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Development and testing of tractor drawn subsurface manure applicator

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Abstract
Application of organic manure in the field is an important input operation in crop production. A tractor drawn subsurface manure applicator was designed and developed in Farm Machinery and Power Engineering Department at G.B.P.U.A &T Pantnagar Uttarakhand to place the manure at a recommended depth below the soil surface to improve the nutrients quality of soil. The nutrients and water are absorbed by the roots of plants from the soil for optimum productivity. Therefore the subsurface manure applicator was designed to place the vermicompost manure at a correct rate below the seed which often improves growth compared to surface applied manure. The performance of the applicator was evaluated for subsurface placement of manure. The performance of subsurface manure applicator was evaluated at four openings of the orifice plate of manure hopper, ranging between 0 to 70 mm and three vermicompost moisture levels *viz.* 13%, 21% and 31% respectively. The application rate was evaluated in the laboratory. From the result it was found that the application rate was increased with increase in area of opening of orifice plate and increase in moisture level of vermicompost was found to be varying between 1.90 to 25.18 t/ha. The average draft force requirement of the subsurface manure applicator at three forward speeds *viz.* 2, 4 and 6 km/h were found to be 338, 349.3 and 371.9 KGF respectively. The fuel consumption at three forward speeds was found to be 3.3, 6.7 and 10 l/h and the power requirement was 1.9, 4.10 and 6.40 kW at 2, 4 and 6 km/h forward speeds. The average theoretical and effective field capacities at 4 km/h forward speed were estimated 0.51 and 0.41 ha/h and the field performance index were found to be 81.17%.

Keywords: vermicompost, subsurface, field capacity, moisture content, manure, draft, power, fuel consumption, wheel slip

Introduction
The role of agriculture in Indian economic development is a predominant one. Agriculture sector provides food for more than one billion people and yields raw materials for agro-based industries. Modernization of Indian agriculture began during the mid-16th century which resulted in the green revolution making the country a food grain surplus nation from a food deficit nation. Modern agricultural practices was based on the use of high yielding varieties of seeds, use of chemical fertilizers and pesticides, multiple cropping systems. These all affected the natural Resources like land & water. One day our agriculture cannot be sustainable in future. To save the environment from all harmful thinks. Organic farming was first adopted in 1940 and aimed that maintained to produce agricultural products by the use of methods and substances that maintain the integrity of organic agricultural products. In organic practices nutrient is returned to the soil by manure and composts have to be cycled via the biological life of the soil before they become available to crops. When vermicompost manure is applied to the soil, there is a chance for increase in earthworm's population. It contains all micro nutrients hence micro nutrient deficiency gets rectified. It contains growth promoters such as cytokinin, auxins and several enzymes. In India manure is applied using manual broadcasting method and bullocks carts resulting in increasing labour cost, more time consumption per unit area and loss of nutrients with poor application uniformity and wide variation in the application rate [15]. In view of the above, suitable technological mediation was needed for mechanization of manure application below the soil surface uniformly and in less time, therefore tractor drawn subsurface manure and seed applicator was developed.

Materials and Methods
A tractor operated subsurface manure applicator machine was developed and evaluated at Department of Farm Machinery and Power Engineering Department at G.B.P.U.A &T Pantnagar Uttarakhand, which is based on the horizontal screw conveyor mechanism. The developed machine mainly consists of manure and seed hopper, T type furrow opener, frame, fluted roller, supporting frame, hitching plates, orifice plate, screw conveyor mechanism, shaft,

driving wheel, counter shaft and chain- sprockets arrangement respectively. The prototype model of machine was developed in workshop. The developed machine was tested in laboratory as well as in field conditions.

Laboratory test

The subsurface manure applicator was calibrated in the laboratory. For calibration, the applicator was jacked up and supported on its frame so that the ground wheel was free to rotate. A polythene bag was laid at the surface below the opening of the vermicompost delivery pipe for collection of vermicompost. The manure hopper was filled with vermicompost to full of capacity. The manure shaft was connected to the electric motor had a provision to fixed it revolution was connected through the torque tube which was connected one side to the motor and another side to the sprocket of the manure metering mechanism delivery shaft. The motor was rotated at 14, 35 and 41 rev/min respectively. The vermicompost was collected from six vermicompost delivery pipes and weighted with the help of electronic balance. The procedure was repeated for different opening of orifice plate which was placed below the manure hopper to regulate the rate of delivery of vermicompost. The machine was also being tested for different moisture levels of vermicompost *viz.* 13, 21 and 31% respectively.

Experimental site and location

The experiment was conducted at Honeybee Research Training and Testing Institute, G.B.P.U.A&T Pantnagar Uttarakhand located in Tarai Region of Uttarakhand as shown in fig.3. The geographical location of field was 29.0155511^0 latitude and 79.4952987^0 longitudes and at the elevation of 243.03 from sea level Pantnagar situated in Tarai region. The area falls under sub humid to sub-tropical zone with four distinct seasons.

Fig 1: Laboratory calibration of prototype vermicompost subsurface manure and seed applicator

Field Performance Test

Field performance tests were connected at Honey Bee Research and Training Centre Pantnagar, Uttarakhand to evaluate the performance of machine in field conditions for sowing of wheat crops. The soil at the experimental site was sandy loam having sand, silt and clay in the ratio of 74.80, 13.30 and 11.90% respectively. The machine was tested in the field of size of 66 m×36 m which was divided into five blocks [Fig.2]. In each block (66×7m) the machine was tested the for different orifice openings *viz*. no opening ¼th ½th, ¾th and full opening respectively. The moisture content of vermicompost was 31% used for testing purpose. The performance parameters like speed of operation, depth of manure placement, effective field capacity, theoretical field capacity, field performance index, draft force, wheel slip, fuel consumption and power requirement were measured.

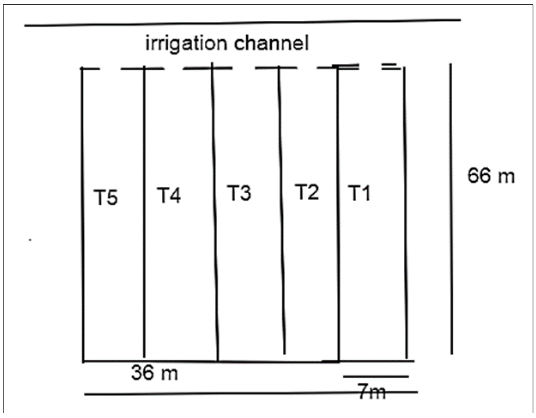

Fig 2: Detail layout plan of experimental site

Fig 3: Experimental site at Honey Bee Research and Training Centre

Fig 4: Field performance of manure applicator in field

Machine Parameters

Operating speed of applicator

The operating speed of tractor drawn subsurface manure applicator was calculated by observing the time required for traveling 22 m distance with the help of stop watch along the longest direction.

$$\text{Speed (m/s)} = \frac{\text{distance travelled}}{\text{time taken to cover the 22 m distance}} \quad [1]$$

Total operating time

The operating time for the complete operation was measured including the time losses during turning and manure hopper filling by using the stop watch. Thus the time loss in turning as well as filling loss per unit area was worked out.

Draft of machine

The draft of the developed machine was determined by connected the strain gauge type of load cell of capacity 1000 kgf between the two tractors. The first tractor pulled the second tractor (Dummy Tractor) [Fig.5]. The machine raised in upward direction by adjusting the depth control wheel and attached behind the dummy tractor and pulled by the front tractor with forward speed of 2 km/h. The raw data was saved in data logger and again the reading was measured when the machine put down and pulled by front tractor. The draft of the machine was calculated by subtracting no load reading from with load readings.

Fig 5: Draft measurement with strain gauge type load cell

Fuel consumption of the manure applicator

Fuel consumption was measured with fuel flow meter transducer in different field's treatments. The range and capacity of fuel meter was 0.5 to 25.0 l/h. The flow meter was attached with fuel supply system of the tractor, its input hose pipe was connected to the output to the output hose pipe of the fuel delivery line**.** The output of flow meter was connected with a T Joint whose lateral hose deliver the fuel to the engine through a pipe [Fig.6]. The fuel which passes through the lateral hose was measured by the flow meter which shows the consumption of diesel fuel for the total operating time. The unused diesel which returned back through the return line was joined with the longitudinal hose of the T joint. Thus, the part of premeasured fuel does not go back into the fuel tank or to the flow meter.

Fig 6: Flowmeter sensor connection arrangement

GPS tracking system

The GPS tracking system was used to determine the location of experimental site was mounted on the tractor at one side.

Theoretical field capacity

It is the rate of field coverage of the implement, based on 100 percent of time at the rated speed and covering 100 percent of its rated width.

$$\text{Theoretical field capacity (ha/h)} = \frac{\text{theoretical width (m)} \times \text{speed}(\frac{km}{h})}{10} \quad [2]$$

Effective field capacity

It is the actual area covered by the machine based on its total time consumed and its width. Rangapara (2014) given the relation of effective field capacity. The relationship was given below;

$$\text{Actual field capacity (ha/h)} = \frac{\text{area covered,ha}}{\text{time taken to cover the test area,h}} \quad [3]$$

Field efficiency

The field efficiency is the ratio of the effective field capacity to the theoretical field capacity, usually expressed in percentage. It is expressed in percentage.

$$\text{Field efficiency} = \frac{EFC}{TFC} \times 100 \quad [4]$$

Where,
EFC= effective field capacity, (ha/h) and
TFC = theoretical field capacity, (ha/h)

Wheel Slip

The wheel slip was calculated by recording total number of revolutions of rear wheel of tractor at no load and total number of revolutions at load conditions. Wheel slip indicates a loss of forward motion of the implement and it represents the loss of power. Wheel slip for any given load was determined by the expression of (Rangapara J., 2014).

$$\text{Wheel slip, (\%)} = \frac{N_0 - N_1}{N_1} \times 100 \quad [5]$$

Results and Discussion

Laboratory calibration of the machine

Effect of orifice opening on vermicompost application rate

Vermicompost application rate at different forward speeds were determined. Accurate application rate of vermicompost manure is very important factor. Application rate was increased with increase in orifice opening. The vermicompost application rate increased from 7.975 to 25.18 t/ha with increasing in orifice opening position from ¼ th to full opening at 2 km/h tractor forward speed and moisture content of 13% on dry basis. Similar trends were also being observed for another forward speeds and moisture contents respectively. Laboratory calibrations in terms of application rate at different moisture contents and different forward speeds were given in Table 1 and Fig.7 respectively.

Table 1: Effect of exposure length on application rate of vermicompost manure

Vermicompost delivery rate, t/ha								
Exposure length of orifice opening								
Moisture Content,%	**Forward speed km/h**	**1/4th**	**1/2th**	**¾ th**	**Full**	**Overall mean**	**Standard deviation**	**CV,%**
31	2	7.975	11.35	19.60	25.18	16.02	7.810	48.78
	4	4.032	8.560	16.92	20.68	12.55	7.600	60.63
	6	2.460	6.570	12.88	16.98	9.720	6.460	66.49
21	2	7.354	10.35	16.91	22.63	14.31	6.830	47.74
	4	3.670	7.400	14.75	19.31	11.00	7.058	64.17
	6	2.010	5.610	12.63	16.98	9.310	6.753	72.54
13	2	6.130	8.510	15.02	20.54	12.54	6.510	51.90
	4	3.160	6.870	13.89	17.67	10.19	6.580	64.57
	6	1.900	5.060	10.66	14.91	8.120	5.800	71.53

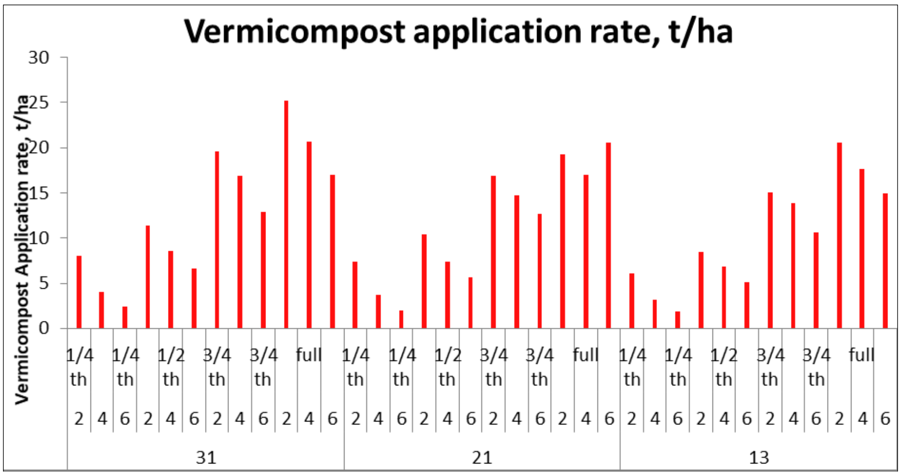

Fig 7: Effect of orifice opening on application rate of manure at different forward speeds

Field Performance of manure applicator

The machine was tested in Honey Bee Research Training and Testing Institute Pantnagar Centre. The field performance data of the machine was presented in table 2. The depth of operation was fixed 100 mm by auto draft and position control lever of tractor. The speed of operation in the field was varied from 2.06 to 6.23 km/h with an average speed of operation was 4.25 km/h. The effective field capacity was varied from 0.214 to 0.581 with an average of 0.41 ha/h. The theoretical field capacity was varied from 0.248 to 0.747 ha/h with an average of 0.510 ha/h and the average field performance index and draft were found to be 81.17% and 349.3 kgf respectively as shown in Fig.8 and 9.

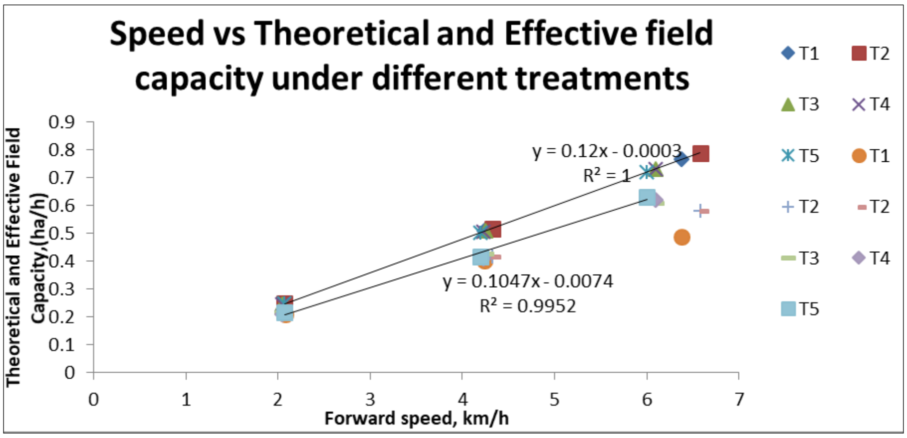

Fig 8: Effect of forward speed on theoretical field capacity and effective field capacity

Field Performance Index

The field performance index of machine under different treatments T1, T2, T3, T4 and T5 were measured at three different forward speeds of machine *viz*. 2, 4 and 6 km/h. The average value of field performance index was obtained 86.43%, 81.17% and 77.83% at 2, 4 and 6 km/h forward speed respectively.

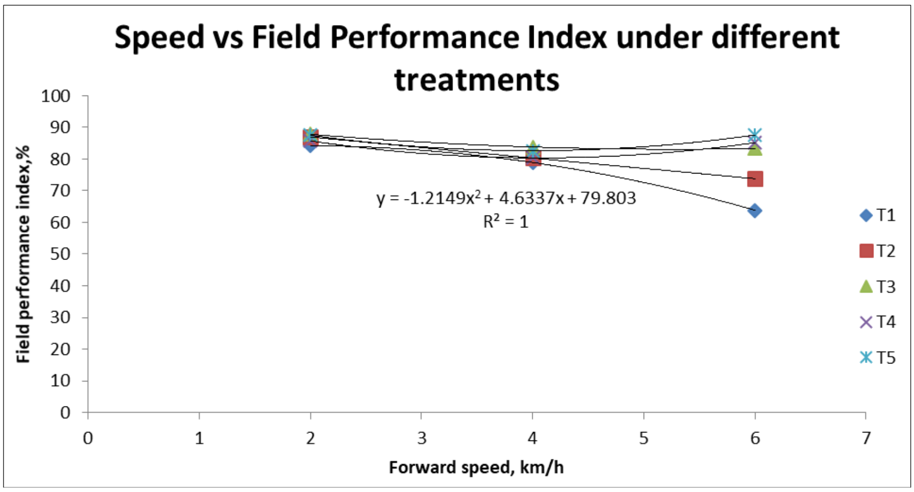

Fig 9: Effect of forward speed on Field Performance Index

Speed of operation

The speed of operation was measured by noted the time when tractor covered a fixed distance of 2200 mm lengthwise in each treatments. The data obtained was presented in Table 2 and the average speed of tractor per treatments was found to be 4.250 km/h respectively. The time loss during turning, filling and other interruptions were also be measured and presented in Table 2. Therefore total time required per hectare was also be measured included all losses in each treatment.

Number of fillings required to fill the manure hopper per hectare

Total 40 numbers of filling required to fill the vermicompost hopper during operation per 0.5 acre field and only one filling required for seed hopper respectively as shown in table 2.

Fuel consumption

The Fuel consumption per hour was obtained 3.318, 6.774, and 10.0 L/h at three different forward speeds *viz*. 2, 4 and 6 km/h under all treatments respectively. From the graph [Fig.10] it was shown that fuel consumption was increased with increase in forward speed of machine.

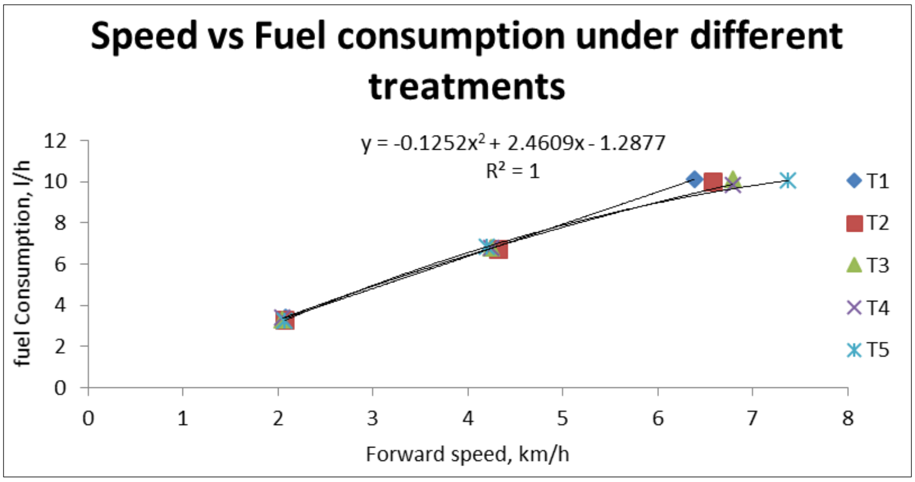

Fig 10: Effect of forward speed on fuel consumption under different treatments

Wheel slip

The result obtained for the wheel slip occurred at different tractor forward speed of the tractor was tabulated in table 3. The result revealed that the wheel slip was increased with increases in forward speed of tractor. The minimum wheel slip was found 1.6% and maximum 3% at speed of 2 and 6 kmh^{-1}. The effect of wheel slip during operation of machine under different treatments was observed and found to be within the range.

Depth of vermicompost placement

The average depth of placement of vermicompost was adjusted100mm by automatic draft and position control lever of tractor so that the machine was worked at constant depth throughout the operation respectively in all treatments.

Table 3: Wheel slips percentage determination

Rep	Speed, kmh^{-1}	Under no load, m	Under load, m	difference	slip,%
1	2	50.67	49.86	0.81	1.624549
2		50.1	49.19	0.91	1.84997
3		50.5	49.71	0.79	1.589217
Avg		50.05	49.26	0.79	1.603735
		50.33	49.505	0.825	1.666498
1	4	50.89	49.98	0.91	1.820728
2		50.8	49.86	0.94	1.885279
3		50.87	49.79	1.08	2.16911
Avg		50.79	49.86	0.93	1.865223
		50.8375	49.8725	0.965	1.934934
1	6	50.6	49.31	1.29	2.616102
2		50.58	49.25	1.33	2.700508
3		50.52	49.16	1.36	2.766477
		50.57	49.29	1.28	2.596876
Avg		50.5675	49.2525	1.315	2.669915

Table 2: Average field performance data of machine under different treatments

Treatment		Width	depth of cut,	Dist	Time	Turning loss	hopper filling	Speed	FC	FC	Draft	Power	TFC	Area covered	[TT]	EFC	FPI
[Orifice opening]	unit	[m]	[cm]	[m]	[sec]	[sec]	[min]	[km/h]	[l/h]	[l/ha]	[kg]	[kW]	[ha/h]	[h/ha]	[h/ha]	[ha/h]	%
T1 [full]	Average	1.2	10	22	38.1	10	1.665	2.08047	3.39	13.58	340	1.954	0.249	4.124	4.7565	0.210	84.211
T2[3/4th]	Average	1.2	10	22	38.2	10	1.29	2.073995	3.21	12.88	336.5	1.928	0.248	3.993	4.62	0.216	86.969
T3[1/2th]	Average	1.2	10	22	38.6	10	1.33	2.051826	3.33	13.5225	339	1.921	0.246	3.9975	4.6257	0.216	87.80
T4[1/4th]	Average	1.2	10	22	38.5	10	1.33	2.057485	3.39	13.725	341.5	1.941	0.246	4.0865	4.723	0.211	85.755
T5[no manure]	Average	1.2	10	22	38.25	10	0.33	2.071385	3.27	12.9	334	1.911	0.248	3.9715	4.597	0.217	87.51
		1.2	10	22	38.33	10	1.189	2.0670322	3.318	13.3215	338.2	1.931	0.248	4.0345	4.66444	0.214	86.43
T1 [full]	Average	1.2	10	22	18.7	10	1.665	4.241235	6.75	13.275	355	4.160	0.508	2.041	2.49	0.401	78.90
T2[3/4th]	Average	1.2	10	22	18.37	10	2.33	4.321065	6.75	13.04	348.5	4.160	0.518	1.9585	2.401	0.416	80.32
T3[1/2th]	Average	1.2	10	22	18.615	10	1.33	4.254634	6.75	13.215	346	4.067	0.510	1.9	2.337	0.427	83.81
T4[1/4th]	Average	1.2	10	22	18.75	10	0.83	4.230765	6.78	13.375	345	4.032	0.507	2.004	2.4505	0.408	80.37
T5[no manure]	Average	1.2	10	22	18.85	10	0.33	4.203041	6.84	13.56	352	4.087	0.504	1.955	2.3985	0.416	82.66
		1.2	10	22	18.657	10	1.297	4.250148	6.774	13.293	349.3	4.101	0.510	1.9717	2.4154	0.414	81.17
T1 [full]	Average	1.2	10	22	12.4	10	1.665	6.38751	10.11	13.185	363.5	6.415	0.766	1.6305	2.0425	0.489	63.87
T2[3/4th]	Average	1.2	10	22	12.1	10	2.315	6.58186	9.99	12.705	370.5	6.737	0.789	1.3305	1.7155	0.582	73.80
T3[1/2th]	Average	1.2	10	22	11.75	10	1.33	6.09468	10.14	12.539	376.5	6.340	0.731	1.262	1.641	0.609	83.32
T4[1/4th]	Average	1.2	10	22	12.4	10	0.845	6.090835	9.87	12.8705	369.5	6.218	0.730	1.2305	1.6065	0.622	85.16
T5[no manure]	Average	1.2	10	22	10.75	10	0.33	6.0000	10.05	11.36	379.5	6.291	0.72	1.215	1.586	0.630	87.57
		1.2	10	22	11.88	10	1.297	6.230977	10.032	12.5319	371.9	6.402	0.747	1.3337	1.7183	0.581	77.83
T1	100% RDN through vermicompost by manure applicator																
T2	75% RDN through vermicompost by manure applicator																
T3	50% RDN through vermicompost by manure applicator																
T4	25% RDN through vermicompost by manure applicator																
T5	Control (no manure)																

Conclusions

The developed subsurface manure and seed applicator was tested under field condition machine for sowing of wheat and other crops along with the placement of organic manure below the seed was tested by farm machinery and power engineering department Pantnagar Uttarakhand and found to be suitable for placing both the organic manure and seed below the soil at desired depth. The machine worked satisfactory and achieved uniform application rate of vermicompost manure in the field with reduced human drudgery.

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