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TILLAGE TOOLS DRAUGHT IN SANDY LOAM SOILS, AT AL-QASSIM ARID AREA (Part II).

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ABSTRACT

Using cone index as indication of soil strength, empirical equations are developed in accordance with soil mechanics theory to relate soil strength or properties to tillage tools draught. A common five tillage tools in Saudi Arabia were tested on sandy loam soils and their empirical draught equations are developed. Chisel, moulldbaord, and field cultivator equations comprise a quasi-static component dependent on cone index and a dynamic component function of specific weight, operating speed. While, for disk plough and tandem disk harrow, the draught equation compromises three components, named depth, operation and penetration dependent on tillage depth, speed and soil penetration resistance. The cone index equation provides a method of predicting tillage draught directly from soil properties and operational parameters. The object of this research was to relate tillage draught to soil strength and operational parameters in sandy loam soils, at Al-Qassim arid area, Saudi Arabia.

INTRODUCTION

It has been widely reported that the draught forces on implements increase significantly with speed and the relationship varies from linear to quadratic (Grisso *et al.*, 1994). Harrigan and Rotz (1994) proposed a simple function for a range of soil conditions to model tillage draught under general conditions, where draught per unit width or cross-sectional area of the tilled zone is a function of soil type, the speed and width, which the implement is pulled.

All the draught data presentea in the ASAE standard (1994) and the data presented by Harrigan and Rotz (1994) were based mostly on USA soils. Presentably, they're a shortage of data available on draught requirements of agricultural implements on sandy loam soils. For Saudi Arabia this point is of great concern, since sandy loam soil is the most common type of soils in the middle region (Al-Suhaibani and Al-Janobi (1997). Al-Suhaibani (1992) reported in Saudi Arabia most of farms were over-powered with an average tractor power provision of 1.84 kW/ha which is about double that in Indian and more than three time in Nebraska (USA), he related this to the lack of farmers' experience with farm machinery and the non -availability of sufficient data on the draught of tillage implements to select the proper tractor for a particular farm situation.

Accordingly, it was decided to model the plough performance empirically using an analysis suggested by Krastin (1973). Using dimensional analysis, (Krastin, 1973) proposed a set of dimensionless groups to describe the plough performance of a particular plough working in different soils and proposed a relationship form:

$$\frac{D_s}{\gamma d^3} = f\left(\frac{w}{d};\frac{\gamma d}{\sigma};\frac{V_a^2}{dg}\right) \quad 1.1$$

where: Ds = soil reaction force; V = plough speed; σ = soil stress; w/d = cut width/ depth ratio; γ = soil specific weight; g = gravitational constant; f = function of.

For geometrically similar agricultural implements, equation 1.2 has been used by researchers to relate chisel draught to soil and implement variables (Reaves, *et al.*, 1968) as in the form:

$$\frac{D_s}{\gamma W^3} = f\left(\frac{V_a}{\sqrt{gw}};\frac{c}{\gamma w};\frac{A}{\gamma w};\frac{w}{d};\varphi;\phi\right) \quad 1.2$$

where: A = Adhesion, kN/m^2; c = soil cohesion, kN/m^2; α = leading apex angle, rad; ϕ = soil internal frictional angle, rad; W = cut width of apex tine, m.

Reaves *et al.* (1968) formulated analytical equations to predict forces on tillage tools. They found that even with simple tool geometry, a large number of variables must be considered and can become quite involved. Similitude techniques have been applied in physical and engineering science. It widely become a design tool, in several studies (Larson *et al.*, 1968 and Schafer, *et al.*, 1968) the principal similitude have been applied to investigate the dynamic interaction between simple tillage tools and agricultural soils.

Singh *et al.* (1978) listed various soil, implement and operation characteristics effect on the depth of penetration of disk harrow such as:

$$D_s = f\{\varphi, \gamma, Ci, d, w, R, D, V_a, g, W\} \quad 1.3$$

where: D_s = disk force, kN; d&w = cut depth and width, m; D = disk diameter, m; R = disk curvature, m; φ = gang angle, rad; W = weight per disk, kN;

They applied the dimensional analysis on the (d/D) term of depth factor, and reported that the, d/D, term depends on various implements and soil parameters. They used the dimensional analysis of the nine variables listed in Eqn 1.3 and developed three regression analysis equations to study the effect of various implement, soil and operation parameters on penetration of tandem disk harrow. As in the form:

$$\frac{d}{D} = k_1 + k_2\varphi \quad \frac{d}{D} = k_3 + k_4\frac{V_a}{\sqrt{gD}} \quad \frac{d}{D} = k_5 + k_6\ln\left(\frac{\gamma W}{C_i D^2}\right) \quad 1.4$$

where: φ = gang angle factor depends on the geometry of the disk gang;
$V_a/\sqrt{gD}$ = operating factor depends on forward speed, V_a;
$W/C_i.D$ = penetration factor depends on weight per disk, W, and the soil cone index, Ci value.
k_1; k_2; k_3; k_4 and k_5 = coefficient constants.

From regression analysis of field experiments data on clay loam soil they found out the individual and combined effect of the above three factors on depth factor as in the form:

$$\frac{d}{D} = -1.71\times10^{-2} + 4.44\times10^{-3}\left\{\varphi + 5.21\frac{V_a}{\sqrt{gD}} + 5945.34\frac{W}{C_i \cdot D^2}\right\} \quad 1.5$$

Soil, design and operating parameters on disks projected area and soil-blade cutting force of disk harrow was studied by Gill and Hendrick (1982) and stated that the projected area of adjacent disks may overlap depending on disk angle, distance between disks, disk diameter and depth of operation with tandem disk harrows. Another approach to study soil disk design, (φ+R/D), depth, (d/D), operating, ($V_a/\sqrt{gD}$) and penetration, ($W/C_i.D^2$) parameters on disk draught force in a wide range of soil types was carried out by Elbanna (1994) such as:

$$D_s = -0.568(\varphi + \frac{R}{D}) + 14.575\frac{d}{D} + 17.215 \times 10^{-2}\frac{V_a}{\sqrt{gD}} + 5445.34\frac{W}{Ci\,D^2} \;....1.6$$

where: D_s = disk harrow (as primary and secondary) tillage draught, kN/m
R = disk curvature radius, m; D = disk radial diameter, m.

From experimental field data (ASAE, 1992 and Collins *et al.*, 1978) concluded that the relation between the unit draught and speed for moulboard ploughs tends to increase with speed, and presented a quadratic form of plough draught. Moreover, Summers *et al.* (1984) concluded that plough draught varies linearly with speed for chisel ploughs, disks and sweep ploughs and is a quadratic functions of speed for moulboard ploughs, and linear with depth for all tillage.

The draught force of a mouldboard plough is a combination of the quasi-static soil shearing resistance and the dynamic component increasing with the square of the velocity influenced by the lateral direction angle of the mouldboard tail angle. Söhne (1960) adapted an equation developed by Goryachkin (1940) to express the draught and speed relation of tillage tools in the form:

$$Z = Z_o + k\,V_a^2(1 - \cos\psi_p) \;.........\;..........\;....1.7$$

where: Z = specific plough draught, kN/m^2;
z_o = quasi-static component of specific draught, kN/m^2;
Va = forward speed, m/s; k = coefficient constant;
ψ_p = lateral direction angle of the mouldboard plough, deg.

Using a similar form of algebraic equation, Voorhees and Walker (1977) identified the effect of soil moisture-content, ? ? ? , on the quasi-static draught component as in the form:

$$Z = k_1 + k_2\theta + k_3 V_a^2 \;..........\;..........\;...1.8$$

where: k_1, k_2 and k_3 = constants depend on soil type and its parameters.
In a more extensive study using field data, Gee-Clough *et al.* (1978) proposed an empirical mouldboard plough draught equation based on the dimensionless groups identified by Krastin (1973) such as:

$$Z = 13.3a\gamma + \frac{3.06\gamma V_a^2}{g} \;............1.9$$

It was argued further, however, that the soil stress parameter could be eliminated from the draught equation to give the quasi-static component dependent only on the specific weight Eqn 1.9. Oskoui and Witney (1982) found that the simplification of Krastins's equation by using only the specific weight term as an indication of soil strength, eliminating the cohesive term from the equation and precluded any effect from changing soil moisture content.

In more comprehensive of theoretical and experimental field data, Elbanna (1992) validated the assumption in equations 1.7 to 1.9 and showed evidence that the quasi-static component of the specific plough draught not either the soil specific weight, (Eqn 1.9) nor the cone index value. He stated that there is practical validity for the assumption; the quasi-static component of the plough draught depends on the soil cohesive, which is a function of the soil type (clay ratio) and its moisture content. While, the dynamic component of the plough draught is function of soil friction, tillage velocity, and blade parameters (eg. tail or apex angle, share width, or depth, etc). Both draught components are affected by logarithmic or soil zone failure terms. So, the chisel and mouldboard ploughs' specific draught are given by equations (1.10 and 1.11).

$$Z_c = \{[30.27\, Cr\, e^{-0.01\theta}] + [0.72\,\gamma\, V_a \sqrt{\frac{w}{g}}(1 - \cos \psi_c)]\}\, e^{\pi \tan\phi} \;\ldots\ldots\; 1.10$$

$$Z_c = \{[35.55\, Cr\, e^{-0.01\theta}] + [\frac{0.72\,\gamma\, V_a^2}{g}(1 - \cos \psi_m)]_c\}\, e^{\pi \tan\phi} \;\ldots\ldots\ldots\; \ldots\; 1.11$$

where: Z_c; Z_m = chisel and mouldboard specific ploughs draught, kN/m^2;
C r = soil type =%clay/(%silt+%sand); tanϕ= =1/(1+2Cr);
ψ_c and ψ_m = chisel and mouldboard tail or apex angle, deg.

Al-Mudimegh *et al.* (1997) studied the effect of soil properties and field operation parameters on tillage machine draught on sandy loam soil. They presented that the specific chisel, mouldboard and disk ploughs can be given equations form:

$$Z_c = 139.35 + 50.57\, V_a + 3.125\,\psi_c + 0.067\,(\psi_c)^2 + 0.047\,d + 0.802\, d^2 \ldots 1.12$$

$$Z_m = 121.12 - 8.32\, V_a + 26.65\, V_a^2 - 3.98\, d + 1.69\, d^2 \;\ldots\ldots\; \ldots\ldots\; \ldots\ldots\; 1.13$$

$$Z_d = 1412.72 - 321.6\, V_a + 72.9\, V_a^2 + 14.31\, d + 1.223\, d^2 - 50.09\,\psi_d + 0.556(\psi_d)^2 \ldots\ldots 1.14$$

where: Z_{cl}, Z_m and Z_d=horizontal draught forces of chisel mouldboard and disk ploughs, respectively; N; d = tillage depths, cm ;
V_{al} = forward speed, km/h; $\psi_{c,\,m,\,d}$ = lifting or tail or tilt angle, deg.;

MATERIALS AND METHODS

Experiments were conducted at Agric. Res Center; Fac. of Agric. & Veter., King Saud Univ. (Al-Qassim), and the soil was sandy loam and loamy sand. The clay ratio slightly varied in the region site (Table 2.1). The first field was grown alfalfa in 1999, the second field was grown by barley and the stubble after harvesting was presented in the field until tillage was carried out. The residues were shared and the field was left fallow until tillage on Oct., 2001.

Each field was irrigated by sprinkler irrigation system for 3 days prior the tillage experiments. Three soil samples were randomized taken from each of the two fields; samples were bagged and carried to the soil and water laboratory where the mechanical analysis test was done, Table 2.1. Soil samples were collected during tillage experiments to determine the average moisture content on dry basis for each plot. Soil strength was measured using a handle-ring cone penetrometer (ASAE standard), with 30° cone base angle and a diameter of 12.83 mm.) at an average tillage depth for each tillage implement measured in each field for determination the draught forces of five tillage tools.

Table 2.1: Soil mechanical analysis, clay ratio and type

Sand, %			Silt, %	Clay, %	Clay Ratio	Soil Type	Crop Cover
Coarse	fine	total					
63.90	20.80	84.70	3.10	12.20	0.139	Sandy loam	Alfalfa
62.70	22.00	84.70	2.00	13.30	0.153	Loamy sand	fallow barley

Three-primary and two-secondary tillage tools comprising a chisel, mouldmoard and disk ploughs, tandem disk harrow and field cultivator were used in field experiments to evaluate draught requirements. The draught was measured in kN and transferred into kN/m^2 "for primary" and kN/m "for secondary" tillage tools. These tillage implements are commonly used for seedbed preparation in Saudi Arabia, and their specifications are listed in Table 2.2.

Table 2.2 Five used tillage tools' specifications.

Implement	Width, m	Specification
Chisel Plough	2.80	Heavy-duty type with 13 shanks each of width 7cm arranged in two rows. Shank stem angle 55°, 40 cm between shanks in each row and 42.5 cm between rows.
Mouldboard plough	1.096	General purpose type, three bottoms in the frame each cut width 36.5 cm, cutting edge 55 cm, tail angle 52°.
Disk plough	1.095	Three disks each of 63.5 cm diameter with tilt angle of 22°, disk angle of 45° and 58.8 cm between disks and 3.44335 kN per disk (350 kg/disk).
Tandem disk harrow	9.65	Eighty-eight disks of 60 cm diameter, 8 gangs, 7 disks in each of the four middle gangs, 15 disks on each of the ends four gangs, two rows, gang angle 35°, with 23 cm between disks in same row and 0.4415kN/disk (45kg/disk).
Field cultivator	5.60	Thirty-five gangs, arranged in three rows, 8, 14 and 13, spacing between 35 cm, shank steam angle 45° rows spacing 25 cm.

Five replications of three forward speeds at each of three tillage depths were measured in the sandy loam and loamy sand fields for determination the draught forces of five tillage tools. A combination of 255 treatments in each field (barley stubble and alfalfa fallow). The used speeds and depths for tillage experiment are listed in Table 3.1. In barley stubble and alfalfa fallow fields' treatments were: 3-tillage depths, and 3-forward speeds using the (three-primary and two-secondary) tillage tools. During the field operations, for each tillage implement, the tractor was kept in a gear range to yield the average speed at different depths. An experimental block length of 100 m was used for each treatment in the two fields. A block approximate 25 m length was used as practice area prior to the beginning of the experimental runs to enable the tractor and the implement to reach the required speed and depth. Five replications of five tillage systems at three forward speeds for the three-primary tillage, and five speeds for the two-secondary tillage tools and three tillage depths were tested and a total 225 treatments were made for each field.

Two hydraulic dynamometers were constructed at Agric. Engineering Dept., Faculty of Agric and Veter., Saud Univ. (Al-Qassim) and the dynamometers were calibrated prior to the experiments using a tensiometer instrument at the Buraydia Technical College. Table 3.1 These dynamometers were used to calculate the horizontal component of the tillage tools' forces (light and heavy duty) in the field. Stats program was used for statistical analysis (Robin, 1980)

RESULTS AND DISCUSSION

Although research on tillage tools draught has been carried out for many years, there is still no satisfactory theory which will allow draught force to be calculated from knowledge of physical characteristics of plough and relevant soil properties. So, it was decided to model some tillage tools performance empirically using analysis suggested from previous review. Using dimensional analysis, a set of dimensionless groups to describe chisel, mouldboard and disk ploughs, and field cultivator and disk harrow and proposed some relationships forms (3.1 to 3.6).

3.1 Theoretical Justifications

Identifying the most important parameters quantitatively from Eqn. 1.2 for chisel, mouldboard and field cultivator (with respecting the speed linearly affects draught for chisel and field cultivator, and square term for mouldboard plough.

For Chisel and Field cultivator

The dimensional groups can be simplified such as:

$$\frac{D_s}{\ell^2} = \gamma\ell * f\left(\frac{V_a}{\sqrt{g\ell}}, \frac{c}{\gamma\ell}, \frac{A}{\gamma\ell}, \frac{\ell}{d}, \psi, \phi\right)$$

$$\frac{D_s}{\ell^2} = \gamma\ell * f\left(\frac{Ci}{\gamma\ell}, \frac{V_a}{\sqrt{g\ell}}\right) \quad \text{.......... ....3.1a}$$

Assuming Ci has an adhesion and cohesion effects and l is share length may represent depth, or width unit, and l/d is a constant ratio represents cut width to depth ratio; ψ and ϕ share and soil friction angle assumed to be constant for each soil and machine.

$$\frac{D_s}{\ell^2} = f\left(C_i, \gamma V_a \sqrt{\frac{\ell}{g}}(1-\cos\psi_p)\right) \quad \ldots\ldots\ldots \quad 3.1b$$

l^2 = fw.d (represents a shared sectional area), so Eqn. 3.1 simplified for chisel, kN/m^2 and field cultivator, kN/m, draught, as in the form:

$$\text{For - chisel} \ \ldots \ \frac{D_s}{f_w d} = k_1 Ci + k_2 \gamma V_a \sqrt{\frac{d}{g}} \ldots\ldots\ldots \quad 3.2a$$

$$\text{for - cultivator} \ \ldots \ \frac{D_s}{f_w} = k_1 d.Ci + k_2 d.\gamma V_a \sqrt{\frac{d}{g}} \ldots\ldots\ldots \quad 3.2b$$

The same procedure applied for mouldboard plough with square term of forward speed affects its draught, kN/m^2, such as:

$$\frac{D_s}{f_w d} = k_1 Ci + k_2 \frac{\gamma V_a^2}{g} \ldots\ldots\ldots \quad 3.3$$

It should be notified that share apex or mouldboard tail angle term of (1-cosψ) in Eqn 3.1b has to be constant for each share or bottom and its affect absorbed into k_2 of the dynamic coefficient of the plough draught.

For disk plough and tandem disk harrow

Soil and machine operating parameters affect specific disk draught are:

a) **Soil parameters:** cohesion, c; and adhesion, A; angle of internal shearing resistance, ϕ and soil specific weight, γ and soil type; Cr (clay ratio).

b) **Machine parameters**: disk diameter, D; concavity, R; bevel angle, β; gang angle, α; weight per disk, W, disk spacing w and acceleration due to gravity, g.

c) **Operation parameters**: ridge width, w; depth d and speed V_a.

Applied the dimensional analysis of the nine variables listed in Eqn 1.3 and parameters' groups in Eqns 1.4 and 1.5 on the disk plough and disk harrow ($D_s/\gamma D^3$) by using the (d/D) term of depth factor; γV_a/(?D/g) the operation factor and ($\gamma W/Ci\ D^2$) the penetration factor. Since disk bevel angle, β, and gang angle φ and radius of concavity are assumed to be constants for each machine (Elbanna, 1994). Joining the three above important terms, the disk plough and tandem disk harrow draught equations take forms (3.4 to 3.6) such as:

For disk plough draught, kN/m^2 *(W=3.4335 kN/disk or 350 kg/disk)*

$$\frac{Ds}{\gamma D^3} = k1\frac{d}{D} + k2\frac{Va}{\sqrt{gD}} + k3\frac{W}{Ci\ D^2} \ldots\ldots\ldots 3\ .4a$$

Assuming D^2 square of machine unit length = fw*.d or disk sectional area, so D_s becomes:

$$\frac{D_s}{f_w d} = k_1 \gamma d + k_2 \gamma V_a \sqrt{\frac{D}{g}} + k_3 \frac{\gamma W}{C_i . D} \ldots\ldots \quad 3.5$$

where: γd = depth factor depends on tillage depth, m;

γVa?(D/g)= operation factor depends on forward speed, m/s;

$\gamma W/C_i.D$ = penetration factor depends on weight per disk, W and soil cone index, C_i.

k_1; k_2; k_3; k_4 and k_5 = coefficient constants.

For disk plough draught, kN/m, *(W= 0.4415 kN/disk or 45 kg/disk)*

$$\frac{D_s}{f_w} = k_1 \gamma d^2 + k_2 \gamma d V_a \sqrt{\frac{D}{g}} + k_3 \frac{\gamma d W}{C_i . D} \quad \ldots\ldots 3.6$$

The average readings of five tillage tools named: chisel, mouldboard, disk ploughs, tandem disk harrow disk and field cultivator were taken in Loamy sand soil after barley and fallow alfalfa, during 2000/2001 and 2001/2002 seasons, Table 3.1. Table (3.1) shows a significant increase in specific draught in all the treatments with an increase in tillage depth. Three-primary tillage tools named chisel, mouldboard and disk ploughs, and two-secondary tillage tools named field cultivator and tandem disk harrow. Draught force was divided by tillage sectional area (depth time width of tillage) to obtain plough specific draught, kN/m^2, (for primary), however, for tandem disk harrow and field cultivator, the measured draught force was divided by operating width to obtain specific draught per meter of machine width, "kN/m", Table (3.1).

3.2 Experimental Evaluation

By means of regression analysis of the experimental data in sandy loam and loamy sand soils, the values of the quasi-static and dynamic coefficients k_1 and k_2 for chisel, mouldboard ploughs and field cultivator, with their standard errors and percentage of explanation, r^2 are listed in Table 3.2. The same procedure was applied to get depth, operation and penetration factors' coefficients k_1, k_2 and k_3 for disk plough and tandem disk harrow by means of using Eqns 3.5 and 3.6 coefficients k_1, k_2 and k_3 with their standard errors and percentage of explanation, r^2 are listed in Table 3.3.

Table 3.1 Average readings of tillage tools parameters.

Implement	Width, m	Speed, km/h	Depth, cm	Soil moisture content, %	Cone index, kPa	Specific draught, kN/m^2 Predicted	Measured
Chisel plough	2.800	2	10	8.50	2 175	33.55	33.93
		3	15	10.00	2 030	36.54	36.47
		4	20	11.40	1 730	39.30	39.39
Mouldboard plough	1.095	2	15	8.50	2 175	94.00	94.90
		3	20	10.00	2 030	101.3	99.70
		4	25	11.40	1 730	105.5	106.25
Disk plough	1.095	2	15	8.50	2 175	55.45	56.68
		3	20	10.00	2 030	79.85	79.46
		4	25	11.40	1 730	97.55	99.27
Field cultivator		4	5	8.50	2 175	2.794	2.948
	5.60	5	10	10.00	2 030	3.746	3.874
		6	15	11.40	1 730	5.823	5.707
Tandem disk harrow		4	5	8.50	2 175	2.622	2.247
	9.65	5	10	10.00	2 030	4.156	4.594
		6	15	11.40	1 730	5.467	5.646

The overall accuracy of the empirical equations for the chisel plough (Eqn 3.2a), field cultivator, (Eqn 3.2b) mouldboard plough (Eqn 3.3); disk plough (Eqn 3.5) and tandem disk harrow, (Eqn 3.6) were over 98.95%, Tables (3.2 and 3.3). Figs 3.1 to 3.5 demonstrated a comparison of the measured and predicted values of those machines specific draught. Although

Fig. 3.6 represents the variation of primarily and secondary tillage tools specific draught. It is declared that about 20 folds increase in specific draught of primarily tillage compared with secondary tillage tools at increasing tillage depth by 2 to 5 folds.

Table (3.2): Prediction specific draught of chisel, mouldboard ploughs and field cultivator coefficients, their standard errors and percentage of explanation on sandy loam soil.

Implement	Coefficients		Standard errors		Expl	DF.
	$k_1 * 10^{-3}$	k_2	$K_1 * 10^{-3}$	k_2	r^2	
Chisel pl.	10.834	5.7446	0.5132	0.6976	99.40	65
Mouldboard	37.522	8.3418	0.6065	1.1884	99.72	65
Field cultivator	11.283	1.8912	1.1265	1.4547	99.36	65

Table (3.3): Prediction specific draught of disk ploughs and tandem disk harrow coefficients, their standard errors and percentage of explanation on sandy loam soil.

Implement	Coefficients		Standard errors				Expl	DF
	k_1	k_2	k_3	k_1	k_2	K_3	r^2	
Disk Plough*	31.806	5.610	-924.66	1.831	1.376	237.17	98.95	65
Tandem disk harrow+	-2.0819	1.746	1981.25	0.357	0.143	187.68	99.73	65

* Disk Plough, kN/m^2; + Disk harrow draught, kN/m length of machine.

The quasi-static component of the draught is a function of soil strength (cone index) while, the dynamic component of plough draught becomes a function of speed (linear term for chisel and field cultivator, and square term for mouldboard), soil specific weight and acceleration of gravity, Figs 3.7, 3.8 and 3.11 represent the effect of operating speed and moisture content on the dynamic and quasi-static components of specific plough draught and their combined for those machines at 3 working depths. While, Figs 3.9 and 3.10 represent depth, operation and penetration factors and their total summation to give the specific draught required for disk plough and disk harrow. It should be noticed as results of the regression analysis of the penetration factor for disk plough have a constant value and the opposite for disk harrow was the depth factor has the constant value as they are listed in Table 3.3.

So the specific draught of most tillage tools versus soil moisture content, forward speed and tillage depth are shown in Figs (3.6 to 3.11). An increase in specific draught was observed with an increase in the tillage depth and speed for all the tillage implements tested in sandy loam soil. In comparison are made (Fig. 3.6) at approximately the same tillage speed 4 km/h at special depths for tillage tools, it is made clear view that about 15 to 20 folds of primary tillage tools required compared with secondary tillage tools. The specific draught requirements for the barley is found to be grater for all tillage implements because of the slightly increase in clay ratio, and lower moisture content levels which exhibited high soil strength than the fallow alfalfa field. It is also was more firm and compact owing to the presence of the stubble residues of barley crop.

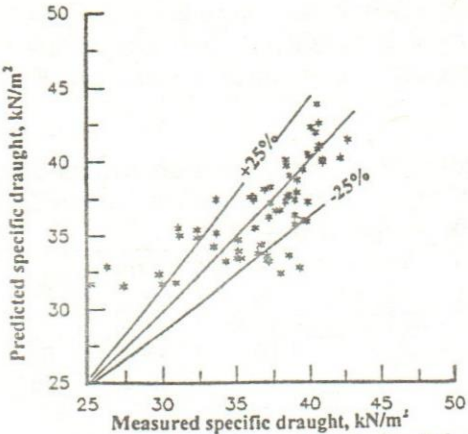

Fig. 3.1 Predicted plotted against measured of specific chisel plough draught on sandy soil.

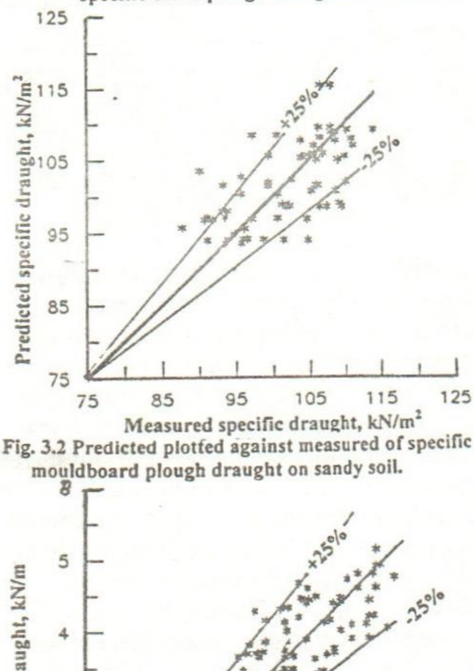

Fig. 3.2 Predicted plotfed against measured of specific mouldboard plough draught on sandy soil.

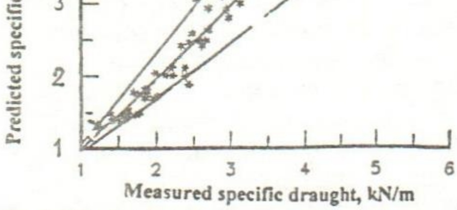

Fig. 3.3 Predicted plotted against measured of specific rigid cultivator draught/m, on sandy soil.

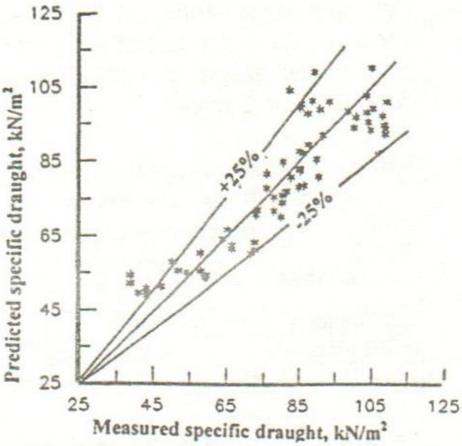

Fig. 3.4 Predicted plotted against measured of specific disk plough draught on sandv soil.

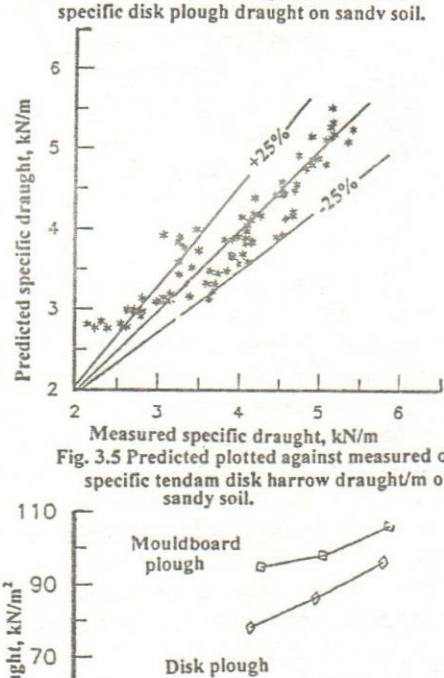

Fig. 3.5 Predicted plotted against measured of specific tendam disk harrow draught/m on sandy soil.

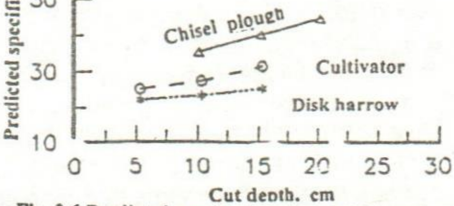

Fig. 3.6 Predicted specific draught of rigid cultivator, disk harrow, chisel, mouldboard and disk ploughs plotted against depth of cut at 4 km/h speed and 2250 kPa of cone index on sandy soil

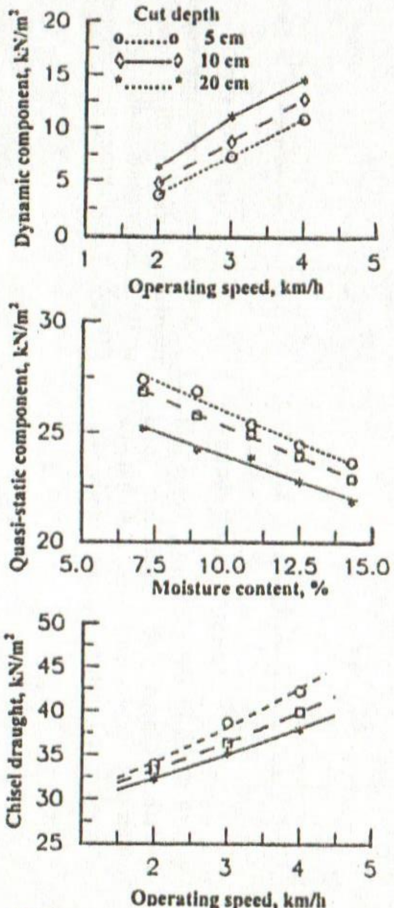

Fig. 3.7 Effect of operating speed and soil moisture content on dynamoic and quasi-static components and total chisel plough specific draught at at three cutting depths on sandy soil.

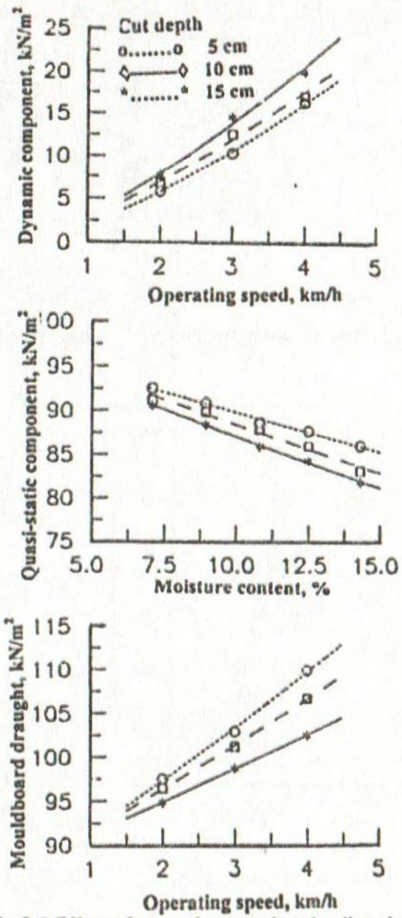

Fig. 3.8 Effect of operating speed and soil moisture content on dynamoic and quasi-static components and total mouldboard plough specific draught at at three cutting depths on sandy soil.

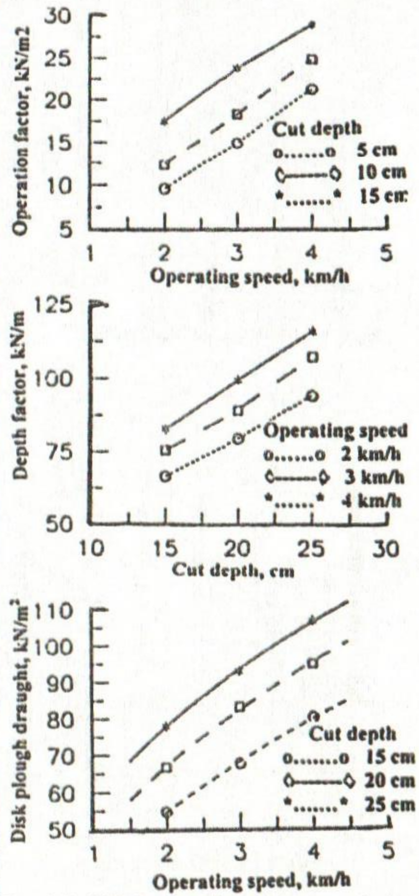

Fig. 3.9 Effect of soil moisture content and operating speed on operation and depthing factors and total disk plough specific draught at three cutting depths on sandy soil.

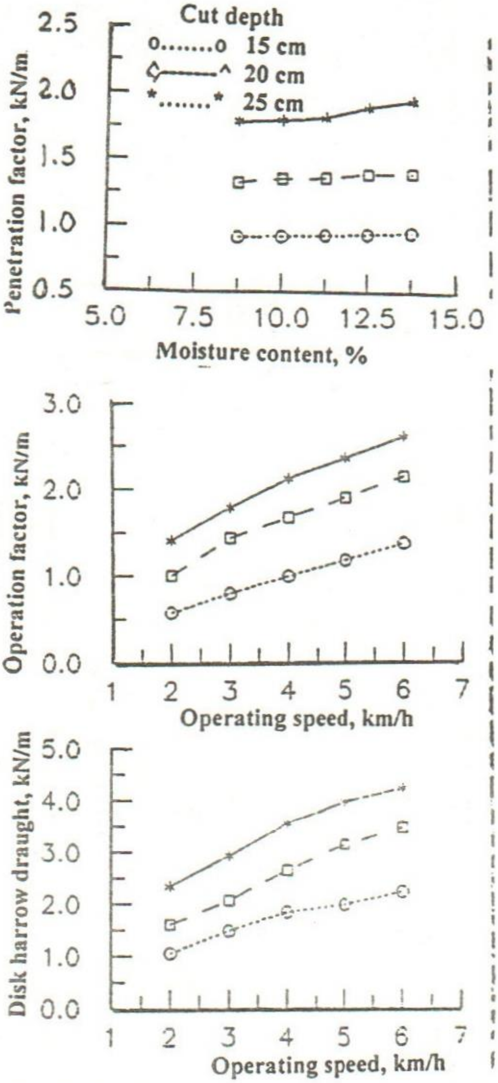

Fig. 3.10 Effect of soil moisture content and operating speed on operation and penetraion factors and total disk harrow draught/m at 3 cutting depths on sandy soil.

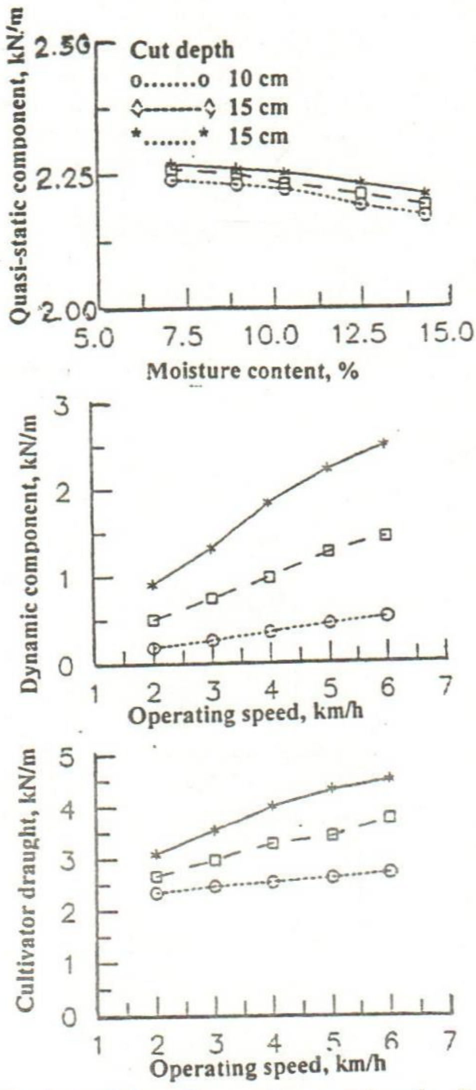

Fig. 3.11 Effect of operating speed and soil moisture content on dynamoic and quasi-static com-ponents and total cultivator draught/m at 3 cutting depths on sandv soil.

CONCULSION

Chisel, mouldboard, and disk ploughs (as primary tillage) and field cultivator and tandem disk harrow (as secondary tillage tools) specific draught were predicted by developing specific empirical equation for each of those machine using the soil and machine theoretical justification, mathematical and statistical analyses of field experimental data on sandy loam soil. The developed equation for primary tillage tools was involved quasi-static component depends on soil con. index, C_i, and dynamic component as a function of forward speed, V_a, soil specific weight, γ and acceleration gravity. However, the developed equation for disk plough and tandem disk harrow has three components: named depth factor is function of tillage depth, d, operation factor depends on forward speeds, V_a, specific weight, γ, and gravity, g and diameter, D. The third factor is penetration depends on cone index, C_i, weight per disk, W and disk diameter. The explanation or correlation of determination was over 98% for all the tillage draught prediction equations, which make them more useful to use in the application programmes.

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قوى الشد لمعدات الحراثة فى التربة الرملية الطمية، بالقصيم–السعودية

الشحات بركات البنـــــا
قسم الهندسة الزراعية – كلية الزراعة–جامعة الملك سعود (القصيم) – السعودية

تم إجراء دراسة حقلية لتقدير قوى الشد لخمس معدات لإعداد الأرض للزراعة (المحـــراث الحفار ١٣ سلاح ، بعرض ٨ر٢متر ، القلاب المطرحى ٣ أبدان ، والقلاب القرصـــى ثلاثـــة أقراص ، بعرض تشغيل ٠٩٥ر١متر و المشط ذو الاسنان المرنة ٣٥ قصبة بعـــرض تشـــغيل ٦ر٥متر والمشط القرصى المزدوج كآله لتتميم مرقد البذرة ٨٨ قرص فى ٨ مجـــاميع بعـــرض تشغيل ٦٥ر٩ متر)، فى التربة الرملية الطميية بمنطقة القصيم بالمملكة العربية السعودية.وقـــدرت مقاومة الإختراق والقص للتربة الرملية فى أماكن قياس قوى الشد للمعـــدات الخمـــس بمحطـــة البحوث الزراعية – كلية الزراعة والطب البيطـــرى بـــالقصيم فـــى موســـمى ٢٠٠٠/٢٠٠١ و ٢٠٠١/٢٠٠٢م. وقد استخدم كل من جـــهازى Cone penetrometer, and Vane shear strength لإيجاد مقاومة الإختراق وجهد القص للتربة الرملية عند نسب مختلفة مـــن الرطوبـــة واعماق مختلفة وإيجاد العلاقة بين قراءاتهم. وربط كل منهم بمقاومة الشد لخمـــس معـــدات لآلات إعداد الأرض للزراعة، بجهاز دينامومتر هيدروليكي يقراء حتى ٢٥ كيلو نيون قوه شد، صمم وتم معايرته بقسم الهندسة الزراعية–بالقصيم.

تم قياس مقاومة الشد للمحاريث الحفارة والقلابة المطرحية والقرصية والأمشاط ذو الأســـنان المرنة والقرصية فى الأراضى الرملية الطمية عند نسب رطوبية مختلفة وثلاث سر عات لمعـــدات الحرث الأولى وخمس سرعات للحرث الثانوى وثلاث أعماق حرث أبتدائى من ١٠سم إلى ٢٥ســم بينما الحرث الثانوى من ٥ إلى ١٥سم وتم قياس مقاومة الإختراق=١٠ مرة جهد أو مقاومة القـــص للتربة، وقياس نسب الرطوبة وسرعة أداء العملية ، تم تحليل النتائج رياضيا وإحصائيا وبناء مود يل رياضى على أساس التحليل العددى وأمكن إستنباط معادلة خاصة بقوى الشد لكـــل مـــن تلـــك المعدات الخمس، فكانت للمحاريث الحفارة والأمشاط المسننة والمحاريث القلابة المطرحية عبـــارة عن معادلة فى جزئين الأول إستاتيكى كمتغير لمقاومة إختراق التربة والجـــزء الثـــانى ديناميكى كمتغير فى السرعة (خطيا للمحراث الحفار والمشط ذو الأســـنان المرنـــة) ، ومربـــع الســـرعة "(للمحاريث القلابة المطرحية) ، والوزن النوعى للتربة كما بالمعادلات التالية:–

For chisel plough, kN/m^2:

$$\frac{D_p}{f_w d} = 0.0108 * C_i + 5.745 \gamma V_a \sqrt{\frac{d}{g}} \quad \text{.........} \ 1$$

For field cultivator, kN/n:

$$\frac{D_s}{f_w} = 0.0113 * d.C_i + 1.891 * \gamma.d.V_a \sqrt{\frac{d}{g}} \quad \text{.........} \ 2$$

For mouldboard plough, kN/m^2:

$$\frac{D_p}{f_w d} = 0.03752 * C_i + 8.342 * \frac{\gamma V_a^2}{g} \quad \text{.........} \ 3$$

where: D_p= draught, kN/m^2 (for chisel, mouldboard and disk ploughs);
D_s = draught, kN/m (for field cultivator and disk harrow);
Ci = soil strength, kN/m^2; γ= soil specific weight, kN/m^2; g =9.81 m/s^2

بينما كانت معادلة قوى الشد للمحاريث والأمشاط القرصية مكونة من ٣ مركبات الأولى متجـــة العمق (كدالة فى عمق الحرث أو التمشيط)، والثانية تشغيله (تعتمد على سرعة التشـــغيل والـــوزن النوعي للتربة وقطر القرص وعجلة الجاذبية)، والمركبة الثالثة الاختراق للأقراص (وهى دالة فـــى الوزن الرأسي على القرص، ومقاومة الاختراق للتربة، والوزن النوعي للتربة) كايلي:–

For disk plough, kN/m^2

$$\frac{D_s}{f_w d} = 31.81 * \gamma d + 5.61 * \gamma V_a \sqrt{\frac{D}{g}} + -924.66 * \frac{\gamma W}{C_i . D} ....3$$

For tandem disk harrow, kN/m

$$\frac{D_s}{f_w} = -2.08 * \gamma d^2 + 1.75 * \gamma d V_a \sqrt{\frac{D}{g}} + 1981.25 * \frac{\gamma dW}{C_i . D} .... 4$$

where: γd = depth factor depends on tillage depth, d , m;
f_w = machine width, m;
γVa√(D/g)= operation factor depends on forward speed,Va, m/s;
γW/CiD =penetration factor depends on weight per disk, W and cone index, Ci.

وكان معامل الإرتباط لثوابت متغيرات المعادلات الخمس السابقة لمعـدات الحرث الأولـى والثانوى (r^2) أكبر من ٩٨% ، مما يشجع إستخدام تلك المعادلات وتطبيقها فى الحقـل لمعـدات إعداد الأرض للزراعة، وبرامج الحاسب لإختيار المعدات الزراعية.

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