

SOME STUDIES ON DRAFT REQUIREMENT OF ANIMAL DRAWN MOULD BOARD PLOW

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**COLLEGE OF AGRICULTURAL ENGINEERING AND
TECHNOLOGY**

**ORISSA UNIVERSITY OF AGRICULTURE AND
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BHUBANESWAR

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A THESIS SUBMITTED TO

**ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
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IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF

**MASTER OF TECHNOLOGY
(AGRICULTURAL ENGINEERING)**

IN
FARM MACHINERY AND POWER

BY
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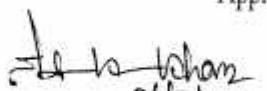
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IN

FARM MACHINERY AND POWER

2012

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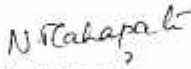
CERTIFICATE

This is to certify that the thesis entitled “Some Studies on Draft Requirement of Animal Drawn Mould Board Plow” submitted in partial fulfillment for the degree of Master of Technology (Agricultural Engineering) in Farm Machinery and Power of Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of bonafide research work carried by Sri Sourajit Acharya (07/FMP/10) under my direct supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged by him.

Bhubaneswar

Date 26.7.12


Dr. N. Mahapatra

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Sourajit Acharya

Date-

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LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTIONS
d	depth
D	Draft
DAs	Draught Animals
DAP	Draught Animal Power
db	dry basis
EORT	Extended Octagonal Ring Transducer
Eqn.	Equation
Fig.	Figure
kWh	kilo Watt hour
L	Length
LVDT	Linear Variable Differential Transformer
M.B.	Mould Board
MC	Moisture Content
MS	Mild Steel
MW	megawatt
R_c	Cone penetrometer resistance
V	Velocity
wb	wet basis
W	Width

CHAPTER – I

INTRODUCTION

CHAPTER -I

INTRODUCTION

1.1 General

The major uses of animal power in the third world countries include: tillage, seeding, weeding, water lifting, threshing and transportation. In most of these countries, the progenies of the animals are readily available for use as draught animals on the farms. For instance, in Indian agriculture, draught animals (DAs) provide the major tractive force for field operations. The DAs are contributing about 27,000 megawatts of power, which is about 30% of the total power of the installed electrical generation capacity of India (Ojha and Michael, 2003). It is estimated that about two-third of the total cultivated area is managed by DAs and remaining area is cultivated by other sources of farm power namely tractors, power tillers and human labors. Thus, it suffices to mention that, DAs are still having a great importance in Indian economy.

Due to rapid growth of agricultural mechanization in India, the contribution of animate (human + animal) sources of energy, in absolute terms, has gone down from about 97.4% in 1951 to about 21.0% in 1999, still it is the main source of tractive energy on Indian farms for plowing and other field operations about 75% of the cultivated land comprising of about 107 million ha area is managed by using animate sources of energy (Srivastava N.S. ,2000). With the modernisation of agriculture, increased availability of electrical and mechanical power in rural areas, development of improved road and transport systems, the annual use of animal energy is going down, however the use of human energy has not gone down due to mechanization. The labour force displaced due to mechanised operations get absorbed in handling and primary processing of additional agricultural produce due to increased yields.

During last few years India has emerged as the largest tractor producing country in the world, yet leaving 5 states namely Punjab, Haryana, Uttar Pradesh, West Bengal and Rajasthan, other states do not have adequate farm power for timely field operations, resulting into reduced yields. Under such situations use of animate sources of energy will

continue to play a complimentary role of providing farm power on Indian farms, specially on small farms and in hill agriculture, in addition to mechanical and electrical sources.

During recent years custom hiring of tractors and high capacity machines like combines, threshers etc. have gained popularity and even small category farmers have also availed this opportunity. Many of such farmers who were finding it difficult to maintain a pair of bullocks have sold their draught animals. However considering the scarcity and rising prices of petroleum fuels, it would be desirable to continue with a proper mix of animate, mechanical and electrical sources of energy so that there is no problem faced in future.

1.2 Indian Draught Animals Power

1.2.1 Importance of draught animals

Draught animals play a dominant role in our rural economy. The draught power of our 83 million draught animals is estimated at equivalent to 30,000 MW in terms of electric power, equivalent to half the generation capacity of India. In terms of energy, it is equivalent to 50,000 million units worth Rs.10,000 crore. Draught animals are being used to plough around 100 million hectares of farm land in India, which forms 60 per cent of total cultivable area, (transport 25,000 million ton km of freight per year saving 6 million ton of diesel worth Rs.4,000 crore annually. (Singhal, 1999).

1.2.2 Machines vs. draught animals

Although an increasing mechanization is replacing the animal power in the villages, reducing the total DAP, yet India has to depend on animal energy for many years to come from agricultural operations and transport of farm produce. The net sown areas increased from 133 to 142.82 million hectares and gross cropped area 153 to 185 million hectares during the last two decades (Anon, 1998). The draught animal power has not been found adequate and, thus this is being supplemented by mechanical power especially for tillage, irrigation and threshing (Singh, 2001).

Ninety percentage of land holdings are distributed in marginal to semi-medium farm holdings. It covers about 50 per cent of total cultivable land. This asset has been cultivated using farm animals like bullocks, buffaloes and camels, where tractors and

tillers, uneconomic, besides being too expensive for small farmers. Fragmentation of land is also continuing. In such situation DAP is important.

The cropping season generally lasts for only some 30 days during Kharif and 30 days during Rabi or a total 60 days in a year. 70 million bullocks exclusively used over 60 days, for cultivation, 6 hr each day, account for a total power output of some 9450 million kWh or power units work animals are used only for 100 days in a year for all purposes together (cultivation and transportation). Their total work output for the 100-day period. The average working year for a work bullock would be 15750 million kWh or units.

On the basis of coverage of land, one bullock pair can cultivate some 0.33 ha in a 6 hr working day. For cultivating 176.66 million ha (gross cropped area in 1987) over a 60-day period, the work animal force required was only 8.6 million pairs of bullock. Alternatively, if the entire cultivation operations were to be completed in a 30-day period 15 days each for Kharif and Rabi, then a total of 17.2 million pairs would be required and we had in 1987, some 35 million pairs. This is however not to conclude that the 70 million bullock were surplus their spatial distribution over millions of holdings all over the country and agricultural operation are time bound. Singhal *et al.* (1996) reported that about 32% of animal energy were being used in the rural sector in the country.

1.3 Animal Traction

1.3.1 Work and power

As an implement is pulled through the soil, the animal or team exerts a tractive force and as it moves across a field, it performs work. Animals are constantly using metabolic energy for maintenance, in a way comparable to the non-stop idling of a vehicle engine, so that a slow job or one involving more than one animal may involve higher metabolic energy expenditure; animals also perform work moving themselves, so that the shorter the distance they travel, the less work they do moving themselves; in such cases pulling a wide implement though a short distance will involve less energy for walking than pulling a narrow implement through a long distance.

For any particular force or amount of work, it is speed that determines power output. Pulling an implement that has a draft of 800 N at a speed of 0.8 m s⁻¹ requires a power of 640 W, while to pull the same implement at 0.3 m s⁻¹ requires only 240 W.

Animals therefore tend to adjust their speed in reaction to the draft load and the reduction in speed is particularly noticeable with cattle (Storkey *et al.* 1989)

The shape, weight, width and working depth of the implement largely determine in draft in the prevailing environment, and thus the force the animals have to apply to pull the implement. The breed, size, weight, training, fitness, temperament and work schedule of the animals, together with the implement draft, will largely determine the walking speed and thus the power output and, depending on the distance covered in the day, the resulting work achievement. Implement draft, walking speed and non-working time are greatly influenced by a wide variety of interacting environmental, operational and human factors (Storkey *et al.* 1989).

Effective utilization of agricultural energy input is highly essential to cope the need for increasing farm production, productivity with reduction in operating cost and also to ensure timely completion of field operations. Proper selection and use of proper matching equipments can enhance the efficiency of power sources which is more important in case of animal powers. The availability of data on the draft requirement of tillage implements is an important factor while selecting tillage implements for a particular farm situation as well as the source of power. Thus, the matching tillage tools can be effectively & efficiently used through the power sources particularly animal power sources.

On the basis of above, the present research work has been taken up with following objectives.

1. To study the effect of various operating and soil parameters which effect the draft requirement of various plows under study; namely CAET plow, Down size OUAT MB plow, Implement Factory plow and Heavy Soil plow.
2. To determine the operating and soil parameters best suited to the above plows under study.

CHAPTER – II

REVIEW OF LITERATURE

CHAPTER- II

REVIEW OF LITERATURE

Over the decades attempts had been made by different researchers to measure the draft of tillage implements accurately and to study the factors affecting drafts so as to predict it. The present review has been classified into following categories namely

- i) Draught Animals & their Power
- ii) Study of Draft of Tillage Implements & Factors affecting it

2.1 Draught Animals & their Power

Phaniraja *et al.* (2009) studied that with the modernization of agriculture, the use of mechanical power in agriculture has increased but draught animal power (DAP) continues to be used on Indian farms due to small holdings and hill agriculture. More than 55% of the total cultivated area is still being managed by using draught animals as against about 20% by tractors. India possessed the finest breeds of draught animals. Bullocks, buffaloes and camels are the major draught animals for field operations. Horses, mules, donkeys, yak and mithun are the pack animals for transport. The quality of work from the draught animals depends upon the power developed by them. The design of traditional implements is based on long experience and these have served the purpose of the farmers. However there is plenty of scope to improve the design based on animal-machine-environment interaction so as to have more output and increased efficiency without jeopardizing animal health

2.2 Study of Draft of Tillage Implements & Factors affecting it

Zoz M.F. (1973) studied the advantages and disadvantages of the alternative means of increasing productivity of tillage operations. Tractor performance and plow draft predictions were made. Tractor and plow prices were estimated, total costs were determined and the optimum width and speed was calculated for least total cost/acre. Investment costs tend to increase at slow speeds due to size and weight of tractor and implement. Operating costs increase at high speed due to higher (per acre) energy

consumption. Total tractor costs per hour increase for slower design plowing speeds due to weight and strength requirements.

Gebresenbet *et al.*(1997) studied that the performance of two conventional animal-drawn mould board ploughs and a reversible prototype mould board plough were studied under field conditions in Kenya on previously ploughed and harrowed clay nitisol. The two mould board ploughs were a Victory plough, manufactured in the United Kingdom, and a cylindrical mould board plough manufactured by the Rumpstad factory of The Netherlands. The reversible prototype wooden mould board plough was developed at the Department of Agricultural Engineering of the Swedish University of Agricultural Sciences as a mould board type, modernized version of the ard type plough. Simultaneous and dynamic measurement of forces, moments, ground speed and tillage depth were made. The results of the comparison between the three ploughs showed that both the horizontal and vertical components of forces resulting from the reversible plough were about 50 and 65% of the forces resulting from the Rumpstad and the Victory ploughs, respectively. In the case of the reversible plough, the effect of a tail angle on horizontal and vertical forces was investigated. The results of field tests confirmed the laboratory results in that the form of graphs and equations describing the relationship between the forces and tail angle were similar to those obtained during the laboratory tests. A single donkey was used to draw the implements throughout the experiment. It pulled about 25% of its body weight at an average speed of 0.8 m s^{-1} and worked for 9 h per day.

Draft measurements were made by Janobi *et al.* (1998) for major primary tillage implements operating on sandy loam soil. Implements included three chisel plows of different shanks, an offset disk harrow, a moldboard plow and a disk plow. The effects of speed and depth upon the draft measurements were investigated. Soil classification, implement specifications and results of tillage experiments are reported. A general regression equation to predict draft of these implements was developed based on speed and depth. A significant increase in draft was observed for all the implements with an increase in depth. The values of specific draft of the six tillage implements tested were affected significantly by speed and depth also.

Onwualu *et al.* (1998) conducted a study to establish the relationship between tool forces and speed as an important parameter in evolving management strategies for optimum performance. The effect of speed on tillage tool forces were studied

experimentally for wide (width=25.4 cm, depth=15 cm) and narrow (width=5.1 cm, depth=22.9 cm) plane tillage blades operating in a Dystric Fluvisol (silty sand texture) in a soil bin. The tools were tested at two depths (10 cm and 15 cm for wide blade, 11.4 cm and 22.9 cm for narrow blade), two rake angles (45° and 90°) and eight speed levels (0.25, 0.5, 0.75, 1.00, 1.25, 1.50, 1.75 and 2.00 m/s). The variables were combined in a 2×2×8 factorial experiment with three replications. The performance of three theoretical models based on the trial wedge approach in predicting the experimental results was evaluated. The first model (Model 1), based on Soehne's approach (with modification for the three-dimensional analysis) assumes that the soil fails in a series of shear planes, forming a wedge that is trapezoidal in shape. The equilibrium of the wedge boundary forces produce the force required for failure. The second model (Model 2), based on Mckyes' approach assumes that soil failure is by the formation of a centre wedge flanked by two side crescents. Equilibrium of the boundary forces on the wedge and crescents produce the forces as a function of an unknown failure angle which is obtained by minimizing the weight component of the total force. Model 3, based on Perumpral's approach assumes the same failure wedge as Model 2 but the total cutting force is minimized instead. Experimental results show that the tool force (draught and vertical force) is a function of the speed and the square of speed whereas the three models assume it to be a function of the square of speed only. The models were not very accurate in predicting the experimental results. The average percent deviation of the predicted forces from the observed values were 43%, 40% and 66% for Models 1, 2 and 3, respectively. Thus, Model 2 had more general agreement with experimental observations. The models were better in predicting the forces (draught and vertical force) for the narrow tool with average percent deviations of 33%, 28% and 46% for Models 1, 2 and 3, respectively, as compared to 53%, 51% and 85% for the wide blade.

Owende *et al.* (1999) conducted experiment to rate the performance of some common ploughs in order to advise farmers on their use. Draught and vertical reaction (suction) on a per-tool basis were measured for four ploughs commonly used in the region; the Victory, the Rumpstad winding-body and two types of Rumpstad cylindrical-body ploughs, using an instrumented rig. The experiments were in Pellic Vertisol, Ferralsol and Nitosol soils under two soil moisture conditions. Draught increased significantly with depth for all four ploughs, hence, regulation of tillage depth is paramount to avoidance of drastic fluctuations. Similarly, vertical reaction increased with

depth of ploughing, which implies a more stable operation, hence, when draught can be sustained over acceptable work duration, it is desirable to set the ploughs to work deeply. Significant speed–depth interactions were also recorded, and these imply that speed is important when operating depth is stochastic as is the case in the dynamics of these ploughs. Overall, the Victory plough had the lowest draught requirement (0.32–1.02 kN) under dry and moist soil conditions, hence, was the best option for use in areas represented by the three soil types in Kenya. Soil-type had a significant effect on mean draught and vertical reaction in the order (Draught, Vertical reaction); Vertisol (1.65 kN, 0.70 kN) > Ferralsol (0.66 kN, 0.44 kN) > Nitosol (0.64 kN, 0.01 kN), and Ferralsol (1.17 kN, 0.71) > Vertisol (1.09 kN, 0.23 kN) > Nitosol (0.49 kN, 0.11 kN) under moist and dry conditions, respectively. These results suggest that the duration of continuous work periods with draught animals should be based on soil-type.

Shoji Koichi (2001) developed a model spot plough to invert the soil slice within its own furrow was designed and tested in a soil bin, with a view to overcoming the disadvantages of conventional tillage systems with mouldboard ploughs. The model was especially designed to avoid soil clogging, whilst the basic structure was not altered from that surveyed from previous research. Followed by the share and main mouldboard at the beginning of the inversion, a tilted disc coulter (TDC) was located on the other side of the main mouldboard to assist the spot inversion and to reduce relative motion to the soil. Towards the end, the tilted disc coulter was replaced by a sub-mouldboard. Optimum width-to-depth ratio and width of the mouldboards were also considered. The mouldboards were expressed as helicoidal surfaces, and were fabricated from a plate of polyvinyl chloride. A series of experiments showed that the model spot plough performed well in wet-plastic soil, acceptably in dry-powdery soil at higher speed, and somewhat less steadily in dry-solid soil conditions. In any soil condition, the function of the rotating tilted disc coulter was found to be essential for stable operation.

Shrestha *et al.* (2001) developed a mathematical model of a mouldboard plough to design it for the minimum amount of operating energy. Using this model, a mouldboard plough requiring the least specific draught was designed for given soil conditions (specific weight of soil, cohesion, soil-metal adhesion, soil-metal frictional angle and soil internal frictional angle) and operating conditions (speed and depth of cut) for a given power availability. Five parameters were set to describe a mouldboard plough,

namely width of cut, share angle, side rake angle, angular acceleration of soil inversion in the transverse plane and length of plough in the direction of travel. The designed plough and a commercial mouldboard plough were tested in two different soils in a laboratory soil bin to validate the model and to compare performance. Specific draught requirements were compared and it was found that the difference between predicted and measured specific draught was not significant. The new plough, however, needed significantly less specific draught than the commercial plough at identical operating conditions

Zhang *et al.* (2001) studied on development of a prototype three-stage soil layer mixing plough based on the results of the soil bin experiments conducted using a half-size model ploughs. This machine was transported to China for field tests and this paper presents the trash mixing rate into the A horizon and the draught of the plough in the meadow soil. The results showed that the optimum approach angle of a second plough body for the meadow soil was 30°. The rolling resistance of the tracked vehicle (T802) on which the plough was mounted was about 10 kN, and the draught of the first plough body which tilled the Ap horizon was also about 10 kN for a working depth of 200 mm and a working width of 500 mm. The draught of the second plough body which tilled the surface of the Ap horizon was about 5 kN for a working depth of 50 mm. The draught of the third plough body increased steeply with the greater working depths. The draught was about 15, 28 and 38 kN, respectively, for working depths of 156, 217 and 278 mm. The wheat stubble and straw were found in the A horizon and even in the layer below a depth of 500 mm

Guo *et al.* (2003) studied to develop a special machine, a four-stage subsoil inverting plough which would improve the permeability of whitish oasis soil by inverting the second horizon (Bca) and the third horizon (C) underground and by lowering the percentage of calcium carbonate (CaCO₃) in the subsoil horizon. Specifically, the Bca horizon (with its high content of CaCO₃) is lowered, and the C horizon (with less CaCO₃) is raised. This paper describes the results from preliminary soil bin experiments, that were conducted in Japan with half-scale model ploughs. Optimum shapes of the third and fourth plough bodies were determined for a full-scale four-stage subsoil inverting plough. The results show that a fold-up type plough body with a window on the mouldboard is effective for the inversion of the Bca and C horizons. The optimum approach angle of the third and fourth plough bodies, which is the angle with respect the travel direction, was

30°. The optimum window height of the third plough body was 0 mm, so that the third plough body had no window, and the plough body cut into the soil halfway up the middle of the body. This design gave the smoothest flow of soil. The optimum window height of the fourth plough body was 130 mm. The draught requirements of the plough body were such that the draught to cut soil was the largest, followed by the draught of the accumulated soil block, then by the draught caused when the soil was folded up and finally by the draught caused when the soil slid horizontally on the mouldboard. When the soil water content was 10.5% and 16.9% d.b., the soil inverting rate was an average of 0.9. Nearly perfect inversion of the Bca and C horizons could be obtained because the soil water content was less than the plastic limit (23.7% d.b.), and the soil was easily broken into small pieces that flowed smoothly over the plough body. However, when the soil water content was 25% d.b., which was greater than the plastic limit, the soil inverting rate decreased, and soil did not flow smoothly over the plough body

Study conducted by Agrawal *et al.* (2003.) revealed that the draft of tillage tools plays a vital role in the design of tillage implements and has a significant influence on the type of mechanical power required for its operation. The compaction level, moisture content of soil and forward velocity of tool affect the pull and specific draft of a mould board plough bottom. An experiment was carried out in laboratory conditions in a soil bin at the Department of Agricultural and Food Engineering, IIT, Kharagpur, in order to determine the effects of soil compaction level, soil moisture content and tool forward velocity on pull and specific draft of a 15cm mould board plough bottom model. The forces acting on the plough bottom were sensed using an octagonal ring transducer and the horizontal and vertical forces were recorded using a two-channel RS-Dynograph model recorder. The compaction level, moisture content and velocity were varied at three levels each and the data were analyzed statistically. The effects of all the three independent variables were significant at 1% level on the pull and specific draft. The interaction of compaction level with moisture content was also significant at 1 per cent level. The interaction of compaction level with velocity was significant at 5 per cent level in the case of pull, but non-significant in case of specific draft. Empirical equations were fitted for pull and specific draft separately. An attempt has also been made in this study to determine the coefficients of ASAE equation for local conditions and it was found that moisture content and cone index have significant effects on coefficients (A,B and C) of

the ASAE equation. The cone index was used in the present investigation as an index for soil compaction level.

Abubakar *et al.* (2005) assessed the effects of soil physical and mechanical properties on field efficiencies of Ox-drawn mould board plough by conducting tests in four sub-locations within Yola environment, between May and July, 2005. Soil samples, taken at 15-20 cm depth and under four (4) moisture regimes (10, 15, 20 and 25%) by means of auger were put into polyethylene bags and properly labeled. The soils were investigated for relevant properties (bulk density- ρ_b , moisture content-M.C., texture, consistency) following laboratory procedures. The data were statistically compared using the Student's t-test. The mould board plough efficiencies at various soil M. C. varied significantly ($P=0.05$) among the soil units at differing compaction limits ($1.35-1.50 \text{ Mg m}^{-3}$). Effective field capacity-EFC, was highest (0.133 ha/h) in Sabon-gari and lowest (0.112ha/h) in Futy demonstration farm-FDF at the same soil M.C. (25%). Lowest time losses of 13 and 14 minutes was at 10 and 25% soil M. C. in Sabon-gari with relatively lower (1.35 Mg m^{-3}) soil compactions. In view of the results obtained, it suffices to recommend that ox-drawn mould board plough utilization should be encouraged in areas with low soil compaction (i.e., 1.35 Mg m^{-3}) and up graded into multiple bottoms implement for team of animal traction, as it effectively conserves valuable physical and mechanical soil properties.

An investigation was carried out by Sahu *et al.* (2006) to predict the draught requirements of commonly used tillage implements in any field condition from the knowledge of : (i) the draught requirements of reference tillage tools in a reference soil condition; and (ii) the scale factors related to soil properties and implement geometry. In the first step, the draught requirements of three different reference tillage tools: (1) a plough with a width of cut of 0.1 m; (2) a tine with a width of cut of 0.075 m and (3) a disc with a diameter of 0.3 m were verified in the soil bin by operating in a reference soil condition (sandy clay loam soil with average cone penetration resistance of 472 kPa and bulk density of $1170 \pm 20 \text{ kg/m}^3$) at three depths (0.05, 0.075 and 0.1 m) and four speeds (1.2, 2.2, 3.2 and 4.2 km/h). In the second step, the draught requirements of six different scale-model implements: two mould board ploughs (0.15 and 0.25 m width); two cultivators (2 and 3 tine); and two disc gangs (0.34 and 0.37 m width) were measured in the same soil with five different soil conditions (average cone penetration resistance and

the corresponding bulk density varied from 470 to 1420 kPa and 1170 to 1680 kg/m³, respectively) at particular depth (0.075 m) and speed of operation (3.2 km/h). The empirical equations for draught requirements of reference tillage tools and hence, scale-model implements were developed using orthogonal and multiple regression techniques. The developed empirical equations were verified in the laboratory as well as in the field conditions. A good general agreement between observed and predicted draught values was found with the average absolute variations of 7.0%, 6.2% and 7.5% in the laboratory as compared to 10.6%, 10.2% and 13.2% in the field for the mould board plough, cultivator and offset disc harrow respectively. This methodology produced sufficiently accurate results to enable the draught prediction of tillage implements in different soil conditions by testing only the reference tillage tool in the desired soil type at reference soil condition.

Sahu *et al.* (2006) developed a methodology to predict the draft requirements of combination tillage implements in any soil and operating conditions was developed. This methodology required the draft requirements of individual tillage implements in undisturbed soil condition and draft utilization ratio of the rear passive set of combination tillage implement, which is defined as the ratio of the drafts of the rear passive set operating in combination and individually. Laboratory experiments were conducted to measure the draft requirements of a reference tillage tool (single disk), three scale-model individual (moldboard plow, cultivator and disk gang) and two combination (moldboard plow with disk gang and cultivator with disk gang) tillage implements at different depths (5, 7.5 and 10 cm), speeds (1.2, 2.2, 3.2 and 4.2 km/h), wet bulk densities (in the range of 1.27–1.85 g/cm³) and cone index penetration resistance values (in the range of 445–1450 kPa) in soil bin filled with sandy clay loam soil. The average draft utilization ratio of the reference tillage tool obtained were analyzed by both orthogonal and multiple regression techniques to develop the regression equation considering soil properties, operating and tool parameters. The developed draft equation based on the above mentioned methodology was verified with the data obtained for the draft of scale-model and prototype combination tillage implements in the laboratory and field conditions, respectively. It was found that the developed equation predicted the draft of both combination tillage implements within an average absolute variation of 18.0 and 13.5%, respectively.

Darmora .D .P (2007) selected a 55 mm shovel type furrow opener of combined seed drill for optimization of its design parameters. Four boot wedge angles (20,40,60 and 80 degree) and four rake angles (30, 40, 50 and 60 degree) of the furrow opener were investigated at four operating depths (40, 60, 80 and 100 mm). The tests were conducted in a factorial randomized block design with two replications under sandy loam and loamy sand soil conditions in an indoor soil bin for optimizing the design parameters of the furrow opener in order to minimize its draft requirement. Boot wedge as well as rake angle of 40° was found as the optimum value under both the soil conditions. Multiple regression equations were also developed to predict the draft requirements precisely under sandy loam and loamy sand soil conditions

Godwina *et al.* (2007) developed a mathematical model to predict the draught force acting on a mould board plough body. An important aspect of the model is that draught force is calculated using the geometric parameters of the plough body components, the plowing speed and the physical properties of the soil. A spreadsheet has been developed to carry out the complex calculations required to determine the total draught force. Experimental work was conducted to examine the validity of the model using two types of plough body working in a sandy loam soil and a sandy clay soil. Plowing depths in a range up to 225mm were used and speeds up to a maximum of 5 m/s. Comparison of measured draught forces with those predicted by the model showed that, overall, the predicted forces were 2.8% less than the measured value and that 90% of all results were within bounds of 720% of a line of equal magnitude. It was shown that the draught force can be expressed as a function of plowing speed and depth. For both of these variables there was a quadratic relationship with draught force. The draught force due to the plough point and share ranged from 52% to 70% of the total force for the range of variables employed in the work. The force at the mould board was 12% to 29% of the total draught and frictional forces were in the range of 15% to 30%. The model enables relationships to be obtained between plough depth, number of plough bodies and speed for particular tractor and power specifications. This showed, in particular, how reducing depth can result in higher work rates by effecting an increase in plowing speed. The work rate was shown to increase by 57%, for example, if depth was reduced from 300 to 225mm and increasing the number of plough bodies from 4 to 6 when using a 177 kW tractor when working in a sandy clay loam. This is of particular interest to minimize the

cost of cultivation techniques where the inversion of surface residues and weeds is required.

Manuwa. *et al.* (2007) carried out soil bin investigations to study the influence of some soil parameters namely: moisture content and cone index, on draught force and soil disturbance of mold tillage tools. The tools were tines in the groups of very narrow tines, narrow tines and wide tines. The soil under study was a sandy clay loam. It was observed that draught increased at a decreasing rate as the soil moisture content increased from 11 to 22.5% (db). Polynomial regression models best described the relationships with high R^2 (coefficient of determination) values. Soil disturbance parameters: ridge-to-ridge distance, width of crescent or width of furrow at the surface, total disturbed width, height of ridge, and furrow depth were determined. Tine draught increased at an increasing rate as compaction increased for a cone index in the range of 150 to 800 kPa with polynomial regression equations best describing the relationships. The models generated in this study were suitable for predictive purposes.

Chung *et al.*(2008) conducted an experiment with an on-the-go soil strength profile sensor (SSPS) previously developed to measure the within-field spatial variability in soil strength at five evenly spaced depths up to 50 cm. In this article, performance of the SSPS was evaluated using soil bin and field data. First, the SSPS was tested in a soil bin at different depths (10, 20, and 30 cm), forward speeds (from 0.5 to 3.0 m s⁻¹), and compaction levels (high and low). Second, data were collected in two fields having variable soil texture, bulk density, and water content. Prismatic soil strength index (PSSI, defined as force divided by the base area of the horizontally operating prismatic tip) and penetrometer cone index were measured at five depths (10, 20, 30, 40, and 50 cm) across entire fields and also more intensively in four 10 × 10 m areas selected for soil texture differences. Auxiliary data collected were soil bulk density, soil water content, and apparent soil electrical conductivity (ECa). When the SSPS was tested in the soil bin, increases in PSSI with speed were less than 15% from 0.5 to 3.0 m s⁻¹ operating speed. Based on soil bin results, we selected 1.5 m s⁻¹ as a maximum field data collection speed, below which speed effects on PSSI were deemed negligible. Mean PSSI values collected in adjacent, parallel transects were not statistically different, confirming the repeatability and stability of soil strength sensing with the SSPS. Field data showed that, in general, PSSI was higher at locations with lower ECa, lower water content, and greater bulk

density. Results of stepwise multiple linear regression showed that variability in PSSI was better explained when interactions among the soil variables were included as independent variables and when data were grouped into subsets by depth and/or ECa level. Over entire fields, R² values for estimating PSSI were 0.66 and 0.61 for a claypan soil field and a flood plain field, respectively. These results will be useful for interpreting PSSI and for future applications of the SSPS in crop management, e.g., delineation of highly compacted within-field areas and control of variable tillage operations.

Jafari *et al.* (2008) studied to design and develop a new shape of bent leg plow (BL). The main difference between modified and conventional BL plows is the direction of angle between cutting blade and the line perpendicular to the plow shank. Soil-bin tests were conducted to study the performance of the modified plow as compared to the conventional one. The draft force requirement was measured in both designs at three rake angles (7.5°, 15°, and 22.5°). Changes in draft force requirements and soil physical properties including plowed soil bulk density and cross-sectional area of soil disturbed were measured and compared for both designs. Soil disturbance efficiency was also calculated for all treatments. Draft force was significantly affected by blade type and rake angle and was minimum at rake angle of 7.5°. Other results showed that the modified BL plow was the most energy efficient treatment when operating at a rake angle of 15°. Minimum plowed soil bulk density (1.04 Mg m⁻³) was observed in the energy efficient treatment (modified BL at rake angle of 15°). The lower draft requirement and considerable improvement in soil physical conditions suggested application of modified BL plow as a replacement for conventional model; it was especially true where the soil had excessive compaction.

McLaughlin *et al.* (2008) used an instrumented research tractor to determine the energy inputs for eight primary tillage implements applied to a Brookston clay loam soil in southwestern Ontario, Canada. The energy measurements included draft, fuel consumption (L ha⁻¹), and specific fuel consumption (L GJ⁻¹), which is an indicator of tractor-implement match. Implements included moldboard plow, chisel plow, disk ripper, combination chisel sweep, disk harrow, fluted coulter, deep zone till, and shallow zone till. The study was conducted over four years (2002-2005) using a randomized complete block design with fall primary tillage occurring in the wheat phase of a corn-soybean-winter wheat rotation. The disk harrow and fluted coulter were not effective primary

tillage implements due to penetration of only 50 to 60 mm into the clay loam soil. Operating depth for the other six implements was 170 to 190 mm, except for deep zone till which was designed to operate at about 340 mm depth to loosen compacted subsoil and break up plow pans. The mean drafts for these implements ranged from 16.3 kN m⁻¹ for the deep zone till to 5.0 kN m⁻¹ for the shallow zone till. Fuel consumption ranged from 21.6 L ha⁻¹ for the moldboard plow to 6.5 L ha⁻¹ for the shallow zone till. Specific fuel consumption ranged from 110 L GJ⁻¹ for the deep zone till to 204 L GJ⁻¹ for the disk harrow. The large ranges in implement draft, fuel consumption, and tractor efficiency indicate that substantial energy savings can be readily obtained by selecting energy-efficient tillage implements and by proper matching of the tractor size and operating parameters to the tillage implement

Rosa *et al.* (2008) developed a monorail test system for studying the draught and power performance of narrow tillage tools operating at high speeds. The system is retrofitted to a small 10-m long linear soil bin, yet is capable of maintaining target tool speeds of 0.5–10 m s⁻¹ over 1 to 3 m distances. Rigid vertical tools with three different blade shapes, two operating depths and two widths were tested in a silty clay loam with soft and hard compaction levels to demonstrate system capabilities. Soil disturbance was measured using a profile meter. Results showed increases in power, tool draught and soil pulverization with increases in speed, and measurable effects of tool geometry (shape, width, operating depth) and of soil strength on power and draught–speed relationships.

Carma *et al.* (2009) conducted the experiment with the aim to evaluate effects of design parameters of a cultivator share on draft force and soil loosening in a soil bin. The test tool variables included rake angle to the horizontal of 12.5, 17.5 and 22.5°, working depths of 70, 110 and 150 mm and forward velocity of 1.08, 1.55 and 2.08 m sec⁻¹. Measurements were taken of draft force and disturbed area of soil by the cultivator share. The resulting draft force was increased with increasing rake angle, forward velocities and working depth. The draft force in different trials varied from 42 to 202.5 daN. The area disturbed of soil was larger when tool rake angle, forward velocity and working depth were increased. The greatest disturbed area occurred at rake angle of 22.5°, forward velocity of 2.08 m sec⁻¹ and depth of 150 mm. The soil loosening increased with rake angle and forward velocity but loosening decreased with increased working depth. The soil loosening varied from 21.07 to 40.45%.

Manuwa .S.I (2009) studied the performance of three model tillage tools (tines). The experimental tillages were made from flat 8 mm plain carbon steel. They were designated T1, T5, and T20, corresponding to tine widths of 1, 5, and 20 cm respectively. Experiments were carried out in a soil bin filled with sandy clay loam soil at average moisture content 11.5% (dry basis) and 600 kPa average cone index. The plastic limit and liquid limit and plasticity index of the soil are 20%, 31% and 11% respectively. Tests were conducted at forward speeds of 0.28, 1.0, and 2.5 m/s. Depths of operation considered were 35, 70, 150, 200 and 250 mm. Draught measurements were made for the different tines and were also calculated using soil mechanics equation. There was reasonable agreement between measured and predicted draught forces. The effects of depth of operation on draught force of the tines were studied and evaluated. It was observed that draught increased at an increasing rate with depth; the relationship was a curvilinear one best fitted by exponential function. The soil disturbance created as a result was also evaluated and reported. The parameters used to define soil disturbance of a single tine were: ridge-to-ridge distance (RRD), maximum width of soil cut (WFS), maximum width of soil throw (TDW), after furrow depth (df), height of ridge (hr) and rupture distance (f). They all increased as the depth of operation of the tool increased but less proportionately. The critical depth of the tines was also estimated. The results of analysis of variance showed that tool type and operating depth significantly affected draught at 5% level of significance ($p < 0.05$) and that, there was interaction between the two factors.

Suhaibani *et al* (2010) conducted field experiments using a fully instrumented MS 3090 tractor to measure the draft of a heavy duty chisel plow in a sandy soil over wide ranges of plowing depths and forward speeds. The data were measured and recorded using an instrumentation system and data logger. The effects of plowing depth and forward speeds on draft, unit draft, vertical specific draft, horizontal specific draft and coefficient of pull were evaluated. The results indicated that increasing the plowing depth and/or the forward speed increased the draft, unit draft and vertical specific draft. Also, increasing the plowing depth increased the horizontal specific draft and the coefficient of pull, while increasing the forward speed decreased the horizontal specific draft and the coefficient of pull. About 16.6% of the draft force was directed towards cutting the soil and 83.4% was consumed in pulverization of soil particles. The plowing depth had more pronounced effect on the draft, unit draft, specific draft and coefficient of pull than the

forward speed. The optimum forward speed was 1.75 m sec^{-1} . The recommended plowing depth should be based on the type of crop (depth of the root system).

From the above study many workers have inferred that there is significant effect of speed and depth of operation of plows on its energy and draft requirement. Accordingly, in the present work these parameters were given priority in studying the draft requirements of the four types of plows under study.

CHAPTER – III

THEORITICAL CONSIDERATION

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THEORITICAL CONSIDERATION

The theory related to draft requirement of tillage implement is vast. The present work is limited to the draft measurement of animal drawn M.B. plow in the soil bin. In this chapter, some of the fundamentals about draft, components of draft force acting on a plow, draft prediction approach for tillage implements and various factors affecting draft have been discussed.

3.1 Draft

The horizontal force in the direction of travel required to pull the tillage tool through the soil is called draft /draught.

The specific draft is the draft per unit cross-sectional area of the furrow. Soil type and condition are by far the most important factors contributing to variations in specific draft. Values of specific draft range from 1.4 to 2 N/cm² for sandy soils and up to 10 to 14 N/cm² to for heavy gumbo soils. Sandy or silt loams may have specific drafts from 2 to 5 N/cm² whereas 4 to 8 N/cm² would be typical for clay loams and heavy clay soils.(Srivastava *et al.* ,1996)

3.2 Components of Draft Force acting on a Plow

The complexity of plough draft force prediction has led to the development of the model based on the principles of Mohr–Coulomb soil mechanics for blade and tine theory and on Newtonian dynamics. (Godwina *et al.* ,2007)

The equations, which comprise the model force predictions, are given below. The total plough draft force H_t in N is calculated from the following expression:

$$H_t = H_p + H_s + H_{mc} + H_e + H_{cs} + H_{ms} + H_{fs}$$

Where,

H_p : Draft force due to the plough point in N;

H_s : Draft force due to the plough share in N;

H_{mc} : Draft force due to the mould board soil momentum change and the draught force due to friction along the mould board in N;

H_e : Draft force due to the increase in soil potential energy at the mould board in N;
 $H_{cs} + H_{ms}$: Draft force components arising from friction forces due to lateral forces at the share and mould board, respectively, in N;
 H_{fs} : Draft force arising from the lateral force at the mould board due to soil lateral movement in N.

The following diagram describes the above equation.

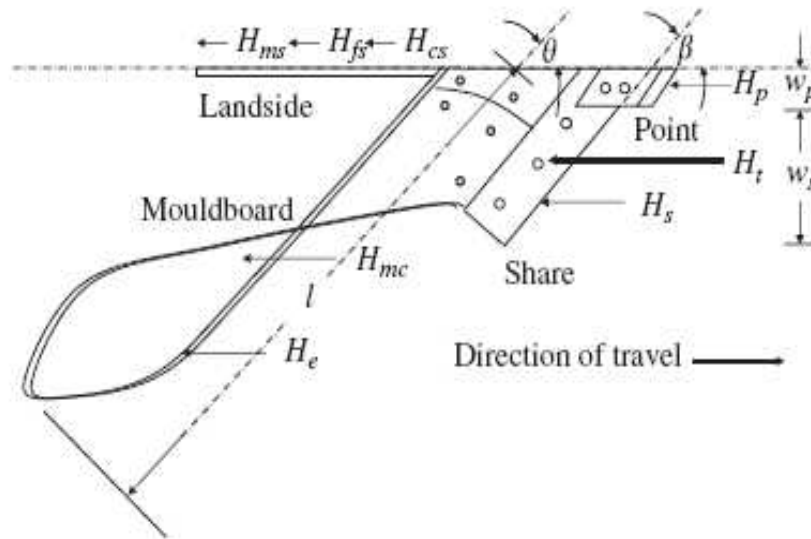


Fig 3.1 Components of Draft Force acting on the Plow

3.3 Draft Prediction approach for Tillage Implement

The draft requirement of any passive tillage implement D_i in N was found to be function of working depth d in m, travel speed V in km/h, width of the implement W_i in m, tool geometry characterised by angle α_i in degree and length L_i in m, and soil properties such as bulk density ρ_w in kg/m³ and cone penetration resistance R_c in kPa (Upadhyaya et al., 1984) and can be expressed as

$$D_i = f(d, V, W_i, L_i, \alpha_i, R_c, \rho_w) \quad (3.1)$$

Eqn. (3.1) can also be written as

$$D_i = f_1(d, V), f_2(W_i, L_i, \alpha_i), f_3(R_c, \rho_w) \quad (3.2)$$

where: f_1 , f_2 and f_3 are functions related to operating parameters, implement geometry and soil conditions respectively.

The contributions of a function towards the draft of an implement can be found by keeping the other two function variables constant. These are discussed in the following three cases.

Case I:

For a given soil condition and implement, Eqn. (3.2) can be expressed as

$$D_i = f_1(d, V) \quad (3.3)$$

According to Glancey and Upadhyaya (1995), the general relationship for the draught of a given implement in a specific soil type and condition can be given as

$$D_i = c_0 + c_1 d + c_2 d^2 + c_3 V + c_4 V^2 + c_5 d V \quad (3.4)$$

These regression coefficients (c_0, c_1, c_2, c_3, c_4 and c_5) are tool and soil specific. The existence of multi-colinearity between the term for d and d^2 as well as V and V^2 in Eqn. (3.4) caused difficulty in quantifying the coefficients. To overcome this problem, an orthogonal regression technique was adopted (Glancey & Upadhyaya, 1995) for correct determination of the coefficients. The transformed equation takes the form

$$D_i = c_0 + c_1 d^* + c_2 d^{**} + c_3 V^* + c_4 V^{**} + c_5 d^* V^* \quad (3.5)$$

where: d^* and d^{**} and V^* and V^{**} are orthogonal depth and speed, respectively; and $c_0 - c_5$ are orthogonal regression coefficients. Quantifying the coefficients and hence, knowing the

significant terms in the orthogonal regression equation [Eqn. (3.5)] for an implement, the draft requirement of a reference tillage tool D_r in N in a reference soil condition can be expressed using Eqn.(3.4) containing significant terms only and neglecting the non-significant terms.

Case II:

The draft requirements of different tillage implements in a given soil at same speed and depth can be expressed as

$$D_i = f_2(W_i, L_i, i) \quad (3.6)$$

In essence the standard tool is an analogue of the implement., Schafer *et al.* (1969) found that the draught of scale-models varied logarithmically with the scale factor for several implements such as triangular chisels, bulldozer blades, mould board plows, sweeps and cone penetrometer tips and concave discs. Although the interaction of implement geometry and soil properties is highly complex, the relationship between the

draught of an implement and a standard tool was found to be consistently logarithmic (Glancey *et al.*,1996). Considering this, the ratio of draft requirements of the prototype/scale-model implement and the reference tillage tool in a given soil at same speed and depth can be expressed as Eqn. (3.7)

$$(D_p/D_r) = (W_p/W_r)^a (L_p/L_r)^b (v_p/v_r)^c \quad (3.7)$$

where the subscripts p and r denote prototype and reference tillage tool, respectively; and a, b, c are multiple regression exponents.

Assuming the set of characteristic lengths and angles to be same for both reference tool and prototype/scale-model implement, Eqn. (3.7) can be reduced to Eqn. (3.8).

$$(D_p/D_r) = (W_p/W_r)^a \quad (3.8)$$

Case III:

The draft of an implement in any soil condition at same speed and depth can be given by

$$D_i = f_3(v, R_c) \quad (3.9)$$

Similar to Eqn. (3.7), the ratio of draught requirements of a reference tillage tool in any soil condition and reference soil condition at same speed and depth is given as Eqn. (3.10)

$$(D_p/D_r) = (v_p/v_r)^b (R_p/R_r)^c \quad (3.10)$$

Multiplying Eqn. (3.8) and Eqn. (3.10) gives Eqn..(3.11)

$$(D_p/D_r) = (W_p/W_r)^a (v_p/v_r)^b (R_p/R_r)^c \quad (3.11)$$

Taking logarithms on both sides of Eqn (11) results in

$$\log(D_p/D_r) = a \log(W_p/W_r) + b \log(v_p/v_r) + c \log(R_p/R_r) \quad (3.12)$$

where, a, b and c are regression exponents that are specific to reference tillage tool–implement combinations. Thus, the draft requirement of a prototype implement in any soil condition can be predicted by knowing the scale factors for implement and soil conditions, and the draft of reference tillage tool in the reference soil condition at any speed and depth. (Sahu *et al.* ,2006)

3.4 Factors affecting Draft

3.4.1 Effect of plough speed

If relationships are fitted to the predicted values of total draft force H_t as functions of plow speed v for a given depth for all the experiments, they are of the form:(Godwina *et al.* ,2007)

$$H_t = a v^2 + b \quad (3.13)$$

with a value for the coefficient of determination of 1, where a and b are empirical functions of depth. The values of a and b are dependent on both soil and plough body parameters.

3.4.2 Effect of plough depth

If the model is used to predict the effect of depth d on the draught force H_t for a given plow speed, it is found that the relationship is quadratic of the form (Godwin *et al.* ,2007)

$$H_t = p d^2 + q d, \quad (3.14)$$

where p and q are empirical functions of speed v which are dependent on the particular soil properties and plough geometric parameters.

3.4.3 Effect of depth and speed on draught force

The effect on draft force of increasing the depth and speed of plowing is similar in proportion for both the field soil and the laboratory soil. However, the change in draught force is much greater for increasing depth than for increasing speed over typical practical ranges

3.4.4 Draft force as a function of plough depth and speed

For a particular soil and a given type of plough body it can be shown that the draught force can be expressed as a function of plough speed and depth. (Godwin *et al.* ,2007)

$$H_t = (A d^2 + B d) v^2 + (C d^2 + D d) \quad (3.15)$$

Where $a = A d^2 + B d$ and $b = C d^2 + D d$

The values of the constants A , B , C and D are specific for a particular soil and plough body geometry.

3.4.5 Relationship between speed and power

The total power P required to pull the plough is given by:

$$P = D v \quad (3.16)$$

3.4.6 Ploughing work rate

The work rate of a plough R is given by

$$R = wNv, \quad (3.17)$$

where R is in m²/s, w is the furrow width in m, N is the number of plow bodies and v is the plow speed in m/s. Hence, for a given plow body or furrow width w the work rate can be increased by increasing the number of furrows or plow bodies N and/or by increasing the plough speed v. For a plow with a particular furrow width and number of furrows, the work rate can be increased by increasing the plough speed at a given depth of operation. A reduction in depth, however, will result in a significant increase in the speed of plowing which can be achieved (Godwin *et al.*, 2007)

3.4.7 Effect of variation of characteristic angle / rake angle on draft

Steeper rake angle results in greater draft requirement and reduced penetration ability but increased lateral soil throw, furrow emptiness and finer tilt .

3.4.8 Effect of variation in moisture content on draft

Soil moisture content is an important factor in regard to both draught and quality of work. A dry soil requires an excessive power and also accelerates wear of the cutting edges.

Koolen and Kuipers (1983) reported a general formula for specific draught (D) as:

$$D = C_1 - C_2(MC) + C_3 (MC)^2 \quad (3.18)$$

where, MC is moisture Content. C₁, C₂, C₃ are positive constants. This is the formula of a parabola with its vertex being a minimum value. The soil moisture content at this minimum is called optimum moisture content.

The maximum width of soil cut, maximum width of soil throw, and ridge-to-ridge distance decreases with increase in moisture content.

3.4.9 Effect of variation in cone index on draft

The regression model that best described the relationships was a quadratic model of the form:

(Manuwa *et al.* , 2007)

$$D = a_2 (CI)^2 + b_2 (CI) + k_2 \quad (3.19)$$

Where a_2 , b_2 & k_2 are regression coefficients and constants respectively

Draft increases at an increasing rate as the cone index increased from about 200 to 850 kPa. This is because the soil strength (cohesion) increased with increased cone index.

3.4.10 Combined effect of different parameters on draft

$$D = F_i [A + B*S + C*S^2] d * n \quad (\text{McLaughlin } et al. ,2004) \quad (3.20)$$

where:

D = draft (N),

F_i = soil parameter,

S = speed (km/h),

d= operating depth (mm),

n = number of tillage tools (one plow the present case), and

A, B, C = regression coefficients.

CHAPTER – IV

MATERIALS AND METHODS

CHAPTER- IV

MATERIALS AND METHODS

This chapter deals with the description of the M.B. plows under test, the test soil bin, calibration procedure of extended octagonal ring transducer , procedure for measurement of operating parameters like speed and depth, the soil parameter like soil strength and soil moisture contents , the tool parameter like width etc and the draft requirement of M.B. plows under test. Details of the methods are explained below.

4.1 M.B. Plows under test.

Plows are generally selected to complete the seed bed preparation in least possible time with maximum field capacity. The draft requirement is an important factor while selecting the tillage implements for a particular farm situation. Draft and power requirement data are used to determine the size of power sources and to calculate cost of energy for different tillage implements. The four type of M.B. plows included in this study has been selected on the basis of their use under different farm situation. These test plows include CAET plow, Down size OUAT MB plow ,Implement Factory plow and Heavy Soil plow. These are all right turning plows and all are bullock drawn implements. The test plows are shown in Fig 4.1 to Fig. 4.4.

4.2 Test Soil Bin

The draft requirement of the test plows was measured in a stationary soil bin with the facilities to vary operational and soil parameters. The study was conducted on sandy loam type of soil at the tillage moisture level and tillage soil resistance level. The description of the various components of soil bin are discussed below .

4.2.1 Stationary bin

The bin was 15.0m long, 1.8m wide and 0.6m deep Two rails on top of each side of the bin wall were used for supporting the soil processing and the implement trolleys. This provides a test soil bed of about 12m long and 1.2m wide over which MB plows runs for draft measurement



(a) Front view



(b) Side view

Fig. 4.1 Down Size OUAT MB Plow



(a) Front view



(b) Side view

Fig. 4.2 CAET Plow



(a) Front view



(b) Side view

Fig. 4.3 Implement Factory Plow



(a) Front view



(b) Side view

Fig. 4.4 Heavy Soil Plow

4.2.2 Processing trolley

The processing trolley as shown in Fig .4.5 consists of

- i) a frame
- ii) Rota-tiller for soil tillage
- ii) Leveler for leveling the soil
- iii) Roller for compacting the soil to obtain the desired soil strength
- iv) A water sprayer for spraying water on the soil to maintain the desired moisture content.

The different speeds of operation were obtained by choosing suitable gears of a gear reduction unit coupled to the input shaft of the revolving drum, which was attached to soil processing trolley with stainless-steel rope. A control unit, placed outside the soil bin, controlled the direction of movement of the soil processing trolley



Fig 4.5 Processing Trolley

4.2.3 Test trolley

The testing tool/ implement was mounted on the frame of the implement trolley, where screw jack arrangements were provided to vary the depth of operation.

The test trolley as shown in Fig. 4.6 comprised of

- i) Extended octagonal ring transducer 1kN capacity. This transducer is the vital component to measure the draft
- ii) Cone penetrometer with 1 kN Proving ring (U9B) with cone diameter of 19mm.
Cone penetrometer records the soil resistance
- iii) Linear voltage displacement transducer (WA200) with linear displacement range of 0-200 mm This records the depth of operation



Fig 4.6 Test Trolley

4.2.4 Power supply to soil bin (Control panel)

Control panel (Fig.4.7) is the panel or switch board which houses all the electrical power supply to the soil bin set up. It has the start, forward, reverse button on it to control the movement of soil bin assembly over the guide rails. It has a knob to control the speed of the soil bin carriage. It has emergency stop button to stop the machine in case of any emergency.

4.2.5 Motors for drive

This is for driving the processing trolley, test trolley and hydraulic system etc through end less steel ropes on cylindrical drum (Fig 4.8). The power to the test soil bin is provided by one 10 hp motor for movement of test and processing trolley, one 5 hp motor for hydraulic system and another 5 hp motor to operate rotary tiller.



Fig. 4.7 Control Panel



Fig. 4.8 Motor for drive of Processing Trolley and Test Trolley

4.2.6 Data acquisition system & lap top

Power at constant voltage with controlled current was supplied to Data acquisition system through power supply twin channel (0-30 V, 0-2 amps with digital display)

Data from the various strain gauges in the soil bin is acquired by automated systems with input to output cords for recording the digital and analogue data, by the Data Acquisition System (Fig. 4.9) for online representation of test parameters. The data further may be exported to excel for further analysis and research. In CAET soil bin set up data acquisition is done by HBM Spider 8 data logger with provision for 8 channels and CATMAN EASY software package for interpretation of data in the computer.



Fig 4.9 Data acquisition system & Lap top

4.3 Calibration of Extended Octagonal Ring Transducer for Draft measurement :

4.3.1 Extended octagonal ring transducer

The Extended octagonal ring transducer of capacity 1 kN used in the study is shown in Fig 4.10



Fig 4.10 Extended Octagonal Ring Transducer

4.3.2 Calibration setup

Calibration of any instrument means to standardize it to give correct measurement before taking up any experimental procedure. For calibration, known weights were applied to the EORT and respective changes in the electrical signals were recorded in the data logger. Using this series of data, graphs were plotted between the electrical signals and known weights, and from this curves calibration equation was developed. After successful calibration unknown loads could be obtained using the calibration equation. When the set up was used with any soil disturbing tool then the values can be obtained in the form of electrical signals and these signals can be changed to physical loads using calibration equation. Thus the various forces/loads acting upon soil tillage tool can be successfully found out.. For finding out the draft force a structure (Fig.4.11) made up of MS angle was fabricated and a pulley arrangement was made with it. A wire was extended from the back face of the EORT and it passed over the pulley groove. The wire was aligned to be perfectly horizontal with the centre of the EORT. After the wire passed over the pulley, known weights were hung from the wire and corresponding change in the electrical output were noted down. These electrical outputs obtained against the known weights were used in the calibration equation.



Fig.4.11 Pulley with bracket and Spring Dynamometer

4.3.3 Calibration procedure

For calibration of EORT known weights were used and corresponding change in electrical signal was obtained through the data acquisition system attached to the test set up. To calculate draft a frame and pulley arrangement was fabricated (Fig.4.11). The frame was fabricated using MS angle of size (25×25×5) and a MS pulley of dia.3 inches was used. The pulley and frame assembly were fixed over a foundation with nuts and bolts, which was strong enough to support the load to be applied on the assembly during operation in the soil bin setup. A brace with a hook was fabricated from MS bar which was to be attached at the back of EORT prior to calibration. A flexible and inextensible wire was attached with the hook at the back of EORT and was aligned to be perfectly horizontal with the inner groove of pulley, so that while taking weights the flexible wire would be in one line with the centre line of hook. Perfectly horizontal alignment reduces the chance of any resolution of force into components.

The wire selected was having yield strength more than that of the load to be applied (> 100kg). After the wire passes over the pulley there was a hook to carry the weights when the EORT was being calibrated. The pulley which was taken for the experiment was well lubricated for minimizing friction.

To get the greater accuracy of the calibration a spring dynamometer (Fig.4.12) was used for measurement of the horizontal forces acting on the EORT. The spring

dynamometer was attached to the hook (which was attached to the EORT). Spring dynamometer was employed to find out the forces with greater accuracy and minimizing chances of occurrence of error. The results of the calibration are discussed in the next chapter.



Fig.4.12 Spring Dynamometer used in calibration of EORT

4.4 Soil description and Soil Bed preparation

Experiments were conducted under laboratory conditions in a sandy loam soil for which the compositions are given in Appendix . Before starting the experiments, the soil bed was prepared to achieve the required levels of cone penetration resistance. Firstly, the tiller was used to pulverise the soil after spraying water to achieve the required moisture content. Then, the soil was leveled with the leveling blade and compacted by the roller to achieve the required cone penetration resistance. At the end of each soil preparation, soil cone penetrometer attached to the soil bin was used for measuring the cone penetration resistance to a depth of 0.15m at intervals of 2.5m at three locations in the soil bin .The locations were chosen so as not to interfere with actual tillage tests. To get soil uniformity, the soil bed preparation was repeated if the cone penetration resistances were significantly different from each other.

4.5 Procedure for measurement of Soil Strength :

Soil strength at different locations in the soil bed (to a depth of 0.15m at intervals of 2.5m at three locations in the soil bin) was measured by soil cone penetrometer attached to the soil bin (Fig 4.13). Cone tip along with the sleeve of cone penetrometer penetrated through the soil by operating the lever attached to the hydraulic system in the

processing trolley. A force transducer (U9B) was attached to the end of the sleeve for recording force applied for penetration. Similarly a LVDT transducer was attached to record the depth of penetration of cone through the soil.

Simultaneous action of penetration of cone of the cone penetrometer and recording were made on the laptop (connected through the data acquisition system (Spider-8) via force transducer & LVDT transducer).The unit of force & penetration depth measurement was in Newton and millimeter respectively It may be noted that initialization of recording for force applied and depth of penetration were made while the tip had already been penetrated and base of the cone was just at the ground level. Diameter of cone base was measured by a slide caliper. The cone index in Pascal was found out for each measurement.



Fig 4.13 Cone Penetrometer

4.6 Procedure for measurement of Soil Moisture Content

The moisture contents of soils were determined using an oven drying method. The soil samples were collected at random, immediately after each tillage treatment for each study location. Each soil sample was collected in a well labeled container and weighed on a digital balance, and then oven dried at a temperature of 105°C in an oven for 24 hours. The soil moisture contents (wet basis) were computed using the expression

Soil M.C (Wet basis) in % = $(m_2 - m_3) / (m_2 - m_1) \times 100$

where; M.C = moisture content (%)

m_1 = mass of container in grams (g)

m_2 = mass of container + wet soil sample in grams (g)

m_3 = mass of container + oven dried soils in grams (g)

4.7 Procedure for measurement of Width

Width of cut for each plow for each depth (10cm & 15cm) is calculated as follows. For example to calculate the width of cut for 10cm depth , plow is marked at two extreme end at a height of 10cm keeping the plow on horizontal position. The projected distance at frontal plane of the marked points is the width of cut for 10cm depth

4.8 Procedure for measurement of Depth

There was a provision for vertical up and down motion of the EORT along with the plow bottom under test by the hydraulic system. A scale was attached to the frame of the test trolley. The initial position of the plow(when the share of the plow just touched the ground level) was marked. The suitable depth as per requirement of the observation (10cm & 15cm) was applied to the plow by the hydraulic lever and scale reading .It may be noted that a opening was previously prepared on the soil bed just in front of the initial position of plow.

4.9 Procedure for measurement of Speed

The initial and final position of the plow in the soil bin were marked while taking observation for draft measurement. The difference between the above gave the distance traveled. Time taken for each observation was recorded by a stop watch. The ratio of distance covered to time taken gave the speed of travel.

4.10 Procedure for measurement of Draft

The laptop was opened with Catman Easy software. The constant voltage power supply was made on with the adjustment of 10V. Data acquisition system (Spider-8) was made on & the signal from data acquisition system was connected to the laptop through USB cable .The sensor of the EORT was connected to the data acquisition system through a cable. The stress signal from EORT was converted to electrical signal and after suitable signal processing through data acquisition system it went to the laptop in recordable form. Suitable adjustment regarding initial value range etc were made on the software .The display was opened with a real time graph (for continuous measurement of

draft in Y-axis verses time in X-axis) and a digital display recorder (for maximum draft value)

While the test plow bottom attached to the EORT moved through the soil at particular speed and depth as shown in Fig. 4.14, the laptop records the draft in mV/V. This value was converted into the actual value of draft in Newton with the calibration curve .The results obtained are described in next chapter.



Fig 4.14 Test run of Plow for measurement of Draft

4.11 Precaution taken for Soil Bin experiment

The following precautions were made while running the Soil Bin experiment

1. No forward or backward motion of test trolley were made while taking cone penetrometer reading..
2. Slow and smooth motion for cone penetrometer was made while taking observation.
3. Cone penetrometer was not operated on very hard soil over the range
4. Plow bottom was securely connected with EORT .Speed adjustment was perfectly made in control panel
5. Forward or backward direction selection was perfectly made with operation of stop switch at each change over.

4.12 Experiment Layout

Laboratory experiments in the Soil Bin were conducted with four MB Plows namely CAET plow, Down size OUAT MB plough, Implement Factory plow and Heavy

Soil plow to determine the effect of speed and depth of operation on draft requirements in a reference soil condition. The experiment was conducted in sandy loam soil with moisture content within 10% to 11% (wb). Soil strength was maintained between 800 kPa to 1000 kPa . Two speeds of operation (1.25 km/h and 2 km/h) and two depths (100mm and 150mm) were selected for study except the down size OUAT plow which was tested at 100 depth only. Draft requirements for all the mentioned plows were obtained as per the procedure explained earlier. The observed data has been presented in the next chapter.

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CHAPTER – V

RESULTS AND DISCUSSION

CHAPTER -V

RESULTS AND DISCUSSION

This chapter deals with the analysis and interpretation of the experimental observations collected during the course of investigation. This also includes the computation of data in shape of graphs and tables to explain the parameters effecting the draft requirement of the plows under test.

5.1 Calibration of EORT.

The data were observed during calibration of the EORT used in the test set up following the procedure explained in the previous chapter under article 4.3.3. The calibration data is presented in Fig 5.1 and Appendix A.

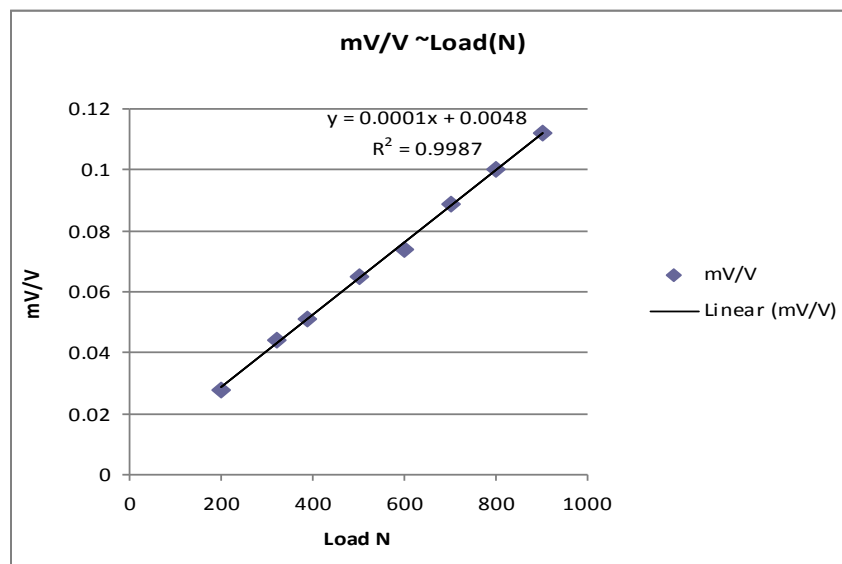


Fig 5.1 Calibration of the EORT

From the graph between the electrical strain(mV/V) and the test load on the EORT it was observed that the straight line curve represents best fit with coefficient of determination, R^2 of 0.9987 which can be satisfactorily used to determine the draft requirement at different operational parameters.

5.2 Measurement of Plow Dimensions

The various dimensions of test plows were measured and are presented below.

5.2.1 Plow width

The plow widths measured at two operational depths such as 100mm and 150mm are presented in the table below (Table 5.1) .

Table 5.1 Plow width at different Depths

Sl.No	Plow Type	Width of cut at different Depth in mm	
		Depth 100mm	Depth 150mm
1	CAET Plow	195	205
2	Down Size OUAT MB Plow	175	-
3	Implement Factory Plow	168	175
4	Heavy Soil Plow	175	190

During the test the Down size OUAT MB plow was tested at depth of 100mm as it could not be used at the second test depth of 150mm due to its size

5.2.2 Plow height, length of plow surface and lift angle

The plow height (max height of the M.B. crest), length of plow surface and lift angle were measured for all the test plows and the data is presented in Table 5.2.

Table 5.2 Plow Height, Length of plow surface and Lift angle

Sl.No	Plow Type	Plow Height	Plow Length	Plow Angle
		in mm	in mm	in degree
1	CAET Plow	210	377	19.8
2	Down Size OUAT MB Plow	135	340	10.8
3	Implement Factory Plow	240	328	21.8
4	Heavy Soil Plow	230	355	16.7

5.3 Effect of Operational Parameters on the Draft requirement

5.3.1 Effect of depth

The draft observed under two depths is 100mm and 150mm at two different speeds is 1.25 km/h and 2km/h are presented in following table (Table 5.3) and graphs (Fig 5.2 & Fig.5.3). This represents the effect of variation of depth on draft.

Table 5.3 Draft of Plows in Newton to show effect of variation of Depth

Sl.No	Plow Type	Draft of Plows , N at different speed and depth					
		Speed 1.25 km/h			Speed 2.0 km/h		
		Depth 100mm	Depth 150mm	% increase	Depth 100mm	Depth 150mm	% increase
1	CAET Plow	564.9	632	11.88	623.6	665.6	6.74
2	Down Size OUAT MB Plow	397	-	-	422.2	-	-
3	Implement Factory Plow	590	657.2	11.39	632	674	6.65
4	Heavy Soil Plow	514.5	598.4	16.31	564.9	632	11.88

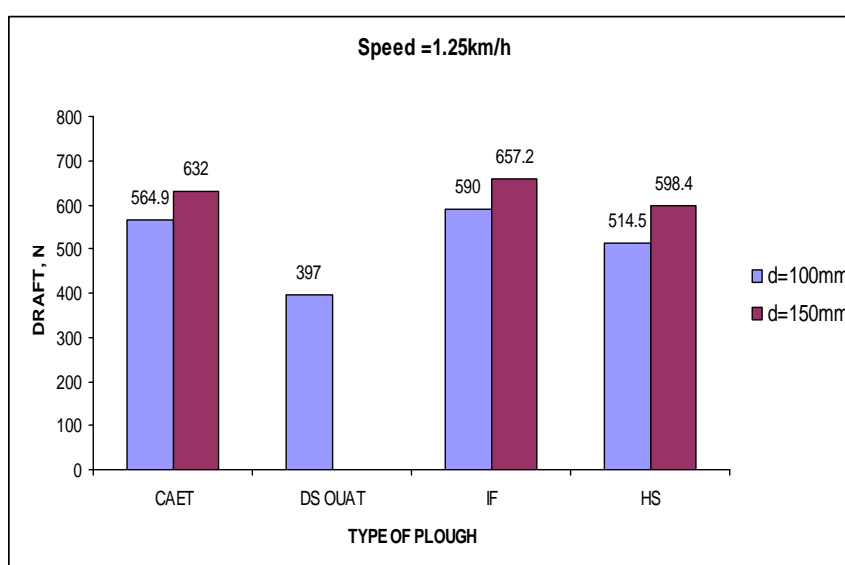


Fig 5.2 Draft of Plows in Newton at speed 1.25km/h

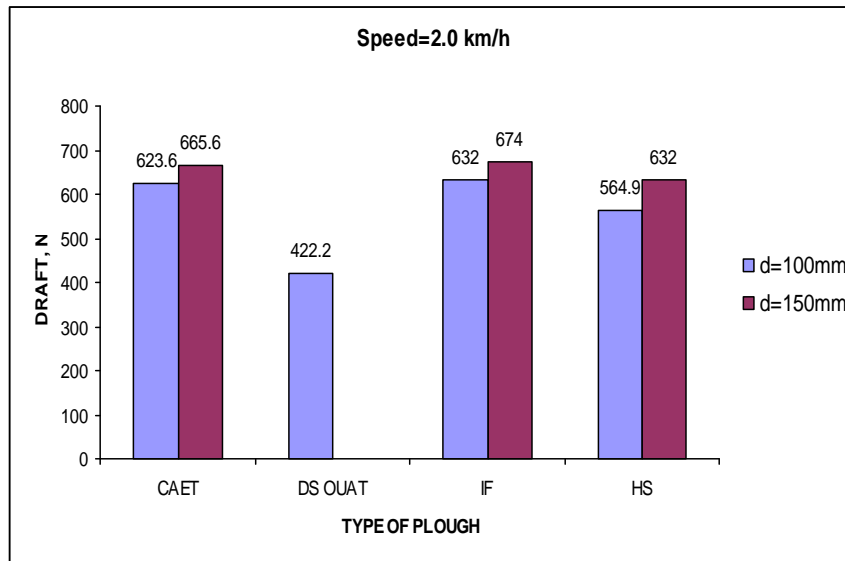


Fig 5.3 Draft of Plows in Newton at speed 2.0 km/h

The data reveals that the draft requirement of the Down size OUAT MB plow is minimum among all but it can be suitable up to 100mm depth. Among other three plows draft requirement of Heavy Soil plow is least at both the speeds and depth. The increase in draft requirement at 150mm depth with respect to that at 100mm depth found to be 11.88% for CAET plow, 11.39% for Implement Factory plow, and 16.31% for Heavy Soil plow at speed of 1.25 km/h, and the increase in draft was 6.74% for CAET plow, 6.65% for Implement Factory plow and 11.88% for Heavy Soil plow at speed of 2.0 km/h.

5.3.2 Effect of speed.

The effect of speed on draft requirement of the test plows is presented in following table 5.4 and graphs (Fig 5.4 & Fig.5.5)

From the data it was observed that draft requirement increased with increase in speed of operation from 1.25km/h to 2km/h. The increase in draft at 100mm depth was found to be 10.39% for CAET plow, 6.35% for Down size OUAT MB plow, 7.12% for Implement Factory plow and 9.8% for Heavy Soil plow. However, the increase in draft requirement at 150mm depth was found to be 5.32% for CAET plow, 2.56% for Implement Factory plow and 5.61% for Heavy Soil plow.

Table 5.4 Draft of Plows in Newton to show effect of variation of Speeds

Sl.No	Plow Type	Draft of Plows in Newton at different speed and depth					
		Depth 100mm			Depth 150mm		
		Speed 1.25 km/h	Speed 2.0 km/h	% increase	Speed 1.25 km/h	Speed 2.0 km/h	% increase
1	CAET Plow	564.9	623.6	10.39	632	665.6	5.32
2	Down Size OUAT MB Plow	397	422.2	6.35	-	-	-
3	Implement Factory Plow	590	632	7.12	657.2	674	2.56
4	Heavy Soil Plow	514.5	564.9	9.80	598.4	632	5.61

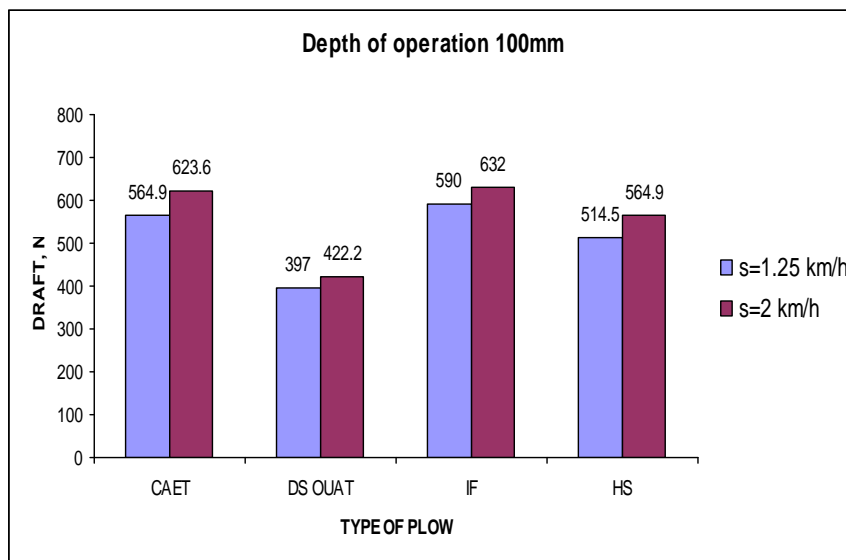


Fig 5.4 Draft of Plows at the test speeds at depth of 100mm

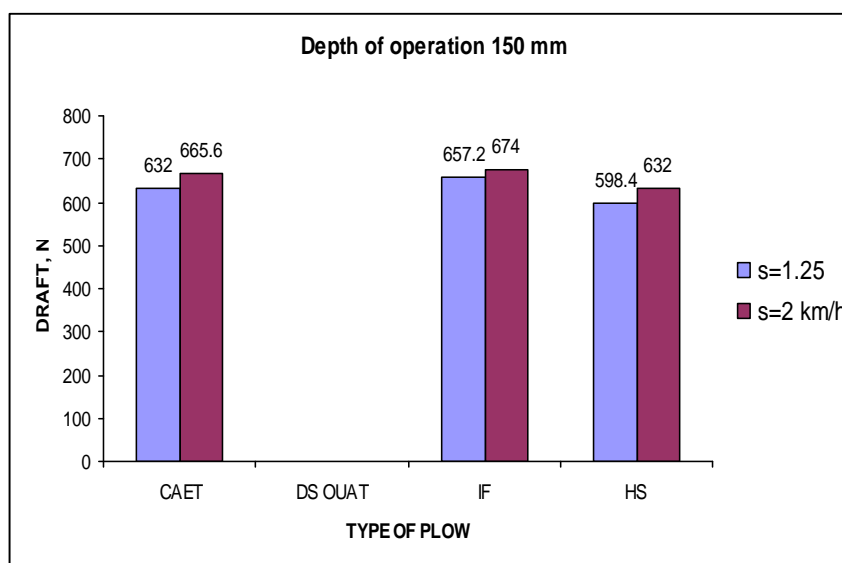


Fig 5.5 Draft of Plows at the test speeds at depth of 150mm

The above results can be attributed to the fact that the Down size OUAT MB plow is the smallest plow in dimension and among other plows the lift angle is minimum (16.7°) in Heavy Soil plow. Implement Factory plow height is maximum which necessitates the lift of the cut furrow to greater heights thereby increasing the draft requirement. Further it was also observed that the effect of depth of operation had pronounced effect on the draft requirement than that of speed. This can be observed from the following observation. The draft requirement increased in the range of 6.65% to 16.31% when the depth was increased from 100mm to 150mm, compared to that of 2.56% to 10.39% when the speed was increased from 1.25km/h to 2 km/h for the test plows.

From the above discussion it can be concluded that the Down size OUAT MB plow is suitable for a pair of bullocks of body weight about 400-450kg, that can develop a draft of 400-450N. Further all the other test plows are found suitable for the bullock pair with total body weight of 700kg. The research findings presented above provide useful information which will help in selection of bullock drawn plows most suitable to the different size of bullocks available in the state of Odisha. This will also help in increasing the efficiency of bullocks for plowing operation.

CHAPTER – VI

SUMMARY AND CONCLUSION

CHAPTER -VI

SUMMARY AND CONCLUSION

In Indian agriculture, draught animals (DAs) provide the major tractive force for field operations. The DAs are contributing about 27,000 megawatts of power, which is about 30% of the total power of the installed electrical generation capacity of India (Ojha and Michael, 2003). It is estimated that about two-third of the total cultivated area is managed by DAs and remaining area is cultivated by other sources of farm power namely tractors, power tillers and human labors. Thus, it suffices to mention that, DAs are still having a great importance in Indian economy. Draught animals are being used to plough around 100 million hectares of farm land in India, which forms 60 % of total cultivable area, (transport 25,000 million ton km of freight per year saving 6 million ton of diesel worth Rs.4,000 crore annually. (Singhal, 1999). Effective utilization of agricultural energy input is highly essential to cope the need for increasing farm production, productivity with reduction in operating cost and also to ensure timely completion of field operations. Proper selection and use of proper matching equipments can enhance the efficiency of power sources which is more important in case of animal powers. The availability of data on the draft requirement of tillage implements is an important factor while selecting tillage implements for a particular form situation as well as the source of power. Thus, the matching tillage tools can be effectively & efficiently used through the power sources particularly animal power sources.

On the basis of above, the present research work has been taken up with following objectives.

1. To study the effect of various operating and soil parameters which effect the draft requirement of various plows under study; namely CAET plow, Down size OUAT MB plow, Implement Factory plow and Heavy Soil plow.
2. To determine the operating and soil parameters best suited to the above plows under study.

To fulfill the above objectives, laboratory experiments in the Soil Bin were conducted with four M.B. plows namely CAET plow, Down size OUAT MB plow, Implement Factory plow and Heavy Soil plow to determine the effect of speed and depth of operation on draft requirements in a reference soil condition. The experiment was conducted in sandy loam soil with moisture content within 10% to 11% (wb). Soil strength was maintained between 800 kPa to 1000 kPa. Two speeds of operation (1.25 km/h and 2 km/h) and two depths (100mm and 150mm) were selected for study except the down size OUAT plow which was tested at 100 depth only. Draft requirements for all the mentioned plows were obtained as per the procedure explained earlier.

The major conclusions drawn from the present study are specified below.

- i. The test soil bin was found very much suitable to determine the draft requirement of the test plows at various depths and speeds accurately.
- ii. The draft requirement of Down size OUAT MB plow was found to be 397N at depth of operation of 100mm at the operating speed of 1.25 km/h and 422.2N at 100mm depth of operation at 2 km/h speed.
- iii. The Down size OUAT MB plow is suitable only at 100mm depth of operation and it is best suitable for light weight bullock pair.
- iv. For the other plows namely, CAET plow, Implement Factory plow and Heavy Soil plow draft requirement were found to be in the range of 500 to 600N at depth of 100mm and speed of operation of 1.25 km/h whereas, the draft requirement of these three plows were in the range of about 600 to 650 N when the depth of operation was increased to 150 mm.
- v. Similarly the draft requirement of the plows namely, CAET plow, Implement Factory plow and Heavy Soil plow were found to be in the range of 550 to 650 N at depth of 100 mm at speed of 2.0 km/h, whereas, it was in the range of 630 to 670 N at depth of 150 mm and speed of 2.0 km/h. These plows were found suitable for size of bullock pair with total body weights about 700kg.

SUGGESTION FOR FUTURE WORK

1. The test plows need to be tested in soils other than sandy loam type.
2. Draft requirement of the test plow included in the study may be determined under different speeds other than the speeds tested.
3. The plows may be tested at different depths beyond the depths included in the study.
4. The study may be extended for other plows available and secondary tillage tools.
5. The test soil bin can be used for designs and development of new plows.

BIBLIOGRAPHY

BIBLIOGRAPHY

- Abubakar M.S., Tekwa I.J. & Ahmed M.,2005, Effects of soil Physical and Mechanical properties on Field Efficiency of Ox-drawn Mouldboard plough In Yola, Adamawa State, Agricultural Engineering International: the CIGR Ejournal, Manuscript 1369-2137-1.
- Agrawal K. N. & Thomas E. V ., 2003, Relationship of Specific Draft with Soil and Operating Parameters for M.B. Plough, AMA 34(2):9-12
- Carma .K. & Marakoglu .T , 2009, Effects of Design Parameters of a Cultivator Share on Draft Force and Soil Loosening in a Soil Bin , Journal of Agronomy , Vol.: 8, No.: 1
- Chung S. O., Sudduth K. A., Plouffe C.,Kitchen N. R. ,2008 , Soil Bin and Field Tests of an on go Soil Strength Profile Sensor , Transactions of the American Society for Agricultural & Biological Engineering Vol.: 51, No.: 1
- Darmora D. P. ,2007 , Draft Requirement of a Shovel Type Furrow Opener under Coarse Textured Soil Condition , Journal of Agricultural Engineering Vol.: 44, No.: 3
- Gebresenbet Girma, Kaumbutho Pascal G. , 1997 , Comparative Analysis of the Field Performances of a Reversible Animal-drawn Prototype and Conventional Mouldboard Ploughs Pulled by a Single Donkey , Soil & Tillage Research Vol.: 40, No.: 3-4
- Godwina R.J., O'Doghertya M.J., Saundersb C., Balafoutisa.A.T ,2007, A forceprediction model for mouldboard ploughs incorporating the effects of soil characteristic properties, plough geometric factors and ploughing speed, Published by Elsevier Ltd ,doi:10.1016/j.biosystemseng.2007.02.001

- Guo G.; Araya K. ,2003 , Improvement of Whitish Oasis Soil, Part 2: Preliminary Soil Bin Experiments with a Four-stage Subsoil Inverting Plough , Bio-systems Engineering Vol.: 85, No.: 1
- Hall H. E., Raper R. L. ,2005 , Development and Concept Evaluation of an On-the-go Soil Strength Measurement System , Transactions of the American Society for Agricultural & Biological Engineering Vol.: 48, No.: 2
- Jafari R.; Raoufat M. H.; Hashjin T. Tavakoli ,2008 , Soil-Bin Performance of a Modified Bent Leg Plow , Applied Engineering in Agriculture Vol.: 24, No.: 3
- Jafari R, Raoufat M.H., Hashjin T.T , 2008.Applied Engineering in Agriculture. 24(3): 301-307
- Manuwa .S and Ademosun.O. C , 2007 , Draught and Soil Disturbance of Model Tillage Tines Under Varying Soil Parameters , Agricultural Engineering International: the CIGR E-journal. Manuscript PM 06 016. Vol. IX.
- Manuwa S.I, 2009 , Performance Evaluation of Tillage Tines Operating under Different Depths in a Sandy Clay Loam Soil , Soil & Tillage Research Vol.: 103, No.: 2
- Marakoglu T. , Carma K. ,2009 , Effects of Design Parameters of a Cultivator Share on Draft Force and Soil Loosening in a Soil Bin , Journal of Agronomy Vol.: 8, No.: 1
- McLaughlin N. B. ,Drury C. F., Reynolds W. D., Yang X. M., Li Y. X., Welacky T. W.,Stewart G. , 2008 ,Energy Inputs for Conservation and Conventional Primary Tillage Implements in a Clay Loam Soil , Transactions of the American Society for Agricultural & Biological Engineering Vol.: 51, No.: 4
- Onwualu A. P., Watts K. C. ,1998 , Draught and Vertical Forces Obtained from Dynamic Soil Cutting by Plane Tillage Tools , Soil & Tillage Research Vol.: 48, No.: 4

- Owende P. M. O., Ward S. M., 1999 Reaction Forces of Lightweight Mouldboard Ploughs at Slow Speeds of Tillage in Nitosol, Vertisol and Ferralsol Soils under two Moisture Conditions , Soil & Tillage Research Vol.: 49, No.: 4
- Phaniraja K..L., Panchasara1 H.H ., 2009, Indian Draft Animal Power , Veterinary World, Vol.2(10):404-407
- Rosa U.A. ,Wulfsohn D. ,2008 , Soil bin monorail for High-speed testing of Narrow tillage Tools , Biosystems Engineering Vol.: 99, No.: 3
- Sahu R. K. , Raheman H. ,2006 , An Approach for Draft Prediction of CombinationTillage Implements in Sandy Clay Loam Soil , Soil & Tillage Research Vol.: 90, No.: 1-2
- Sahu R.K.; Raheman H., 2006 , Draught Prediction of Agricultural Implements using Reference Tillage Tools in Sandy Clay Loam Soil , Biosystems Engineering Vol.: 94, No.: 2
- Shoji Koichi ,2001 , PM-Power and Machinery:Design of a Model `Spot Plough' for Inversion of the Soil Slice within the Furrow , Biosystems Engineering Vol.: 79, No.: 3
- Shrestha D. S.; . Singh G; Gebresenbet G. ,2001 , PM-Power and Machinery:Optimizing Design Parameters of a Mouldboard Plough , Biosystems Engineering Vol.: 78, No.: 4
- Srivastava A.K. , Goering C.E. , Rohrlach R.P. , 1996 ,Engineering Principle of Agricultural Machines ,ASAE Text Book No 6
- Suhaibani S.A. and Ghaly A.E. , 2010 ,Effect of Plowing Depth of Tillage and Forward Speed on the Performance of a Medium Size Chisel Plow Operating in a Sandy Soil., Am. J. Agricultural Biological .Science., 5: 247-255.

Zoz Frank M , 1973, Optimum Width and Speed for Least Cost Tillage , American Society of Agricultural Engineers, Paper No 73-1528

Zhang C., Araya K., Kudoh M.,Liu F., Jia H., Zhang H., Yang S.,2001 , PM-Power and Machinery:A Three-stage Soil Layer Mixing Plough for the Improvement of Meadow Soil, Part 3: Field Evaluation , Biosystems Engineering Vol.: 79, No.: 1

APPENDIX

APPENDIX-A

SAMPLE CALCULATIONS

A.1 Calibration Table

The calibration table obtained from original reading of weights applied in Newton and observed electrical strain in mV/V while calibrating the EORT are mentioned in the following table. The trend-line equation was found to be $y=0.0012x +0.0048$

Table A.1 Calibration of EORT from known Weights

Load ,N	mV/V
200	0.028
320	0.044
390	0.051
500	0.065
600	0.074
700	0.089
800	0.1
900	0.112

A.2 Draft Calculation Sheet

Draft calculation sheet was prepared to to know the value of the actual draft in Newton accurately at any electrical value in mV/V obtained from the laptop while test run of plows. For this excel sheet was prepared by reversing the calibration table and trend-line equation was obtained. From the trend-line equation $y=8390.03x-39.215$ thus obtained the following Draft calculation sheet (Table No. A.2)

Table A.2 Draft Calculation from any known Electrical values

mV/V	Draft N	mV/V	Draft N	mV/V	Draft N
0.02	128.59	0.06	464.20	0.1	799.82
0.021	136.98	0.061	472.59	0.101	808.21
0.022	145.37	0.062	480.98	0.102	816.60
0.023	153.76	0.063	489.37	0.103	824.99
0.024	162.15	0.064	497.76	0.104	833.38
0.025	170.54	0.065	506.15	0.105	841.77
0.026	178.93	0.066	514.54	0.106	850.16
0.027	187.32	0.067	522.94	0.107	858.55
0.028	195.71	0.068	531.33	0.108	866.94
0.029	204.10	0.069	539.72	0.109	875.33
0.03	212.49	0.07	548.11	0.11	883.72
0.031	220.88	0.071	556.50	0.111	892.11
0.032	229.27	0.072	564.89	0.112	900.50
0.033	237.66	0.073	573.28	0.113	908.89
0.034	246.06	0.074	581.67	0.114	917.28
0.035	254.45	0.075	590.06	0.115	925.67
0.036	262.84	0.076	598.45	0.116	934.06
0.037	271.23	0.077	606.84	0.117	942.45
0.038	279.62	0.078	615.23	0.118	950.84
0.039	288.01	0.079	623.62	0.119	959.23
0.04	296.40	0.08	632.01	0.12	967.62
0.041	304.79	0.081	640.40	0.121	976.01
0.042	313.18	0.082	648.79	0.122	984.40
0.043	321.57	0.083	657.18	0.123	992.79
0.044	329.96	0.084	665.57	0.124	1001.18
0.045	338.35	0.085	673.96	0.125	1009.57
0.046	346.74	0.086	682.35	0.126	1017.96
0.047	355.13	0.087	690.74	0.127	1026.35
0.048	363.52	0.088	699.13	0.128	1034.74
0.049	371.91	0.089	707.52	0.129	1043.13
0.05	380.30	0.09	715.91	0.13	1051.52
0.051	388.69	0.091	724.30	0.131	1059.91
0.052	397.08	0.092	732.69	0.132	1068.30
0.053	405.47	0.093	741.08	0.133	1076.69
0.054	413.86	0.094	749.47	0.134	1085.09
0.055	422.25	0.095	757.86	0.135	1093.48
0.056	430.64	0.096	766.25	0.136	1101.87
0.057	439.03	0.097	774.64	0.137	1110.26
0.058	447.42	0.098	783.03	0.138	1118.65
0.059	455.81	0.099	791.42	0.139	1127.04

A.3 Calculation Sheet For Cone Index

The following steps indicates the procedure for calculation of Cone Index and data sheet was prepared for calculation of Cone Index at any value of force as observed from U9B transducer recorded in the laptop during the penetration of the sleeve of the cone penetrometer

Diameter of cone(d) of the on cone penetrometer =1.9cm=0.019m

Area of Cone base = $A = (\pi/4)d^2 = 0.000284m^2$

Let force applied on cone-penetrometer =F

Cone Index (C.I.) = F/A

Table A.3 Calculation of Cone Index

Cone Dia in meter	Area in sq.m	Force in Newton	C. I in Pascal	C. I in kPa
0.019	0.000284	100	352112.7	352.11
0.019	0.000284	110	387323.9	387.32
0.019	0.000284	120	422535.2	422.54
0.019	0.000284	130	457746.5	457.75
0.019	0.000284	140	492957.7	492.96
0.019	0.000284	150	528169	528.17
0.019	0.000284	160	563380.3	563.38
0.019	0.000284	170	598591.5	598.59
0.019	0.000284	180	633802.8	633.80
0.019	0.000284	190	669014.1	669.01
0.019	0.000284	200	704225.4	704.23
0.019	0.000284	210	739436.6	739.44
0.019	0.000284	220	774647.9	774.65
0.019	0.000284	230	809859.2	809.86
0.019	0.000284	240	845070.4	845.07
0.019	0.000284	250	880281.7	880.28
0.019	0.000284	260	915493	915.49
0.019	0.000284	270	950704.2	950.70
0.019	0.000284	280	985915.5	985.92
0.019	0.000284	290	1021127	1021.13
0.019	0.000284	300	1056338	1056.34
0.019	0.000284	310	1091549	1091.55
0.019	0.000284	320	1126761	1126.76
0.019	0.000284	330	1161972	1161.97
0.019	0.000284	340	1197183	1197.18
0.019	0.000284	350	1232394	1232.39
0.019	0.000284	360	1267606	1267.61

In the present study the Cone Index were tried to be kept fix with variation from 800 kPa to 1000 kPa

A.4 Calculation Sheet For Moisture Content

For quick view of moisture content with all possible variation, data sheet were prepared as mentioned in tables below. The value of wet sample taken was kept fixed

Let m_1 = weight of container (gram)

m_2 = weight of container + weight of wet sample (gram)

m_3 = weight of container + weight of oven dried sample (gram)

Soil Moisture Content (Wet basis) in % = $(m_2 - m_3) / (m_2 - m_1) \times 100$

Soil Moisture Content (Dry basis) in % = $(m_2 - m_3) / (m_3 - m_1) \times 100$

Table A.4 Calculation of Soil Moisture Content

Sample 1

m_1	m_2	m_3	M.C. %,wet	M.C. %,dry
22	120	108	12.24	13.95
22	120	108.1	12.14	13.82
22	120	108.2	12.04	13.69
22	120	108.3	11.94	13.56
22	120	108.4	11.84	13.43
22	120	108.5	11.73	13.29
22	120	108.6	11.63	13.16
22	120	108.7	11.53	13.03
22	120	108.8	11.43	12.90
22	120	108.9	11.33	12.77
22	120	109	11.22	12.64
22	120	109.1	11.12	12.51
22	120	109.2	11.02	12.39
22	120	109.3	10.92	12.26
22	120	109.4	10.82	12.13
22	120	109.5	10.71	12.00
22	120	109.6	10.61	11.87
22	120	109.7	10.51	11.74
22	120	109.8	10.41	11.62
22	120	109.9	10.31	11.49
22	120	110	10.20	11.36
22	120	110.1	10.10	11.24
22	120	110.2	10.00	11.11
22	120	110.3	9.90	10.99
22	120	110.4	9.80	10.86
22	120	110.5	9.69	10.73
22	120	110.6	9.59	10.61
22	120	110.7	9.49	10.48
22	120	110.8	9.39	10.36
22	120	110.9	9.29	10.24
22	120	111	9.18	10.11

Table A.5 Calculation of Soil Moisture Content

Sample 2

m₁	m₂	m₃	M.C. %,wet	M.C. %,dry
21.5	120	108	12.18	13.87
21.5	120	108.1	12.08	13.74
21.5	120	108.2	11.98	13.61
21.5	120	108.3	11.88	13.48
21.5	120	108.4	11.78	13.35
21.5	120	108.5	11.68	13.22
21.5	120	108.6	11.57	13.09
21.5	120	108.7	11.47	12.96
21.5	120	108.8	11.37	12.83
21.5	120	108.9	11.27	12.70
21.5	120	109	11.17	12.57
21.5	120	109.1	11.07	12.44
21.5	120	109.2	10.96	12.31
21.5	120	109.3	10.86	12.19
21.5	120	109.4	10.76	12.06
21.5	120	109.5	10.66	11.93
21.5	120	109.6	10.56	11.80
21.5	120	109.7	10.46	11.68
21.5	120	109.8	10.36	11.55
21.5	120	109.9	10.25	11.43
21.5	120	110	10.15	11.30
21.5	120	110.1	10.05	11.17
21.5	120	110.2	9.95	11.05
21.5	120	110.3	9.85	10.92
21.5	120	110.4	9.75	10.80
21.5	120	110.5	9.64	10.67
21.5	120	110.6	9.54	10.55
21.5	120	110.7	9.44	10.43
21.5	120	110.8	9.34	10.30
21.5	120	110.9	9.24	10.18
21.5	120	111	9.14	10.06

Table A.6 Calculation of Soil Moisture Content

Sample 3

m₁	m₂	m₃	M.C. %,wet	M.C. %,dry
21	120	108	12.12	13.79
21	120	108.1	12.02	13.66
21	120	108.2	11.92	13.53
21	120	108.3	11.82	13.40
21	120	108.4	11.72	13.27
21	120	108.5	11.62	13.14
21	120	108.6	11.52	13.01
21	120	108.7	11.41	12.88
21	120	108.8	11.31	12.76
21	120	108.9	11.21	12.63
21	120	109	11.11	12.50
21	120	109.1	11.01	12.37
21	120	109.2	10.91	12.24
21	120	109.3	10.81	12.12
21	120	109.4	10.71	11.99
21	120	109.5	10.61	11.86
21	120	109.6	10.51	11.74
21	120	109.7	10.40	11.61
21	120	109.8	10.30	11.49
21	120	109.9	10.20	11.36
21	120	110	10.10	11.24
21	120	110.1	10.00	11.11
21	120	110.2	9.90	10.99
21	120	110.3	9.80	10.86
21	120	110.4	9.70	10.74
21	120	110.5	9.60	10.61
21	120	110.6	9.49	10.49
21	120	110.7	9.39	10.37
21	120	110.8	9.29	10.24
21	120	110.9	9.19	10.12
21	120	111	9.09	10.00

In the present study Moisture Content (Wet Basis) were tried to be kept fix with variation from 10 % to 11 %

A.5 Calculation of Speed

The following procedure was followed for calculation of speed of plows under test. Fixed distance of 10 meter was selected for test run of all the plows for calculation of speed and draft measurement. However for quick view of speed obtained with all possible variation within the range, data sheet was prepared as mentioned in table below.

Distance between two consecutive location = 1.25 m

Let the total location traveled by the plow during the test run = x

Total distance covered by the plow = 1.25 x

Let time measured by the stop watch during test run = t sec

Speed = $(1.25 * x / t)$ m/sec = $3.6 (1.25 * x / t)$ km/h

Table A.7 Calculation of Speed

Location traveled x	Distance in meter	Time in sec	Speed in m/sec	Speed in km/hr
8	10	35	0.28	1.02
8	10	34	0.29	1.05
8	10	33	0.30	1.09
8	10	32	0.31	1.13
8	10	31	0.32	1.16
8	10	30	0.33	1.2
8	10	29	0.34	1.24
8	10	28	0.36	1.28
8	10	27	0.37	1.33
8	10	26	0.38	1.38
8	10	25	0.40	1.44
8	10	24	0.42	1.50
8	10	23	0.43	1.57
8	10	22	0.45	1.63
8	10	21	0.48	1.71
8	10	20	0.5	1.8
8	10	19	0.53	1.89
8	10	18	0.55	2
8	10	17	0.59	2.12
8	10	16	0.63	2.25
8	10	15	0.66	2.4
8	10	14	0.71	2.57
8	10	13	0.77	2.76
8	10	12	0.83	3

All the settings were made in control panel to obtain either the speed of 1.25 km/h or the speed of 2 km/h

A.6 Composition of test Soil

All the observations in the present study was made on Sandy Loam type of soil. Different composition of sandy loam soil are mentioned below

Sand – 76.34%

Silt- 10.3%

Clay-13.36%

A.7 Weight of Plow Bottom

Weights of different plows under study were measured in a digital balance as mentioned below

Weight of Down Size OUAT MB Plow Bottom – 3.5 kg

Weight of CAET Plow Bottom – 4.06 kg

Weight of Implement Factory Plow Bottom – 3.6 kg

Weight of Heavy Soil Plow Bottom – 5.7 kg