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Research Paper :

Design, farbrication and field testing of sand filling system to the mole plough

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ABSTRACT

The subsurface drainage system is highly expensive and may not be affordable to the small, medium size farmers, whereas the wastage of land, maintenance are the big problems with the surface drainage system. Keeping these points in view, a mole plough was designed and then further modified with the additional sand filling system. The field tests were conducted in the heavy clay soil with 1.5 % slope. A 60 Hp tractor was selected and operated with modified mole plough in I-L gear .The speed of operation was 0.75 Km/hr .The mole channels were formed as 3 m wide spacing and to a depth of 55 cm .The rate of coverage was calculated on the basis of length of mole channel. An auxiliary fuel supply system was utilized for the measurement of fuel consumption. The cost of formation of mole channels was calculated by straight line method. The result of the tests were collected, analyzed and reveled that, the sand filling system designed works suitably with a fuel consumption of 0.3 lit/100 m length of mole channel. The cost of operation was Rs. 9450 /ha while operating at 3 m spacing of mole drains the % filling of mole channels was 77.59 per cent.

Key words : Mole plough, Sand filling system

Mole drains are unlined circular soil channels, which function like pipe drains. Mole drainage is an effective method of drainage, which is widely used in the clay soils of temperate region such as United Kingdom, northern Europe and in New Zealand (Aulifte and Home, 1994). It is generally confined to soils having clay content of about 30-35%. Their diced is their restricted life (5 to 10 years), but, providing benefit cost ratios are favorable, a short life can be acceptable. Mole drains are formed with a mole plough, which comprises a cylindrical foot attached to a narrow leg, followed by a slightly larger diameter cylindrical expander. The foot and expander from the drainage channel and the leg generates the shot with associated soil fissures which extend from the surface down into the channel. The leg fissures are vertical and formed at an angle of approximately 45^0 to the direction of travel.

Mole drains are commonly installed at depths between 0.4 and 0.7 m, but can be installed up to depth of 1.2 m. The mole drain spacings range between 2 to 5 m. Common length of mole drains vary from 20 m to 100 m long depending on the grade, which may range from nearly level to 5 per cent. Mole drains are installed using a mole plough, pulled by a powerful tractor (drawbar pull 40-60 KN). The success of a mole drainage system is dependent upon satisfying two requirements achieving the desired water flow path for the particular drainage situation, and installing stable mole channels.

The cost of installation of sub-surface system depends mainly on the drain spacing. Draining of heavy clays soils require closer spacing due to poor physical properties of the soil. The high initial cost of pipe drainage resulted in few adopters of the subsurface drainage technology. A viable alternate to pipe drainage could be mole drainage. The life of these drains is short as compared to pipe drainage, which needs to be improved. The life of mole channels can be improved by filling of sand in the moles during formation. So the study was undertaken to design, fabricate and evaluate the sand filling system (Anonymous, 1999).

METHODOLOGY

The field tests were conducted in heavy clay soil with 1.5 % slope. A 60 Hp tractor was selected and operated with modified mole plough in I-L gear. The average speed of operation was 0.75 Km/hr. The mole channels were formed at 3 m wide spacing and to a depth of 55 cm. The rate of coverage was calculated on the basis of length of mole channel formed. An auxiliary fuel supply system was utilized for the measurement of fuel consumption. The cost of formation of mole channels was calculated by straight line method.

Consideration and calculations for the design of sand filling system :

Shape of mole cross section = Circular

Diameter of mole channel = 75 mm

Cross sectional area of mole channel = 4.415 x

10^{-3} m^2

The volume of mole channel per meter length= 4.415 x 10^{-3} m^3

Bulk density of sand (Measured) = 1740 kg/ m^3

For 100 m length of mole, sand required =0.44 m^3

The length of mole channel per hectare = 3333 m at 3 m drain spacing

The quantity of sand required per hectare

(Assuming filling factor =1.0)

At 3 m spacing = 25604.4 kg

= 5.19 brass

Selection and specifications of different parts of sand filling system:

Hopper:

The Hopper is fabricated in two shapes combined. The upper part of hopper was kept rectangular while lower part was made like rectangular-pyramid. The hopper was made adjustable with depth of operation by welding it with the shank. The capacity of hopper was 0.117 m^3 and was fabricated in 16 gauge M.S.

Sand carrying tube :

The expander provided behind the bullet was removed and the sand filling system was designed and mounted on the plough for filling sand in the mole channels (Fig. 1). Sand carrying tube was also made up of 16 gauge mild steel and welded to the bottom of hopper and was placed by welding it to the shank at the rear side. The carrying tube was made rectangular in shape with the dimensions as 55 mm length and 35 mm in width. At the lower end of shank, the carrying tube was set at an angle of 30° with the shank to put the sand in the mole channel exactly after the bullet body. At the bottom, the end of sand carrying tube is welded to the rear end of bullet.

Metering mechanism:

The rectangular thin plate of mild steel was placed at the joint of sand hopper and sand carrying tube from a rectangular orifice type metering mechanisms. The movement of thin plate was used to meter the sand flow from hopper and also to stop the sand flow while taking turns in field.

Modifications made in the previous design:

The previous mole plough was provided with expander at the rear end of the bullet for compressing the collapsed soil in the mole channel and to make the finished surface of the mole channel (Fig. 1). In new design the sand filling system was attached on the plough to fill the sand, in the mole channel formed by the bullet, just at the rear end of the bullet. (Fig. 2).

Calculations of flow rate and speed of operation:

Laboratory experiments were carried out for designing the size of opening. It was observed that, if the width of opening is increased then the width of shank also gets increased and this leads to increase in draft. So to keep the draft of the implement same, the width of opening (*i.e.* c/s width of sand carrying tube) was kept same as that of width of shank and laboratory experiments were carried to decide length of opening. This was done

Fig. 1: Mole plough fabricated previously

Fig. 2: Newly fabricated mole plough with sand filling system

by using different models of hopper with different sizes of length of opening.

The dimensions of opening was fixed as 35 mm width and 55 mm length. With these dimensions selected the flow rate observed was 105 kg/ min.

Dimension of cross-section of sand carrying tube = 35 mm x 55 mm.

Flow rate of sand observed = 0.0468 m^3/min.

Forward speed needed for 100 % filling of the mole channels.

$$= \frac{\text{Flow rate observed } (m^3/min)}{\text{Volume of mole per meter } (m^3/m)}$$

$$\frac{0.0468}{4.415 \times 10^{-2}}$$

= 10.60 m/min

= 0.636 km /hr

Rate of work:

It was defined, as the actual area covered by the implement, based on it is time consumed and its width. It was calculated as

$$\text{Rate of work} = \frac{A}{Tt}$$

where,

A = Actual Area covered, ha and

Tt = total timed required, h.

Fuel requirement:

It is the measure of amount of fuel required for a given tractor implements system to cover one hectare field. It was calculated as

$$\text{Fuel efficiency} = \frac{\text{Fuel consumption unit length of drain} + \text{fuel consumed during turning}}{\text{Length per unit area}}$$

Success in formation of mole and sand filling:

The success of formation of mole was determined by visual observations of roundness of the mole, formation of the leg fissures, filling of sand and collapse of the soil through the fissures in the mole.

RESULTS AND DISCUSSION

A modified mole plough with sand filling system was designed, fabricated and its performance was studied. The results of the field tests are explained and discussed.

Forward speed of tractor:

A modified mole plough with sand filling system was designed to operate at a forward speed of 0.636 km/hr. During the field operations with 60 hp, two wheel drive tractor, average speed of operation was 0.75 km/hr. An increase of 18.41 % was observed due to the unfamiliarisation of the operator with the newly designed mole plough.

Fuel requirement:

An average fuel consumption of tractor was found to be 0.30 lit/ 100 m length of mole channel and 30 lit/ha for 3 m wider spacing of mole drains.

Success in sand filling system:

The sand filling system designed works suitably in pouring the sand in the mole channels (Fig. 3). The hopper with 275 kg sand (0.1580 m^3) required filling after a distance of 40-45 m length of mole channel. As the average speed of operation is quite slow, it enables the labours for easy filling of sand when the sand hopper becomes empty.

The average sand required during the field tests was 600.8 kg/ 100 m length of mole channel that ensures average 77.59 % filling of mole channels.

The reduction observed in the percentage filling of mole channels was due to failure to maintain the designed forward speed exactly the same time due to a bit clogging of channel of sand filling system due to the use of a bit moist sand.

Field performance of modified mole plough in given in Table 1.

Table 1 : Field performance of modified mole plough

Line No	Mole channel length m	Total time min	Speed Km/hr	Fuel required ml	Fuel required lit/100 m length	Sand pored		Sand required		% Filling
						kg	m^3	kg	m^3	
1	78.70	6.56	0.72	235.0	0.30	467.20	0.27	604.42	0.35	77.30
2	81.50	6.26	0.78	230.0	0.28	496.40	0.29	625.92	0.36	79.31
3	76.00	5.89	0.77	225.0	0.30	414.00	0.24	583.68	0.34	70.93
4	72.00	5.51	0.78	240.0	0.33	422.00	0.24	552.96	0.32	76.32
5	83.00	7.05	0.71	220.0	0.27	536.00	0.31	637.44	0.37	84.09

Fig. 3 : Success of mole formation and sand filling

Cost of mole formation with sand filling:

Cost of formation of moles by the tractor and the requirement of sand was calculated at 3 m drain spacing and was found to be Rs. 9520 /ha .

Conclusion:

– The sand filling system designed works suitably and requires refilling after 40- 45 m length of mole channel with the hopper containing 275 kg sand, 90 kg in slanting lower portion and 185 kg in upper rectangular portion.

– An average fuel consumption was found 0.3 lit/ 100 m length of mole Channel.

– The cost of formation of mole channels is Rs.9450 / ha.

– The percentage filling of mole channels was found 77.59%.

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