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Influence Analysis of Factors Related to the Clod Heaping Quantity of Subsoilers

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ABSTRACT

In order to increase the performance of three working parts of this machine at the same time, it needs to increase its operating speed, 1MG11-200type compound paddy tiller consists of the mounted compound structure arranged the subsoiler with cutting edge at the front part and rotary-tiller without power in the middle part and curved tooth-beam harrow in the rear part, this be able to plough and harrow and level at a time. As operating speed increases in clay loam, the clod heaping occurs in the space of subsoilers, even fill up in the spaces. Therefore, during the working, it is one of important matter to found the optimum operating speed and subsoiler's interval without clod heaping. In a field study conducted at MiGok co-op farm, Sariwon, Democratic People's Republic of Korea, were tested for clod heaping quantity on different operating speed and subsoiler's intervals for clay loam. Mathematical response model was built on clod heaping quantity relative to operating speed and subsoiler's interval to found the operating levels without clod heaping. It was found that the subsoiler, while working in clay loam, should have operating speed 6.2km/h, subsoiler's side interval 0.5m and subsoiler's front-rear interval 0.46m for optimum level without clod heaping.

Keywords : Subsoiler, Working speed, Interval, Clod heaping, Optimum level, Design

I. INTRODUCTION

The subsoiler is an implement, whose action is design ed to life the soil over its leg and cause significant soil cracking, but with little disturbance to the residue on the surface. Hence, it is considered an excellent moist ure conserving implement. Literature[1] analyzed ho w these machines interact with soil in consideration o f the rigid body mechanics of agricultural machines in volved in the ground, and the motion and interaction force of the machine in the tool and the base were use d using the parametric equation for the system in whi ch the machine and soil were combined. The paramet ers of the system can be estimated by measuring. In ag ricultural practice, primary tillage is considered as the largest power consuming operation.Many researchers have tried to improve the performance of subsoilers i n many different ways, mainly have been developed t o design it for the minimum amount of operating ener gy and for the maximum amount of soil pulverization [2]. For the design of an energy efficient subsoiler in d ifferent operating conditions, an understanding of the interactive effects of different subsoiler, soil and oper ational parameters is essential. Optimizing a subsoiler for every soil condition in th to understand the eis ma nner is cumbersome and almost an impossible task as there may by any number of different conceivable fiel d conditions. A rigorous mathematical expression is n eeded to describe the interaction of the factors involv ed in order to understand the effect of different param eters and to optimize the overall performance in diffe rent working conditions.In literation, were made mea sure and analysis of the predicted draft force on the di fferent front-rear space for depth 510 and 600mm of s ubsoiler [3]. The effects of soil bulk density, water me tric potential, and depth on penetrometer resistance were analyzed through field experiments [4]. Using th e equilibrium temperature approach, a mathematical model was created that reflects the effects of air temp erature, insolation, wind speed and oil conditions on t he heat transfer process [5]. Corn samples were collec ted to determine the concentrations of Cd, Cu, Mn, Ni , Pb, and Zn, and the BCR sequential extraction meth od was used here [6]. Two soil management systems f or the corn (Zea mays L)-cotton (Gossypium hirsutum L.) crop cultivation system in Cordoba (Southern Spai n): a permanent bed (PB) that maintains crop retentio n in the surface ground and a conventional bed. Was analyzed [7]. The past, present and future impacts of human activities on agricultural soils were analyzed, i ncluding essential data for the development, testing a nd calibration of agricultural, climate and environme ntal models[8]. Based on the detailed analysis of soil s urface roughness and soil roughness, the effects of till age treatment on soil surface roughness (RR) and rate (T) were analyzed and evaluated [9]. The effect of basi c influence factors such as fie, ripping depth, and oper ational speed in sand clay ground on draft requiremen t was studied in detail [10]. The design and manufactu ring method of a circular plow that cultivates the soil in the form of a peripheral circle rather than a straigh t line like a traditional plow was analyzed [11]. In this paper, on the basis of sufficient research and analysis of the preceding literature, the effects of the working speed and subsoiler's interval on the clod heaping qua ntity of the subsoiler were analyzed, and through an e xperiment, the best working speed and the subsoiler's interval were determined when there was no clod hea ping quantity.

II. EXPERIMENTAL DETAILS

2.1. Experimental conditions of field

A 1MG11-200type compound paddy tiller for field ex periments shown in Figure 1.and this was mounted o n a DongfanghongYTO80-90 tractor.

Figure 1. 1MG11-200type compound paddy tiller for f ield experiments

III. METHODS AND MATERIAL

We developed research methodology that is adapted PRISMA. This methodology is consisted of four main steps for reviewing scientific articles (Liberati et al., 2009; Mohamed, Ghazali, & Samsudin, 2020; Moher, Liberati, Tetzlaff, & Altman, 2009). The four steps of phases of this research can be seen in Figure below.

The experimental soil is chose a clay loam to influence greatly clod heaping of subsoiler, as operating speed of machine increases (4.0km/h and above).

The soil condition of experimental field at Sariwon MiGok co-operative farm in North HwangHae province of Korea in 2019 year shown Table 1.

Table 1. Soil condition of experimental field

Soil parameter	Value	
Soil	Clay loam	
Horizon, (m)	0-0.10	0.10-0.20
Moisture, (%)	19.86	21.36
Bulk density, (kN/㎥)	13.68	14.102

The main dimensions of the subsoiler of the 1MG11-200type compound paddy tiller are also summarized in Ta ble 2.

Table 2. Main dimensions of subsoilers

Parameters	Value
Ploughing depth, m	0.20
Cutting width, m	0.25
Lift angle, deg	23
Operating speed, km/h	4.0-9.5
Amount of subsoiler	11

2.2. Experimental method

The main aim of the test is to measure the clod heapin g quantity, as the operating speed and subsoiler's inter val increase and to determine the relation of them.

The test place was took the number of 45. The workin g length of each test place was decided at 50 meter. T he operating speed was varied at 5 working speed stai rs of DongfangYTO80-90 tractor, namely 4.0km/h (a medium-speed first stair), 5.2km/h (a low speed fourt h stair), 6.2km/h (a medium-speed second stair), 7.6k m/h (a medium-speed third stair), 9.5 km/h (a high sp eed first stair). For each working speed, the side inter val of subsoilers was varied from 0.3 to 0.5m at interv als of 0.1m. For the each side interval of subsoilers, th e front-rear interval of subsoilers was varied also each at 0.3, 0.4 and 0.5 m.

The each subsoilers were tested in the same soil and working depth. For the same soil and ploughing depth, only the speed was varied, and the intervals of subsoi lers kept constant. In the second interval conditions i n each type of speed, the clod heaping were made by t he subsoilers, the clod heaping height was measured a t this point.

The quantity M of the clod heaping was introduced in order to define the phenomenon of the clod heaping in quantity. The value of the clod heaping quantity M was calculated at the rate of the clod heaping height (h) on the vertical distance from the ploughing botto m to the subsoiler's beam(H=520mm), namely M=h/H. The height of the clod heaping was defined at the ver tical distance from the ploughing bottom to the top of the clod. In this way, the different test runs were ma de for each subsoiler.

It were computed the value of the clod heaping quantity for each subsoiler's condition and the analysis of results was performed by statistical operation.

IV.RESULTS

3.1 The effects of operating speed on the clod heaping quantity for different both intervals

While studying the effect of one parameter, all other parameters were kept constant at the parameter's values given in Table2. An arrangement plan of subsoiler is shown in Figure 2.

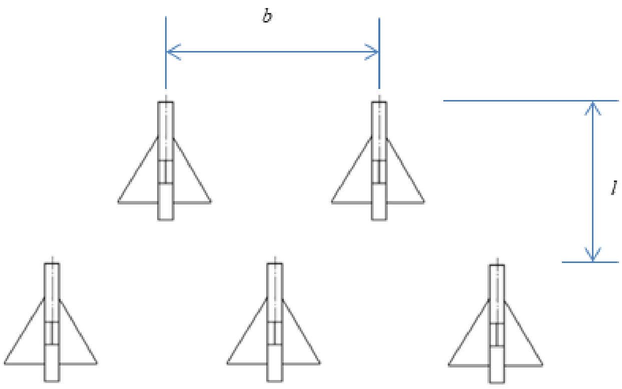


Figure 2. Arrangement plan of subsoiler

The measured values of M for both intervals in different operating speeds were plotted in a scatter plot as shown in Figure 3

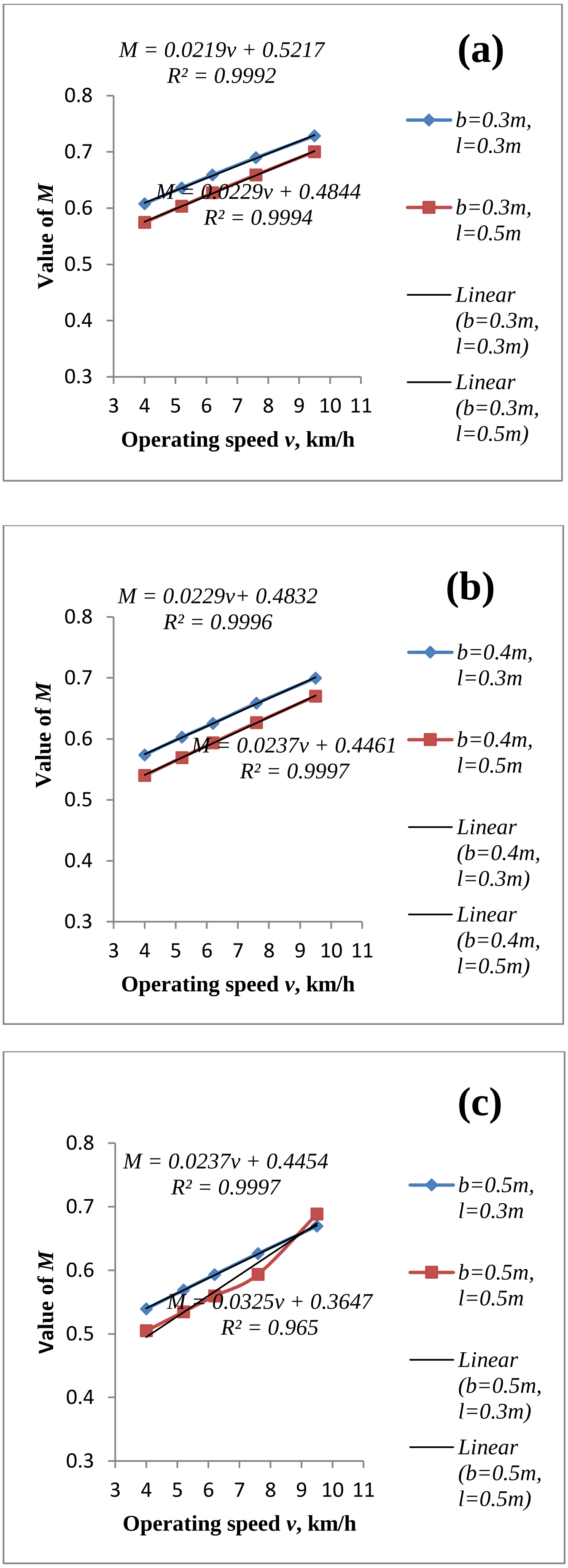
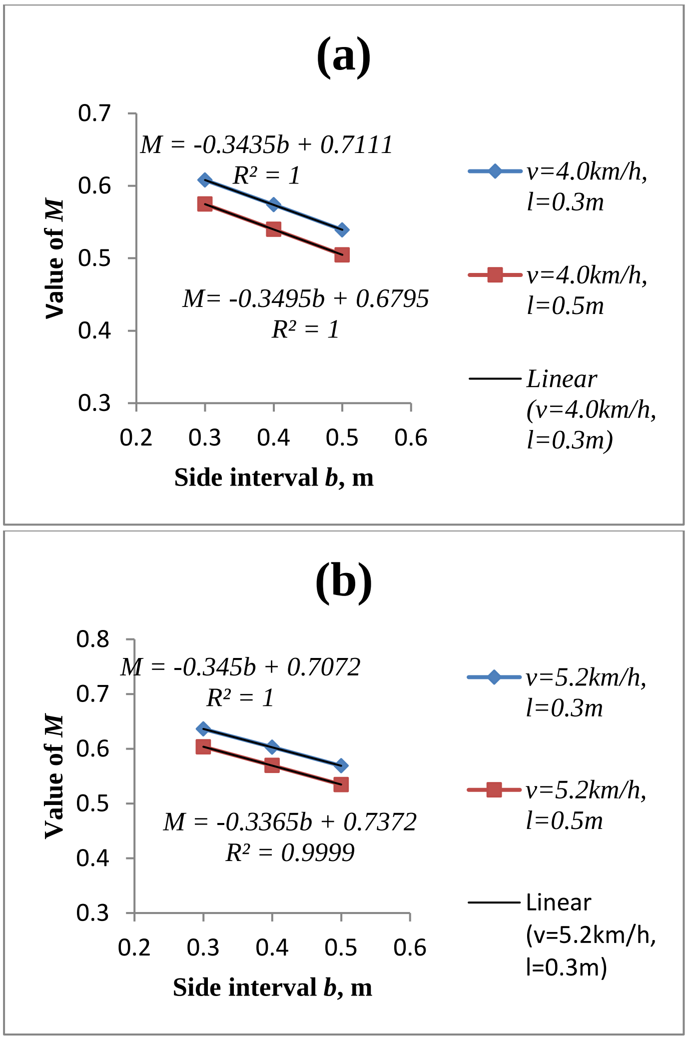


Figure 3. Scatter plots for the measured values of M fo r both intervals at different operating speed

The analysis showed that the effects of operating spee d on the clod heaping quantity for different both inter vals of subsoiler was essentially a linear relationship. When speed varied from 4.0 to 9.5 km/h, the value of clod heaping quantity increased from 0.505 to 0.729 f or different both intervals of subsoiler (*b*=0.3~0.5m, *l*= 0.3, 0.5m). This indicates that the operating speed of s ubsoiler influences on the clod heaping quantity.

3.2 The effects of clod heaping quantity on different si de intervals

The measured values of clod heaping quantity for diff erent both intervals of subsoiler in each speeds were p lotted in a scatter plot as shown in Figure 4 and Figur e 5.



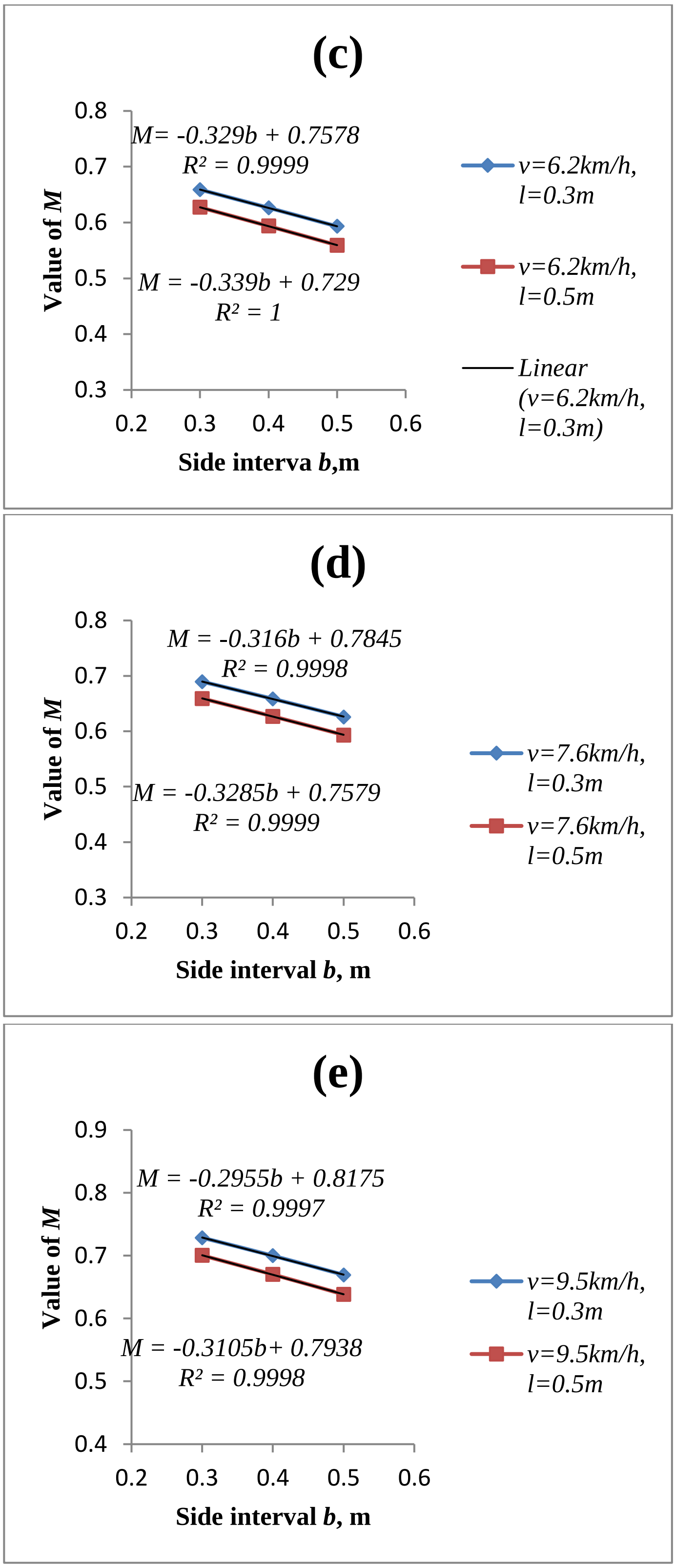
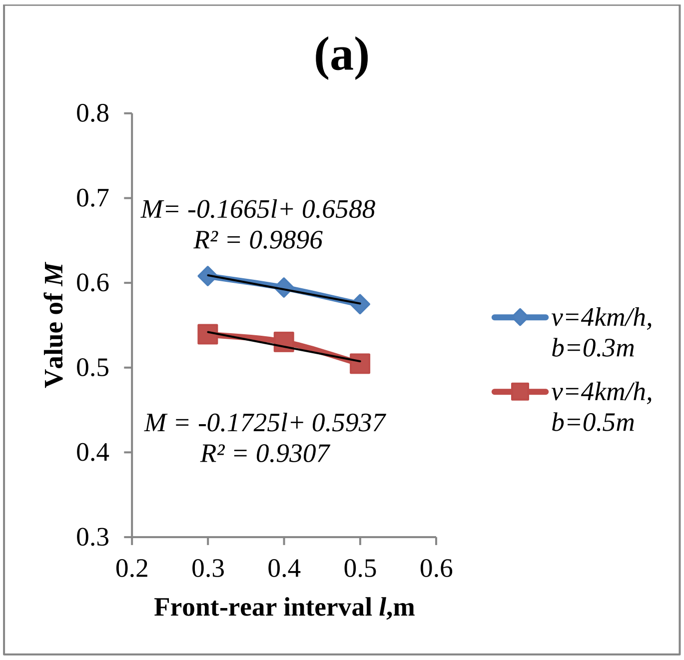
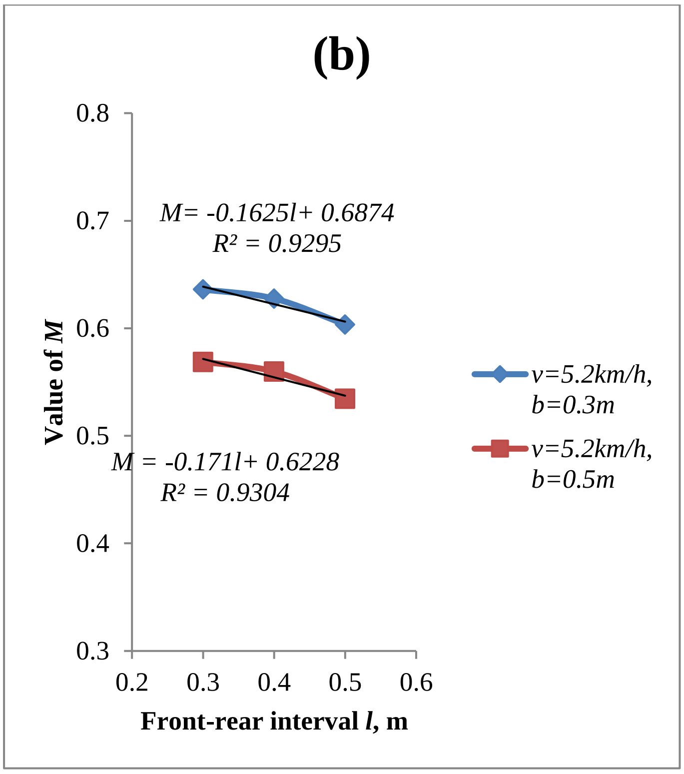


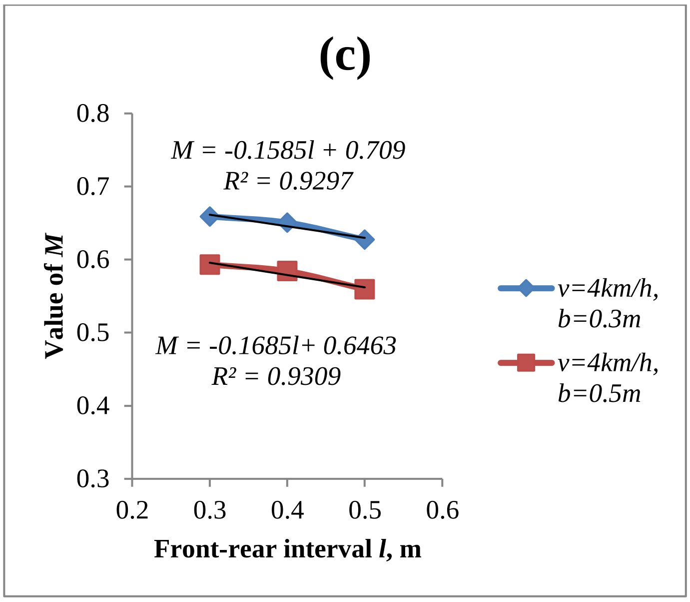
Figure 4. Scatter plots for the measured values of clod heaping quantity for different side intervals of subsoil ers in each speed

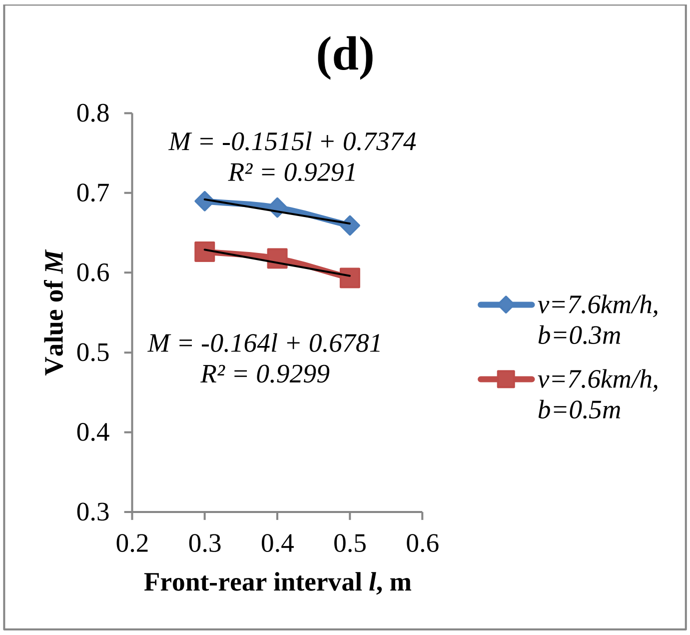
In Figure 4, the effects of clod heaping quantity on dif ferent side intervals of subsoiler for each operating sp eeds were rather linear. However, up to a value for th e side interval of subsoiler of 0.1m in constant speed, the value of clod heaping decreased from 0.729(largest quantity) to 0.505(least one).

3.3 The effect of clod heaping on the different front-rear interval for each speed









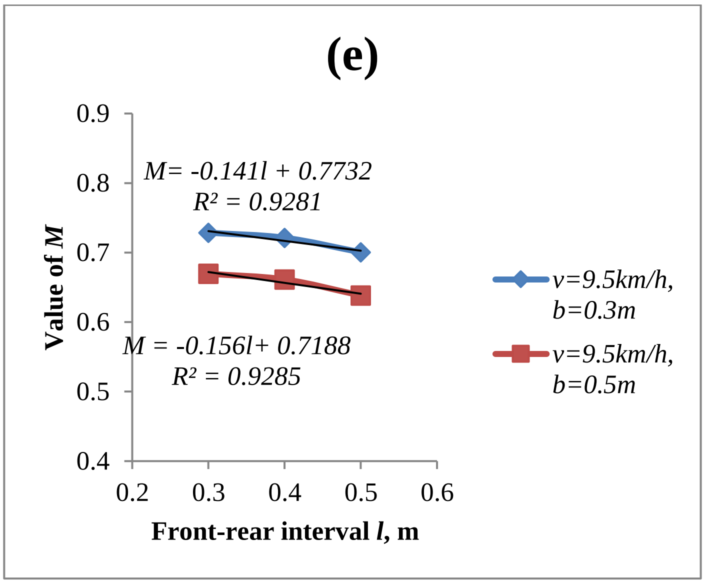


Figure 5. Scatter plots for the measured values of clod heaping quantity for front-rear intervals of subsoilers in each speed

In Figure 5, the effect of clod heaping on the different front-rear interval for each speed were linear, and up to a front-rear interval of subsoilers increases from 0.3 to 0.5m, a clod heaping quantity decreases as above.

The analysis of Figure 4 and Figure 5 showed that the both intervals of subsoiler for given constant speed greatly were rather influenced on the clod heaping quantity. This indicates that up to the both intervals of subsoiler, a clod heaping small occurs, in given constant speed. The test result showed that the both intervals of subsoiler and operating speed are influenced on the clod heaping for the relationship involved each.

Hence, it needs to find a rigorous mathematical expression of the clod heaping quantity occurring by the involved relationship of the both intervals of subsoiler and operating speed.

3.4 Mathematical modelling by design of experiment

In order to describe the influence of the both intervals of subsoiler quantities and operating speed on the clod heaping, it can be built as following the mathematical model.

$$M = a_0 + a_1 v + a_2 b + a_3 l + a_4 v^2 + a_5 b^2 + a_6 l^2 + a_7 vb + a_8 vl + a_9 bl + a_{10} vbl \quad (1)$$

Where M is the clod heaping quantity， b is the side interval of subsoiler in m， l is the front-rear interval of subsoilers in m， v is the operating speed in km/h， a_0, a_1, a_2, …,a_{10} are regression coefficients.

The statistical operation was performed to estimate the regression coefficients.

From the statistical analysis, the following equation of best-fit model was obtained:

$$M = -0.0423 - 0.2937b + 4.0131l - 5.746l^2 + 0.0676vl \quad (2)$$

A statistical analysis at the 95% confidence interval for the intercepts between the measured values of clod heaping quantity and the predicted values of the above regression equation was found to be ±0.016. This shows that the measured values agreed well the predicted values. From a model, it can be found a quantity of clod heaping for any operating speed and any both intervals of subsoilers. And it can be also found the operating speed and the both intervals of subsoilers without clod heaping.

V. DISCUSSION

Base on the test's experience, the state of clod heaping was divided as follows.

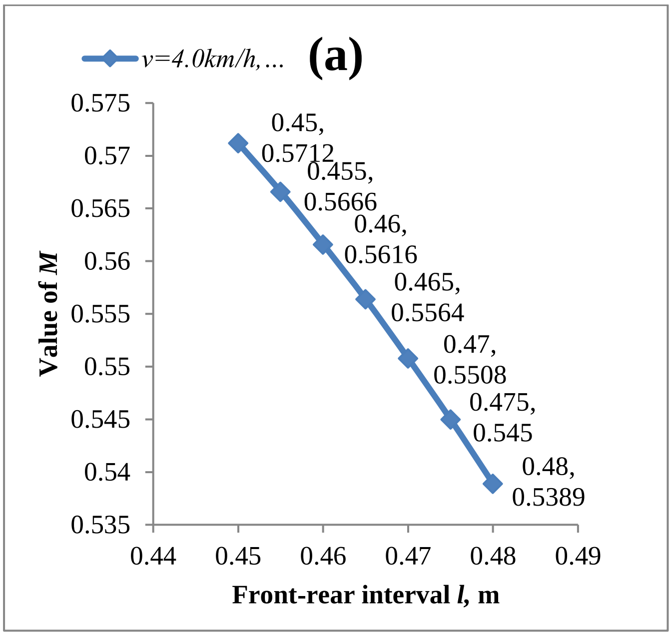
State①: this state is an one that values of M are lower 0.63(M≤0.63), namely the difference(($\Delta = \mathrm{h} - a,\ a = 0.2$m) between the clod heaping height(h) and ploughing depth(a) are extremely small, hence a state① was defined as a state without clod heaping. State②: this state is an one that value of M is from above 0.63 to 0.68(0.63<M≤0.68). It is subsisted the any amount of Δ in this state, that is way, this state was defined as some clod heaping state. State③: this state is an one that value of M is above 0.68(M>0.68). It is subsisted the comparatively great values of Δ in this state, hence this state obstructs the working of machine. Therefore this was defined as a severe clod heaping.

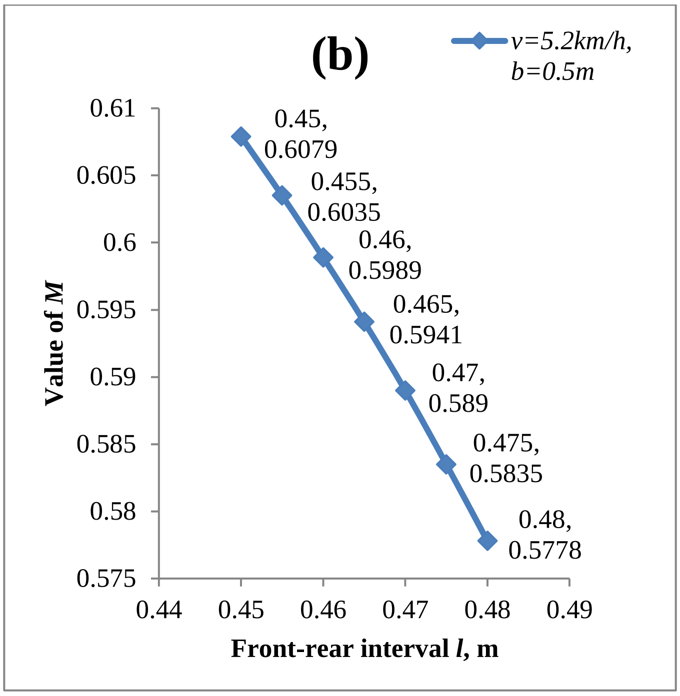
The severe state of clod heaping not only were occurred in operating speed of above 6.2km/h (b=0.3m, l=0.3, 0.4m), but also in all speed of 9.5km/h. The some clod heaping were comprised no small proportion for mainly speed conditions of 5.2km/h and 6.2km/h in different both intervals of subsoiler. The state without clod heaping mainly not only were occurred in operating speed of 4.0km/h and 5.2km/h for side interval of 0.5m, but also for both intervals of b=0.4, 0.5m and l=0.4, 0.5m in operating speed of 6.2km/h.

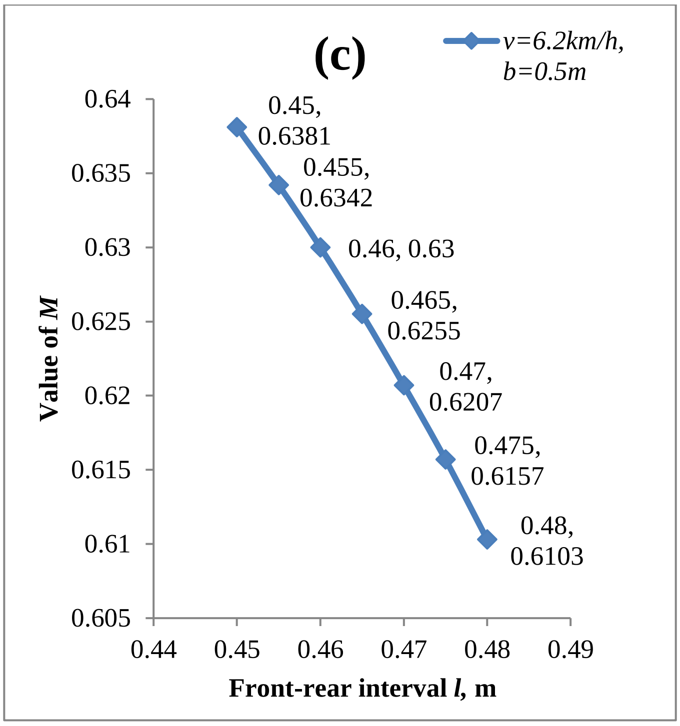
In order to the design of a subsoiler with the high performance, it was arisen the following conditions. (1) During the working, the subsoiler must not leave the unploughed parts at the ploughing bottom. (2) During the working, the subsoiler must not make the clod filling in the space of subsoilers. (3) The operating speed of subsoiler must be least high. (4) The front-rear interval of subsoilers must not be great too.

From the above condition (1), a side interval of subsoilers decided at 0.5m, and from the condition (2), a value of M decided at 0.63. The calculating result by a model was comparatively satisfied the above conditions, when the operating speed is lower than 7.6km/h ($v <$ 7.6km/h) and a front-rear interval of subsoilers is from above 0.4 to 0.5m ($0.4< l \leq 0.5$m). When a side interval of subsoilers is 0.5m, it needs to find the operating speed and front-rear interval of subsoilers to satiate M≤0.63.

In order to this, when the operating speed varied from 4.0 to 7.6km/h, it was analyzed the varying of clod heaping quantity on the varying of subsoiler's front-rear interval (Figure 6).







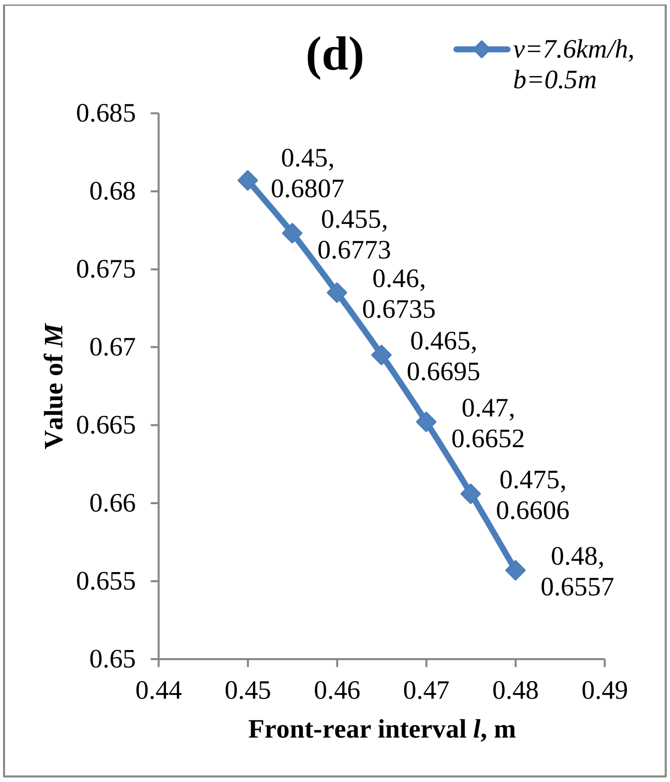


Figure 6. Scatter plots for the varying of clod heaping quantity on the varying of subsoiler's front-rear inter val, when the operating speed varied from 4.0 to 7.6k m/h in clay loam

An analysis of Figure 6 showed that the values of M is all 0.63 and less in 4.0km/h and 5.2km/h of operating speed, hence it is satiated the condition (2), but it is n ot satiated the condition (3), and when the operating s peed is 7.6km/h, the condition (3) is satiated, but the value of M is 0.63 above, hence it is not satiated the c ondition (3). When the operating speed is 6.2km/h, it is satiated the condition (3) and is subsisted the limite d value of M 0.63. At this time, a value of the subsoile r's front-rear interval l was 0.46.

Hence, when the value of M is 0.63 in clay loam, the operating speed 6.2km/h and subsoiler's front-rear int erval 0.46m can be chose at an optimum valve satisfyi ng the above all designing conditions. Thus, based on a model, it was found an optimum interval of subsoile rs ensuring the state without clod heaping and the hig h working speed at the same time. All things consider ed, an operating speed, side interval and front-rear int erval and 1MG11-200type compound paddy tiller sub soilers was decided 6.2km/h, 0.5m and 0.46m, respecti vely.

The designed subsoiler (b=0.5m, l=0.46m) and a comp arative subsoiler (b=0.5m, l=0.4m) were tested at iden tical soil and operating conditions (operation speed: 6. 2km/h, ploughing depth: 0.2m) to validate the model and to compare the performance and it was found the that the difference between designed subsoiler's clod heaping quantity and comparative subsoiler's one was 0.03. From the comparative test, it was validated that the clod heaping of designed subsoiler are extremely l ess.

VI. CONCLUSION

An optimum design model of subsoiler was developed and the describing equation was evaluated to get the optimum value of parameters of subsoiler. Three para meters were considered to affect the clod heaping of s ubsoiler: operating speed, side interval and front-rear interval of subsoiler. Statistical analyses showed that t hough the effect of front-rear interval was most predo minant, complicated interactions existed between the operating speed and interval of subsoiler. Our experi ments showed that the subsoiler, while working in a c lay loam, should have an operating speed 6.2km/h, sid e interval 0.5m and front-rear interval 0.46m for the o ptimum levels ensuring state without clod heaping. T he comparison of performance between a design subs oiler and a comparative one showed that the value of clod heaping quantity of design subsoiler are less 0.03 than one of comparative subsoiler.

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