# APPLICATION OF RESPONSE SURFACE METHODOLOGY FOR OPTIMIZING FUEL CONSUMPTION OF A DISK PLOW IN LOAMY SAND SOIL

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***Abstract***

Disk plow is considered to be effective tool used for cutting, pulverizing, elevating and inverting furrow slices as primary tillage. Tillage is the most fuel demanding in crop production. Thus, appropriate management and use of modern management techniques are essential to reduce fuel consumption. Thus, the purpose of this study was to determine the optimum conditions for the fuel consumption of a disk plow operating in loamy sand soil using Response Surface Methodology. Initially, values of fuel consumption were produced from field experiments. The fuel consumption data was collected at different factors of plowing speed, plowing depth, disk angle, tilt angle and soil moisture content according to the experimental design which was recommended by Response Surface Methodology of MINITAB software version 16. The coefficient of determination ($R^2$) was 94.967% meaning that the experimental data were acceptable. It was found that the lowest fuel consumption could be optimized at plowing speed of 3.24 km/h, plowing depth of 10.03 cm, disk angle of 40°, tilt angle of 15° and soil moisture content of 6.06% db. The verification value of fuel consumption at the optimum conditions which was determined by the experimental work was 3.25 lit/h. Since the difference between the verification and predicted values was less than 5%, therefore, the optimum conditions for the fuel consumption predicted by MINITAB software Version 16 could be accepted. The model can be used to estimate fuel consumption of a disk plow operating in loamy sand soil within the studied range of the investigated factors.

## INTRODUCTION

Soil tillage is the most expensive and complicated operation, fuel demanding and time consuming (Zugec *et al.*, 2000) in crop production. Disk plows are well adapted for plowing in extremely hard soil; for cutting, pulverizing, elevating and inverting furrow slices in primary as well as in secondary tillage. However, during soil tillage there are multiple independent factors affecting the fuel consumption of a plow such as speed of operation, area of cut, plowing depth, type of soil, skills of operator, soil moisture content and type of the plow (Leghari *et al.*, 2016). Consequently, appropriate management and use of modern management techniques are essential to apply an optimum method which can show the main and interaction effect of all the factors on the fuel consumption of such plow.

Response surface methodology has been reported to be an effective tool for optimization of a process when the independent factors have a combined effect on the desired response (Koocheki *et al.*, 2009). It is a collection of a mathematical and statistical technique that can be useful for modeling and analysing situations in which a response of interest is influenced by several factors and the objective is to optimize this response (Pishgar-Komleh *et al.*, 2012). Although several studies were done by applying response surface methodology for optimization, there was no related research to the current study. However, Mamkag (2002) found that forward speed, disk and tilt angles had clear effect on fuel consumption of a disk plow. Osman *et al.* (2011) indicated that tilt angle of the mounted disk plow had strong effect on performance of a disk plow. Abdalla *et al.* (2014) reported that angles of a disk plow (tilt and disk) affect fuel consumption of a tractor. The disk angles were 43° and 45° and the tilt angles were 15°, 20° and 25°.

Since soil tillage is one of the main greatest energy consumers (Namdari *et al.*, 2011) and it is the most expensive and complicated operation, fuel demanding and time consuming (Zugec *et al.*, 2000) in crop production. Thus the purpose of this study was to determine the optimum conditions for reducing fuel consumption of a disk plow operating in loamy sand soil using Response Surface Methodology.

## MATREIALS AND METHODS

### Disk plow

The disk plow has disks inclined rearwards for additional penetration (Vozka, 2007). The angle of attachment of the disk to the direction of travel is called the disk angle (Vozka, 2007). However, the disk angle is the angle in the horizontal plane between the path of the travel and the line passing through the plane of the disk. The tilt angle of a disk plow is the slant (tilt) backward of the disk from the vertical (Bukhari *et al.*, 1992).

### Field experiments and fuel consumption measurements

The field experiments were carried out at special farm located in Riyadh, Saudi Arabia. The coordinators were longitude of 47.1° E and latitude of 24.33 °N. The purpose of the field experiments was to determine fuel consumption of a disk plow as affected by five factors, namely: plowing speed, plowing depth, disk angle, tilt angle and soil moisture content. The soil in the experimental site was loamy sand (sand percentage was 80.22%, silt percentage was 14.57% and clay percentage was 5.21%). Additionally, average soil bulk density was 1.52 g/cm$^3$.

The disk plow (Nardi, mounted category II, weight 362 kg, Italy), model MF 38, serial No. TDPE48/D was utilized in the field experiments. It had three disks with 66 cm disk diameter and the distance between the disks was 60 cm (Fig. 1). The disk plow was hitched to New Holland tractor model 100-90 (power=74.57 kW). Three levels of the investigated factors were considered. However, plowing speeds were obtained by changing tractor gear box gears. Also, soil moisture content was adjusted by centre pivot irrigation.

Fig. 1. Adjusting level of the used mounted disk plow.

An experimental block of 30 m long by 2 m wide was used for each treatment. A small block of approximately 10 m long by 2 m wide in the beginning of each tested block was used to enable the tractor and the disk plow to reach the required plowing speed and plowing depth. The depth of cut was measured with a steel tape from the bottom of the furrow to the surface level of the soil at eleven randomly selected places.

Fuel consumption rate for each treatment was measured by starting plowing the plot with full tank capacity. After finishing plowing one strip, the fuel tank was refilled with a graduated cylinder and the amount of fuel used for refilling the tank was recorded and the time taken to finish a specific strip was also recorded. The consumed fuel quantity was divided on the consumed time to get the fuel consumption rate in lit/h. Field experiments were performed using different levels of factors as seen in Table (1).

Table 1. Investigated factors and their levels.

| Independent factors (unit) | Levels | | |
|---|---|---|---|
| | -1 | 0 | +1 |
| Plowing speed (X1,km/h) | 3 | 4 | 5 |
| Plowing depth (X2,cm) | 10 | 15 | 20 |
| Disk angle (X3,°) | 40 | 45 | 50 |
| Tilt angle (X4,°) | 15 | 20 | 25 |
| Soil moisture content (X5,%db) | 6 | 9 | 12 |

The factors listed in Table (1) were then applied into MINITAB software Version 16 whereby half factorial Central Composite Design (CCD) was employed to obtain the experimental design as shown in Table (2). According to half $2^5$ factorial design, there is at least 32 experiments as seen in Table (2). If a researcher decides to provide experiments in 3 replications, it means more experiments. Although more than one replication may produce more powerful results (Gençosman *et al.*, 2012), in this study, as each experiment takes time and effort, only one replication was chosen. The data collection for the fuel consumption was achieved according to the experimental design as shown in Table (2).

Table 2. Experimental design recommended by MINITAB software Version 16.

| No. | Plowing speed (X1) | Plowing depth (X2) | Disk angle (X3) | Tilt angle (X4) | Soil moisture content (X5) |
|---|---|---|---|---|---|
| | (km/h) | (cm) | (°) | (°) | (%db) |
| 1 | 5 | 20 | 40 | 15 | 12 |
| 2 | 4 | 15 | 45 | 20 | 9 |
| 3 | 4 | 15 | 45 | 20 | 6 |
| 4 | 3 | 10 | 50 | 15 | 6 |
| 5 | 4 | 15 | 45 | 20 | 9 |
| 6 | 3 | 20 | 40 | 15 | 6 |
| 7 | 4 | 15 | 45 | 15 | 9 |
| 8 | 4 | 20 | 45 | 20 | 9 |
| 9 | 3 | 20 | 50 | 15 | 12 |
| 10 | 4 | 15 | 45 | 20 | 9 |
| 11 | 5 | 10 | 50 | 25 | 6 |
| 12 | 4 | 15 | 45 | 20 | 9 |
| 13 | 4 | 15 | 40 | 20 | 9 |
| 14 | 3 | 10 | 40 | 25 | 6 |
| 15 | 4 | 10 | 45 | 20 | 9 |
| 16 | 5 | 20 | 50 | 15 | 6 |
| 17 | 4 | 15 | 45 | 20 | 9 |
| 18 | 5 | 10 | 50 | 15 | 12 |
| 19 | 3 | 20 | 50 | 25 | 6 |
| 20 | 4 | 15 | 45 | 20 | 12 |
| 21 | 4 | 15 | 45 | 20 | 9 |
| 22 | 5 | 10 | 40 | 25 | 12 |
| 23 | 3 | 10 | 50 | 25 | 12 |
| 24 | 5 | 10 | 40 | 15 | 6 |
| 25 | 5 | 15 | 45 | 20 | 9 |
| 26 | 4 | 15 | 50 | 20 | 9 |
| 27 | 3 | 20 | 40 | 25 | 12 |
| 28 | 5 | 20 | 50 | 25 | 12 |
| 29 | 3 | 10 | 40 | 15 | 12 |
| 30 | 3 | 15 | 45 | 20 | 9 |
| 31 | 4 | 15 | 45 | 25 | 9 |
| 32 | 5 | 20 | 40 | 25 | 6 |

## Data analysis

Response surface regression analysis was performed to obtain a second-order polynomial equation or model. Statistical analysis of the model was represented in the form of Analysis of Variance (ANOVA). The MINITAB software Version 16 was also used for optimization analysis.

# RESULTS AND DISCUSSION

## Model fitting

Results in Table (3) show that the actual and predicted fuel consumption. The lowest actual and predicted fuel consumption were 3.28 lit/h and 2.47 lit/h, respectively. The lowest actual fuel consumption was at factors whereby plowing speed was 3 km/h, plowing depth was 10 cm, disk angle was 50°, tilt angle was 25° and soil moisture content was 12 %db. Meanwhile, the lowest predicted fuel consumption was at factors whereby plowing speed was 3 km/h, plowing depth was 15 cm, disk angle was 45°, tilt angle was 20° and soil moisture content was 9 %db.

Table 3. Factors and comparison between response (fuel consumption) actual and predicted.

| No. | Factors | | | | | Fuel consumption | |
|---|---|---|---|---|---|---|---|
| | X1 (km/h) | X2 (cm) | X3 (°) | X4 (°) | X5 (%db) | Actual (lit/h) | Predicted (lit/h) |
| 1 | 5 | 20 | 40 | 15 | 12 | 9.63 | 9.6976 |
| 2 | 4 | 15 | 45 | 20 | 9 | 4.92 | 5.0397 |
| 3 | 4 | 15 | 45 | 20 | 6 | 4.26 | 4.5002 |
| 4 | 3 | 10 | 50 | 15 | 6 | 5.30 | 4.9426 |
| 5 | 4 | 15 | 45 | 20 | 9 | 4.64 | 5.0397 |
| 6 | 3 | 20 | 40 | 15 | 6 | 3.69 | 3.8490 |
| 7 | 4 | 15 | 45 | 15 | 9 | 4.24 | 5.3991 |
| 8 | 4 | 20 | 45 | 20 | 9 | 5.52 | 4.6347 |
| 9 | 3 | 20 | 50 | 15 | 12 | 3.71 | 3.6340 |
| 10 | 4 | 15 | 45 | 20 | 9 | 4.69 | 5.0397 |
| 11 | 5 | 10 | 50 | 25 | 6 | 8.57 | 8.3509 |
| 12 | 4 | 15 | 45 | 20 | 9 | 4.60 | 5.0397 |
| 13 | 4 | 15 | 40 | 20 | 9 | 9.28 | 7.6902 |
| 14 | 3 | 10 | 40 | 25 | 6 | 8.03 | 8.3598 |
| 15 | 4 | 10 | 45 | 20 | 9 | 4.29 | 4.7658 |
| 16 | 5 | 20 | 50 | 15 | 6 | 8.36 | 7.9701 |
| 17 | 4 | 15 | 45 | 20 | 9 | 4.87 | 5.0397 |
| 18 | 5 | 10 | 50 | 15 | 12 | 12.24 | 11.7912 |
| 19 | 3 | 20 | 50 | 25 | 6 | 3.37 | 3.5237 |
| 20 | 4 | 15 | 45 | 20 | 12 | 6.12 | 5.4702 |
| 21 | 4 | 15 | 45 | 20 | 9 | 4.88 | 5.0397 |
| 22 | 5 | 10 | 40 | 25 | 12 | 13.24 | 13.4784 |
| 23 | 3 | 10 | 50 | 25 | 12 | 3.28 | 3.3748 |
| 24 | 5 | 10 | 40 | 15 | 6 | 6.24 | 6.0262 |
| 25 | 5 | 15 | 45 | 20 | 9 | 6.55 | 7.1558 |
| 26 | 4 | 15 | 50 | 20 | 9 | 4.58 | 5.7602 |
| 27 | 3 | 20 | 40 | 25 | 12 | 8.78 | 9.3912 |
| 28 | 5 | 20 | 50 | 25 | 12 | 8.25 | 8.3123 |
| 29 | 3 | 10 | 40 | 15 | 12 | 3.72 | 3.8201 |
| 30 | 3 | 15 | 45 | 20 | 9 | 3.49 | 2.4747 |
| 31 | 4 | 15 | 45 | 25 | 9 | 8.94 | 7.3714 |
| 32 | 5 | 20 | 40 | 25 | 6 | 12.42 | 12.7173 |

Response surface regression analysis was performed and results of estimated regression coefficients of second-order polynomial model for optimizing fuel consumption are as shown in Table (4). Based on the results in Table (4), the second-order polynomial model equation for optimizing fuel consumption of a disk plow operating in loamy sand soil is as given in equation (1):

$$Y = 84.4618 + 0.4231X1 + 1.425X2 - 4.7652X3 + 1.051X4 + 0.6249X5 - 0.2236X1X1 - 0.0136X2X2 + 0.0674X3X3 + 0.0538X4X4 - 0.006X5X5 - 0.0107X1X2 + 0.0556X1X3 - 0.0129X1X4 + 0.1806X1X5 - 0.0225X2X3 + 0.0045X2X4 - 0.0075X2X5 - 0.0633X3X4 - 0.013X3X5 - 0.0190X4X5 \quad (1)$$

Where: X1 = plowing speed (km/h), X2 = plowing depth (cm), X3 = disk angle (°), X4 = tilt angle (°) and X5 = soil moisture content (%db). The significant second-order polynomial model equation at the 5% level for the optimization of fuel consumption of a disk plow operating in loamy sand soil is same as in Eq. (1).

Table 4. Estimated regression coefficients of second-order polynomial model for optimizing fuel consumption of a disk plow operating in loamy sand soil.

| Term | Regression coefficients | SE Coefficient | T | P |
|---|---|---|---|---|
| Constant | 84.4618 | 51.2966 | 1.647 | 0.128 |
| X1 | 0.4231 | 6.1363 | 0.069 | 0.946 |
| X2 | 1.4250 | 1.0053 | 1.418 | 0.184 |
| X3 | -4.7652 | 2.4715 | -1.928 | 0.08 |
| X4 | 1.0510 | 1.2273 | 0.856 | 0.41 |
| X5 | 0.6249 | 1.6755 | 0.373 | 0.716 |
| X1X1 | -0.2236 | 0.6784 | -0.330 | 0.748 |
| X2X2 | -0.0136 | 0.6784 | -0.499 | 0.627 |
| X3X3 | 0.0674 | 0.0271 | 2.486 | 0.03 |
| X4X4 | 0.0538 | 0.0271 | 1.982 | 0.073 |
| X5X5 | -0.0060 | 0.0271 | -0.08 | 0.938 |
| X1X2 | -0.0107 | 0.0754 | -0.201 | 0.844 |
| X1X3 | 0.0556 | 0.0532 | 1.044 | 0.319 |
| X1X4 | -0.0129 | 0.0532 | -0.243 | 0.813 |
| X1X5 | 0.1806 | 0.0532 | 2.036 | 0.067 |
| X2X3 | -0.0225 | 0.0887 | -2.111 | 0.058 |
| X2X4 | 0.0045 | 0.0106 | 0.424 | 0.68 |
| X2X5 | -0.0075 | 0.0177 | -0.425 | 0.679 |
| X3X4 | -0.0633 | 0.0106 | -5.951 | 0.000 |
| X3X5 | -0.0130 | 0.0177 | -0.732 | 0.48 |
| X4X5 | -0.0190 | 0.0177 | -1.072 | 0.306 |
| $R^2$ = 94.94% | | $R^2$ (adjusted) =85.79% | | |

SE = standard error, T = student test, P = probability.

By referring to Table (4), it was found that the linear factor of disk angle (X3) showed negative coefficient and similar result was seen by Ismail (2002), who reported that increasing disk angel decreased the draft requirements until the disk angle equal to 43° then the draft was increased. Meanwhile, linear factors of plowing speed (X1), plowing depth (X2), tilt angle (X4) and soil moisture content (X5) showed positive coefficients. Square factors such as disk angle (X3X3) and tilt angle (X4X4) showed positive coefficients. Meanwhile, square factors of plowing speed (X1X1), plowing depth (X2X2) and soil moisture content (X5X5) showed negative coefficients. Quadratic or interaction factors of plowing speed and disk angle (X1X3), plowing speed and soil moisture content (X1X5) and plowing depth and tilt angle (X2X4) showed positive coefficients. Meanwhile, interaction factors of plowing speed and plowing depth (X1X2), plowing speed and tilt angle (X1X4), plowing depth and disk angle (X2X3), plowing depth and soil moisture content (X2X5), disk angle and tilt angle (X3X4), disk angle and soil moisture content (X3X5) and tilt angle and soil moisture content (X4X5) showed negative coefficients.

Student T test was used to determine the significance of the estimated coefficients of the regression model equation (Eq.1). The student T test value can be obtained by dividing each coefficient by its standard error (Mullai *et al.*, 2010). However, P values were used as a tool to evaluate the significance and contribution of each factor (Thanapimmetha *et al.*, 2011). The present study showed that square factor (X3X3) and interaction factor (X3X4) terms were highly significant.

**Model validation**

The goodness of fit of the regression model was determined by coefficient of determination ($R^2$) which provides a measure of how much variability in the observed response values can be explained by the experimental factors and their interactions. Results in Table (4) showed that $R^2$ value was 94.96% which signified 94.96% of the variability in the observed response values could be explained by the model while only 5.04% of the variability in the observed response values cannot be explained by the model. The remaining $R^2$ value of 5.04% of the total variations may be attributed to other factors like skills of the operator (Leghari *et al.*, 2016) which were not included in the model. The adjusted $R^2$ was a corrected value for $R^2$ after the elimination of unnecessary model terms. The adjusted $R^2$ would be remarkably smaller than the $R^2$ if there were many non-significant terms have been included in the model (Fang *et al.*, 2010). In this study, it was found that the adjusted $R^2$ was 85.79%. The high adjusted $R^2$ value was attributed to the absence of non–significant terms in the model. The high adjusted $R^2$ and $R^2$ values thus, indicated a high dependence and correlation between the observed and predicted value responses.

ANOVA was performed to test for the significance and adequacy of the second-order polynomial model. The results are as summarized in Table (5). The significance of regression was evaluated by F and P values using Fischer's and null-hypothesis tests. The regression model found in this study was highly significant as denoted by the F and P values with 10.36 and 0.000, respectively. The square and quadratic factors were highly significant as denoted by F values of 7.75 and 4.72, respectively and P values of 0.002 and 0.009, respectively.

Lack of fit test was also performed. It describes the variation in the data around the fitted model (Noordin *et al.*, 2004). Patel *et al.* (2011) testified that insignificant lack of fit indicates a good model. However, insignificant lack of fit is desired as significant lack of fit indicates that there might be contributions in the regresses-response relationship that are not accounted for by the model. Principally, the lack of fit describes the variation in the data to the fitted model. In the case that the model does not fit the data sufficiently, the lack of fit will be significant. The F value for the lack of fit can be obtained by dividing the lack of fit mean square by its pure error mean square. Results of the lack of fit are shown in Table (5) and it was found that the F and P values for the lack of fit were 106.12 and 0.000, respectively. The significant P value thus indicates there might be contributions in the regresses-response relationship that are not accounted for by the model like cubic terms. In application of response surface methodology for optimization of picker-husker harvesting losses in corn seed, Pishgar-Komleh (2012) found that there was a significant difference ($P < 0.05$) lack of fit for obtained linear model, so in order to appraise the adequacy of the fitted model several indicators were used. Swain *et al.* (2014) found that the lack of fit was significant and $R^2$ values were low for modeling drying rate and drying efficiency, indicating that a high proportion of the variability was not explained by the data.

**Optimization analysis**

Response optimizer was performed and the result at optimum conditions for the lowest fuel consumption is shown in Fig. (2). Results of optimum conditions for the lowest fuel consumption obtained from response optimizer of MINITAB software Version 16 were occurred at plowing speed of 3.24 km/h, plowing depth of 10.03 cm, disk angle of 40°, tilt angle of 15° and soil moisture content of 6.06% db. The difference between the verification and predicted values of the fuel consumption was less than 5%, therefore, the optimum conditions for the fuel consumption predicted by MINITAB software Version 16 could be accepted. The surface plots for all pairs of investigated factors are illustrated in Fig. (3) and Fig. (4). As example, from Fig. (4), it is clear that the fuel consumption increased at increasing of plowing speed (X1) and plowing depth (X2). The positive effect of both the independent factors suggested higher fuel consumption at a higher level of these factors.

Table 5. ANOVA for optimization of fuel consumption of a disk plow operating in loamy sand soil.

| Source | DF | Squared SS | Adjusted SS | Adjusted MS | F | P |
|---|---|---|---|---|---|---|
| Regression | 20 | 234.581 | 234.581 | 11.72905 | 10.36 | 0.000 |
| Linear | 5 | 137.201 | 6.528 | 1.3056 | 1.15 | 0.39 |
| X1 | 1 | 98.614 | 0.005 | 0.005 | 0.00 | 0.946 |
| X2 | 1 | 0.076 | 2.275 | 2.275 | 2.01 | 0.184 |
| X3 | 1 | 16.777 | 4.21 | 4.21 | 3.72 | 0.08 |
| X4 | 1 | 17.492 | 0.83 | 0.83 | 0.73 | 0.41 |
| X5 | 1 | 4.242 | 0.158 | 0.158 | 0.14 | 0.716 |
| Square | 5 | 43.874 | 43.874 | 8.7748 | 7.75 | 0.002 |
| X1X1 | 1 | 23.957 | 0.123 | 0.123 | 0.11 | 0.748 |
| X2X2 | 1 | 3.039 | 0.283 | 0.283 | 0.25 | 0.627 |
| X3X3 | 1 | 12.26 | 6.996 | 6.996 | 6.18 | 0.03 |
| X4X4 | 1 | 4.61 | 4.447 | 4.447 | 3.93 | 0.073 |
| X5X5 | 1 | 0.007 | 0.007 | 0.007 | 0.01 | 0.938 |
| Interaction | 10 | 53.506 | 53.506 | 5.3506 | 4.72 | 0.009 |
| X1X2 | 1 | 0.046 | 0.046 | 0.046 | 0.04 | 0.844 |
| X1X3 | 1 | 1.235 | 1.235 | 1.235 | 1.09 | 0.319 |
| X1X4 | 1 | 0.067 | 0.067 | 0.067 | 0.06 | 0.813 |
| X1X5 | 1 | 4.695 | 4.695 | 4.695 | 4.15 | 0.067 |
| X2X3 | 1 | 5.047 | 5.047 | 5.047 | 4.46 | 0.058 |
| X2X4 | 1 | 0.203 | 0.203 | 0.203 | 0.18 | 0.68 |
| X2X5 | 1 | 0.205 | 0.205 | 0.205 | 0.18 | 0.679 |
| X3X4 | 1 | 40.1 | 40.1 | 40.1 | 35.41 | 0.000 |
| X3X5 | 1 | 0.606 | 0.606 | 0.606 | 0.51 | 0.48 |
| X4X5 | 1 | 1.302 | 1.302 | 1.302 | 1.15 | 0.306 |
| Residual Error | 11 | 12.457 | 12.457 | 1.132455 | | |
| Lack of fit | 6 | 12.360 | 12.36 | 2.06 | 106.12 | 0.000 |
| Pure error | 5 | 0.097 | 0.097 | 0.0194 | | |
| Total | 31 | 247.038 | | | | |

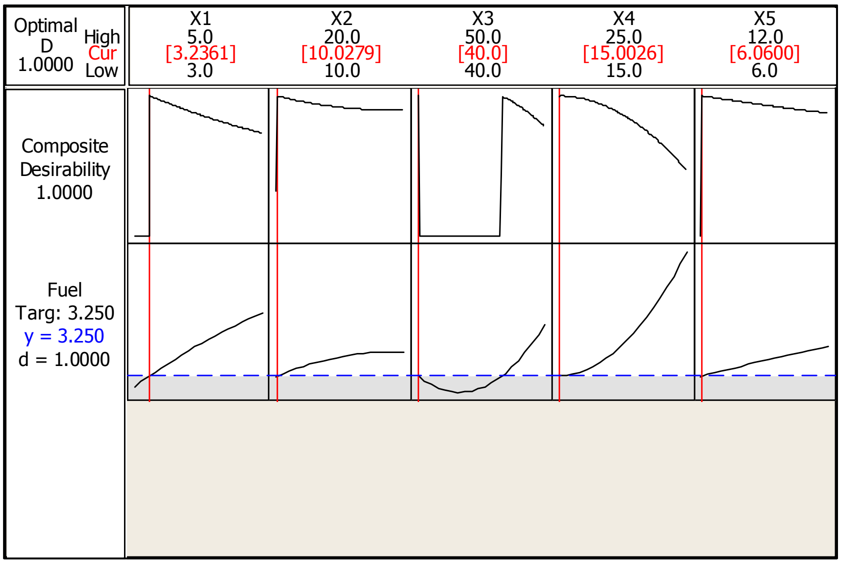


Fig. 2. Response optimizer at optimum conditions for lower fuel consumption.

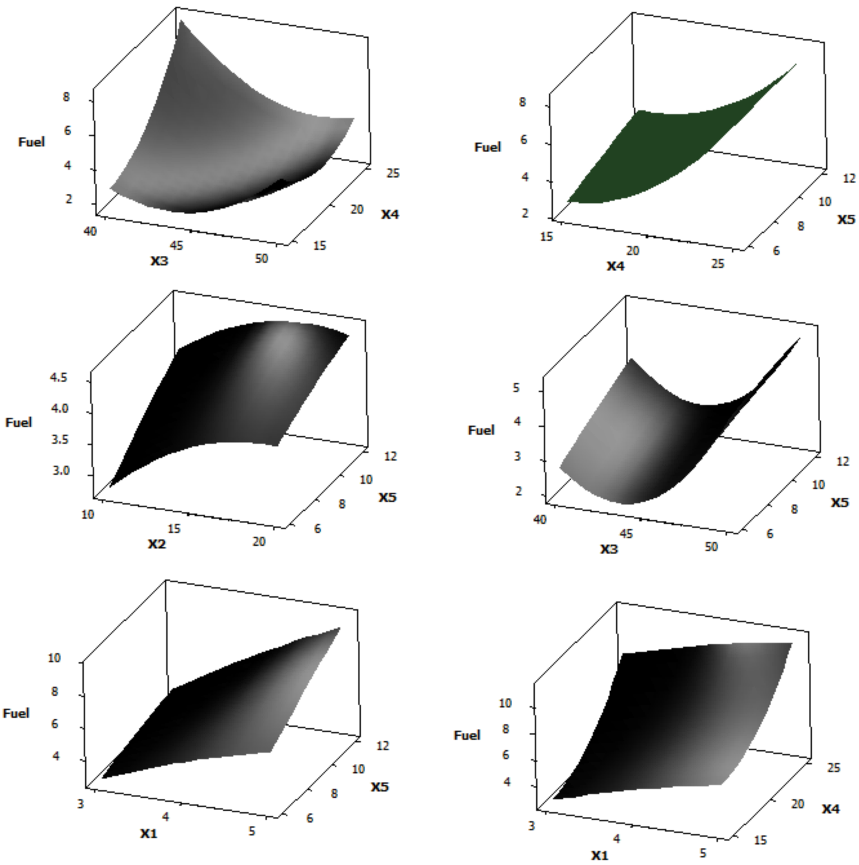


Fig. 3. The surface plots for two pairs of investigated factors (X1, X5;X1,X4;X2,X5;X3,X5;X3,X4; X4,X5): Fuel in lit/h.

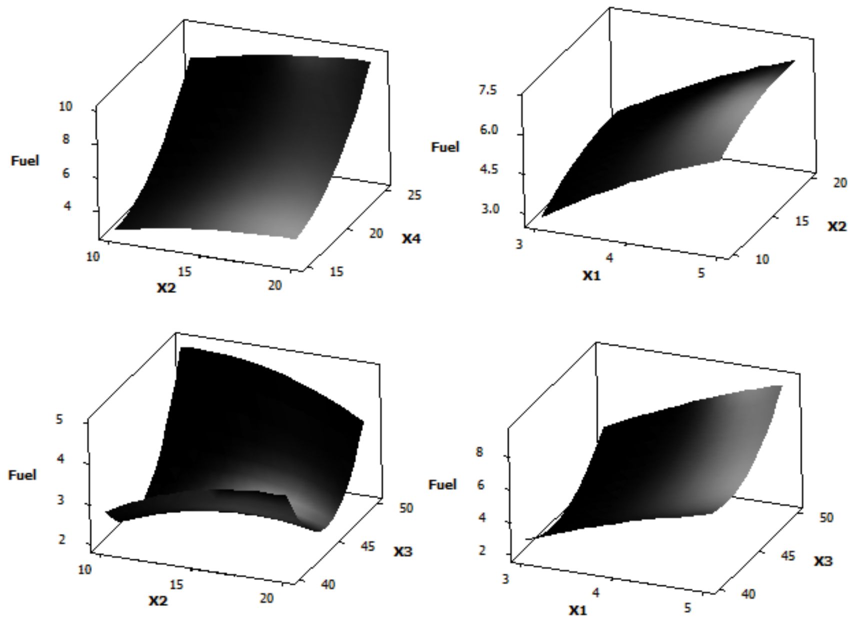

Fig. 4. The surface plots for two pairs of investigated factors (X2, X4; X2, X3; X1, X3; X1, X2): Fuel in lit/h.

## CONCLUSION

The coefficient of determination ($R^2$) of 94.96% was high, thus the experimental data was acceptable. Optimum conditions for the lowest fuel consumption of a disk plow operating in loamy sand soil using response surface methodology had been determined. It was found that lower fuel consumption could be optimized to be 3.25 lit/h at the optimum conditions at plowing speed of 3.24 km/h, plowing depth of 10.03 cm, disk angle of 40°, tilt angle of 15° and soil moisture content of 6.06% db. It was also found that the difference between the actual and predicted values of the fuel consumption was less than 5%, therefore, the optimum conditions for the fuel consumption predicted by MINITAB Software Version 16 could be accepted.

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# تطبيق طريقة استجابة السطح لأمثلة استهلاك الوقود لمحراث قلاب قرصي في تربة لومية رملية

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يعتبر المحراث القرص أداة فعالة تستخدم لقطع التربة في عمليات الحرث الابتدائي. كما تستهلك عملية الحرث كميات وقود كثيرة في عمليات الإنتاج الزراعي، وبالتالي فإن إدارة التشغيل الحقلي وتقنيات الإدارة الحديثة لمعدات الحرث يساهما في تقليل استهلاك الوقود. وكان الهدف من هذه الدراسة هو تحديد الظروف المثلي لأقل إستهلاك وقود لمحراث قلاب قرصي يعمل في تربة لومية رملية للمتغيرات المتفاعله المؤثره فيه مثل زاوية القرص، زاوية ميل القرص، سرعة الحرث وعمق الحرث ونسبة الرطوبة في التربة والحصول على أنسب التفاعلات لهذه المتغيرات التي تساهم في تقليل استهلاك الوقود أثناء عملية الحرث من خلال تطبيق طريقة استجابة السطح. في البداية تم الحصول على استهلاك الوقود من التجارب الحقلية بناءًا على التصميم الاحصائي المقترح والموصى به من خلال برنامج MINITAB الإصدار 16، ومن النتائج اتضح أن معامل التحديد $R^2$ لنموذج استهلاك الوقود بناء على المتغيرات المدروسة كان 94.96 %، مما يعني أن البيانات التجريبية مقبولة. من المعادلة المستنبطة وجد أن أقل استهلاك الوقود كان 3.25 لتر/ساعة ويمكن أن يتم الحصول عليه عندما تكون سرعة الحرث 3.24 كم/ساعة، وعمق الحرث 10.03 سم، وزاوية القرص 40°، وزاوية الميل للقرص 15° والمحتوى الرطوبي للتربة 6.06% على أساس جاف. وحيث أن الفرق بين القيم الصغرى الفعلية لاستهلاك الوقود والقيم الصغرى لاستهلاك الوقود المتوقعه عند الظروف المثلى أقل من 5%، لذا يمكن استخدام النموذج المطور لتقدير استهلاك الوقود لمحراث قلاب قرصي يعمل في تربة لومية رملية ضمن حدود متغيرات التجربة.