	0.14
10	0.17	0.15	0.17	0.14
20	0.14	0.12	0.12	0.10
30	0.11	0.09	0.107	0.08
45	0.085	0.076	0.081	0.07
60	0.07	0.068	0.068	0.065
90	0.064	0.061	0.053	0.053
120	0.051	0.053	0.045	0.046
180	0.031	0.042	0.032	0.037

*Cumulative time

erally considered a rough approximation of soil structural changes (Liebig et al., 2004). Several studies have reported higher bulk density under zero-tillage (ZT) at the soil surface compared with tilled soil (Wu et al., 1992, Hill, 1990). Tillage loosens the soil and decreases soil macro porosity (Vazquez et al., 1991). Significantly lower core (0-15 cm) soil bulk density with conventional tillage (CT) system could be due to the incorporation of crop residues by tillage to the surface soil depth.

The effect of tillage methods on soil structural properties needs to be discussed in terms of tillage-induced differences in: (i) soil organic carbon (SOC) content, and (ii) activity of soil fauna. Higher SOC content in the surface layer of ZT system (measured by us) may lead to more and stable aggregation. Tisdall and Oades (1982) indicated marked reductions in water stable aggregates following cultivation. The decline in the size of aggregates with tillage could be credited to mechanical disruption of macroaggregates, which might have exposed SOM previously protected against oxidation. Although we did not measure root density of soil, from the results we can speculate that T_2 would have resulted in greater root density at the surface soil layer due to greater aggregate stability.

The high initial infiltration rate in the plots under CT system might be due to high soil porosity at the surface soil layer. The effect of ZT management might be to reduce the volume fraction of large pores and increase the volume fraction of small pores with better pore continuity relative to CT management, which ultimately resulted in higher steady state infiltration rate under ZT systems. Final infiltration rate is highly dependent upon the size, continuity and arrangement of pores. Greater final infiltration rate in tilled soils was an indication of better pore continuity, as the proportion of larger pores was comparatively less. Greater content of water stable aggregates in the reduced tillage system T_2 probably also contributed to its higher final infiltration rate (Singh et al., 1994). Although infiltration rate can be extremely variable, it is possible that the higher steady flow rates for the plots under ZT might have been partially due to the burrows of the endogenic earthworms (Joschko et al., 1992).

Considering the performance of the present seed-cum-fertilizer drill and its operational feasibility in hill farming, it can be concluded that Vivek seed-cum-fertilizer drill is an effective mean for reducing the cost of cultivation and offers good scope for mechanization in hill farming, having small and scattered land holdings.

Table 6 Soil moisture during wheat growing season

Soil depth, cm	Sowing time		60 days after sowing		Harvest	
	T_1	T_2	T_1	T_2	T_1	T_2
0-15	16.12	16.15	11.86	12.01	9.86	10.05
15-30	15.22	15.59	10.95	11.06	8.68	8.91
30-45	13.09	13.99	8.22	8.17	7.09	7.23
Mean	14.81	15.24	10.34	10.41	8.54	8.73
S.D.	1.1	1.09	1.34	1.62	1.49	1.71

Table 7 Soil moisture during lentil growing season

Soil depth, cm	Sowing time		60 days after sowing		Harvest	
	T_1	T_2	T_1	T_2	T_1	T_2
0-15	15.47	15.99	12.22	13.15	10.21	11.13
15-30	15.01	15.44	11.10	12.12	8.78	9.58
30-45	13.22	13.85	9.25	9.44	7.05	7.33
Mean	14.56	15.09	10.86	11.57	8.68	9.35
S.D.	1.15	1.07	1.44	1.82	1.70	1.80

Conclusion

The following conclusions are drawn: The machine is suitable for zero-tillage sowing as well as sowing in prepared seedbed for wheat and lentil crops. The saving of 157 % energy, 650 % time and 264 % money as compared to prepared seedbed sowing (T_1) can be achieved with help of developed zero-till seed-cum-fertilizer drill in zero-till sowing of wheat crop (T_2). Similar trends can also be achieved in lentil sowing. Yields were comparable under tilled and un-tilled conditions. In this sub-temperate climate of the Indian Himalayas, a sandy clay loam soil can effectively be managed with conservation tillage to increase water storage and transmission properties.

REFERENCES

Anonymous. 1984. AICRP on energy requirement in Agricultural Sectors. Annual Report. G.B. Pant University of Agriculture and Technology, Pantnagar.

Azooz, R. H. and M. A. Arshad. 1996. Soil infiltration and hydraulic conductivity under long-term no-tillage and conventional tillage systems. Can. J. Soil Sci. 76, 143-152.

Kay, B. D. 1990. Rates of change of soil structure under different cropping systems. Advs. Soil Sci. 12, 1-52.

Lal, R., T. J. Logan, N. R. Fausey, and D. J. Eckert. 1989. Long-term tillage and whell traffic effects on a poorly drained molic ochraqualf in Northwest Ohio: 1. Soil physical properties, root distribution and grain yield of corn and soybean. Soil Till. Res. 14, 341-358.

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betel leaves. This may have been due to the favourable environmental conditions that prevailed inside the zero energy cool chamber as shown in **Fig. 1**. Although there was no appreciable difference in range of temperature as well as RH of the ambient conditions with respect to optimum storage conditions of betel leaves, the zero energy chamber maintained a relatively constant environment, which probably prevented the spoilage of the biochemical qualities of the leaves. Leaves stored in ventilated packs maintained nutritional qualities almost at par with those in other packages but the freshness of the leaves were lost because they did not obtain sensory acceptability.

Conclusion

The study exclusively concludes that though there was a change in all the biochemical qualities, The changes were not noticeable to an extent that could affect the nutritional quality. The zero energy cool chamber gave better performance in comparison to ambient conditions in storing green betel leaves for a short period. Among the different packaging system used in the experiment, the leaves store.d in traditional package fetched highest sensory acceptability. Ventilated polyethylene packs are not to be recommended at all as it losses the moisture rapidly. Polyethylene packs are to be used if the leaves are to be stored for a limited period only.

REFERENCES

AOAC. 1990. Official Methods of Analysis.15th edn Association of Official Analytical Chemists, Washington DC.

Chattopadhyay, N. C., A. K. Dey, S. Mukherjee, S. Das, and A. K. Mishra. 1984. Phytochemistry of betel leaves and some aspects of storage, importance of betelvine cultivation, Lucknow, India, 130-145.

Jana, B. L. 1996. Improved technology for betel leaf cultivation. A note presented in the workshop on betel leave marketing, June 5-6.

Mohanty, B. K. and J. M. Panda. 1990. Study on rapid multiplication of betel vine cutting and prolonging storage life of betel leaf. M. Sc. (Ag), Thesis, submitted to OUAT, pp 71.

Mordi, J. I. and A. O. Olorunda. 2003. Effect of evaporative cooler environment on the visual qualities and storage life of fresh tomatoes. J. Fd. Sci. and Tech. Vol. 40 (6): 587-591.

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Oades, J. M. 1984. Soil organic matter and structural stability: mechanisms and implication for management. Plant Soil. 76, 319-337.

Osman, M. S. 1964. The mechanics of soil cutting blades. J. agric. Engg. Res. 9:313-328.

Hill, R. L. 1990. Long term conventional and no-tillage effects on selected soil physical; properties. Soil Sci. Soc. Am. J.54, 161-166.

Seely, F. B. and J. O. Smith. 1952. Advance mechanics of material (IInd Ed.). John Wiley and Sons vInc. London.

Siemens, J. G., J. A. Weher, and Thornborn .1965. Mechanics of soil influenced by tillage. Transaction of ASAE. 8(1): 1-7

Singh, B., D. S. Chanasyk, W. B. McGill, and M. P. K. Nyborg. 1994. Residue and tillage management effects on soil properties of a typic cryoboroll under continuous barley. Soil Till. Res. 32, 117-133.

Singh, G. 1997. Data book on mechanization and agro processing since independence. Bhopal, Central institute of Agricultural Engineering. 194 p.

Timoshenko, S. and D. H. Young. 1964. Element of strength of strength of material (Fourth Ed.). Affiliated East - West Press, Pvt. Ltd. New Delhi.

Tisdall, J. M. and J. M. Oades. 1982. Organic matter and water stable aggregate in soils. J. Soil Sci. 33, 141-163.

Vazquez, L., D. L. Myhre, E. A. Hanlon, and R. N. Gallher. 1991. Soil penetrometer resistance and bulk density relationship after long-term no-tillage. Communi. Soil Sci. Plant Analy. 2, 2101-2117.

Wu, L., J. B. Swan, W. H. Paulson, and G. W. Randall. 1992. Tillage effects on measured soil hydraulic properties. Soil Tillage Res. 25, 17-33.

Yoder, R. E. 1936. A direct method of aggregate analysis of soils and study of the physical nature of Soil erosion losses. American Society of Agronomy Journal 28, 337-351.

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