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# PREDICTION OF TOTAL MILK YIELD OF FRIESIAN X BUNAJI HEIFERS IN EARLY LACTATION USING BODY MEASUREMENTS

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**ABSTRACT**

This study was conducted to determine whether there is a stable relationship between milk yield and body measurements, and if so how accurate could total milk yield (TMY) be predicted in early lactation of Friesian x Bunaji heifers. The data used for the study was collected from 38 primiparous Friesian x Bunaji heifers at the dairy herd of National Animal Production Research Institute (NAPRI) Shika -Zaria Nigeria. Eight body measurements and eight body indices were used to develop the prediction models. Base on the evaluation criteria, the best model that could optimally predicts TMY in early lactation using the original body measurements was the model that combined body weight (BW), body length (BL) and heart girth (HG); TMY= 3484.60-5.20BW+120.44BL-85.21HG. The model explained about 94.49% of the variation in the TMY of the heifers in early lactation with a low prediction error (RMSEP) and AIC values of 70.67 and 52.50, respectively and the P-value of the resultant model was 0.032. The best model for the prediction of TMY in early lactation using the body indices was the model that combined weight index (WI) and body index (BI) in the form TMY= -11594.00-0.04WI + 213.034BI. This model could explain over 99% ($R^2$-adj =99.43) of the variation in TMY with low prediction error (RMSEP) and AIC values of 29.36 and 42.39, respectively and the P-value of 0.0004.Therefore, findings of this study suggest that body conformation should be included in the evaluation of replacement heifers in dairy production programme.

**Keywords:** dairy, Friesian x Bunaji, heifers, milk yield, prediction, body measurements

## INTRODUCTION

In dairy breeding and management programme the animal breeder is expected to group cows and manage them according to their genetic potential for milk production. To achieve this, the breeder must use certain generalizations or indicators to help him make early decision on the type of action to be taken. One of those generalization is the use of correlated traits which must have high genetic correlation with milk yield, high heritability and could be measured early in the life of the cow (Berry *et al.,* 2005). These correlated traits could be used as indicator traits to assess or predict the cow's potential for cows for milk yield Early prediction of the performance of the cow can allow the farmer to decide whether cows should be kept for breeding (Gorgulu, 2012). The cow milking potential could be assed early in life by exploring the closed association between the cows' body conformation and milk yield. For example, Makusfeld and Ezra (1993) reported that withers height (WH) of Holstein replacement heifers at first calving was a better determinant of peak 305 day first lactation yield. Similarly, Sieber *et al*. (1998) reported strong relationship between first lactation milk yield and WH, chest depth or pelvic width. Mantysaari (1996) and Neuenchwander *et al.* (2005) also reported that cows with larger HG and CW phenotypically showed stronger production increase from first to third lactation. De Haas *et al*. (2007) reported that the heritability of body related traits ranged from moderate (0.34) to high (0.74) and that the genetic correlation between the conformation traits and milk yield were moderately high. This genetic relationship suggested that there could be a real genetic variation between individual cows that could be modeled.

Base on the foregoing, it could be postulated that body measurements and their indices could be used with high degree of reliability to predict first lactation total yield of heifers in early lactation. One way of validating this hypothesis is to assess the association between the milk yield and body indices of the cows. A clear understanding of this relationship in dairy cows would enable the development of prediction model for early evaluation of the dairy potential of the cows using it body indices. If this hypothesis is tested to be true then selection for total milk yield in cattle could be made early in the life of dairy cows using their body indices.

Therefore, the purpose of this study was to investigate whether there is a stable relationship between milk yield and body measurements, and if so how accurate could total milk yield be predicted in early lactation of Friesian x Bunaji heifers

## MATERIALS AND METHODS

The data used for this study was collected from 38 primiparous Friesian x Bunaji heifers in the dairy herd of National Animal Production Research Institute (NAPRI) Shika-Zaria, Nigeria. Shika is located on Latitude $11^0$ $12^I$N and $7^0$ $34^I$E, at an altitude of 640 m above sea level, and lies within the Northern Guinea Savannah Zone (Google map, 2016). The heifers were raised under semi-intensive management whereby they were grazed during the rainy season on both natural and paddock sown pasture, while hay and/ or silage were offered during the dry season. Concentrate mixture of undelinted cotton seed cake and grinded maize were offered to the cows during milking. They had access to water *ad-libitum*; unrestricted grazing was allowed under the supervision of the herdsmen for about 7 hours per day (Alphonsus *et al.,* 2015). The animals were in there first lactation and the milking frequency was twice daily (morning and evening) commencing 3-4 days postpartum and the milk yield was recorded on daily basis.

### Measurements of Morphological traits and Body indices

Eight morphological traits comprising of stature (ST), chest width (CW), withers height (WH), heart girth (HG), body length (BL), body depth (BD) rump width (RW) and body weight (BW) were measured two times within the first two months of lactation. The measurements of the morphological traits were taken just before the morning milking while locked in the milking parlour. The morphological traits were measured in centimeter (cm) using graduated calibrated measuring pole and flexible meter tape, while the body weight was measured using weighbridge (Avery weighbridge Birmingham England (500 kg). The eight original morphological variables were used to calculate other eight body indices. The details of the measurements and definition of the traits are presented in Table 1.

**Table 1: Details of measurements of morphological traits and calculation of body indices**

| | Measurements | Abbrev | Description | Instrument |
|---|---|---|---|---|
| Original morphological measurements (adopted from Fisher 1975 and IHFA 2006) | | | | |
| 1 | Stature | ST | Measured from top of the spine in between hips to ground | Calibrated measuring pole |
| 2 | Withers height | WH | Highest point over the scapulae vertically to the ground or measured from the highest point on the dorsum of the animal to the ground surface at the level of front legs | Calibrated measuring pole |
| 3 | Heart Girth | HG | Measured as a circumference of the body at a point immediately behind the fore legs, perpendicular to the body axis | Measuring tape |
| 4 | Chest width | CW | Measured from the inside surface between the top of the front legs. | Measuring tape |
| 5 | Body depth | BD | Distance between the top of spine and bottom of barrel at last rib, the deepest point independent of stature. | Measuring tape |
| 6 | Body length | BL | Measured from the point of shoulder to the ischium | Measuring tape |
| 7. | Rump width | RW | The distance between the most posterior point of pin bones | Measuring tape |
| 8 | Body weight | BW | Live weight of the animal | Weigh bridge |
| **Body indices and their calculations (Alderson 1999; Sarma2006).** | | | | |
| 1 | Height slope | HS | Withers height – stature | Calculated |
| 2 | Width slope | WS | Rumps width/ chest width | Calculated |
| 3. | Length index | LI | Body length / withers height | Calculated |
| 4 | Depth index* | DI | Body depth/withers height | Calculated |
| 5 | Foreleg length* | FL | Withers height- body depth | Calculated |
| 6 | Body index | BI | (Body length/heart girth)x 100 | Calculated |
| 7 | Height index | HI | Withers height/body length | Calculated |
| 8 | Weight index | WI | Body weight x withers height | Calculated |

*= in the original formula chest depth was used instead of body depth

**Statistical Analysis and Models development**

Preliminary analysis was performed to screen for the body conformation traits and body indices most useful for the prediction of total milk yield (TMY). This was achieved by determining the correlation structure of the body conformation and body indices with TMY using Pearson's Correlation Procedure of SAS (2000). All the body variables that were strongly correlated with milk yield in the preliminary analysis were retained and used for the models development. The models were developed using Ordinary Least Square (OLS) Regression Procedure of SAS (2000): a generalized linear modeling technique that is used to model a single response variable which has been recorded on at least an interval scale (Hutcheson 1999). The subset model selection was performed using Mallow's CP statistics. The CP statistics is not a standalone procedure but an option under PROC REG. it measures how well a specific subset model predicts the observed data and estimates how well the model will predicts new observation. The CP statistics was run to find models (in both the body conformation traits and body indices) with 1, 2, 3 and 4 predictors that maximized the selection criteria.

The form of the model used was as follow:

$Y = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_iX_i + e_i$

Where:

Y = dependent variable, α = intercept, $\beta_1$, $\beta_2$, and $\beta_i$ = regression coefficients of explanatory or independent variables $X_1$, $X_2$,$X_i$, which indicates the average change in Y that is associated with a unit change in X, and $e_i$ is random error (Hutcheson,1999)

**Model Validation**

The models developed were validated using 4 criteria or goodness of fits such as the percentage of variance explained by the model measured by the $R^2$ –adjusted, the residual standard deviation or root mean square error of prediction (RMSEP), and Akaike's information criteria (AIC). The AIC is a good statistic for comparison of models of different complexity because it adjusts the residual sum of squares (RSS) for number of parameters in the model. A small numerical value of AIC indicates a better fit when comparing models, and the P-value of the fitted regression model. The model that maximized $R^2$ –adjusted and minimized the RMSEP and the AIC is preferable. The final models were cross validated using Dubin-Watson (dw) and residual plots of the final models fitted regarding homogenous variance assumption.

**RESULTS AND DISCUSSION**

The phenotypic correlation between total milk yield (TMY) and the body measurements ranged from -0.681 to 0.443, while correlations between TMY and body indices ranged from -0.687 to 0.492 (Table 2). This suggested that there is a strong relationship between milk yield and the body conformation traits of the animals that could be modeled. For example, the phenotypic correlations of chest width (CW), heart girth (HG) and body length (BL) with milk yield were all positive suggesting that from genetic point of view, in this crossbred, cows with larger HG and CW produces more milk than those with smaller measurements. Similar observation has been reported by Neuenschwander *et al.*(2005) and that cows with lager HG and CW showed stronger production increase from first to third lactation. This is probably so because the HG and CW are more closely related to muscle and fat deposition than bone structure of the animals and are therefore affected more by the nutritional status of the animal (Kamalzadeh *et al.*, 1998). Cows under good nutrition usually have good body condition for milk yield (Alphonsus *et al.*, 2014). The negative correlation between milk yield and body depth (-0.232), rump width (-0.576) and body weight (-0.681) suggested that in this crosses, the narrow and lighter cows produces more milk than the fat and heavy cows. This is probably because, good dairy animals have been genetically selected overtime to efficiently convert feeds they consume into milk production rather than meat thus, are relatively narrow and lighter than the beef breeds. This confirmed the earlier observation of De Haas *et al.* (2007) in Brown Swiss. Also, studies have shown that high yielding cows generally have poor genetic merit for body condition because body tissue reserves act as biological buffers for milk synthesis (Kadarmideen, 2004; Berry *et al.*,2005) However, the negative correlation of TMY with ST (-0.396), WH (-0.232) and RW (-0.576) in this study is contrary to the findings of De Haas *et al*. (2007) in Holstein and Red and White cows where all these conformation traits were positively correlated `with milk yield. This suggested that the relationship of conformation traits with milk yield is different between breeds which could have implication for the use of conformation traits in different dairy cattle breeding programmes.

**Table 2. Descriptive statistics and relationship of conformation variables and total milk yield in Friesian x Bunaji cows**

| **Body Measurements (n=38)** | **Mean ±SE** | **CV(%)** | **Min** | **Max** | **r[i]** |
|---|---|---|---|---|---|
| Body weight | 390.07 ± 8.04 | 12.69 | 323.57 | 457.86 | -0.681** |
| Stature | 128.67 ± 0.33 | 1.59 | 127.20 | 133.45 | -0.396* |
| Chest width | 25.83 ± 0.11 | 2.67 | 25.10 | 27.35 | 0.387 |
| Body depth | 97.33 ± 0.45 | 2.90 | 94.50 | 103.47 | -0.232 |
| Height-at withers | 126.5 ± 0.21 | 1.00 | 125.80 | 129.34 | -0.232 |
| Heart girth | 174.67 ± 0.37 | 1.31 | 170.43 | 177.90 | 0.215 |
| Body length | 123.17 ± 0.43 | 2.17 | 120.00 | 126.23 | 0.443* |
| Rump width | 17.50 ± 0.08 | 2.89 | 17.25 | 18.45 | -0.576* |
| **Body indices** | | | | | |
| Height slope | -2.167± 0.17 | -49.98 | -4.00 | -1.000 | 0.490* |
| Width slope | 0.678 ± 0.01 | 2.44 | 0.629 | 0.720 | -0.621** |
| Length index | 0.974 ±0.01 | 2.60 | 0.945 | 1.008 | 0.492* |
| Depth index | 0.769 ± 0.01 | 2.32 | 0.746 | 0.798 | -0.191 |
| Foreleg length. | 29.167 ± 0.35 | 7.48 | 26.00 | 32.00 | 0.170 |
| Body index | 70.512 ± 0.17 | 1.46 | 68.57 | 71.59 | 0.468* |
| Height index | 1.028 ± 0.01 | 2.42 | 0.992 | 1.058 | -0.496* |
| Weight index | 49356± 1030.09 | 12.85 | 40770 | 57233 | -0.687* |

*= P<0.05; ** = P<0.01 i= correlation coefficient of morphological parameters and total milk yield; Min = minimum, Max= maximum; SE=standard error; CV= coefficient of variability; n=number of animals used.

The models for estimation of total milk yield (TMY) in early lactation of heifers using morphological measurements and body indices are shown in Table 3. The regression coefficient and the evaluation criteria are also shown. The four most informative morphological traits selected for the models development during the exploratory analysis were body weight (BW), body length (BL), heart girth (HG), and withers height (WH), while the four most informative body indices selected for the development of the prediction models were weight index (WI), body index (BI), depth index (DI) and length index (LI). These variables were significant in the exploratory analysis and had strong relationship with total milk yield. Using the Mallow's CP statistics, the models were developed sequentially starting from the single most informative body conformation traits and single most informative body indices. Each of the variables that improved the evaluation criteria (goodness of fits) were chosen and used in the subsequent models. Generally, the evaluation criteria improves as more variables were been added to the models; for the original morphological traits, body weight (BW) was the single most informative trait for estimation of TMY in early lactation, it explained 32.91% of the variation in TMY and had a prediction error (RMSEP) and Akeike's information criteria (AIC) values of 246.67 and 67.66, respectively. When the other body traits (BL, HG, WH) were sequentially added to the model already containing BW, the model evaluation criteria improves at increasing rate to the third model and thereafter increased at a decreasing rate. This suggested that the best model that could optimally predicts TMY in early lactation using body measurements is the model that combined BW, BL and HG, the form of the model was TMY=3484.60-5.20BW+120.44BL-85.21HG. This model explained about 94.49% of the variation in the TMY of the heifers in early lactation with a low prediction error (RMSEP) and AIC values of 70.67 and 52.50, respectively and the P-value of the resultant model was 0.032.

**Table 3. Regression models for the prediction of total milk yield using body measurements and body indices**

| **Model** | **Predictors** | **Regression coefficients (Prediction models)** | **Evaluation criteria** | | | | |
|---|---|---|---|---|---|---|---|
| **Original body measurements** | | | **AIC** | **RMSEP** | **$R^2$** | **Adj-$R^2$** | **P-value** |
| 1 | BW | 2911.52 - 3.85BW | 67.66 | 246.66 | 46.30 | 32.90ns | 0.137 |
| 2 | BW BL | -4369.13- 4.43BW + 60.91BL | 64.11 | 179.29 | 78.73 | 64.56* | 0.098 |
| 3 | BW BL HG | 3484.60 – 5.20BW +120.44BL – 82.21HG | 52.50 | 70.67 | 97.80 | 94.49* | 0.033 |
| 4 | BW BL HG HW | 8269.14 – 5.07BW + 123.31BL – 90.74HG – 33.37WH | 32.25 | 15.64 | 99.95 | 99.73* | 0.035 |
| **Body indices** | | | | | | | |
| 1 | WI | 2900.85- 0.030WI | 67.57 | 244.79 | 47.14 | 33.93* | 0.022 |
| 2 | WI BI | -11594.00– 0.041WI + 213.03BI | 42.39 | 29.36 | 99.43 | 99.05** | 0.001 |
| 3 | WI BI DI | -10955 – 0.040WI – 213.63BI – 923.941DI | 38.71 | 22.39 | 99.78 | 99.45** | 0.003 |
| 4 | HS BI DI LI | - 10621 – 0.039WI + 199.99 BI – 1181.278DI + 810.94LI | 16.07 | 4.070 | 1.000 | 99.98* | 0.009 |

*=P<0.05; ** = P< 0.01; BW=body weight, BL=body length, HG=heart girth, WH=withers height, WI= weight index, BI= body index, DI= depth index, LI= length index ; AIC= Akaike's information criteria; RMSEP= root mean square error of prediction, Adj-$R^2$=coefficient of variation adjusted

The single most informative body index that could be used to estimate TMY in early lactation is the weight index (WI) which is the function of body weight and height of the animal. It explained about 33.9% of the variation in TMY with RMSEP and AIC values of 244.79 and 67.57, respectively. When body index (BI) was added to the model already containing the WI, the evaluation criteria improved significantly; the $R^2$ adjusted value increased to 99.05 and the RMSEP and AIC decreased to 29.36 and 42.39, respectively, and the P-value of the resultant model was 0.0001. However, when additional body indices were been added to the model the evaluation criteria improved but at a decreasing rate. This suggested that the best model for the prediction of TMY in early lactation using the body indices is the model that combined WI and BI, the form of the model was TMY= -11594.00-0.04WI + 213.034BI. This model could explain over 99% ($R^2$-adj =99.43) of the variation in TMY with low prediction error (RMSEP) and AIC s 29.36 and 42.39, respectively and the P-value of the resultant model of 0.0004.

The high percentage of variance explained and the corresponding low prediction error obtained using the regression models of the body measurements and body indices suggests that there is a stable biological based relationship between milk yield with body conformation of the cows. However, looking at the evaluation criteria, the models that were developed using body indices had better prediction ability and were more stable than those of the original body measurements. This is probably so because the body indices present superior option for assessing type and function of the cattle better than the single body measurement. therefore, body indices could be used to enhance the ability of the dairy breeders to select potential breeding stock early without waiting for the complete lactation records of the cows before making appropriate selection decision.

A further indication of the goodness of fits for the body indices was represented by the absence of serial correlation amongst the residuals. The pattern of the residuals did not show definite trends in all the four regression models (Fig 1-4) suggesting that the residuals were independent of the fitted values. This impression was confirmed by the Durbin-Watson (Dw) statistics. The Dw statistics states that when there is no serial correlation among residuals, the expected value of the Dw statistics will be approximately 2.0 and that as a practical rule, the value of Dw<1.5 suggest positive autocorrelation, whereas value > 2.5 show the existence of negative autocorrelation (Saxton,2004). In the present study, the Dwvalues were reasonably closed to 2.0 for all four models fitted using the body indices except the third model. The Dw values for the first, second, third and fourth models for the body indices were 2.186, 2.051, 0.975 and 2.048, respectively.

**CONCLUSION**

Although this study was conducted on a few numbers of animals suggesting that the generalization of this result has to be taken cautiously. However, body conformation traits and its indices could be used in early lactation to evaluate the potential of dairy cows for milk yieldthus; it is recommended that body conformation traits should be included in the evaluation of replacement heifers in dairy production programme.

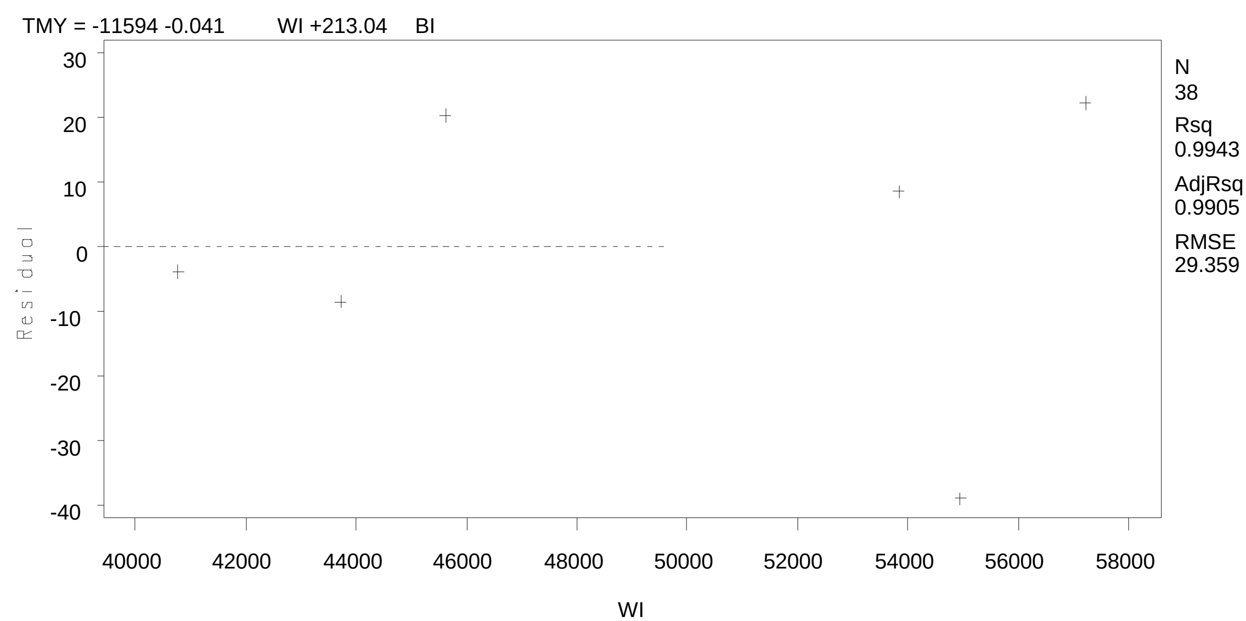


**Fig 1: Residual plot of model 1**

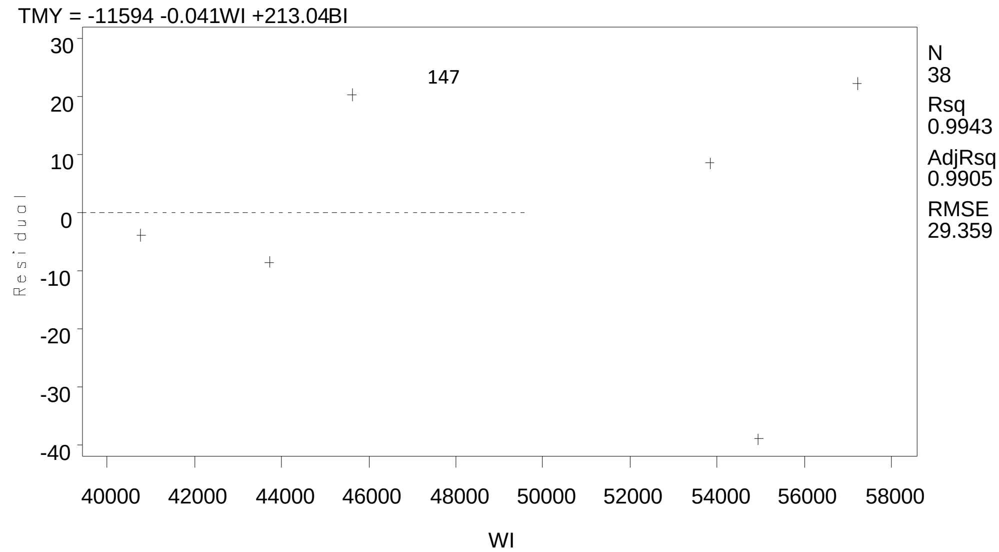


**Fig 2: Residual plot of model 2**

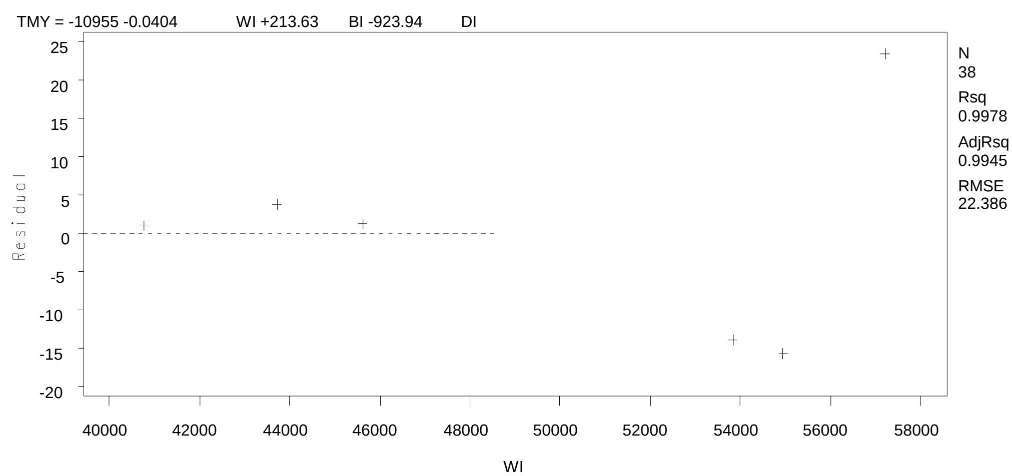


**Fig 3: Residual plot of model 3**

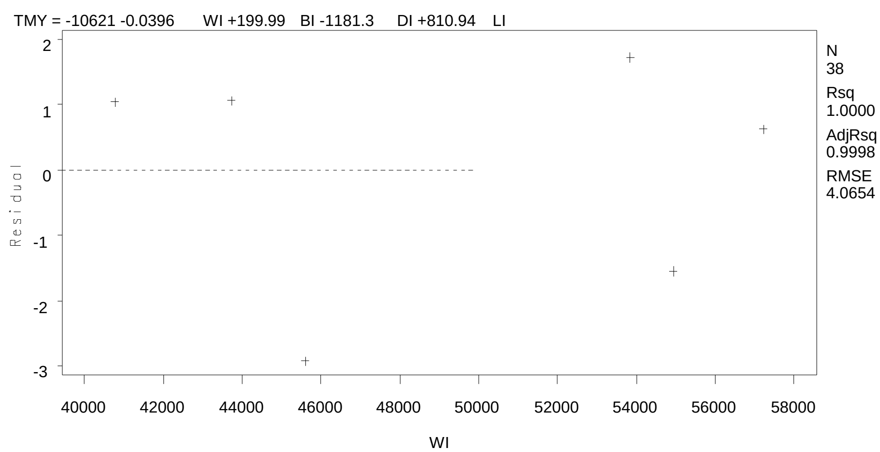


**Fig. 4: Residual plot of model 4**

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