The Optimization of Multiple Responses of Watermelon to Organic Manure Using Response Surface Methodology

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ABSTRACT

This paper discusses the use of Central Composite Design approach to plan the experiments for growth and yield of watermelon with an overall objective of optimizes the multiple responses of watermelon to organic manure. Response Surface methodology (RSM) has been adopted to express the output parameters (responses) that are decided by the input process parameters. Poultry manure, cow manure and goat manure were the independent variables to optimize the response values of interest that includes; watermelon fruit weight, number of branches and vine length per plant. The predicted values were found to be in good agreement with the experimental values which define the propriety of the models and the achievement of CCD in the optimization of multiple responses of watermelon. The results of the study found that the optimal values of responses were 93.148 ton/Ha of fruit weight of watermelon in the study area, 8 branches of watermelon plant and vine length of 224 cm at 8weeks.Based on the findings of the study, it was recommended that farmers in the study area apply 17.125 tons/Ha of poultry manure, 13.27 tons/Ha of cow manure and 18.08 tons/Ha of goat manure for increased growth and yield of watermelon. Finally, this study represented the development of mathematical models for crop production based on statistics that can be useful for predicting and understanding the effects of experimental factors. Also, it would be a scientific and economic approach to obtain the maximum amount of information in a short period of time and with the lowest number of experiments.

Key Words: Central Composite Design; Response Surface Methodology; Optimization; Watermelon; Fruit Weight; Organic Manure; Model; Growth

1.0 INTRODUCTION

Watermelon *(Citrulluslanatus thumb)* is a member of the cucurbitaceous family. According to Jarret [7], it originated from the Kalahari and Sahara deserts in Africa. In Kenya, the crop is mainly grown in lower and dry Semi-arid areas of the Country, namely Nyanza, Central, Eastern, Coast and Rift valley regions. Watermelon is a crop with huge economic importance to man as well as highly nutritious, sweet and thirst quenching, Mangila et al., [10]. It is mostly used to make a variety of salads, juice and food flavor. It is a cash crop for farmers due to its high returns on investment. Watermelon contains Vitamin C and A in a form of disease-fighting beta-carotene. In spite of the increasing relevance of watermelon in Kenya, yields across the country are decreasing and not encouraging because of rapid reduction in soil fertility caused by both continuous cropping and use of inappropriate soil amendment materials. One of the ways of increasing the soil fertility is by application of organic material such as poultry manure, cow manure, and goat manure which are available in most parts of the country. Animal waste is essential for establishing and maintaining the optimum soil physical, chemical and biological condition that are appropriate for plant growth and development. Although readily available, utilization of these organic manures in watermelons has not been optimized for increased plant growth and fruit production.

Response surface methodology (RSM) is an important subject in the statistical design of experiment. RSM is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes, Myers, [15]. It also has important applications in the design, development and formulation of new products, as well as in the improvement of existing product designs. For instance, the growth of a plant is affected by a certain amount of water x_1 and sunshine x_2. The plant can grow under any combination of treatment x_1 and x_2. Therefore, water and sunshine can vary continuously and obtain an optimal combination. When treatments are from a continuous range of values, then a response surface methodology is useful for developing, improving and optimizing the response variable. In this case, the growth of a plant is the response variable, *y* and it is a function of water and sunshine.

$$y= f(x_1, x_2) + e \quad (1)$$

The variable x_1, and x_2 are predictor variables upon which the response *y* depends on. The dependent variable *y* is a function of x_1, x_2 and the experimental error term, denoted by *e*. The error term represents any measurement error on the response, as well as other type of variations not counted in the function. It is a statistical error that is assumed to be distributed normally with zero mean and variance. In most RSM problems, the true response function *f* is unknown. In order to develop a proper approximation for function the experimentation usually starts with a lower order polynomial in some small region. If the response can be defined by a linear function of an independent variable, then the approximation function is a first order model. This model can be expressed as follows

$$y= \alpha_0+ \alpha_1x_1+ \alpha_2x_2+ e \quad (2)$$

If there is a curvature in the response surface, then a higher degree polynomial should be used. In this, an approximating function with two variables is known as second order model given as follows.

$$y= \alpha_0+ \alpha_1x_1+ \alpha_2x_2+ \alpha_{11}x^2_1 + \alpha_{22}x^2_2+ \alpha_{12}x_1x_2+e \quad (3)$$

In order to get the most efficient result in the approximation of empirical model the proper experimental design must be used to collect data. The data is then used to develop an empirical model that relates the process response to the factors. The Method of Least Square is used to estimate the parameters in the empirical model, Box & Hunter, [1]. The response surface analysis is performed by using the fitted surface. The response surface designs are types of designs for fitting response surface. These methods are exclusively used to examine the “surface” or the relationship between the response and the factors affecting the response. Regression models are used for the analysis of the response as well as the nature of the relationship between the response and the factors. Details of experimental designs for fitting response surfaces are found in, Montgomery, [12] and Khuri, [9].

In many fields such as Biological and Clinical Science, Agricultural sciences and the process industries, a response of interest is usually influenced by several variables and the objective is to optimize the value of the response. Response surface methodology has been applied in such fields, but not much application of the same has been done in Agriculture. In order to increase crop production, there is need to increase soil nutrient content with application of organic manure such as poultry manure, cow manure or other animal wastes. Presently, there are no optimization standards with respect to the application rate of poultry manure, cow manure and goat manure for enhancement of yield of watermelon in Kenya. The challenge is to determine the optimal level that guaranteed optimal returns on investment. The purpose of the experiment was to obtain the optimal application levels of poultry, cow and goat manure and the optimal value of responses on watermelon crop.

The main objective of the study was to optimize the multiple responses of watermelon to organic manure using Central Composite Design and Response Surface Methodology (RSM).The study was guided by the following specific objectives;

i. To use Central Composite Design in establishing the effect of organic manure on growth and yield of watermelon
ii. To fit an appropriate second-order models with the best fittings
iii. To find the optimal set of experimental parameters that produces a maximum value of response

2.0 MATERIALS AND METHODS

2.1 Materials

Sukari F1 watermelon a newly developed variety from East Africa Seed Company was used in the study. Similarly, poultry, goat and cow manure used for the experiment was sourced from Chuka University Agricultural farm and from local community. Data was obtained from an experiment carried out at horticultural research and teaching farm of Chuka University, Kenya. A land measuring 448 meters squared (28 M by16 M) was selected for the study and prepared for planting. Twenty plots of 4M by3M each was made and composite samples collected from the plots at 0-15 cm depth in order to assess the initial physical-chemical properties of the soil. The composite soil samples collected from individual plots was analyzed in the laboratory to determine initial physical-chemical properties of soils for the study. Similarly, the chemical analysis of poultry, goat and cow manure used for the experiment was evaluated using appropriate method. Each plot had 3 seeds per stand at a depth of 3cm, using a spacing of 200cm by 100cm, with 100cm Alley pathways. Data on watermelon fruit weight at maturity, number of branches and vine length per plant were collected.

2.2 Response Surface Methodology

Response surface methodology is a collection of statistical and mathematical techniques that are useful for the modeling and analysis of problems in which a response of interest is influenced by several (three) variables and the objective is to optimize this response, Montgomery, [13]. The RSM enables to evaluate operation variable that may or may not have a significant effect in the main response. The design procedure of RSM is as follows;

i. Develop an original design of experiment for adequate and reliable measure of the response of interest (Fruit weight of watermelon at maturity, number of branches and vine length per plant)
ii. Develop a statistical model of the second-order model with best fittings
iii. Find the optimal set of experimental parameters, that produces a maximum value of response
iv. Present the direct and interactive effect of process parameter through two and three-dimensional plots

Response Surface Methodology design allows estimation of interaction and even quadratic effect and therefore, gives an idea of the shape of the response surface under investigation. Box-Behnken design and CCD are an effective design for a fitting second-order model to response surface because they use a relatively small number of observations to estimate the parameters. Rotatability is a reasonable basis for the selection of a response surface design. The purpose of RSM is optimization and the location of optimum is unknown prior to running the experiment. It makes sense to use a design that provides an equal precision of estimation in all directions. The CCD and RSM is a mathematical tool for evaluating the responses necessary to optimize watermelon yields.

2.3 Design of Experiment

The experiment was carried out as a CCD consisting of 20 experimental runs determined by the $\mathbf{2^3}$ full factorial designs with six axial points and six center points as shown in Figure 1.

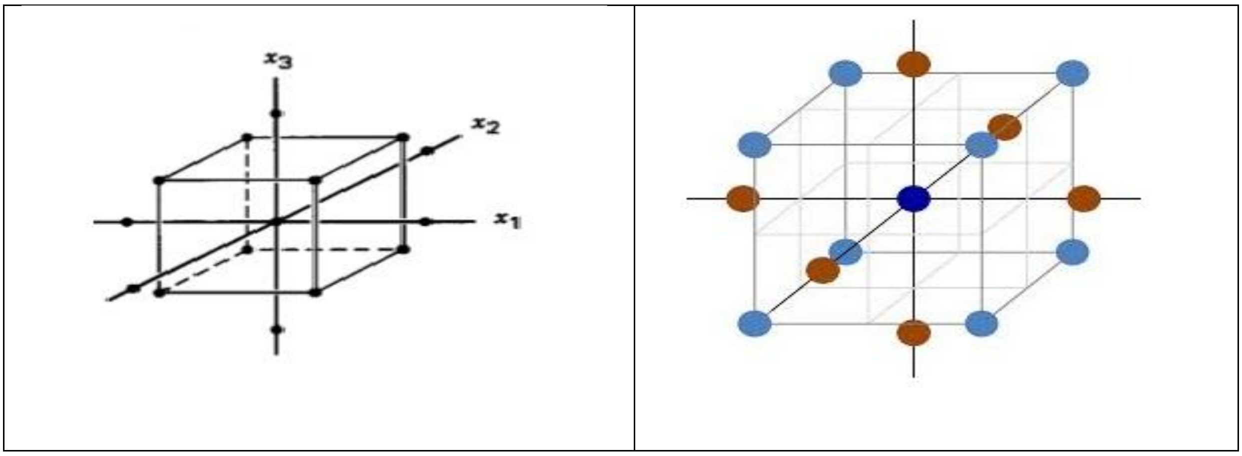

Figure 1: Layout of the Central Composite Design (CCD) for 3 variables at 5 levels

In this study, Central Composite Design was used for experimental design model with 5-level- 3 factors experiment. A 5-level-3-factor central composite design was employed in watermelon crop experiment where optimization required 20 experimental runs. Poultry manure (X_1), cow manure (X_2) and goat manure (X_3) were the independent variables to optimize the response values of interest (Fruit weight of watermelon at maturity, number of branches and vine length per plant). In developing the regression model, the test factors were coded according to the formulae given as $x_i = \frac{X_i - X_0}{X}$ where x_i is a coded variable of the i^{th} variable, X_0 is an average of the variable in high and low level, X is (variable at high level- variable at low level)/2 and X_i is an encoded value of the i^{th} test variables. Analysis of data was done using R- Program and Design Expert version 10

Table 1: Three Factors at Five Levels Estimated Values

Symbols	Predictor Variable	Code Levels				
		-1.682	-1	0	+1	+1.682
X_1	Poultry manure (Tons/Ha)	1.6	5	10	15	19.4
X_2	Cow manure (Tons/Ha)	1.6	5	10	15	19.4
X_3	Goat manure (Tons/Ha)	1.6	5	10	15	19.4

Table 2: Full Factorial Central Composite Design Matrix and Experimental Results

	Coded values			Fruit Weight (Tons/Ha)		Number of Branches		Vine Length (cm)	
Runs	X_1	X_2	X_3	EXPV	PREDV	EXPV	PREDV	EXPV	PREDV
1	-1.682	0	0	51.6	50.2	5	5	170.5	168.1
2	-1	1	1	54.0	56.7	6	7	176.0	180.6
3	-1	-1	1	46.0	49.2	3	4	169.2	167.2
4	-1	-1	-1	50.0	52.7	5	5	169.0	167.9
5	-1	1	-1	46.0	45.2	4	5	165.4	165.6
6	0	0	0	60.8	60.6	6	6	180.2	181.2
7	0	0	-1.682	50.0	50.0	5	5	168.6	167.1
8	0	0	0	68.0	60.6	7	6	190.6	181.2
9	0	1.682	0	58.0	50.8	6	5	178.9	177.2
10	0	0	0	56.0	60.6	6	6	174.9	181.2
11	0	0	1.682	76.0	71.2	7	7	200.9	195.3
12	0	0	0	56.0	60.6	6	6	175.8	181.2
13	0	0	0	58.0	60.6	6	6	179.6	181.2
14	0	-1.682	0	48.0	50.8	5	5	169.2	167.8
15	0	0	0	64.0	60.6	6	6	185.7	181.2
16	1	1	-1	48.0	49.0	4	4	172.9	171.6
17	1	-1	1	66.0	70.1	7	7	188.4	192.5
18	1	1	1	76.0	77.6	7	8	208.1	205.9
19	1	-1	-1	56.0	56.5	6	7	174.1	173.8
20	1.682	0	0	72.0	71.0	7	7	195.9	194.4

***EXPV=Experimental Value** ***PREDV= Predicted Value**

2.4 Mathematical Models

The second- order model representing the watermelon fruit weight at maturity, number of branches and vine length per plant each were expressed as a function of poultry manure, cow manure and goat manure being in the input variable of watermelon response. To define the response equation, X_1, X_2 and $X_3$are assigned to poultry manure, cow manure and goat manure respectively. An appropriate polynomial (second-order) models were expressed as;

$$Y_1 = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_{11} X_1^2 + \alpha_{22} X_2^2 + \alpha_{33} X_3^2 + \alpha_{12} X_1 X_2 + \alpha_{13} X_1 X_3 + \alpha_{23} X_2 X_3 + e \quad (5)$$

$$Y_2 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + e \quad (6)$$

$$Y_3 = \delta_0 + \delta_1 X_1 + \delta_2 X_2 + \delta_3 X_3 + \delta_{11} X_1^2 + \delta_{22} X_2^2 + \delta_{33} X_3^2 + \delta_{12} X_1 X_2 + \delta_{13} X_1 X_3 + \delta_{23} X_2 X_3 + e \quad (7)$$

Where Y_i ; (i=1,2,3) is the i^{th} predicted response (1= for Fruit weight of watermelon at maturity, 2= for Number of branches per plant and 3= for Vine length at 8 weeks), X_i represent the control factors in the experimental data,α_0,β_0 and $\delta_0$the constant, α_i,β_i and δ_i the linear coefficient, α_{ii},β_{ii} and δ_{ii} are the quadratic coefficient and α_{ij} ,β_{ij} and δ_{ij} the cross-product coefficient (For *i=1,2,3; j=2,3 and i<j).* **Note** that equation (5), (6) and (7) will be referred as Model 1, 2 and 3 respectively in the subsequence discussion.

3.0 RESULTS AND DISCUSSION

3.1 Models Summary Statistics

The researcher sought to evaluate the component of the second order models in order to assess their suitability and the results are portrayed in Table 3

Table 3: Model Summary Statistics

Statistics	Model 1	Model 2	Model 3
R-Squared	0.9337	0.959034	0.956697
Adjusted R-Squared	0.8591	0.912947	0.907981
Predicted R-Squared	0.5489	0.764972	0.790799

Model summary statistics focus on the model maximizing the Adjusted R-Squared and the Predicted R-Squared. R-Squared refer to a measure of proportion of the variation in the dependent variable that is explained by the independent variable for a regression model. Adjusted R-Squared it is used to adjust the statistic based on the number of independent variable in the model. It compares the explanatory power of regression model that contain different independent predictors. In this case, since the multiple regression models have more than one variable, Adjusted R-Squared is the most preferred. The study found that quadratic models were suggested for the data fitting with an Adjusted R-Squared value of 85.91%, 91.3% and 90.8% for model 1, model 2 and model 3 respectively. For instance, Model 1 explains about 85.9% of the variability in the response variable. The adjusted R-squared is often used to summarize the fit as it takes into account the number of variables in the model.

3.2 Mathematical Model

The data obtained from the experiment were analyzed to develop mathematical models. The multiple regressions were obtained by employing a least square technique to predict quadratic polynomial model for the fruit weight, number of branches and vine length of watermelon and pertinent results are presented in Table 4

Table 4: Regression Coefficients Estimates

	Model 1				Model 2				Model 3			
Variable	**Estimate**	**SE**	**t-Value**	**P-value**	**Estimate**	**SE**	**t-Value**	**P-value**	**Estimate**	**SE**	**t-Value**	**P-value**
Constant	15.14838	0. 46321	32.703	1.69e-11 ***	6.1848	0.2139	28.921	5.69e-11 ***	181.2218	1.9721	91.893	5.70e-16 ***
X_1	1.54326	0.30731	5.022	0.00052 ***	0.6856	0.1419	4.832	0.000689 ***	7.8065	1.3084	5.967	0.000138 ***
X_2	0.41770	0.30731	1.359	0.20395	0.1231	0.1419	0.868	0.405743	2.7833	1.3084	2.127	0.059286
X_3	1.56923	0.30731	5.106	0.00046 ***	0.5392	0.1419	3.800	0.003485 **	8.3926	1.3084	6.415	7.69e-05 ***
X_1^2	-0.09017	0.29912	-0.301	0.76924	-0.1777	0.1381	-1.287	0.227124	0.1502	1.2735	0.118	0.908443
X_2^2	-0.86780	0.29912	-2.901	0.01580 *	-0.3544	0.1381	-2.567	0.028050 *	-3.0840	1.2735	-2.422	0.035956 *
X_3^2	0.01587	0.29912	0.053	0.95874	-0.1777	0.1381	-1.287	0.227124	0.6981	1.2735	0.548	0.595603
X_1X_2	-0.06250	0.40154	-0.156	0.87941	-0.5000	0.1854	-2.697	0.022423 *	1.9125	1.7095	1.119	0.289412
X_1X_3	1.06250	0.40154	2.646	0.02448 *	0.5000	0.1854	2.697	0.022423 *	4.8375	1.7095	2.830	0.017861 *
X_2X_3	0.93750	0.40154	2.335	0.04171 *	0.7500	0.1854	4.046	0.002340 **	3.9125	1.7095	2.289	0.045119 *

$$Y_1 = 15.148 + 1.543X_1 + 0.418X_2 + 1.569X_3 - 0.868X_2^2 + 1.063X_1X_3 + 0.938X_2X_3 \quad \text{Model 1}$$

$$Y_2 = 6.1848 + 0.6856X_1 + 0.1231X_2 + 0.5392X_3 - 0.3544{X_2}^2 - 0.500X_1X_2 + 0.500X_1X_3 + 0750X_2X_3 \quad \text{Model 2}$$

$$Y_3 = 181.2218 + 7.8065X_1 + 2.7833X_2 + 8.3926X_3 - 3.084X_2^2 + 4.8375X_1X_3 + 3.9125X_2X_3 \quad \text{Model 3}$$

Where Y_i;*(i=1,2,3)* represent the fruit weight, Number of branches and vine length of watermelon plant respectively

$X_{1,}$ is the poultry manure

$X_{2,}$is the cow manure

X_3 is the goat manure

These are coded equations, useful for identifying the relative impact of the factors by comparing the factor coefficients.

Organic manure (especially poultry manure) is most important parameter affecting growth and production of watermelon, Enujeke, [5]. In order to study the interaction factors (combine effect of poultry, cow and goat manure) experiment were conducted varying physical parameter using CCD. A multiple regression data analysis was carried out with “R-Gui” statistical package. The study found that poultry and goat manure had positive significant effect on fruit weight of watermelon at P-value=0.00052<0.05 and 0.00046<0.05 respectively). In addition, it was observed that goat manure was slightly superior in terms of its effect on fruit weight of watermelon. In the findings, one unit change of goat or poultry manure influenced the fruit weight by a factor of 1.57 and 1.54 respectively. However, cow manure had insignificant effect on the fruit weight of watermelon at 5% level (P-value=0.204>0.05). The study found that combined poultry and goat manure had a significant effect on the fruit weight of watermelon at P-value less than 0.05. Poultry manure is the richest known animal manure (Enujeke et al., [4] and Mangila et al., [10], and it is essential for establishing and maintaining the optimum soil physical condition for plant growth and production. In this study, combining cow and goat manure had a significant effect on watermelon production. The results indicates that a one unit change in combined poultry and goat manure, led to change in watermelon fruit weight by a factor of 1.0625 whereas combining cow and goat manure changed the same by a factor of 0.9375. This implies that combined poultry and cow manure would be more superior compared to combine cow and goat manure in influencing the fruit weight of watermelon. The adjusted model obtained for watermelon production as a function of the significant variables is indicated in Model 1.

The regression coefficient estimates shows that for one unit change in poultry manure and goat manure, number of branches of watermelon would increase by a factor of 0.6856 and 0.5392 respectively. This implies that poultry manure is slightly more effective than goat manure on growth (number) of branches of watermelon plant. In addition, it was found that combined application of poultry and goat manure had a regression coefficient value of 0.5 and a P-value of 0.022423<0.05, hence statistically significant at 5% significance level. This implies that for one unit change in combine poultry and goat manure (X_1X_3), growth of branches (in number) of watermelon plant would increase by a factor of 0.5. Moreover, it was observed that quadratic terms were not statistically significant except goat manure where the parameter estimate was -0.3544 with a P-value of 0.028<0.05. The results indicate that for one unit increase of quadratic term goat manure, growth of watermelon would be negatively affected by a factor of 0.3544. The predicted model for number of branches of watermelon plant in terms of coded factors is as shown in Model 2.

The study found that goat and poultry manure were statistically significant at 5% significance level with a P-value of 0.00008<0.05 and 0.00014<0.05 respectively. The regression coefficient estimates shows that for one unit change in goat manure and poultry manure, vine length of watermelon would increase by a factor of 8.3926 and 7.8065 respectively. This implies that goat manure is slightly more effective than poultry manure on growth of watermelon plant. In addition, it was found that combined application of poultry and goat manure had a regression coefficient value of 4.8375 and a P-value of 0.018<0.05, hence statistically significant at 5% significance level. This implies that for one unit change in combined poultry and goat manure (X_1X_3), growth of watermelon plant (vine length) would increase by a factor of 4.84.

Similarly, it was noted that quadratic terms were not statistically significant except goat manure where the parameter estimate was -3.0840 with a P-value of 0.035956 <0.05. The results indicate that for one unit increase of quadratic term of goat manure, growth of watermelon would be negatively affected by a factor of 3.0840. The adjusted model obtained for watermelon growth (vine length) as a function of the significant variables is given in Model 3.

3.3 Analysis of Variance

Analysis of variance (ANOVA) was used to check the adequacy of the model for the response (fruit weight, Number of Branches and Vine Length) of watermelon in the experimentation at 95% confidence level and the result are as shown in Table 5.

Table 5: Analysis of Variance

Source	DF	SS	MSS	F	F-critical	Pr(>F)
Model 1	9	95.647	10.627	8.239	3.0204	0.00141
Residuals	10	12.899	1.290			
Total	19	108.546				
Model 2	9	21.4480	2.3831	8.6690	3.0204	0.00114
Residuals	10	2.7493	0.2749			
Total	19	24.1973				
Model 3	9	2392.47	265.83	11.37	3.0204	0.00036
Residuals	10	233.80	23.38			
Total	19	2626.27				

$F(9,10,0.95)=3.0204$

ANOVA results revealed that the predicted response models were statistically significant since F-Value were 8.239>3.02038, 8.669> 3.02038 and 11.37>3.02038 (critical value) and p-value of 0.00141<0.05, 0.001143<0.05 and 0.00036<0.05 respectively. The suggested regression model is statistically significant in the prediction of fruit weight, number of branches and vine length of watermelon as a measure of growth and production of watermelon plant in the study area. From Table 5, it is observed that the model1, model 2 and model 3 satisfy the adequacy conditions in non-linear form. In general, the overall models are adequate for prediction purpose in this study.

3.5 Determination of the Optimum Values

The aim of the study was to find the optimal set of experimental parameters that produces maximum values of response (fruit weight, number of branches and vine length) of watermelon. The best solution satisfying the above criteria was obtained using "Design Expert" software as portrayed in Table 6.

Table 6: Optimum Values of the process parameters for Growth and yield of watermelon

Model 1			
Variables	**Description**	**Optimal Value**	**Actual Value**
X_1	Poultry Manure	1.425	17.125 tons/Ha
X_2	Cow Manure	0.654	13.27 tons/Ha
X_3	Goat Manure	1.615	18.075 tons/Ha
Y_1	Fruit Weight	23.287	93.148 tons/Ha
Model 2			
Variables	**Description**	**Optimal Value**	**Actual Value**
X_1	Poultry Manure	0.935	14.675tons/Ha
X_2	Cow Manure	0.700	13.5tons/Ha
X_3	Goat Manure	1.553	17.765tons/Ha
Y_2	No. of branches	8.407	8 Branches/Plant

Model 3			
Variables	**Description**	**Optimal Value**	**Actual Value**
X_1	Poultry Manure	1.510	17.55 tons/Ha
X_2	Cow Manure	0.704	13.52 tons/Ha
X_3	Goat Manure	1.673	18.37 tons/Ha
Y_3	Vine length (cm)	223.743	223.743cm

The optimum values of selected variables were obtained by solving the regression models and also analyzing the response surface contour plots. It was found that for maximum (optimal) production of water melon fruit weight,17.125 tons/Ha of poultry manure, 13.27 tons/Ha of cow manure and 18.08 tons/Ha of goat manure are required to produce 93.148 ton/Ha of fruit weight of watermelon in the study area. This translates to 37.26 tons per acre piece of land of watermelon fruit weight for a period of 75 -85 days after sowing. This study indicates that, a peasant farmer can generate about 745,184 Kenya shillings within a period of 85 day in one acre piece of land. The price of watermelon ranges from 20 to 40 Kenya shillings per kilogram of watermelon. In this study, the number of branches of watermelon plant was predicted to be 8.407≈8.This suggest that to achieve maximum value of response (8 branches of watermelon plant), about 14.7 tons/Ha, 13.5 tons/Ha and 17.8 tons/Ha of poultry, cow and goat manure respectively are required. This is optimal conditions for maximum number of branches of watermelon plant. The optimum values of selected variables were obtained by solving the regression model and also analyzing the response surface contour plots. It was found that for a maximum (optimal) growth of vine length of watermelon plant, about 17.6tons/Ha of poultry manure, 13.5tons/Ha of cow manure and 18.4tons/Ha of goat manure are required to produce vine length of 224 cm.

3.6 Effect Estimates of Organic Manure on Growth and Production of Watermelon

3.6.1 Effect Estimates of Organic Manure on Fruit Weight of Watermelon

The study sought to establish and understand the effect of main and interactive effect of organic manure on fruit weight of watermelon crop and the effect estimates are as shown in Figure 2

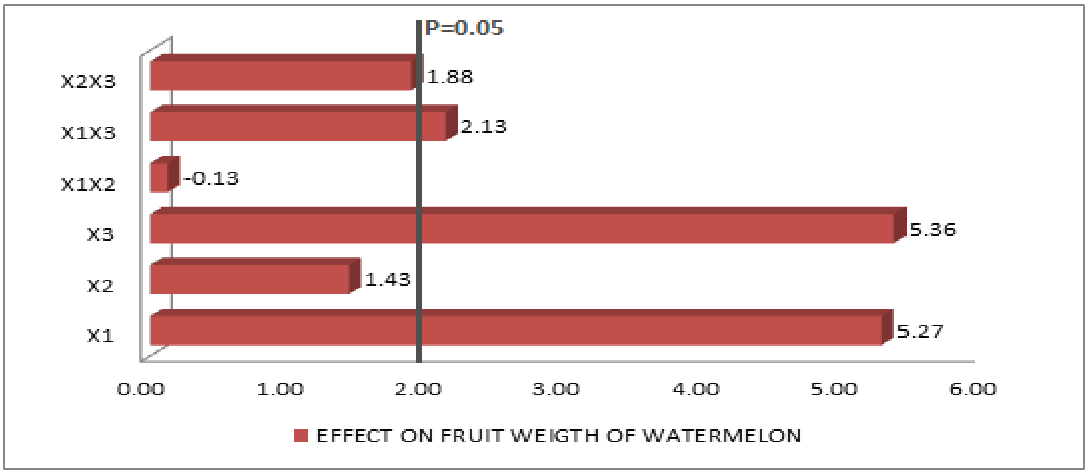

Figure 2: Standardized Effect of Organic manure on Fruit Weight of Watermelon

As indicated in Figure 2, goat manure (X_3) and poultry manure (X_1) were the most significant variables for fruit weight of watermelon (effect of X_3=5.36 and effect of X_1=5.27, followed by their interaction poultry and goat manure (effect of X_1 X_3=2.13) , as well as cow manure (X_2) and goat manure (X_3) (effect of X_2 X_3=1.88). In the presence of an interactive effect, the variable cannot be analyzed separately, therefore the application of statistical method reveals the interactions (X_1 X_3 and X_2 X_3) were significant at 5% significance level. However, interaction of poultry and cow manure (X_1 X_2) had negative effect (effect of X_1 X_2=-0.13) and was insignificant at 95% confidence level. In general it was observed that main effects (where poultry, cow or goat manure were applied alone) were more influential on fruit weight of watermelon crop. Plant that received adequate amount of poultry or goat manure had higher fruit weight possibly because higher rate of manure not only improve the soil conditions for crop establishment, but also released adequate nutrient element for yield enhancement. This is in harmony with reports of Enujeke, [5] and Mangila, [10] who found that 20 tonnes per hectare of poultry manure account for an average of 1300 tonnes of watermelon fruit per hectare.

3.6.2 Effect Estimates of Organic Manure on Number of Branches per Plant

The study sought to establish the significant of linear and interactive effect of independent variables on number of branches of watermelon plant and result are provided in Figure 3.

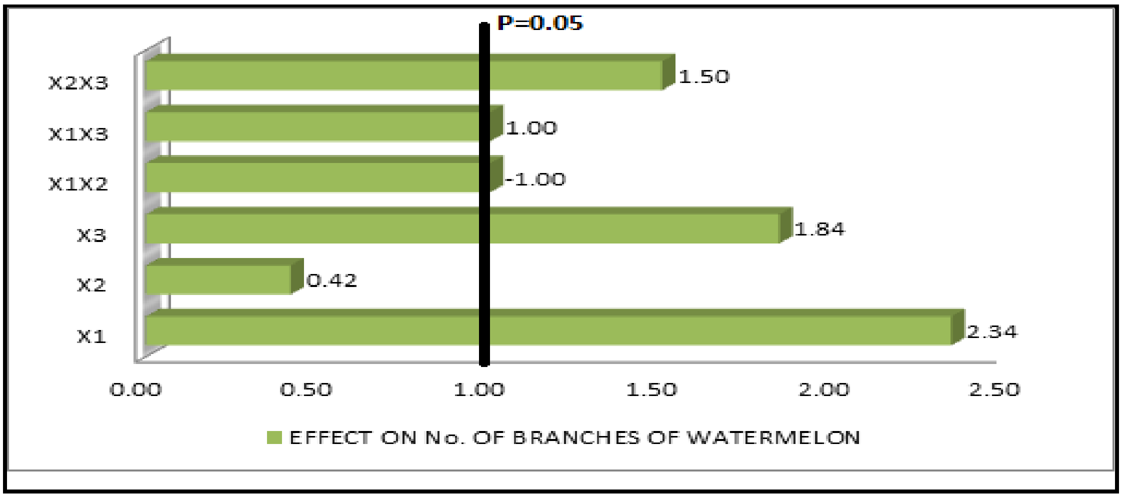

Figure 3: Standardized Effect of organic manure on No. of Branches of Watermelon

As shown in Figure 3, it was observed that poultry manure (X_1) significantly affected the growth of watermelon plants (effect of X_1=2.34), followed by goat manure (X_3) (effect of X_3 =1.84), as well as interaction cow and goat manure (effect of X_2 X_3=1.50). In the presence of an interactive effect, the variable cannot be analyzed separately, therefore the application of statistical method reveals the interaction (X_1 X_3 and X_2 X_3) are significant at 5% significance Level. In general, it was observed that main effects especially for poultry and goat manure were more influential on growth of watermelon plant (number of branches). Plants that received adequate poultry manure were superior with respect to higher number of branches of watermelon plant over their counterparts possibly because higher rates of manure supplied nutrients required for vigorous growth. This is similar to the finding of Dauda, [3] who attributed the vigorous growth of watermelon to increased supply of nutrient from higher rates of poultry manure. The findings are also similar to those of Enujeke (2013) who indicated that higher rates of poultry manure increased growth parameters of maize in Nigeria.

3.6.3 Effect Estimates of Organic Manure on Vine Length of Watermelon Plants

The study sought to establish the significant of linear and interactive effect of independent variables on vine length of watermelon plant and result are as shown in Figure 4.

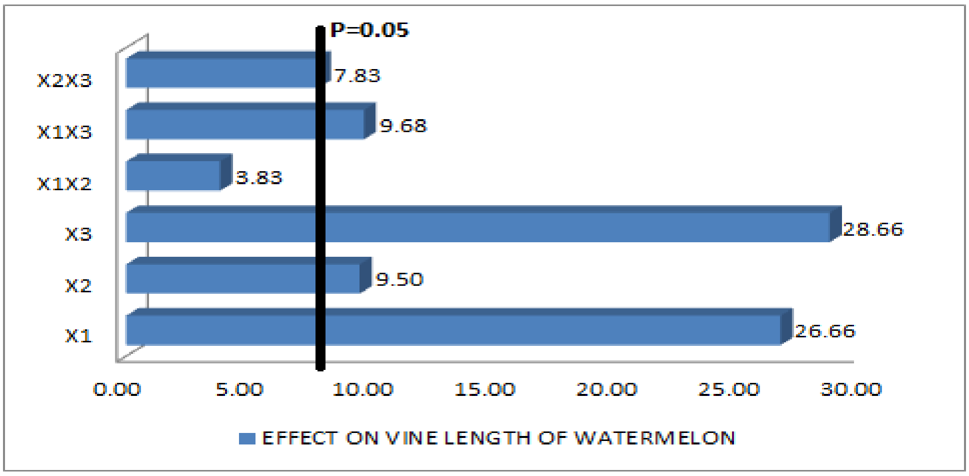

Figure 4: Standardized Effect of organic manure on Watermelon Vine Length

Figure 4, indicates the effect estimates of linear and quadratic terms and their significant in enhance growth of watermelon plant. Goat manure (X_3) significantly affected growth of watermelon plant (effect of X_3=28.66, followed by poultry manure (X_1) (effect of X_1 =26.66), as well as interaction poultry and goat manure (effect of X_1 X_3=9.68). In the presence of an interactive effect, the variable cannot be analyzed separately, therefore the application of statistical method reveals the interactions of (X_1 X_3 and X_2 X_3) were significant at 5% significance level. Meanwhile, cow manure is deemed statistically significant at 5% significance level, perhaps if applied in large quantities. In general, it was observed that main effects especially where poultry and goat manure were applied were more influential on vine growth. Plant that received adequate amount of poultry or goat manure had higher vine length than other plants possibly because higher rate of manure improve nutrient availability which enhanced increased vine growth. This is consistent with the finding of John *et al.*, [8] who reported that poultry manure released essential elements associated with high photosynthetic activities which promoted growth and yield of watermelon.

3.7 Response Surface and Contour Plots

3.7.1 Response Surface and Contour Plots of Fruit Weight on Organic Manure

Contour plot play a very important role in the study of the response surface. By generating contour using R-Gui/Design Expert software for response analysis, the experimenter can usually characterize the shape of the surface and locate the optimum with reasonable precision. The graphical visualization is very helpful in understanding the second-order response surface. Figure 5, 6 and 7 shows a plot of 3 dimension (3D) for different combination of variables (poultry, cow and goat manure) which exhibit the trend of variation of response (fruit weight) within the selected range of input variables and also influence of each variable over the other variable.

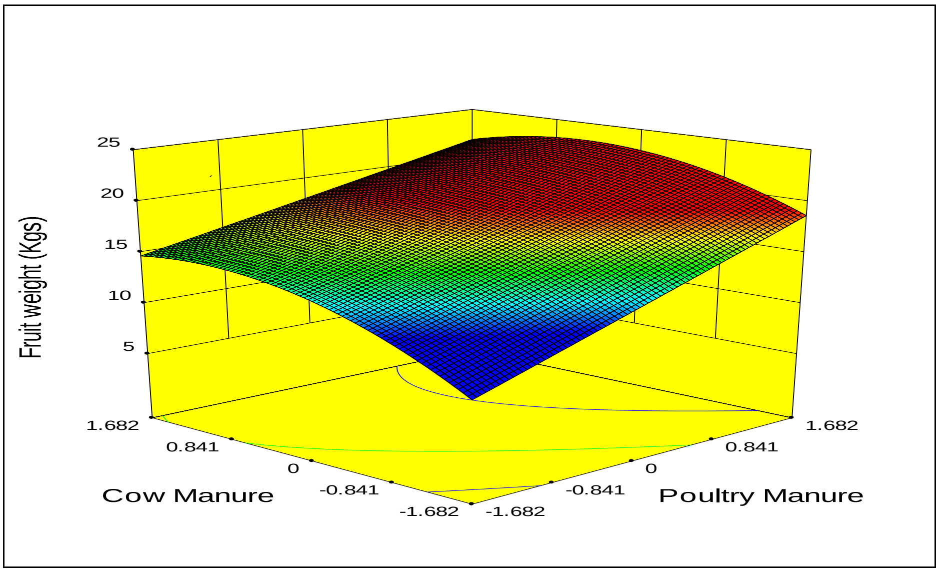

Figure 5: Watermelon fruit weight as a function of Poultry and cow manure at fixed goat manure of 18.075 ton/ha

In Figure 5 the fruit weight of watermelon is shown as a function of poultry manure and cow manure. It was found that poultry (X_1) and cow manure (X_2) had positive effect on watermelon production. This suggests that increasing X_1X_2 from low to high will increase the fruit weight of watermelon up to a certain level. The response surface corresponding to the second order model indicates that moderately low cow manure and high poultry manure increases yields of watermelon. This is because poultry manure has been reported to be rich in nutrient concentration especially nitrogen which enhance growth and production of watermelon Enujeke, [5].

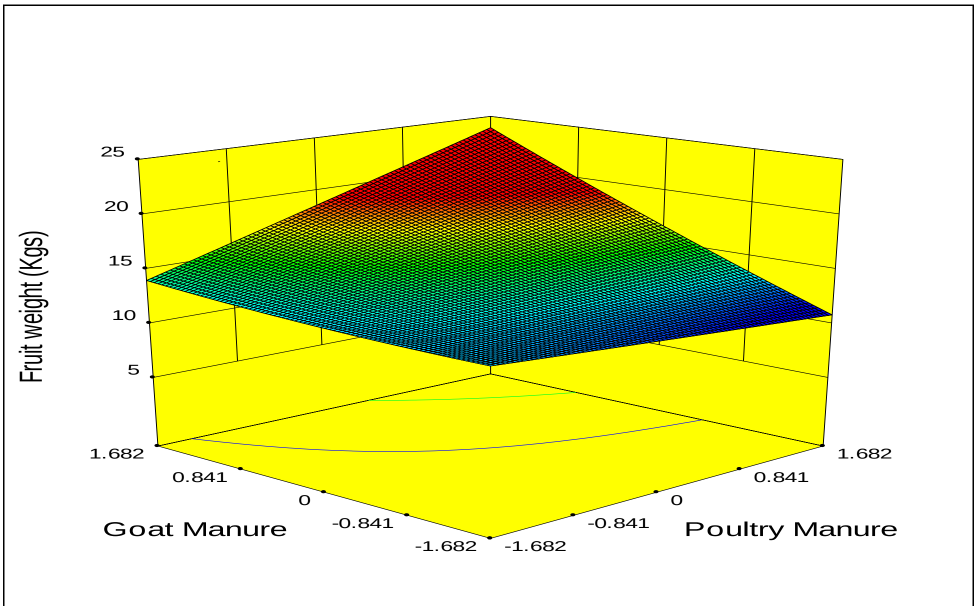

Figure 6: Watermelon fruit weight as a function of Poultry and goat manure at fixed cow manure of 13.27 ton/ha

Figure 6 shows fruit weight of watermelon as a function of poultry manure and goat manure. It was noted that lowering the amount of goat manure and high amount of poultry manure levels can attain maximum fruit weight. In this study, poultry manure clearly influenced the production of watermelon yield.

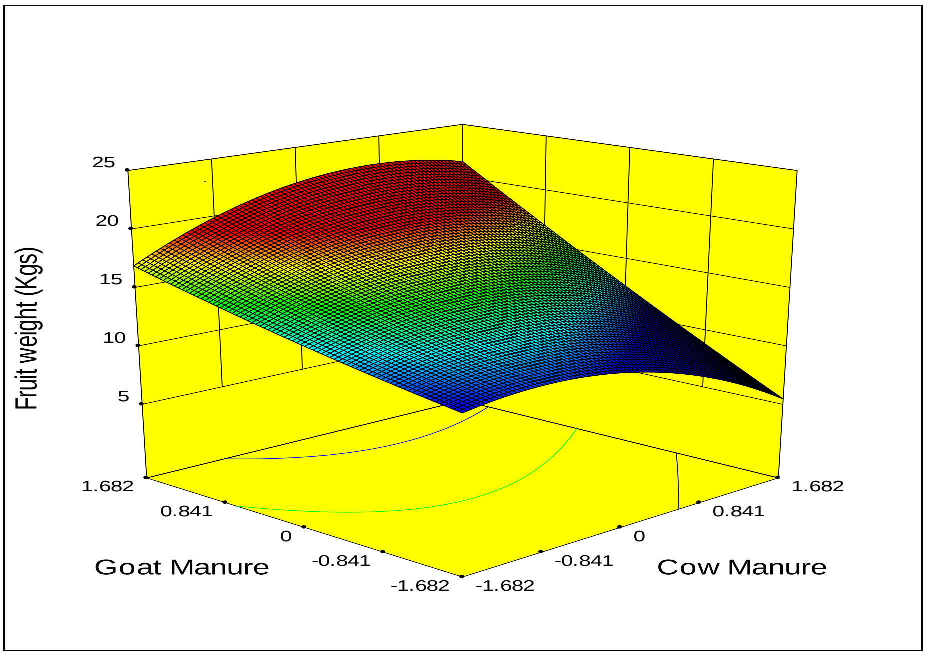

Figure 7: Watermelon fruit weight as a function of cow and goat manure at fixed poultry manure of 17.13 ton/ha

Figure 7 denotes the surface plot of the fruit weight (yields) as a function of cow and goat manure at constant/fixed poultry manure. The results indicated show that cow and goat manure have direct effect on the fruit weight (yields) up to a certain level and then yield's decreases with increase of cow manure. It was observed that watermelon production is favoured when fruit weight is maximized (apply little amount of cow manure, high poultry manure and high goat manure levels)

3.7.2 Response Surface and Contour Plots of Number of Branches on Organic manure

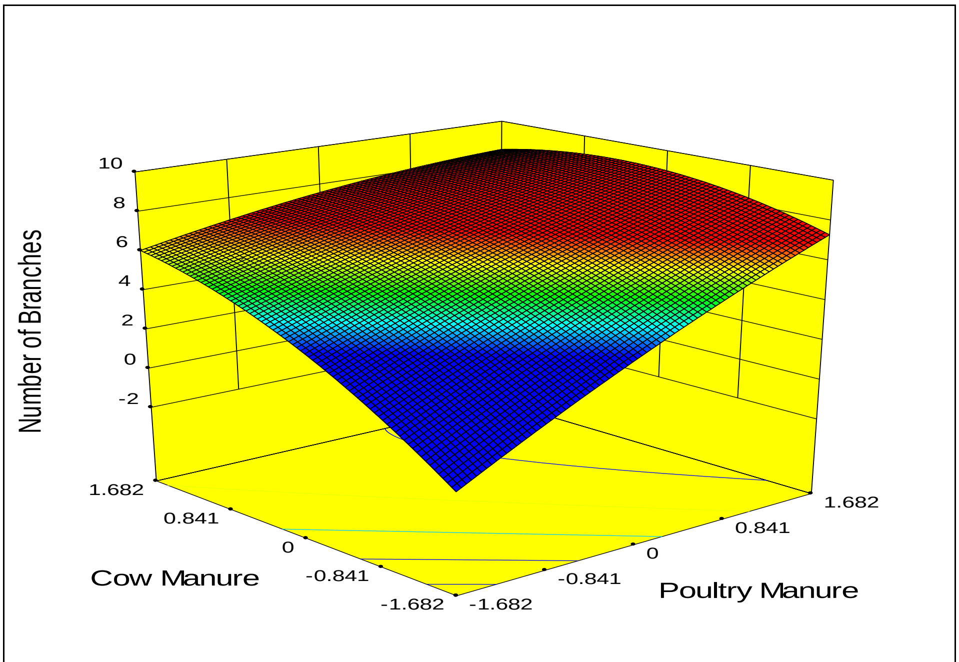

Figure 8: Number of branches as a function of Poultry and cow manure at fixed goat manure of 17.77 ton/ha

Figure 8 shows growth of watermelon in terms of number of branches as being a function of poultry and cow manure. It was observed that, increasing cow manure and poultry manure resulted to high number of branches of watermelon plant. Poultry manure clearly influenced the growth of watermelon plant. The response surface corresponding to the second order model indicates that moderately high cow manure and high poultry manure increases number of branches of watermelon. As indicated earlier, poultry manure has been reported to be rich of nutrient especially nitrogen which enhance growth of watermelon plant, Enujeke, [5].

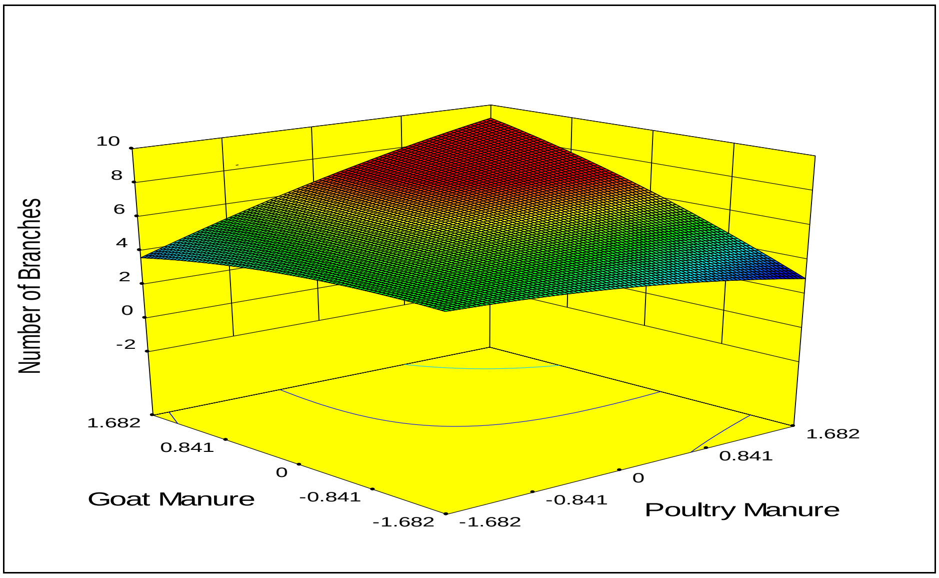

Figure 9: Number of branches as a function of Poultry and goat manure at fixed cow manure of 13.5 ton/ha

Figure 9 shows growth of watermelon in terms of number of branches as being a function of poultry and goat manure. It was observed that poultry and goat manure affected the number of branches of watermelon plant. At a higher rate of poultry manure and goat manure, one can observe that number of branches increase to reach maximum level.

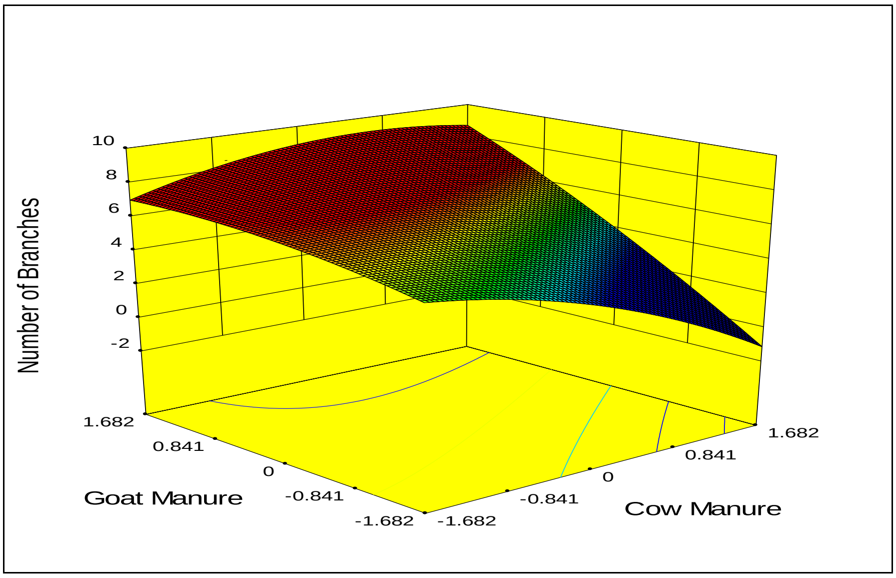

Figure 10: Number of branches as a function of goat and cow manure at fixed poultry manure of 14.68 ton/ha

Figure 10 shows the surface plot of the number of branches as a function of cow and goat manure at constant/fixed poultry manure. It was observed that cow and goat manure have direct effect on the number of branches. The number of branches decreases with increasing cow manure and increase of goat manure.

3.7.3 Response Surface and Contour Plots of Vine length on Organic Manure

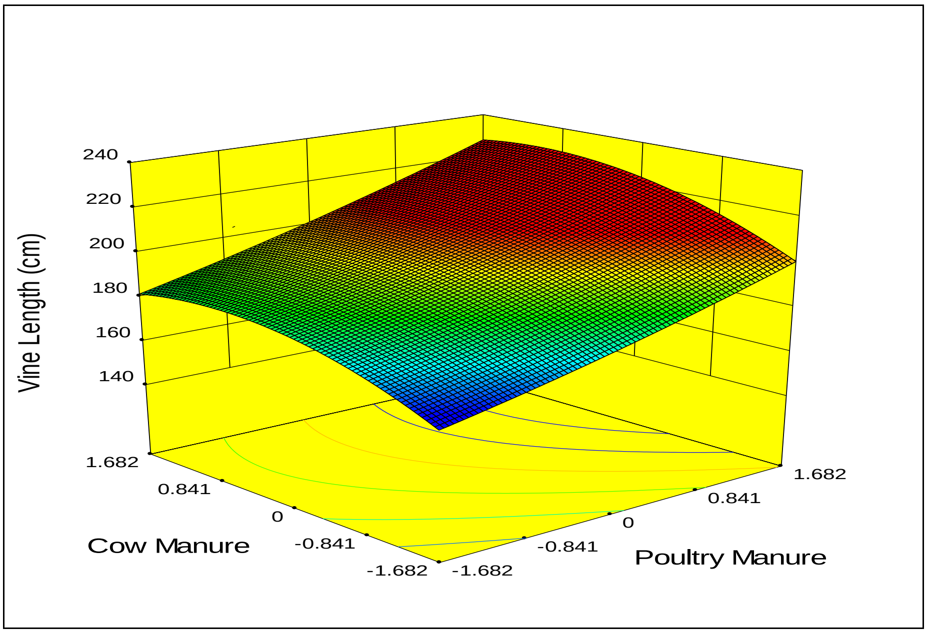

Figure 11: Vine Length as a function of poultry and cow manure at fixed goat manure of 18.37 ton/ha

Figure 11 shows a plot of 3D for combination of variables (poultry and cow manure) which exhibit the trend of variation of response (vine length) within the selected range of input variables and also influence of each variable over the other variable. The response surface corresponding to the second order model indicates that moderately high cow manure and high poultry manure level influenced the vine length of watermelon plant. An earlier study found that poultry manure is rich in nutrients especially nitrogen which enhance growth of watermelon plant, Enujeke, [5].

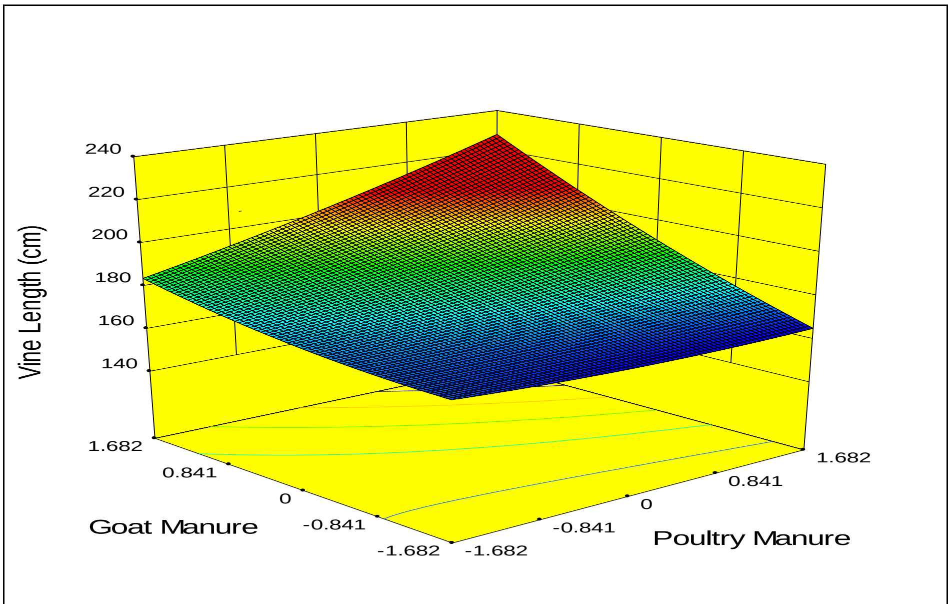

Figure 12: Vine Length as a function of poultry and goat manure at fixed cow manure of 13.52 ton/ha

Figure 12 shows vine length of watermelon as a function of poultry manure and goat manure. It was observed that increasing the amount of poultry manure and high amount of goat manure can enhance attain maximum vine length of watermelon plant. Therefore, poultry and goat manure clearly enhance the growth of watermelon plant.

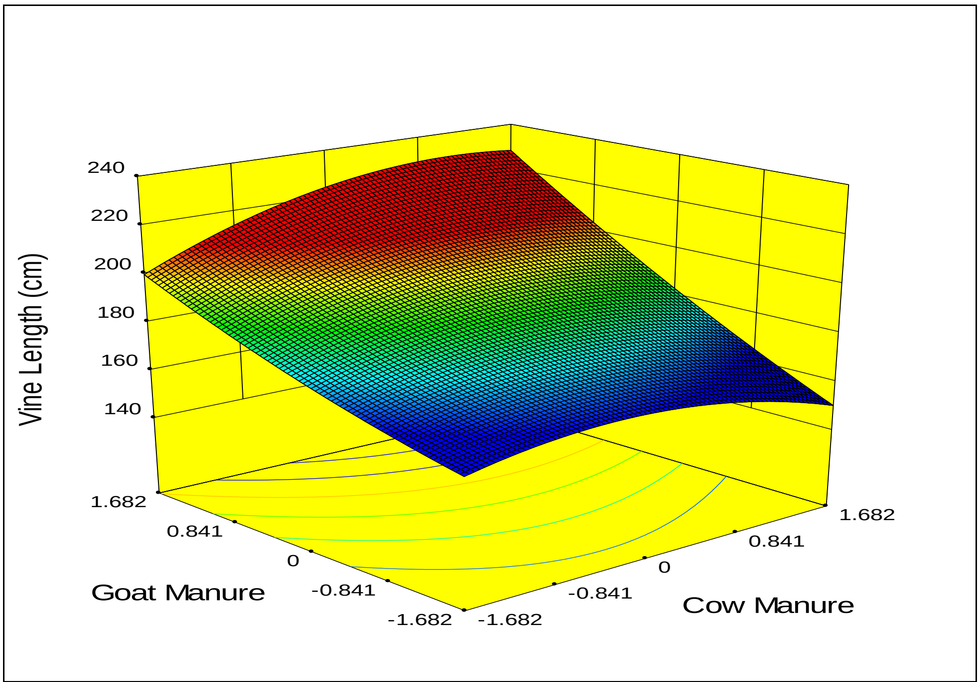

Figure 13: Vine Length as a function of goat and cow manure at fixed poultry manure of 17.55 ton/ha

Figure 13 denotes the surface plot of the vine length as a function of cow and goat manure at a constant 17.6 ton/Ha of poultry manure. The results showed that cow and goat manure have direct effect on the vine length but the same decreased with increasing cow manure and increase of goat manure.

4.0 CONCLUSION AND RECOMMENDATION

Using response surface analysis, it was possible to study the effect of key parameters on growth and production of watermelon. Process optimization was accomplished by applying CCD and response surface methodology. A quadratic model was suggested for the prediction of yield of watermelon crop. The multiple adjusted R-squared value was 0.859=85.9% for model I that indicated an acceptable fitting to the experimental data. The variance analysis of the model proved that the poultry manure and goat manure were significant factors. Based on the findings of the study, it was recommended that farmers in the study area apply 17.125 tons/Ha of poultry manure, 13.27 tons/Ha of cow manure and 18.08 tons/Ha of goat manure for increased growth and yield of watermelon. Finally, this study exemplified that the development of mathematical models for crop production based on statistics can be useful for predicting and understanding the effects of experimental factors. What must be noted here is that RSM does not explicate the mechanism of the studied crop production, but only a certain the effects of variables on response and interactions between the variables. It can also be stated that it would be a scientific and economic approach to obtain the maximum amount of information in a short period of time and with the lowest number of experiments.

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