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# PERFORMANCE EVALUATION AND ANALYSIS OF BULL DRAWN MULTIPURPOSE FERTILIZER DRILL DEVICE

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**Abstract:** A Bull Drawn Multipurpose Fertilizer Drill Device is a seed sowing and fertilizer applying machine in the farm. It is designed and developed by selecting the best parameters from previous model studies. The equipment consist of a main rectangular frame, three sets of tines of different depths, and two hoppers for carrying seed in one and fertilizer in another, supporting wheels with depth control provision, fertilizer metering device and a lugged (drive) wheel with chain and sprockets for transmitting power to the metering mechanism. The equipment has the provision to place the fertilizer up to a depth of 6 inches (152.4 mm), 4 inches (101.6 mm) and 2 inches (50.8 mm) using the three sets of tines, thereby helping to place the fertilizer at different depths in vertical soil profile in a single pass. The equipment was tested into the field to observe its performance on cotton crop with results showing presence of P and K fertilizer upto depth of 6 inches even after 30 days of sowing and fertilizing. The laboratory evaluations indicate 21.7% P & 25% K fertilizer available in the testing field of farm at deep soil region when machine is used. Thus, fertilizers can be applied effectively, cheaply and uniformly at all growth stages of crop thereby increasing nutritious value and yield quality of crop.

**Keywords:** Fertilizer; cotton; tines; metering mechanism.

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## INTRODUCTION

In India, estimated annual food grain requirement in the year 2010 was 300 million tonnes. To produce this much food grain, there was a requirement of 45 million tons of inorganic fertilizers for growing these crops. Most of this fertilizer is currently being imported by India. Also, the per unit area usage of fertilizers is higher than the world average (Survey of Indian agriculture 2006). Therefore, care should be taken to increase the fertilizer use efficiency by crops. For maximum efficiency of applied fertilizer, it is essential to deliver nutrients to the root zone of plants and at a rate which is sufficient for maximum uptake while avoiding fixation with clay particles. The attention should, therefore, be given towards addition of fertilizers in subsoil to increase its nutritive status. In situations where deep loosening was required, the incorporation of fertilizer had been found to be beneficial (Godwin and Spoor, 1981).

Hence, it is important to incorporate P fertilizers into the soil especially when using low water soluble phosphates. By increasing the efficiency, the same level of yield could be obtained with fewer amounts of fertilizer and vice-versa (Cooke, 1982). In developing countries, a lot of work has been conducted on deep tillage with results showing substantial increases in crop yields.

Earlier experiments (McEven and Johnston, 1979; Rowse and Stone, 1980; Godwin and Spoor, 1981 and Liu et al., 1988) highlighted the potential yield increase for different crops, which could arise from amelioration of compaction and the incorporation of granular phosphate (P) and potassium (K) fertilizers into the subsoil. Therefore, incorporation of granular fertilizers with subsoiling operations for deep loosening and hard pan breaking may be effective and beneficial. Fertilizers may be placed either in continuous or intermittent bands as per the cropping pattern, root density of crops and metering system available. The evenness of placement should be maintained in vertical and horizontal soil profiles. Limited research has been conducted on subsoil delivery of fertilizers and tillage to reduce compaction while improving nutrient uptake. Subsoiling and fertilizer application by making two different passes across a field may not prove to be economical therefore combining into one pass is desired. Keeping the above points in view, the present investigation was carried out with the following objectives:

1. To design and develop bull drawn multipurpose fertilizer drill device for carrying out subsoiling and application of fertilizers in one pass.

2. To evaluate the developed machine on performance of cotton crop.

Concept of Deep Soil Placement of Fertilizer:

The application of fertilizers is usually accomplished by methods such as manual spreading, broadcasting, placement or mixing in upper soil layer of 20-50 mm only. Broadcasting of fertilizers, especially P and K, produces fixation problems due to more soil contact, whereas volatilization of N results in reduction of applied N content to the soil. Only 40 to 50% of N fertilizers, 20 to 30% of P and K fertilizers are effectively used by crops while the remaining become volatilized, leached to groundwater, or get fixed within the soil as per the properties of their contents (Olsen et al., 1971; Rowse and Stone, 1980). Contrary to this loss, the basal application of fertilizers using planters and seed -drills have been found to be effective, but application of fertilizers even by these methods does not distribute fertilizers evenly as per the needs of roots and therefore, more research works are needed to be done on these aspects.

It is essential to consider the following requirements for achieving maximum effectiveness of mineral fertilizers concerning their techniques of application:

i. Uniform distribution of fertilizer on the desired area of the field,
ii. Shortening the duration between the application of fertilizer and start of utilization by the plants,
iii. Optimum depth of application of fertilizer in the soil, and
iv. Optimum spatial distribution of fertilizer based on planted rows and crop root system (Cooke, 1982).

Band placement of fertilizer in sub-surface zones has been established as an effective method to increase the fertilizer use efficiency. Deep placement in band is also a similar and an advanced practice with the concept of applying fertilizer within root zone (Nathan, 2000). Lee (1926) found that in irrigated cane generally had more than 50% of the roots developed in the upper 200-mm of the soil profile and 85% above 600-mm. Root distribution profiles of other crops are presented in table 1. It is clear from these data that roots of these crops reach nearly 1.5 m in depth within the soil profile. Depth-wise, root distributions showed that more than 20% of roots grow vertically beyond a depth of 300 mm. Therefore, attention should be given to the nutrient availability below 300 mm. The concept of bull drawn multipurpose fertilizer drill device is that fertilizer are applied in bands according to the distribution of root could make sense in order to maximize nutrient availability at these root depths. The necessary depth of application could be important and could vary depending upon the crop and soil conditions. This is decided after the study of hard pan generally developed below the normal ploughing depth.

**MATERIALS AND METHODS**

The complete machine is shown in figure 1. The first prototype of bull drawn multipurpose fertilizer drill device consisted of two main units i.e. a subsoiling unit and a fertilizer application unit. The equipment consist of a main rectangular frame, three sets of tines of different depths, and two hoppers for carrying seed in one and fertilizer in another, supporting wheels with depth control provision, fertilizer metering device and a lugged (drive) wheel with chain and sprockets for transmitting power to the metering mechanism.

**Fig. 1: Pro-E 3D view of Assembled Model**

**Fig. 2: Fabricated Assembled Model showing Main Frame**

Soil Cutting Mechanisms

Mathematical models of soil cutting postulated by different researchers whether two or three dimensional, have assumed that soil is moved upward over the entire working depth range of the cutting tool which is not true at all time. Below certain working depths, termed as 'critical depth', the soil movement changes from a predominantly forward and upward manner (crescent failure) to mainly forward and sideways known as 'lateral failure'. A mathematical model was postulated by Godwin (1974) in which the regime of forces in the soil can be analyzed when a critical depth is present.

There are two types of soil failure mechanism as given below:

Crescent soil failure

The soil above the critical depth fails in brittle manner during crescent failure. The models suggested for crescent soil failure make three assumptions as given below:

i. Yielding of soil in shear obeys the Mohr-Coulombs failure criterion.

ii. A distinct rupture surface is formed in front of the tine, bounding a volume of soil in a state of plastic equilibrium.

Rate effects on the relevant soil parameters are negligible.The magnitude of the resultant passive force (P) can be calculated from the equation given by Hettiartchi et al. (1966):

$P= [\gamma z2\ N\gamma + c\ z\ Nc + ca\ z\ Na + q\ z\ Nq]\ w$ (1)

$H1 = P \sin (\alpha + \delta)$ (2)

where, γ = Bulk density of soil (kN/m3)

z = Depth of operation (m)

c = Soil cohesion, (kN/m2); ca = Soil adhesion (kN/m2); q = Surcharge load (kN/m2);

w = Width of tool (m)

H1= Horizontal component of passive force i.e. draft

α = Rake angle of tine, degree

δ = Angle of soil-metal friction, degree

ϕ = Angle of internal friction, degree

The N-factors are dimensionless numbers and depend upon the magnitudes of α, δ and ϕ

Lateral soil failure:

The soil below the critical depth fails in a two-dimensional manner within the horizontal plane regardless of the rake angle of tine (figure 3). The soil moves to the lateral sides of the tool at a depth greater than critical depth, along logarithmic spiral paths, similar to the deep foundation model postulated by Meyerhof (1951) and the resultant stress on the tine can be obtained using:

$q' = c\,N'c + P0\,N'q$ (3) and

$P0 = \gamma\,zK0 = \gamma\,z\,[1-\sin\phi]$ (4)

where,

$\phi$ = Angle of internal friction of soil, degree

K0 = Ratio of horizontal to vertical stress on the soil at rest

K0= $[1-\sin\phi]$ after Lambe and Whitman (1969).

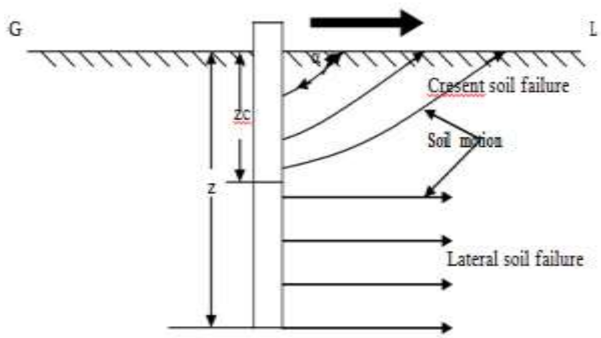


**Fig. 3: Soil movement for a very narrow cutting tool**

Therefore, the total force, Q, on the tine face width of w below critical depth, is given by integrating equation 3 between limits of critical depth (zc) and total working depth (z) by neglecting tine roughness and multiplying by 'w' as:

$Q = [c\,N'c\,(z-zc) + \gamma/2\,Ko\,N'q\,(z2-zc2)]\,w$ (5)

where, zc = Critical depth of operation, m

The N′c and N′q can be determined from graphical representation (Meyerhof, 1951).

The total horizontal force component (H1) of P in the direction of travel including interface adhesion above the critical depth is represented by:

H1 = P sin (α+δ) + ca zc w cot α (6)

Thus, the total horizontal component (Draft force), D in the direction of travel is the sum of Q below critical depth and H1 above it, can be expressed by:

D = Q + H1 (7)

DESIGN AND ANALYSIS OF TYNE:

Design of Tyne:

The primary purpose of tine is to apply fertilizer as well as to perform subsoiling up to a depth of 500 mm. A 75-mm wide share was selected for the central tine from the previous research completed by Arun Kumar (2003). Thus, to design the different parts, it was required to determine the draft force.

Tool parameters:

Width of share (w) = 75 mm;

Rake angle of share (α) = 220;

Depth of operation (z) = 500 mm;

Aspect ratio (z/w) = 500/75 = 6.67

Soil parameters:

Cohesion (c) and angle of internal friction (ϕ) of soil layer having the maximum density of 17 kN/m3 was taken as 17 kPa and 250, respectively as found by Arun Kumar (2003). Soil to metal friction (δ) = 2/3rd ϕ = 16.60 ≈ 170

Bulk density of soil (γ) = 17 kN/m3

Soil adhesion (Ca) = 0 (assumed).

According to Spoor and Godwin (1978), the critical depth (zc) of a conventional straight leg subsoiler ranged between the aspect ratios of 5 and 7. Therefore, taking zc/w = 5, the critical depth was computed at 375 mm. For α = 220, zc/w = 5, δ = 170, ϕ = 250, z =500 mm, the values of Nγ and Nc were found as 10 and 9, respectively from graph presented by McKyes (1985) and N'c = 40 and N'q = 20 were found from graphical relation of ϕ and N factors provided by Meyerhof (1951). Further, the addition of wings added 30% more to the total draft (Spoor and Godwin, 1978). Substituting these values and considering addition of wings, the total draft force (D) on the leg of subsoiler was calculated as 14.3 kN which was rounded up to 15.0 kN.

Analysis of Tyne:

Modal Analysis of single set of Tynes is done by using HYPERMESH AND NASTRAN Software as follows:

Step 1: Cad Model:

In this CAD Model Maximum Force is applicable in Tyne Portion so we require stress developed in tynes and displacement due to force.

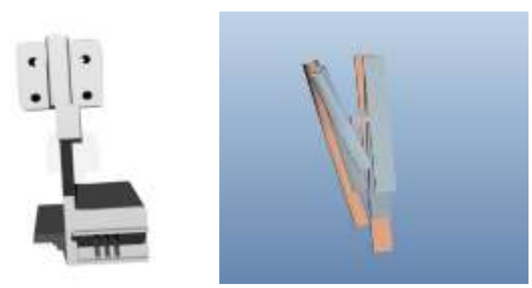

**Fig. 4: Clamping Device and set of the Tyne**

Step 2: Meshing:

1. Meshing is Dividing components into small parts.

2. In this model Hex meshing is used.

3. Created hex mesh for a tyne set.

4. Element size 3mm used.

5. 96% quad elements used and remaining are trias.

**Figure 5: Meshing of the Model**

Step 3: Material Specification:

For cost purpose and machining purpose Mild steel is used.

Properties of mild steel used:

E = 200 GPA; NU = 0.3; Yield stress = 260 MPA

Step 4: Constraints:

1. Tyne is attached to frame by nut bolt assembly so constraint is given on the nodes which is connected to the assembly.

2. Tyne set is fixed on all the node where constraint applies.

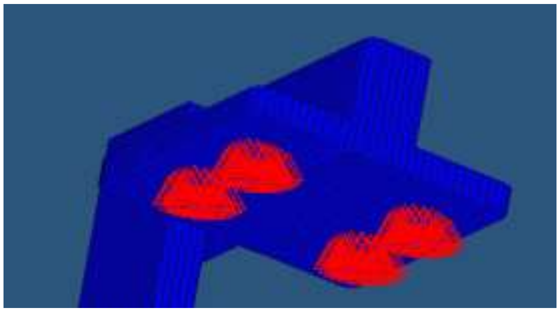

**Figure 6: Constraints applied on the model**

Step 5: Force:

Force is applied on the nodes of all three tynes.

Total force is used on single tyne set is 700 N.

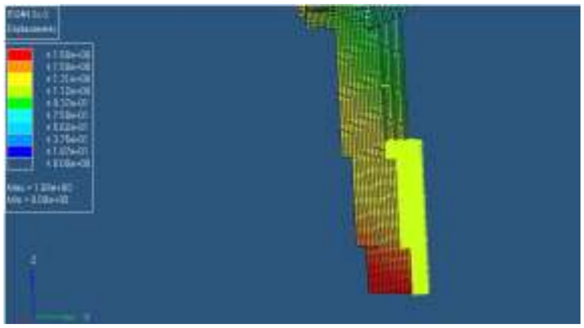

**Figure 7: Forces applied on the model**

Step 6: Control cards:

Solver card is user for stress, strain and displacement.

1. Time card is used.

2. Define all the constraints and force in the form of load steps and control cards.

Step 7: Solve (Post procedure):

After completion of pre procedure of analysis solve the model with constraints.

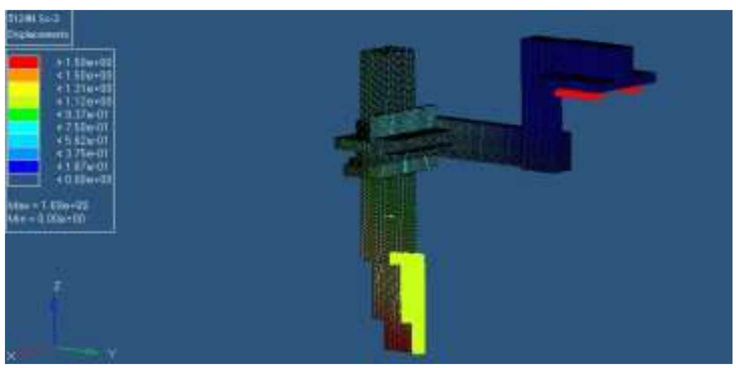

**Figure 8: After pre procedure analysis of Model**

Step 8: Results of the Analysis:

1. After solving 0.01 to 1.5 mm displacement found.

2. Maximum stress developed at tyne portion.

3. Maximum stress is 114 mpa which is under yield stress.

4. So component is in safe condition.

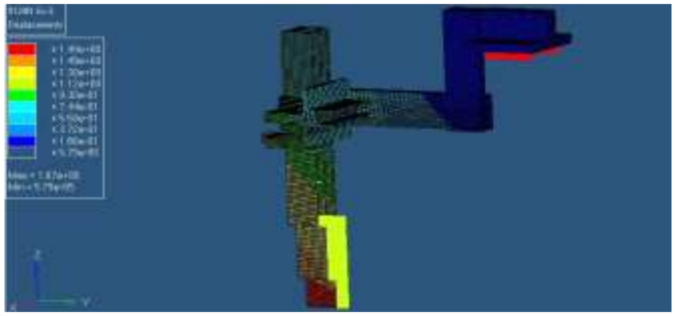

**Figure 9: Post Procedure of the model**

Step 9: Conclusion of the Analysis:

1. In upper part of tyne stress is very low.

2. If our machine allows us than we can remove material from those places where stress is very low. It reduces material cost and machining works.

RESULT AND CONCLUSION

After design, analysis and fabrication of Fertilizer drill device it was tested on the field. Experimentation was carried out for proving weather fertilizers which were applied are utilized by crop at late vegetation stage or not.

**Figure 10: Seed and Fertilizer placement with the help of Bull Drawn Multipurpose Fertilizer Drill Device**

Hence, we can conclude that with the use of Bull drawn fertilizer drill device on land, fertilizers are effectively applied into the soil and are available for the crop throughout the growth period of the crop.

Thus fertilizer drill is a device that permits farmers to have a precise control over the depth at which fertilizers are applied.

It has been made keeping in mind the poor farmers who cannot afford tractors so that they are able to apply fertilizers in all the 3 stages of crop growth properly. We have successfully overcome the problems which are there in some of the existing models in the market.

**FUTURE SCOPE**

The unit has been made keeping in view the power of the bull which is around 2hp. For the future purpose we try to make the unit compatible with low power tractors available in the market of power 15hp or 8hp power tiller tractor or 12hp diesel walking tractors.

The main components of the unit have been made detachable. So if in a future a need arises for modification in the design of the main components it can be done with too many in the whole unit.

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