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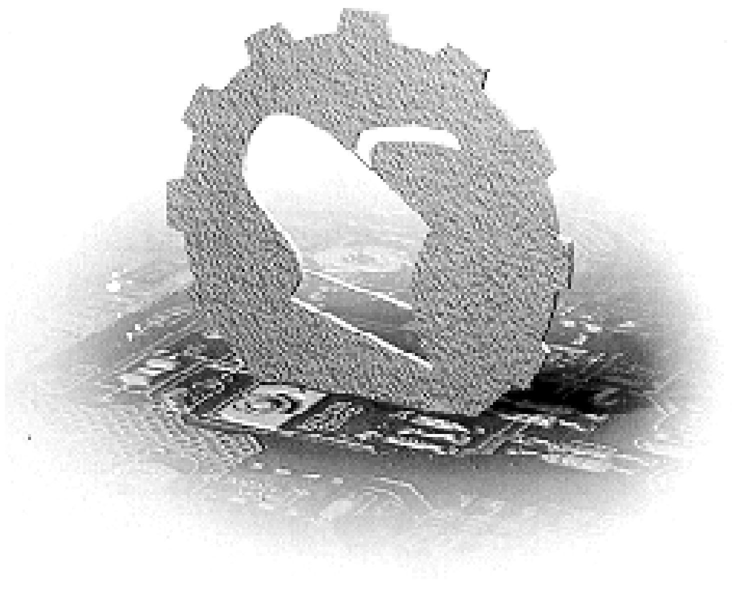

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ИНСТИТУТ ЗА ПОЉОПРИВРЕДНУ ТЕХНИКУ
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THE EFFECTS OF VARIOUS SOIL TREATMENTS ON CROP YIELD IN SOUTHEASTERN NIGERIA

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Abstract: In this study, a PVC drip irrigation system was designed to investigate the effect of different soil treatments on crop yield, using Oba Super 13 maize variety as test crop, on three major plots, each representing a different tillage method. Each plot has three levels of each of the three soil treatments involved including irrigation deficit, tillage method and NPK Application rate, totaling 27 subplots. The three levels of irrigation treatments were 50%, 30% and 10% management allowable depletion levels; tillage treatments were conventional tillage, conservative tillage and no tillage methods, while the NPK application treatments were 400 kg/ha, 500 kg/ha and 600 kg/ha rates, and experimentally designed using the Central Composite Design (CCD) in Design Expert 11 software. The crop yield for all the subplots were determined, and maximum crop yield of 2540 kg/ha was obtained at conservative tillage with 10%MAD, and 600 kg/ha NPK application rate, while minimum tillage of 1234.67 kg/ha was obtained at no tillage, 50%MAD and 400 kg/ha NPK application rate.
Controllable variables were optimized using response surface methodology (RSM) with crop yield for all the subplots. The optimum values based on the run gave irrigation deficit as 11.594%, NPK Application rate as 596.406 kg/ha, best tillage method as conservative tillage, crop yield of 2543.589 kg/ha. The highest maize yield was obtained in conservative tillage and the results confirm the viability of obtaining high yield in the study area using drip irrigation system during the dry season.

Key words: *Irrigation, Management allowable depletion, Tillage, NPK Application rate*

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INTRODUCTION

Water availability for agriculture has been globally identified as one of the threats to crop production and food security according [1]. Presently, according to [2], only four percent of the total arable land in sub-Saharan Africa is irrigated, which implies that agriculture is predominantly rain-fed, thus, making the sector particularly vulnerable to the vagaries of climate variability and change. [3] Posits that agriculture remained the main source of livelihood and Gross Domestic Product in most African countries but faces threats from climate change and variability. Climate change and variability has generally posed critical challenges to sustainable development in South Eastern Nigeria, including agricultural activities and farming systems. [4] Described climate change as a situation when a change in climate condition continues in one direction, at rapid rate and for an unusual long period of time. It has also been defined by [2] as statistically significant variations that persist for an extended period, typically decades or longer and it includes shifts in the frequency and magnitude of sporadic weather events as well as the slow continuous rise in temperature. These changes occur due to variations in different climate parameters such as temperature and precipitation.

According to [5], climate change could manifest in a number of ways such as changes in average climate conditions where some regions become drier or wetter on average, and changes in climate variability where rainfall events become more erratic. Also, [6] observed that with increasing incidences of flooding, erosion, bush burning, pest and diseases, increased temperature, erratic rainfall and drought, it becomes pertinent that agricultural productivity under these circumstances will be very low. The low yield will distort the supply and demand pattern, commodity prices, profitability of farming and affordability of food and food security. It therefore becomes imperative to develop sustainable dry season farming in South-eastern Nigeria through irrigation that will supply the required amount of water needed in both quantity and quality, with drip irrigation being most favorable for water management purposes.

MATERIALS AND METHODS

Study Area

Field experiment was conducted at the Department of Agricultural and Bioresources Engineering Experimental Site/Farm Workshop, Nnamdi Azikiwe University, Awka, which lies between latitudes 6°15’11.8N to 6°15’5.3E and longitudes 7°7’118N to 7°7’183N and altitude of 142 m.

Previous studies identified the soil type of the area to be sandy loam, and typically of savanna covered with grass with geologic formation of Imo shale. The Anambra River and its tributaries are the major Rivers that drain the area, while there are two major climatic seasons, dry season (November to March) and rainy season (April to October) with reduced rain (August break) in August.

Dry season temperature ranges from 20°C to 38°C which increases evapotranspiration, while rainy season temperature ranges from 16 to 28°C, with lower evapotranspiration. The experiment was conducted between January 2022 to April 2022.

Materials and Equipment.

The materials used for the experiment included: 25mm, 19mm and 12.5mm PVC pipes for the main lines, the laterals and the sub mains, respectively, 19mm end cap, 25mm by 12.5 bend, 12.5mm by 19mm inch bend, 25mm ball gauge, 12.5mm ball gauge, 25mm by 12.5mm Tee, 12.5mm by 19mm Tee, 2mm drill machine. The equipment included: Design expert 11 software, Pressure gauge, Moisture meter, Storage tank, Block stand, Surveying instrument, Measuring cylinder, Tractor, Collection cans, Pressure plate apparatus.

Field Preparation

The field is a level ground and field preparation was done by dividing the plot into three major sections A, B and C, with each measuring 27m x 27m. Conventional tillage was done in the section A by thoroughly tilling with plough and harrow, conservative tillage was applied in section B by ploughing with one tractor pass, while section C received no tillage. The mapped out sections were levelled to obtain a level ground.

Field Layout

The experiment was laid out using central composite design (CCD), with experimental field consisting of 3 plots with 9 sub plots in each plot. The experimental design was performed as follows: Tillage methods (conventional tillage, where the area was tilled thoroughly with plough and harrow; conservative tillage, where tillage was done with plough and one tractor pass, while zero tillage received no tillage); Irrigation deficit levels (50% MAD, 30% MAD and 10% MAD) and NPK fertilizer application rates (450 kg/ha, 550 kg/ha and 650 kg/ha). The experimental plot was divided into 27 sub-plots with each sub-plot measuring 3m x 3m. PVC pipes of 25mm, 19mm and 12.5mm were used as the main line, sub-main and laterals respectively, with the laterals spaced 0.5m intervals, while holes were perforated on the laterals at 0.45m spacing to serve as emitter, with this, crop spacing was 0.5m x 0.45m. All other necessary operations such as pest and weed controls were performed according to general local practices and recommendations.

The Test Crop

The crop used for the experiment was OBA SUPER 13 *Zea mays L.* hybrid, and Table 1. shows the duration and growth stages.

Table 1. Duration and Period Within the Various Growth Stages

Growth stages	Duration(days)	Period
Initial stage	14	January 27 to February 10
Crop development stage	24	February 11 to March 6
Mild stage	27	March 7 to April 3
Late stage	20	April 4 to April 24

Drip Irrigation System

The 25 mm PVC pipes were used as main line, connected from the overhead tank, to the field layout, where they were connected to the sub mains through 19 mm x 25 mm tees. The laterals were connected to the sub mains through 19mm by 12.5mm tees, including all necessary accessories. The field capacity was determined at a pressure of 0.01 MPa while the permanent wilting point (PWP) of the soils was also determined at 1.5 MPa using the pressure plate apparatus.

Yield Components

For cobs plant per cob (Cob^{-1}), five plants were selected randomly from each plot and the number of maize ears in each plant was counted. Ears that have less than 5% of the kernels of normal ears were discarded. To obtain the grain per cob (Cob^{-1}), three ears were selected from each subplot at random and number of kernels in each ear was counted. The 1000- grain mass is a measure of the grain size weight in grams for 1000 seeds. Maize ears were selected at random from each subplot and one thousand grains counted from each subplot and weighed. Cob mass were determined as average weight values from randomly selected cobs from each subplot while the cob thickness was determined from cobs selected at random from each subplot and the thickness recorded, and average for each subplot determined. The grain yield was determined from the yield components.

Experimental Design and Optimization Parameters

Response Surface Methodology (RSM) was used to investigate the influence of irrigation deficit, NPK fertilizer application and tillage on crop yield. The central composite design and their values are shown in Table 2. For this research, the factors irrigation deficit (%), NPK Application rate (kg/ha) and Tillage were represented with A, B and C respectively.

Table 2. Independent variables and levels used for response surface design

Independent variables	Symbols	Ranges and levels			
			-1	0	+1
Irrigation Deficit (%)	A		10	30	50
NPK Application rate (kg/ha)	B		400	500	600
Tillage	C		1	2	3

For statistical analysis, the experimental data obtained from central Composite design were analyzed by Response Surface Methodology (RSM), while a mathematical model, following a second order polynomial which includes interaction terms was used to calculate the predicted responses.

RESULTS AND DISCUSSION

Field Capacity

The result showed that the field capacity was minimum at no tillage ($0.07cm^3/cm^3$, $0.11cm^3/cm^3$, $0.12cm^3/cm^3$, and $0.14cm^3/cm^3$) for soil depths 0-25cm, 25-50cm, 50-75cm and 75-100cm respectively, and for conservative tillage ($0.11cm^3/cm^3$, $0.11cm^3/cm^3$, $0.11cm^3/cm^3$, $0.14cm^3/cm^3$) for 0-25cm, 25-50cm, 50-75cm and 75-100cm soil depths respectively, while conventional tillage recorded ($0.09cm^3/cm^3$, $0.13cm^3/cm^3$, $0.15cm^3/cm^3$, $0.17cm^3/cm^3$) for 0-25cm, 25-50cm, 50-75cm and 75-100cm soil depths respectively. At 0-25cm soil depth, there was a bigger value of field capacity in conservative tillage than conventional tillage, and this could be because of runoff which occurred in the top soil in conventional tillage as there was maximum disturbance of soil, which disagreed with the observation reported by (7). This is because the soil type is clay loam where highest FC was observed in no tillage ($0.14cm^3/cm^3$), followed by conservative tillage ($0.08cm^3/cm^3$). Also from the results, increase in soil depth increased field capacity which is in agreement with (8), where field capacity increased from $0.24cm^3/cm^3$ to $0.3cm^3/cm^3$.

Permanent Wilting Point (PWP)

From the result, permanent wilting point increased with increase in soil depth in conventional tillage and no tillage with PWP of $0.01cm^3/cm^3$, $0.05cm^3/cm^3$, $0.09cm^3/cm^3$ and $0.11cm^3/cm^3$ at 0-25cm, 25-50cm, 50-75cm and 75-100cm soil depths respectively for conventional tillage and PWP of $0.02cm^3/cm^3$, $0.05cm^3cm^3$, $0.05cm^3/cm^3$ and $0.08cm^3/cm^3$ at 0-25cm, 25-20cm, 50-75cm and 75-100cm soil depths respectively for no-tillage. This is in agreement with (8), which recorded an increase in permanent wilting point with increase in soil depth of $0.10cm^3/cm^3$ to $0.15cm^3/cm^3$. For conservative tillage pwp of $0.05cm^3/cm^3$, $0.04cm^3/cm^3$, $0.09cm^3/cm^3$, and $0.07cm^3/cm^3$ were recorded for 0-25cm, 25-50cm, 50-75cm and 75-100cm soil depths respectively. There was variation in permanent wilting point for conservative tillage which could be as a result of the bulk density of the soil.

Grain Cob^{-1}

This is the number of grains contained in a corn cob and the values for different treatments are presented in Table 3.

Table 3. Grain Cob^{-1}

kg/ha NPK	Conventional Tillage	Conservative Tillage	No Tillage
10% MAD/600	504	594g	467g
10% MAD/500	503	591g	467g
10% MAD/400	501	577g	461g
	Conventional Tillage	Conservative Tillage	No Tillage

Contin. Tab.3			
30% MAD/600	495	509	433
30% MAD/500	416	495	401
30% MAD/400	396	439	371
Contin. Table 3.			
	Conventional Tillage	Conservative Tillage	No Tillage
50% MAD/600	453	471	409
50% MAD/500	433	450	391
50% MAD/400	390	410	351

From the result of grain Cob^{-1} in Table 3., highest grain cob^{-} of 594 was obtained in conservative tillage at 10% MAD and 600 kg/ha NPK, while the lowest was obtained at No tillage, 50% MAD and 400 kg/ha NPK application. The average grain per cob obtained were 454.5, 515.1, and 416.7 for conventional tillage, conservative tillage and no tillage respectively. This is not in agreement with (9), where highest number of grain Cob^{-} of 528 was obtained in conventional tillage, while the lowest number of grain cob^{-} of 319 was obtained on no tillage. The difference in result could be as a result of soil type, infiltration rate and permeability.

1000 Grain Mass

This is the mass of 1000 grains in grams for the different treatment methods and the values are presented in Table 3.1.

Table 3.1. Result for 1000 Grain mass

kg/ha NPK	Conventional Tillage	Conservative Tillage	No Tillage
10% MAD/600	324g	342g	245g
10% MAD/500	280g	288g	190g
10% MAD/400	263.1g	271g	151.1g
	Conventional Tillage	Conservative Tillage	No Tillage
30% MAD/600	316g	316g	231g
30% MAD/500	296g	299g	219g
30% MAD/400	275g	279g	197g
	Conventional Tillage	Conservative Tillage	No Tillage
50% MAD/600	301g	295g	219g
50% MAD/500	290g	291g	196g
50% MAD/400	279g	279g	190g

From the result of 1000 grain mass in Table 3.1., the same trend as in grain cob^{-} was observed, with the highest 1000 grain mass recorded in conservative tillage/10%MAD/600 kg/ha, while the lowest was in no tillage/50%MAD/400 kg/ha.
For conventional tillage, conservative tillage and no tillage, average 1000 grain weight of 291.5g, 295.5g and 158g respectively were obtained.
This also disagrees with (9), where highest 1000 grain mass of 265g at conventional tillage and lowest value of 204g at no tillage were obtained, and this variance in results could be attributed to the difference in soil types of the study areas.

Cob Mass

The cob weight is the weight of each corn cob in gram for all the treatments, and the values are tabulated in Table 3.2.

Table 3.2. Result for Cob Mass

kg/ha NPK	Conventional Tillage	Conservative Tillage	No Tillage
10% MAD/600	406g	406g	370g
10% MAD/ 500	397g	399g	370g
10% MAD/ 400	370g	391g	354g
	Conventional Tillage	Conservative Tillage	No Tillage
30% MAD/600	401g	405g	367g
30% MAD/500	397g	397g	361g
30% MAD/400	379g	390g	360g
	Conventional Tillage	Conservative Tillage	No Tillage
50% MAD/600	400g	405g	359g
50% MAD/500	395g	403g	351g
50% MAD/600	390g	395g	347g

The results of the cob mass shown in Table 3.2., recorded average cob mass values of 392.g, 399g and 283.3g for conventional tillage, conservative tillage and no tillage respectively, with the highest cob mass of 406g obtained in conventional and conservative tillage/10%MAD600 kg/ha. The lowest cob weight of 347g was also obtained in no tillage/50%MAD600 kg/ha. This is in agreement with (8), where maximum cob mas of 455g was obtained for conventional tillage, followed by cob weight of 408 for reduced tillage and lowest cob weight of 234g for no tillage.

Grain Yield

The grain yield is the crop yield for the treatments and the values are presented in Table 3.3.

Table 3.3. Result for Crop Yield

kg/ha NPK	No Tillage (kg/ha)	Conservative Tillage (kg/ha)	Conventional Tillage (kg/ha)
10% MAD/600	1401.73	2540.09	2195.03
10% MAD/500	1390.36	2505.19	2059.64
10% MAD/400	1334.9	2345.24	1643.89
	Conventional Tillage	Conservative Tillage	No Tillage
30% MAD/600	1354.16	2475.1	1976.09
30% MAD/500	1323.7	2401.09	1904.57
30% MAD/400	1301.23	2395.19	1701.67
	Conventional Tillage (kg/ha)	Conservative Tillage (kg/ha)	No Tillage (kg/ha)
50% MAD/600	1301.34	2309.9	1860.49
50% MAD/500	1291.67	2345.24	1791.19
50% MAD/400	1234.67	2301.06	1506.91

Table 3.3., shows that the highest crop yield of 2540 kg/ha was obtained in conservative tillage/10%MAD/600 kg/ha, while lowest crop yield of 1234.67 kg/ha, was obtained in no tillage/50%MAD/400 kg/ha, while, average grain yields of 1848.8 kg/ha, 2135.8 kg/ha, and 1325.9 kg/ha, were obtained for conventional tillage, conservative tillage and no tillage respectively. This result is in agreement with [9], where they compared maize yield in conventional and conservative tillage and obtained maximum crop yield of 6221.08 kg/ha, for conservative tillage and lowest crop yield of 5372.0 kg/ha for conventional tillage. In contrast [8], obtained highest crop yield of 7.34 ton ha^{-1} in sub-soiling and lowest crop yield of 6.70 ton ha^{-1} in zero tillage.

Development of Regression Model

Central Composite Design (CCD) was used to optimize properties. The statistical combination of the independent variables along with the experimental response are presented in Table 4. To develop a statistically significant regression model, the significance of the coefficient was evaluated based on the p-values. The coefficient terms with the p-value more than 0.05 are insignificant because the p value of ≤ 0.005 was used.

Table 4. Design Summary

Factor Name	Units	Type	Min	Max	Coded Low	Coded High	Mean	Std. Dev.
A Irrigation Deficit	%	Numeric	10.00	50.00	-1 ↔ 10.00	+1 ↔ 50.00	30.00	16.64
B NPK App.	kg/hA	Numeric	400.0	600.0	-1 ↔ 400.00	+1 ↔ 600.00	500.00	83.21
C Tillage		Categoric	1	3	Levels:3			

Response	Name	Units	Observat.	Analysis	Min/ Max	Mean/ Std. dev.	Ratio	Transf.	Model
R1	Crop Yield	kg/ha	27	Polynomial	1234.67 2540.09	1858.94 466.62	2.06	None	Reduc Cubic

The values presented in Table 4., were used for the design of the experiment. The factors are Irrigation deficit %, NPK Application Rate (kg/ha) and Tillage, while the response is Crop Yield (kg/ha). Irrigation deficit, which is a numeric factor with minimum range of 10% and maximum of 50% has a mean of 30% and standard deviation of 16.64. The NPK Application rate, which is also a numeric factor with a minimum value of 400 kg/ha, and maximum of 600 kg/ha has a mean of 500 kg/ha standard deviation of 83.21. Tillage is a categorical factor with three levels, namely, no tillage, conservative tillage and conventional tillage. The response which is crop yield has maximum value as 2540.09 and minimum as 1234.67, with a mean of 1858.94 and standard deviation of 466.62.

Statistical Analysis for Crop yield

The sequential model sum of squares for crop yield is presented in Table 5.

Table 5. Sequential Model Sum of Squares for Crop yield

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Mean vs Total	9.330E+07	1	9.330E+07			
Linear vs Mean	5.483E+06	4	1.371E+06	169.81	<0.0001	
2FI vs Linear	1.291E+05	5	25817.90	9.05	0.0002	Suggested
Quadratic vs 2FI	15019.15	2	7509.58	3.36	0.0621	
Cubic vs Quadratic	22533.64	8	2816.71	1.80	0.2268	Aliased
Residual	10961.18	7	1565.88			
Total	9.896E+07	27	3.665E+06			

From the sequential model (linear, two factor interactions 2FI, Quadratic and Cubic polynomial), on Table 5., the 2FI and linear model was selected by Design Expert 11.1.2.0 version due to its highest order polynomial.

Table 6. Analysis of Variance (ANOVA) for the Fitted Quadratic Model for Crop yield

Source of variables	Sum of Squares	df	Mean Square	F-value	p-value	
Model	5.645E+06	17	3.320E+05	182.70	< 0.0001	Significant
A-Irrigation deficit%	1.206E+05	1	1.206E+05	66.38	< 0.0001	
B-NPK Application rate	1.511E+05	1	1.511E+05	83.14	< 0.0001	
C-Tillage	5.212E+06	2	2.606E+06	1433.80	< 0.0001	
AB	12270.73	1	12270.73	6.75	0.0288	
AC	16990.60	2	8495.30	4.67	0.0405	
BC	99828.17	2	49914.08	27.46	0.0001	
A^2	1746.03	1	1746.03	0.9607	0.3526	
B^2	13273.12	1	13273.12	7.30	0.0243	
ABC	6136.70	2	3068.35	1.69	0.2385	
A^2C	1031.88	2	515.94	0.2839	0.7594	
B^2C	9969.09	2	4984.55	2.74	0.1175	
Residual	16357.15	9	1817.46			
Cor Total	5.661E+06	26				

Std.Dev.	42.63	R^2	0.9971
Mean	1858.94	Adjusted R^2	0.9917
C.V. %	2.29	Predicted R^2	0.9690
		Adeq Precision	37.6191

The analysis of variance (ANOVA) was carried out to determine the significance of the fitness of the selected Quadratic Model as well as the significance of individual terms and their interaction on the chosen responses.

From Table 6., the regressors incorporated in the model F-value of 182.70 with P-value of <0.0001 implies that the model is significant at 95% confidence level.

The P-value (probability of error value) is used to check the significance of each regression coefficient and the interaction effect of each cross product. In the case of the model terms, the p-value less than 0.05 shows that the model terms are significant, in this case A, B, C, AB, AC, BC, and B^2, are significant model terms.

The model as fitted presents an R- square of 0.9971 and standard deviation of 42.63. The three factors (Irrigation deficit, NPK Application rate, and Tillage) were found to be statistically important (significant) at confidence level of 95%. A low value of Coefficient of variation (0.073%), showed a high degree of precision and reliability of the values.

The predicted values versus actual value for the Crop yield with R^2 value of 0.9917 shows a model with 99.17% of variability as shown on Figure 1. The Predicted R-Squared of 0.9690 is in reasonable agreement with the Adjusted R-Squared of 0.9917; with the difference being less than 0.2 and their R^2 values close to unity. This indicates that the data fits with the model.

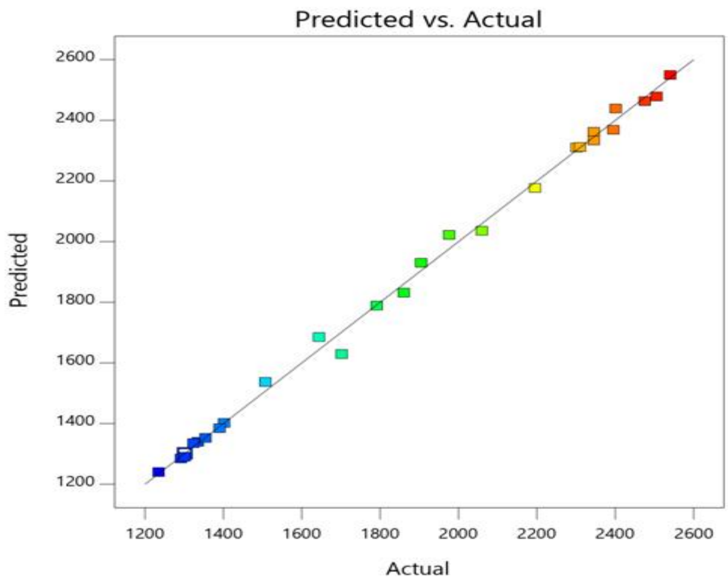

Figure 1. Diagnostics Plots of the fitted Quadratic Model for Crop yield

Investigation on residuals to validate the adequacy of the model used was performed; residual is the difference between the observed response and predicted response. The plot of actual versus predicted on Figure 1., shows that there is a very good correlation between the observed value and the values predicted by the model, and the model does not show any variation of the constant variance.

Model Equation for Crop yield

Model equation for crop yield (No Tillage) is as equation 1

$$905.86125 - 2.39650A + 1.70182B - 0.000020\,A * B - 0.001463A^2 - 0.001391B^2 \quad \ldots(1)$$

For the crop yield, conservation tillage, the model equation is given as equation 3.2

$$1320.33514 + 12.90729A + 3.44454B - 0.023251A * B - 0.081683A^2 - 0.002274B^2 \quad \ldots(2)$$

Equation 3.3 gives the model for crop yield (Conventional Tillage) as

$$1889.28653 + 8.86883A + 13.15142B - 0.024695A * B - 0.044796A^2 - 0.010445B^2 \quad \ldots(3)$$

Eliminating the non-significant terms for the different tillage methods, the equations reduce to equations 4, 5 and 6 respectively.

The model equation for crop yield (No Tillage) thus, becomes:

$$905.86125 - 2.39650A + 1.70182B - 0.000020\,A * B + 0.001391B^2 \quad \ldots.(4)$$

For the conservative tillage method, equation 2 yields:

$$1320.33514 + 12.90729A + 3.44454B - 0.023251A * B + 0.002274B^2 \quad \ldots(5)$$

Equation 3 yields equation 6 depicting the equation for conventional tillage method as:

$$1889.28653 + 8.86883A + 13.15142B - 0.024695A * B + 0.010445B^2 \quad \ldots.(6)$$

These equations can be used to make predictions about the response for given levels of each factor.

Statistical 3D plots for Crop yield

From the 3D plots of crop yield in Figures 2, 3, 4., increasing irrigation deficit and NPK application reduces crop yield, this is because high crop yield occurs when there is adequate supply of water, that is, when soil moisture is not depleted beyond reasonable moisture range.

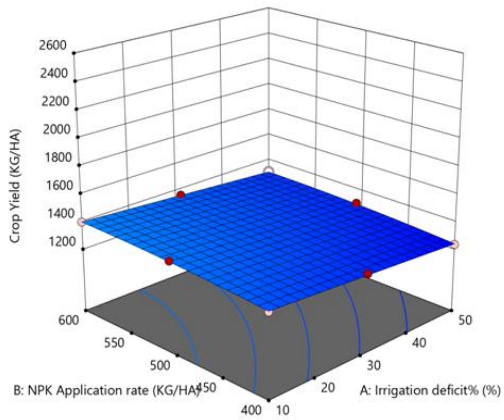

Figure 2. Statistical 3D plots for Crop yield (No Tillage)

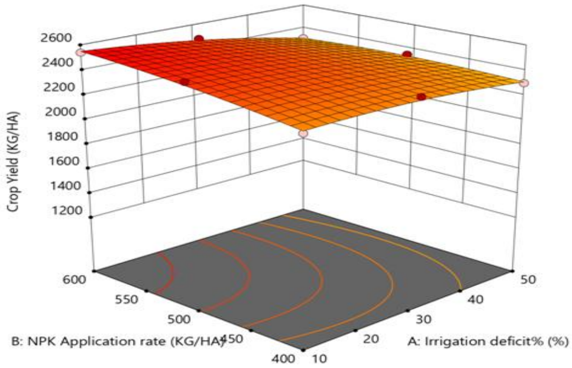

Figure 3. Statistical 3D plots for Crop Yield (Conservative Tillage)

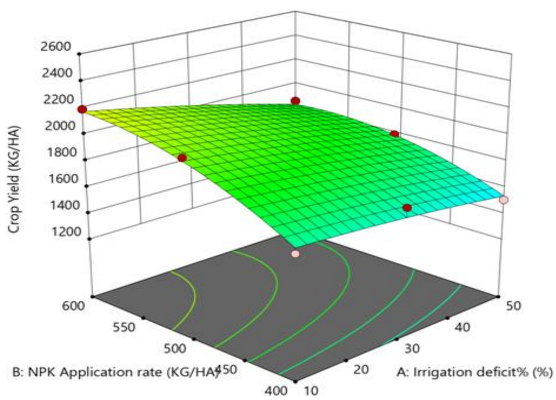

Figure 4. Statistical 3D Plots for Crop Yield (Conventional Tillage)

Table 7. Optimization Solutions

Number	Irrigation deficit%	NPK Application rate kg/ha	Tillage	Crop Yield	Desirability	
1	11.594	596.406	2	2543.589	1.000	Selected
2	10.154	599.069	2	2548.833	1.000	
3	12.194	599.053	2	2543.018	1.000	
4	11.048	597.860	2	2545.808	1.000	
5	10.428	595.845	2	2546.531	1.000	

The responses of the variables in Table 7. were generated by Design Expert 11.0 software for optimization based on the model obtained and the experimental data input. From Table 7., the run 1 order gave the optimum condition and was selected.

The optimum values based on the run order 1 gave irrigation deficit as 11.594%, NPK application rate as 596.406 kg/ha, best tillage method as conservative tillage, and crop yield of 2543.589 kg/ha.

CONCLUSION

The study showed that it was possible to produce good crop yield from drip irrigation in the study area during the dry season in the Southeastern Nigeria. The crop yield determined from the experiment shows that there was greater crop yield in conservative tillage than conventional and no tillage conditions, this is because of minimum disturbance of the soil that did not further reduce soil quality. Increase in NPK application and decrease in irrigation deficit increased crop yield in all the tillage practices.

The Central Composite Design (CCD) optimization model was used for finding the best levels of the process factors.

The model shows that for Irrigation deficit of 11.594%, at NPK Application rate of 596.406 kg/ha, and conservative tillage, the optimum response values obtained is Crop yield of 2.543.589 kg/ha (kg ha^{-1})

REFERRENCES

[1] Kang, Y, Khan S and Ma X.2009. Climate change impacts on crop yield, crop water productivity and food security. A review. *Progress in Natural Science* 19: pp.1665 – 1674.

[2] ACPC (Economic Commission for Africa). 2011. Climate change and Agriculture: Analysis of Knowledge gaps and needs. *UN Economic Commission for Africa*, Working paper 7.

[3] Mendelson R., Dinar A., and Dalfelt A. 2008. Climate change impacts on African Agriculture, In: B. Brates, Z.W. Kundewicz, S. Wu and Palutikof, Eds., Climate and Water. http//www.csmonitor.com/ 2006/1106/p04501-woaf.html

[4] Anyadike R.N.C. 2009. Climate change and sustainable development in Nigeria: Conceptual and Empirical issues. Enugu forum policy paper 10 African Institute for Applied Economics. pp. 13-18.

[5] Eboh, E. 2009. Debating policy option for national development: Enugu forum policy paper10 African Institute for Applied Economics Enugu, Nigeria. pp. 9-12.
[6] Ozor N. 2009. "Understanding Climate Change: Implication for Nigerian Agriculture. Policy and Education". Paper presented at the National conference on climate change and the Nigerian environment, organized by the department of Geography", University of Nigeria, Nsukka 29th June – 2nd July.
[7] Alam K, Monirul I, Salahin N, Hasanuzzaman M. 2014. Effect of Tillage practices on Soil Properties and Crop productivity in Wheat – Mungbean – Rice Cropping System under Subtropical Climatic Conditions. *The Scientific World Journal*. pp.1-15. http://dx.doi.org/10.1155/2014/437283
[8] Alam MK and Salahin N. 2013. Changes in soil physical properties and crop productivity as influenced by different tillage depths and cropping patterns. *Bangladesh J. Agril. Res.* 38(2): pp. 289-299.
[9] Anjum S.A., Raza M.M., Ullah S., and Yousaf M.M. 2019. Influence of different tillage practices on yield of Autumn planted Maize 9 *Zea mays L.*). *Pakistan Journal of of Agricultural Research* 32(2): pp.293-301.

EFEKTI RAZLIČITIH TRETMANA ZEMLJIŠTA NA PRINOS USEVA U JUGOISTOČNOJ NIGERIJI

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Apstrakt: U ovoj studiji, PVC sistem za navodnjavanje kap po kap je dizajniran zbog istraživanja uticaja različitih tretmana zemljišta na prinos useva, koristeći kao test usev određenu sortu kukuruza Oba Super 13.
Ogled je postavljen na tri osnovne parcele, od kojih svaka ima drugačiji metod obrade zemljišta i različita tretiranja useva kukuruza. Svaka parcela ima tri nivoa svakog od tri ispitivana tretmana zemljišta: deficit navodnjavanja, metodu obrade zemljišta i procenat primene đubriva NPK, što znači ima ukupno 27 različitih načina tretiranja useva .
Tri tretmana upravljanja sa navodnjavanjem kod 50%, 30% i 10% dozvoljene potrošnje vode. Tipovi obrade zemljišta su: konvencionalna, konzervacijska i tretman bez obrade zemljišta.
Primene NPK bile su: 400 kg/ha, 500 kg/ha, i 600 kg/ha (kg ha^{-1}).
Za eksperimentalno dizajniranje ovog ogleda upotrebljen je Central Composite Design (CCD) sa programom Design Expert 11.
Utvrđen je prinos za sve podparcele, gde je maksimalni prinos useva od 2540 kg/ha dobijen pri konzervacijskoj obradi sa tretmanom 10%MAD i 600 kg/ha NPK.
Minimalna obrada zemljišta imala je prinos 1234,67 kg/ha, bez obrade zemljišta, 50%MAD i primenjenom dozom od 400 kg/ha NPK.
Kontrolisani promenljivi parametri ogleda su optimizovani korišćenjem metodologije kontrolne površine (RSM) sa prinosom useva za sve podparcele.
Optimalne vrednosti na osnovu ciklusa pokazuje deficit navodnjavanja od 11,594%, dozu primene NPK 596,406 kg/ha, dok je najbolja metoda obrade konzervacijska obrada zemljišta sa prinosom useva 2.543,589 kg/ha.

Najveći prinos kukuruza je dobijen sa konzervacijskim načinom obrade zemljišta i rezultati potvrđuju održivost dobijanja visokog prinosa na ispitivanom području korišćenjem sistema za navodnjavanje kap po kap tokom sušne sezone.

Ključne reči: *Navodnjavanje, upravljanje dozvoljenom potrošnjom, obrada zemljišta, doza primena NPK.*

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PHYSICO-CHEMICAL PROPERTIES OF SOILS DERIVED FROM DIFFERENT GEOLOGIC FORMATIONS IN TYPICAL RAINFALL AGRO-ECOLOGICAL ZONE

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Abstract: Climatic conditions and geologic formations have been found to influence the nature of soils formed. Therefore, this study seeks to study the physical and chemical properties of the soils derived from the different geologic formations of a typical West African rainforest agroecological zone. 90 soil samples were generated from the field using standard field procedures. Standard laboratory method was used in carrying out the physico-chemical analysis of the collected soil samples. The results obtained showed the range of some selected soil properties coarse sand (32.25 to 61.62), fine sand (18.17 to 29.87%), total sand (62.22 to 85.93), silt (2.88 to 19.86%), Clay (10.3 to 18.46%), the structural code (1.77 to 3.77), porosity (50.55 to 61.20%), permeability (2.98 to 9.27 cm/hr), bulk density (1.35 to 1.57g/cm^3) and a permeability class (1.77 to 2.87 cm/hr), pH (5.22 to 5.62), organic matter (5.17 to 6.60%), available phosphorus (19.43 to 28.37%), calcium (4.98 to 19.11%), magnesium (1.39 to 3.34%), sodium (0.06 to 2.8%), potassium (0.04 to 0.29%) and ECEC (8.96 to 17.14 Cmol$_c$/kg).

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The results indicate the different physico-chemical properties of the formed from the different geologic formation of the study area. There is no statistical difference on the soils across the depth of the each geologic formation. The results obtained show that geologic formation have impact on the physicochemical properties of the soils. The results obtained in this research can served as a guide in soil management, utilization and conservation.

Key words*: Soil properties, geologic formation, rainfall agroecological zone physicochemical properties, soil conservation.*

INTRODUCTION

Climatic condition have been found to influence the nature of soils formed [1] and soils are formed from their different geologic formations [2], which serves as the bedrock on which other soil forming agents are being acted upon.

The spatial pattern of soils across the earth's surface has resulted in studying the properties of the different types of soils formed across time and space for understanding and utilization for proper land use management.

The physical and chemical properties of the soil are vital for agricultural activities such as, fertility management, crop selection, irrigation and other aspect of agriculture requiring the knowledge of the soil. Agricultural soil contains micro and macro nutrients, water, air and micro-organisms needed by plants for survival [3, 4]. However, soil has been found to play an important role in balancing the ecosystem [5] through the provision of food, fibres, woods, shrubs, vegetation, balancing of the natural cycles and sequestration of carbon, amongst others. Therefore, soil represents a lot of meaning to different profession, based on their usage.

[6] studied the influence of parent materials on mineral association and sorption capacity of soils in Akwa Ibom state, using a profile pits. [7] in their study compared the physical properties and organic matters of soils derived from three (3) different parent materials of Akwa Ibom state. [8] modelled the erodibility of soils formed from different geologic formation of the study area, using some selected soil properties. However, [9] studied the impact of plant materials and land use on soil quality indicators of soils in Akwa Ibom state, using laboratory method. [10] found soil particles to be important in the processes of bioavailability of organic compounds in soil through the sorption processes.

The knowledge of the spatial pattern of soil properties becomes imperative for the continuous study of soil properties. The formation of different geologic formation across the rainforest agro-ecological climatic zone influences the type of soil formed. Therefore, it is necessary to study the properties of the soils derived from the different geologic formations of the climatic zone. The objective of this paper is to study the physical and chemical properties of the soils derived from the different geologic formation of a typical West African rainforest agro-ecological zone using field work and laboratory analysis.

MATERIAL AND METHODS

Study Area

The location of the study is Akwa Ibom state, Nigeria, which represents a typical West African rainforest agroecological zone. The study area is located within the trigonometric boundaries of 4°32' and 5°33' North latitude and 7°25' and 8°25' East longitude.

The climate of the study area comprises of two seasons, the wet and dry season. The study area experiences an annual total rainfall ranging from 1875mm to 2500mm with a mean annual temperature that varies between 21ºc and 29ºc and a relative humidity of 60% and 85%.

Description of the Geologic Formation

The geologic formation of the study area is made up of 5 different geologic formations, namely; Alluvium, Ameki, Benin, Imo and Ogwashi. The geologic map was obtained from the Cross River Basin Development Authority as shown on Figure 1. The distribution of the different geologic formation is given as shown on Table 1. These geologic formations have been described by [8] in their research.

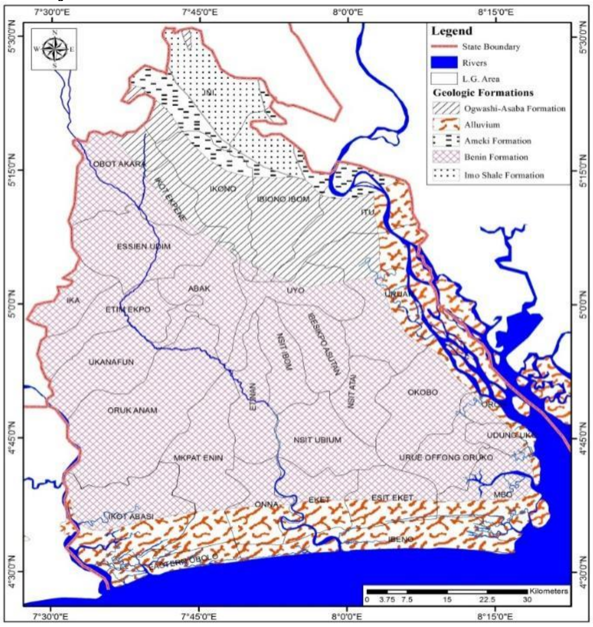

Figure 1: Geologic Map Formation of the Study Area, [8]

Table 1: Geologic Formation Coverage of Akwa Ibom State [8]

Geologic Formation	Area covered (ha)	Area covered (%)
Alluvium	144396.82	20.47
Ameki	29886.59	4.24
Benin	421706.4	59.8
Imo	26253.91	3.72
Ogwashi	82991.83	11.77
Total	705235.55	100

Field Sampling

During field sampling, soil auger was used to collect 15 soil samples randomly from each of the geologic formations identified to represent the soils formed at a varying depth of 0-10, 10-20, 20-30cm using the geologic map.

Undisturbed core samples were also collected for bulk density and porosity determinations. Therefore, a total of 90 soil samples were generated for the laboratory analysis.

Experimental Procedures

Standard methods were used in carrying out the laboratory analysis of the soil samples collected from the field. During experimental procedure, the soil samples were air-dried, grinded and passed through 2mm mesh size sieve for physical and chemical analysis.

Soil physical analysis

Two (2) grams of each soil series were passed through a 2 mm sieve, then 0.5g were put into the mortar and grinded. The grinded soil particles were put into a dry nylon for particle size analysis.

Particle size distribution was determined using the Hydrometer method [11].

Soil bulk density was determined using the Core method of [12].

Soil chemical analysis

Soil pH was determined according to the method of [13].

Organic carbon and organic matter were determined using the wet digestion method of [14], however, percentage organic matter was calculated by multiplying the percentage organic matter with Van denmelen's correction factor as shown on equation (1).

$$\%\ \text{organic matter} = \%\ \text{organic carbon} \times 1.724 \quad (1)$$

Where; 1.724 is the Vandenmelen's correction factor.

Available phosphorus was measured using the electrophotometer (Shimadzu, AA-6200) at a wave length of 660nm and the standard curve was prepared with 1μgP/ml (or ppm P).

Exchangeable cation (Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}) were extracted according to the Ammonium acetate extraction method of [14]. K and Na were determined on a flame photometer (Systonic Microprocessor Flame Photometer S-935) while Mg and Ca were determined on an atomic absorption spectrometer.

Total Nitrogen was determined using Macro Kjeldahl method of [15].

RESULTS AND DISCUSSION

Physical Properties of Soils Derived from Different Geologic Formations of the Rainforest Agroecological Zone of Akwa Ibom State

The results obtained across the soils formed from the different geologic formations of the study area show that at an averaged depth of 0-30cm, coarse sand (Cs) had an average value ranging from 32.25 to 61.62%. Fine sand (Fs) had a mean value ranging from 18.17 to 29.87%. Total sand (Ts) ranged from 62.22 to 85.93. Silt (Si) had a value ranging from 2.88 to 19.86%. Clay (Cl) had a value ranging from 10.3 to 18.46%. The structural code (Sc) of the soil sample ranged from 1.77 to 3.77. Porosity (Por) ranged from 50.55 to 61.20%. Permeability (Perm) ranged from 2.98 to 9.27 cm/hr. Bulk density (Bd) ranged from 1.35 to 1.57g/cm^3 and a permeability class (Perm Class) ranging from 1.77 to 2.87 cm/hr. Table 2 shows the physical properties of the soils derived from the different geologic formation of the study area at 0-10, 10-20, 20-30cm depth.

Table 2. Physical Properties of Soils Derived from Different Geologic Formations of the Rainforest Zone of Akwa Ibom State

Geologic Formations	Depth (cm)	Cs (%)	Fs (%)	Ts (%)	Si (%)	Cl (%)	SC	Por (%)	Bd g/cm^3	Perm cm/hr	Perm Class
Alluvium	0 - 10	32.43	29.83	62.26	20	18.43	1.75	61.19	1.58	9.81	1.75
	10 - 20	32.36	29.9	62.26	19.83	18.48	1.77	61.05	1.57	9.69	1.77
	20 - 30	32.25	29.89	62.14	19.76	18.46	1.79	61.01	1.57	8.32	1.79
Mean		32.35	29.87	62.22	19.86	18.46	1.77	61.08	1.57	9.27	1.77
SD		0.09	0.04	0.07	0.12	0.03	0.02	0.01	0.01	0.83	0.02
CV		0.28	0.13	0.11	0.62	0.14	1.13	0.15	0.37	8.93	1.13
Ameki	0 - 10	60.21	26.2	86.41	2.88	10.16	3	59.7	1.36	2.79	2.75
	10 - 20	60.86	25.28	86.14	2.88	10.29	3	60.32	1.34	2.99	2.69
	20 - 30	61.5	23.75	85.25	2.89	10.45	3	60.17	1.34	3.16	2.64
Mean		60.86	25.08	85.93	2.88	10.3	3	60.06	1.35	2.98	2.69
SD		0.65	1.24	0.61	0.01	0.15	0	0.32	0.01	0.19	0.06
CV		1.06	4.94	0.71	0.20	1.41	0	0.54	0.86	6.21	2.04
Benin	0 - 10	68.86	14.27	83.13	5.17	11.04	3	57.78	1.51	4.78	2.83
	10 - 20	64.5	13.98	78.48	5.22	10.14	3.08	57.65	1.5	6.2	2.77
	20 - 30	51.5	26.25	77.75	5.69	10.15	3.14	57.56	1.38	5.66	3
Mean		61.62	18.17	79.79	5.36	10.44	3.07	57.66	1.46	5.55	2.87
SD		9.03	7.00	2.92	0.29	0.52	0.07	0.11	0.07	0.72	0.12
CV		45.16	35.01	14.59	1.43	2.58	0.35	0.55	0.36	3.58	0.60
Imo	0 - 10	59.1	21.19	80.29	6.27	13.88	3.75	61.13	1.45	5.04	2.58
	10 - 20	59.14	21.05	80.19	6.21	13.74	3.77	61.24	1.46	5.64	2.46
	20 - 30	59.21	21.01	80.22	6.12	13.65	3.79	61.24	1.47	6.15	2.36
Mean		59.15	21.08	80.23	6.2	13.76	3.77	61.20	1.46	5.61	2.47
SD		0.06	0.09	0.05	0.08	0.12	0.02	0.06	0.01	0.56	0.11
CV		0.09	0.45	0.06	1.22	0.84	0.53	0.10	0.68	9.90	4.47
Ogwashi	0 - 10	57.49	19.97	77.46	8.6	17.23	2.83	50.65	1.48	4.81	2.58
	10 - 20	56.3	19.85	76.15	8.43	17.07	2.92	50.5	1.49	4.93	2.54
	20 - 30	58.07	19.76	77.83	8.31	16.95	3	50.5	1.5	5.03	2.5
Mean		57.29	19.86	77.15	8.45	17.08	2.92	50.55	1.49	4.92	2.54
SD		0.91	0.11	0.88	0.15	0.14	0.09	0.09	0.01	0.11	0.04
CV		2.65	0.31	2.60	0.43	0.41	0.25	0.25	0.03	0.32	0.12

Cs: Coarse sand, Fs: Fine Sand, Ts: Total sand, Si: Silt, Cl: Clay, Sc: Structure Code, Por: Porosity, Perm Class: Permeability Class

Chemical Properties of Soils Derived from Different Geologic Formations in Rainforest Agroecological Zone of Akwa Ibom State

The results obtained show that the average pH value obtained for the different geologic formation ranged from 5.22 to 5.62, while the organic matter had an average value of 5.17 to 6.60%. Available phosphorus found within the sampled soils of the different geologic formation ranged from 19.43 to 28.37%. Calcium was found to be within the limit of 4.98 to 19.11%. Magnesium ranged from 1.39 to 3.34%. Sodium had a range of value of 0.06 to 2.8%. Potassium had a value ranging from 0.04 to 0.29%, while ECEC had a value range of soil 8.96 to 17.14 $Cmol_c$/kg. Table 3 shows the chemical properties of the different soils obtained from the different geologic formation at a depth of (0-10, 10-20, 20-30) cm obtained from the laboratory analysis.

Table 3. Chemical Properties of Soils Derived from Different Geologic Formations of the Rainforest Agroecological Zone of Akwa Ibom State

Geologic Formations	Depth	pH	OM %	Av P %	Ca %	Mg %	Na %	K %	ECEC $Cmol_c$/kg
Alluvium	0 - 10	5.52	6.01	18.57	19.18	1.4	0.06	0.25	21.42
	10 - 20	5.5	5.64	19.45	19.09	1.39	0.06	0.39	21.08
	20 - 30	5.49	5.34	20.28	19.07	1.39	0.06	0.23	20.83
Mean		5.50	5.66	19.43	19.11	1.39	0.06	0.29	21.11
SD		0.02	0.34	0.86	0.06	0.01	0	0.09	0.30
CV		0.28	5.93	4.40	0.31	0.41	0	30.06	1.40
Ameki	0 - 10	5.48	7.94	22.88	7.51	3.5	0.18	0.15	12.53
	10 - 20	5.45	7.49	22.15	7.17	3.33	0.18	0.15	12.04
	20 - 30	5.44	3.78	21.53	6.88	3.18	0.17	0.15	10.05
Mean		5.46	6.40	22.19	7.19	3.34	0.18	0.15	11.54
SD		0.02	2.28	0.68	0.32	0.16	0.01	0	1.31
CV		0.38	35.65	3.05	4.39	4.80	3.27	0	11.38
Benin	0 - 10	5.25	5.82	21.49	11.06	1.67	0.05	0.04	8.96
	10 - 20	5.2	4.5	21.8	11.18	1.69	0.05	0.04	9.1
	20 - 30	5.2	5.18	25.85	11.26	1.63	0.05	0.04	8.87
Mean		5.22	5.17	23.05	11.17	1.66	0.05	0.04	8.98
SD		0.03	0.66	2.43	0.10	0.03	8.5E-18	0	0.12
CV		0.15	3.47	12.80	0.53	0.16	4.47E-17	0	0.61

Contin. Table 3.									
Imo	0 - 10	5.6	6.93	28.63	6.28	2.62	0.12	0.18	16.43
	10 - 20	5.62	6.58	27.23	6.23	2.6	0.12	0.18	16.61
	20 - 30	5.63	6.28	26.05	6.2	2.59	0.13	0.18	16.74
Mean		5.62	6.60	27.30	6.24	2.60	0.12	0.18	16.59
SD		0.02	0.33	1.29	0.04	0.02	0.01	3.4E-17	0.16
CV		0.27	4.93	4.73	0.65	0.59	4.68	1.89E-14	0.94
Ogwashi	0 - 10	5.4	7.14	29.87	5.23	2.81	2.93	0.16	17.73
	10 - 20	5.38	6.76	28.3	4.96	2.73	2.79	0.16	17.1
	20 - 30	5.37	5.38	26.93	4.74	2.67	2.68	0.16	16.58
Mean		5.38	6.43	28.37	4.98	2.74	2.8	0.16	17.14
SD		0.02	0.93	1.47	0.25	0.07	0.13	0	0.58
CV		0.28	14.41	5.19	4.93	2.57	4.47	0	3.36

OM: Organic Matter, Av P: Available Phosphorus, Ca: Calcium, Mg: Magnesium, Na: Sodium, K: Potassium, ECEC: Exchangeable

DISCUSSION

Implication of the Different Geologic Formation on the Soil Physical Properties of the Soils Derived

The effects of the geologic formation on the soil physical properties can be seen as shown on Table 2. The aggregate of the soils obtained within the study area show that soils formed from the different geologic formations are basically sandy in nature [16]. The results obtained show that the ranges of coarse sand found within the different geologic formations are in the ascending order of Benin, Ameki, Imo, Ogwashi and Alluvium. The standard deviation and coefficient of variance among the different depths of similar points sampled across the different geologic formations shows that there is no significant difference ($p \leq 0.05$) of the sampled mean from the mean of the data collected except Benin formation having a CV of 45.16, which may be a reflection of the land use/land cover pattern of the geologic formation.

The range of fine sand obtained across the different geologic formation shows that the different soils obtained from the study area contains sand content of below 2.00mm, which shows that the study area is made up of sandy soil.

Total sand (TS) of the soil aggregate obtained shows that soils formed from the different geologic formation are basically sandy in nature, however, the coefficient of variance obtained, which ranged from 0.11 to 14.59 shows that the total sand content differs across the geologic formations.

The silt content of the soils sampled show that Alluvium had the highest silt content which signifies that soils from Alluvium geologic formation are basically from the activities of the river [6], while the amount of silt content sampled across other geologic formations shows low silt content. The coefficient of variance (0.20 to 1.43) of the silt content across the different depth of the geologic formation shows that the silt content are similar with depth but different with geologic formations.

The clay content of the soil aggregates obtained across the different geologic formations show the presence of clay contents in all the soil obtained across the different geologic formations. This shows that clay have an effect on the soil structural class of the different soils formed across the geologic formations [17]. The soil structural code across the different geologic formation is a function of the textural class of the soils obtained. The structural code obtained shows that soils obtained from the different geologic formation within the study area are classified as very fine sand and very thin, fine or thin, medium or coarse in nature which affects their particle sizes. The textural class across the different geologic formation ranges from sandy loam, sandy clay loam as shown from the result of the soil analysis**.**

The porosity of the soil obtained from the different geologic formation shows the nature of the geologic formation to be sandy in nature and sandy soils are known to have high porosity rate [6]. The lowest porosity range was found in Ogwashi geologic formation which depicts a sand stone property, while Imo had the highest porosity within the different geologic formations of the study area. Lower values of CV were obtained within the different geologic formation showing that the porosity varies slightly among depth across the different geologic formations. This shows that soils within the study area will support infiltration of water, which will support irrigation practices and also encourage rapid movement of water, thereby leading to soil loss.

Alluvium and Benin had similar range of bulk density, followed by Imo and Ogwashi, while Ameki had the lowest bulk density. The bulk density obtained across the different geologic formations implies that the soils formed within the study area had similar bulk density. The results indicate that the soils found within the study area have good function for water movement and soil aeration, which aids infiltration and reduce runoff and possibly erosion [7].

Permeability defines the ease of flow of water in the soil, however, the results obtained across the geologic formations shows that Alluvium had the highest permeability rate with a permeability class of moderate to high. The other geologic formation had a range of 2.00 to 6.25 cm/hr with a permeability class of 3 indicating that soils formed within Ameki, Benin, Imo and Ogwashi geologic formation has moderate permeability rate. The coefficient of variation shows variations within the permeability rate across the depth of the geologic formation and similar permeability class across the depth of the different geologic formations. The analysis of variance of the physical properties of the soil among the different geologic formations of the study area gave a P value of 0.99 and F critical value of 2.58, indicating variation that is not statistically significant among the physical properties of the soils obtained from the different geologic formations of the study area. This can be attributed to the simulation climate as an agent of soil formation.

Implication of the Different Geologic Formation on the Soil Chemical Properties of the Soils Derived

The effects of the geologic formations on the soil chemical properties are given as shown on Table 3. Soil pH defines the degree of soil acidity or alkalinity. The pH of the soils obtained from the different geologic formation shows that the soils are acidic in nature. The pH of the geologic formations is found to be suitable for plant growth and development [18], hence encourages crop productivity.

Available phosphorus has been found to be similar in the different geologic formation across the depth sampled. Calcium was found to be high at Alluvium, which could be as a result of the deposits from the fluvial activities of the nearby water bodies [19, 20]. Benin had high calcium that is significantly different from the rest of the geologic formation. Ameki, Imo and Ogwashi had similar range; this could be affected by the proximity of the geologic formation to each other. Magnesium had a higher value at Ameki, Ogwashi and Imo which is as a result of its distance from the ocean, which has result in low leachate and chemical reaction. However, Benin and Alluvium had lower Magnesium due its closeness to the ocean, thereby, resulting to leaching and chemical reaction.

Ameki, Imo and Ogwashi had high value of sodium while Alluvium and Benin had low values of sodium. Alluvium had the highest value of potassium while Ameki, Imo and Ogwashi had similar range for potassium while Benin had the lowest value. The effective cation exchange capacity (ECEC) is highest at Alluvium, Ogwashi and Imo had similar range of ECEC followed by Ameki. Benin had the lowest ECEC across the geologic formations. It shows the ability of the soils to supply important nutrients of plants such as potassium, calcium and magnesium. The results imply that Alluvium had the highest potentials of soil nutrients than other geologic formations. [19, 20] observed soils formed from alluvium deposits to be rich in plant nutrients. The analysis of variance of the chemical properties of the soil among the different geologic formations of the study area shows a P value of 0.98 and F critical value of 2.64, which indicates variation of soil chemical properties that is not statistically significant among the chemical properties of the soils obtained from the different geologic formations of the study area, which is a function of the geologic formation and the environmental condition found within the study area.

CONCLUSION

Soil properties are considered to be an important aspect in agriculture and environmental utilization. These properties are affected by geologic and climatic conditions of its environment. Different geologic formations have been identified within the study area. The study shows that the geologic formations and the climatic condition of the study affected the properties of the soils formed, as the properties of the soils differ slightly from the coastal zone to the upland zone of the study area. Therefore, this research indicates that geologic formations and climate have impact on the soil physico-chemical properties. This research will be useful in planning agricultural activities such as fertility management, crop selection, field usage and soil conservation activities as related to soil properties.

REFERENCES

[1] Sindelar, M. (2015). Soil and Climate: Climate influences soil. 2015 international year of soils, Soil Science Society of Nigeria. Retrieved on the 9/09/2022 from www.soil.org/IYS

[2] Gray, J. and Murphy, B. W. 1999. Parents Material and Soils: A Guide to the influence of Parent Materials on Soil Distribution in Eastern Australia, NSW Department of Land and Water Conservation, Technical Report, No 41.

[3] Powlson, D. S., Gregory, P. J., Whalley, W. R., Quinton, J. N., Hopkins, D. W.,Whitmore, A. P., Hirsch, P. R. and Goulding, K. W. T. 2011. Soil Management in Relation to Sustainable Agriculture and Ecosystem services. Food Policy Guidelines 36 (2): pp.72-87.

[4] Obasi, R. A. 2013. Vulnerability of Soil Erosion in Okitipupa Area of Ondo State, Southwest Nigeria: A Climatic Problem. International Journal of Science and Technology Volume 2 No. 4, pp 326-335.

[5] Schoonover, J. E. and Crim, J. F. 2015. An Introduction to Soil Concepts and the Role of Soils in Watershed Management. Journal of Contemporary Water Research & Education. Issue 154 pp. 21-47.

[6] Akpan and Ukut .2015. Influence of Parent Material on Organo-Mineral Association and Sorption Capacity of Soils of Akwa Ibom State, Nigeria. International Journal of Innovative Agriculture and Biology Research 3(3). Pp. 9-17

[7] Oguike, P. C. and Utin, U. E. 2017. Comparative assessment of some physical properties and organic matter content of soils derived from different parent materials in akwa ibom state, Nigeria. J. Agric. Sci. & Env. 18(1&2). pp.107-125.

[8] Ekpo, A. E., Orakwe, L. C., Nwanna, E. C., Anoziba, D. C. and Nwachukwu, C. P. 2021. Determination of Soil Erodibilty (K) Factor Derived from Different Geologic Formations of Akwa Ibom State. Nigerian Journal of Technology (NIJOTECH), 40(6), pp. 1096 – 1103.

[9] Akpan, U. S. and Uwah, I. D. (2018). Impact of Land Use Systems and Parent Materials on Soil Quality Indicators in Soils of Akwa Ibom State, Nigeria. Agricultural Extension Journal 2018; 2(1):44-50 ISSN 2521 – 0408

[10] Pignatello, J. J. and Nason, S.L.2020. Importance of Soil properties and processes on Bioavailability of Organic Compounds. In book: Bioavailability of Organic Chemicals in Soils and Sediments. pp. 1-428.

[11] Bouyoucous, G. J.1962. Hydrometer Method Improved for Making Particles Size Analysis of Soils. Agronomy Journal 54(5). pp. 464 – 465.

[12] Grossman, R. B. and Reinsch, T. G. 2002. Bulk density and linear extensibility. In Dane, J. H., and Topps, G. C. Eds. Methods of soil analysis, Part 4 SSSA Nadison, WI. pp 201–254.

[13] McLean, E. O.1982. Soil pH and Lime requirement. In: Page, A. L, Miller, R. H, and Keeney, D. R (eds). Methods of soil analysis. Part 2. Agron. Monogr. 9, Am, soc, Agron, Madison WI. pp. 199–223.

[14] Black, C. A.1965. Method of soil analysis; American society of Agronomy, Madison WI., p.978

[15] Bremmer, J. M. and Mulvaney, C. S.1982. Total-Nitrogen. In: Méthodes of soil analysis, part 2. Page, A. L, Mille, R. H and Kecney, D. R. (eds). American society of Agronomy. Madison, pp. 595 – 624

[16] Ogban, P. I.2017. Structural Stability and Erodibility In Soils Formed on Different Parent Materials In Southern Nigeria. Nigerian Journal of Agriculture, Food and Environment. 13(4). pp.63-74

[17] Tisdall, J. M. and Oades J. M.1982. Organic matter and water-stable aggregates. J Soil Sci 33(2): pp.141-163.

[18] Akpan, U. S. and Udoh, B. T.2015. Buffering Mechanism and Sensitivity to Acid Deposition of Soils of Akwa Ibom State, Nigeria. Nigerian Journal of Agriculture, food and environment 11(3): pp.91-96
[19] Udotong, I., John, O. and Udotong, J. 2008. Microbial studies of wetland soils in Eket, Nigeria, World Academy of Science, Engineering and Technology, Open Science Index 20, International Journal of Biomedical and Biological Engineering, 2(8). pp. 176 – 181.
[20] Eden, S. O. and Ndon, B. A. 2001. Evaluation of Management properties of wetland soils of Akwa Ibom State, Nigeria for sustainable crop production. Journal of Applied Chemistry and Agricultural Research, Vol 7, pp. 26 – 36.

FIZIČKO-HEMIJSKE OSOBINE ZEMLJIŠTA NASTALIH IZ RAZLIČITIH GEOLOŠKIH FORMACIJA U TIPIČNOJ KIŠINOJ AGRO-EKOLOŠKOJ ZONI

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Apstrakt: Utvrđeno je da klimatski uslovi i geološke formacije utiču na prirodu formiranog zemljišta. Zato ova studija nastoji da prouči fizičke i hemijske osobine zemljišta koje potiču iz različitih geoloških formacija tipične zapadno-afričke agro-ekološke zone prašume.

Na terenu je uzeto 90 uzoraka zemljišta standardnim terenskim procedurama. Za fizičko-hemijske analize prikupljenih uzoraka zemljišta korišćene su standardne laboratorijske metode.

Dobijeni rezultati su pokazali sadržaj (učešće) pojedinih odabranih frakcija zemljišta: krupnog peska 32,25 do 61,62%, sitnog peska 18,17 do 29,87%, ukupnog peska 62,22 do 85,93%, praha 2,88 do 19,86%, gline 10,3 do 18,46%). Strukturni agregati 1,77 do 3,77%, ukupna poroznost 50,55 do 61,20%, propusnost za vodu 2,98 do 9,27 cm/h, zapreminsku masu 1,35 do 1,57 g/cm^3 i klasu propusnosti 1,77 do 2,87 cm/h. Vrednost pH je od 5,22 do 5,62, sadržaj organske materije 5,17 do 6,60%, raspoloživi fosfor 19,43 do 28,37%, kalcijum 4,98 do 19,11%, magnezijum 1,39 do 3,34%, natrijum (0,06%), kalijum 0,04 do 0,29% i ECEC 8,96 do 17,14 Cmolc/kg.

Rezultati ukazuju na različita fizičko-hemijske osobine zemljišta formiranih iz različitih geoloških formacija istraživanog područja.

Ne postoji statistička razlika osobina zemljišta po dubini svake geološke formacije. Dobijeni rezultati pokazuju da geološke formacije utiču na fizičko-hemijske osobine zemljišta.

Rezultati dobijeni u ovom istraživanju mogu poslužiti kao vodič u upravljanju, korišćenju i očuvanju zemljišta istraživanog područja.

Ključne reči: *Osobine zemljišta, geološka formacija, fizičko-hemijske osobine agroekološke zone padavina, konzervacija (očuvanje) zemljišta.*

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INSTRUMENTATION AND EVALUATION PROCESS OF SOME ENGINEERING CHARACTERISTICS OF GRAIN CROPS AND UTILIZATION FOR MECHANIZED PRODUCTION AND PROCESSING IN NIGERIA: A REVIEW

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Abstract: A review of Instrumentation and Evaluation Process of some Engineering Characteristics of Grain Crops and Utilization for Mechanized Production and Processing in Nigeria was conducted. Various related works which were relevant to the study were explored and used for the review. Proper evaluation and utilization of engineering characteristics of grain crops would enhance the design and/or development of equipment which would effortlessly boost up the production and post-harvest handling/processing process of grain crops and minimize unnecessary damage/loss of the seeds. The review revealed that moisture content had great influence on the engineering properties of grain kernels. Results of researchers showed an increase in mass of coriander seed from 8.89 to 9.826 g when the moisture content was increased from 8.5 % to15.89 % (w.b.); angle of repose increased from 25.5 to 31^{o} with increase of moisture content from 8.5 % to 15.89 % (w.b.). The coefficient of friction for various surfaces increased with the increase in the moisture content while the bulk density decreases with the increase in moisture content.

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Furthermore, the compression force required to initiate grain kernel rupture decrease with the increase in moisture content. Thus, the deformation at the grain rupture increases as the moisture content increases.
Results from the review indicated a decrease in fracture forces range from 63 t0 38 N for IT86D-I0I0, 64 to 40 N and 70 to 46 N, respectively for IAR-339-1 and Ife Brown cowpea varieties at moisture content varying from 15 to 30 % (w.b).
The review further showed that most studies were focused on a few grain crops and that data on engineering properties obtained for various grains seeds vary from one crop to another and from one variety to another.
This variation requires studies of engineering properties of different types and varieties of grain crops at different moisture content levels that would guide farmers, processors and designers/manufacturers of machine tools in developing and selecting appropriate machines for their operations at any level in order to increase their production at reduced loss or damage of the seeds.

Key words: *Grain crops, engineering properties, instrumentation, evaluation, machines, processing*

INTRODUCTION

Grain crops such as maize, rice, sorghum, cow pea, pigeon pea, beans, wheat etc. constitute the staple food of a large chunk of the population in Nigeria and many other regions of the world. They are also responsible for about sixty percent by weight of most livestock feed formulation. The importance of grain crops in the economy of Nigeria cannot be over emphasized; but despite their nutritional and economic values, much attention has not been given to mechanization of their production (planting/ sowing and harvesting) and post-harvest handling especially in the rural areas. For instance, in Nigeria, harvesting of pigeon pea and other related grain crops are done by manual picking and breaking of the dry mature prods. This method is tedious, tasking, time consuming and limits pigeon pea production [1]. Cutting of mature pigeon pea stalks and feeding into a whole shoot/stalk thresher to extract the seeds is a better method of harvesting as recommended by [2] and [3]. Ordinarily, grain crops can best be harvested using combine harvester which cut and threshes the mature stalks/pods bearing the grains. This mechanized method of processing grain crops cannot be achieved without the knowledge of some engineering properties of the crops such as physical, mechanical and aerodynamic properties of the grain kernels, stalks and hulls for chaff separation from the grains (winnowing). Furthermore, processing of the grain crops which may include cutting the mature stalk, threshing, cleaning, cooking, drying, mechanical milling, grinding and general handling of the grains require the knowledge of some engineering properties such as physical, mechanical, biological, thermal, optical, aerodynamic and electrical properties. It is based on these properties that processing machines and handling operation could be designed for efficiency and to obtain the highest quality of the end product with minimum damage of the seeds [1]. Authors [4] reported that grain crops are been underutilized because of the fact that its mechanization in terms of processing has not received any attention in Nigeria; because little is known about the engineering properties of the grain kernels.

Author [5], noted that, the increase in food production coupled with the complexity of modern technology for their production, handling, processing, storage, utilization marketing and development of new varieties demands the knowledge of physical and mechanical properties of these biomaterials; this is because from the production units on the farm down to the consumers, food materials are subjected to various physical, mechanical and to some extent electrical devices [1].

Mechanization of the processing operation of agricultural products influences the quality, quantity and storability of agricultural materials especially in size reduction.

The nature and extent of the influence are dependent on the physical and mechanical properties of the materials [6].

Mechanical planting, harvesting and post-harvest handling of grain crops should be based on the knowledge of the physical and mechanical characteristics of the grains. Mechanical damages to grains which occur in sowing, harvesting, threshing, and general handling of the material are attributed to the poor knowledge of the physical and mechanical properties of the grains in design of machines that handles the various operations. Previous works by Authors [7] and [8], revealed the need for adequate information on the physical and mechanical properties of biomaterials under static or dynamic loading. According to [6] such information is an essential step in any work relating to the processes of size reductions and prevention of mechanical damages during physical handling, processing, packaging and storage of these materials. Author [9] in the report of their study on "some properties of palm kernel and shell relevant in nut cracking and product separation" added that the properties of some agricultural materials are needed as base line data in optimal design of machines to handle the product. Authors [10] noted that the development of any machinery for harvesting and processing of agricultural material depend greatly on the physical and mechanical properties of such agricultural products. Authors [11] maintained that physical and mechanical properties of agricultural products are the most important parameters required to determine the standards of design of product handling; processing and packaging systems. Autor [12] added that physical properties of granular solids are essential to design appropriate, efficient, and economic bulk solids handling and storage equipment. Authors [13] posited that, engineering properties are important in problems associated with the design of machines and the analysis of the behavior of the product during agricultural process operations such as handling, planting, harvesting, threshing, cleaning, sorting and drying. According to them, solutions to problems of these processes involve proper evaluation/knowledge of the physical and other engineering properties of the seed kernels. For instance, bulk density, true density, and porosity can be useful in sizing grain hoppers and storage facilities while distinctive shapes and sizes of the grains as may be identified by the values of sphericity and size distribution pattern can be effectively utilizes for the selection of sizes and shapes of screans that can be employed in mechanical separation of grains [10]; [1]. Design of grain harvesting and handling system requires the determination of friction coefficient between grain and structural surface in contact with the grain [14]; [15]; [16].

Due to some differences in the engineering properties of crops coupled with the varietal differences and proximate compositions, characteristic data of the various agricultural crops is very essential for machinery design and selection; the characteristic data are the essential parameters for sowing, harvesting, processing, handling and/or packaging of various bio-products.

But regrettably information on the engineering properties of some grain crops is not available to farmers and manufacturers of the processing machines in Nigeria, to guide them in the design and development of these machines. Agricultural machines and equipment are imported into the country to aid the various governments' mechanization policies [6].

At the moment, the cost of importation of agricultural machinery has been sky rocketed due to the deflation of the local currency and most farmers especially in the rural areas cannot afford the cost, and to operate within such a bad economic condition, farmers and processors of this agro-products should be knowledgeable of the engineering properties of individual crops to enable them design and fabricate or develop machines that will aid them in handling the production process of the crops.

The objective of this work is to review the instrumentation and measurements of engineering behaviors of grain crops for improved in-field, post- harvest processing and handling operations of the crops.

POTENTIAL IMPACT OF SOME ENGINEERING PROPERTIES OF BIOMATERIALS IN MACHINE DESIGN/DEVEOPMENT AND SELECTION

Author [11] noted that, physical and mechanical properties of agricultural products are the most essential parameters required to determine the criterions of design of product handling; processing and packaging systems. The knowledge of some physical properties such as shape, size and density is valuable in designing the planting, threshing and grading process equipment. Author [17] noted that, in the cultivation procedure, from planting to transportation, the size, shape and mechanical behaviors of seeds or grains should be ascertained for selecting appropriate types of machinery for harvesting, separating, sizing and grinding. Previous study by [18] stated that mass and size values are vital for broadcasting machines. Authors [19] and [20] noted that, grain volume and surface area ought to be known for developing drying apparatus, and frictional characteristics of the grain are required for designing the conveyors and hoppers.

According to Author [21], mechanical properties of a material are those properties that involve a reaction to an applied load. Frequently, food materials are subject to forces (loads) when they are processed. They noted that, deformation Force evaluation and material deformation features such as compression, elongation, twisting are the function of applied load, time, temperature, and other condition. Results of such tests according to them are used for engineering design (for instance, failure theories based on strength, or deflections based on elastic constants and component geometry) and quality control either by the materials producer to confirm the process or by the end user to verify the material specification and quality. Mechanical properties are equally used to categorize and identify material. The properties considered for food material are strength, failure force, failure deformation, fracture or rupture force, deformation, bioyield, inflection, stiffness, stress index, toughness, modulus of elasticity and modulus of deformability.

The aerodynamic properties are basically applicable in the pneumatic separation, conveying and handling of biomaterials during processing while the knowledge of some physical properties such as moisture content, size, surface area, bulk density, shape, volume, and weight affect the aerodynamic behaviours of biomaterials [6].

Proper cleaning, i.e. separation of the grain kernels from the hulls and stalks during threshing operation requires the knowledge of some physicals and aerodynamic characteristics of grain crops, hulls and stalks.

This will enable the engineers to include a cleaning mechanism (Winnower or blower) in the design of grain whole stalks and hulls of the mature grain crops without damage to the grain kernels during threshing [22].

EFFECTS OF MOISTURE CONTENT ON SOME ENGINEERING PROPERTIES OF GRAIN CROPS

Studies from researchers [23]; [11]; [24]; [25]; [26]; [27]; [13] revealed that most physical properties of grain seeds increase with increase in moisture content.
Authors [21], observed an increase in mass of coriander seed from 8.89 to 9.826 g when the moisture content was increased from 8.5 % to15.89 % (w.b.); angle of repose increased from 25.5 to 31° with increase of moisture content from 8.5 % to 15.89 % (w.b.). The coefficient of friction for various surfaces increased with the increase in the moisture content. Others followed the same trend except the bulk density (Figure 1) that decreased with the increase in the moisture content.

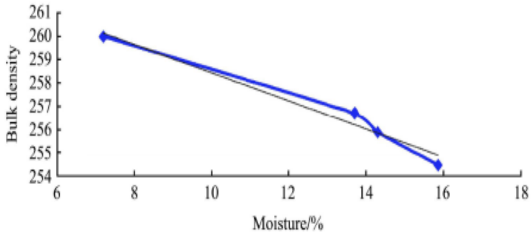

Figure 1. Effect of moisture content on bulk density of coriander seeds, [21]

Furthermore, the compressive force required to initiate grain kernel rupture decrease with the increase in moisture content (Figure 2). Thus, the deformation at the grain rupture increases as the moisture content increases [22]; [21]; [27]. Author [28] noticed seed hardness at range of 6-8 kgf for 20 different varieties of cowpea at moisture content varying from 9 % to 12 % while [27] observes a decrease in fracture forces range from 63 t0 38 N for IT86D-I0I0, 64 to 40 N and 70 to 46 N, respectively for IAR-339-1 and Ife Brown cowpea. This implies that grain kernels are sensitive to moisture content.

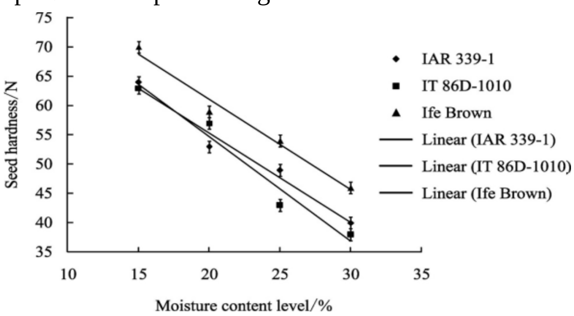

Figure 2. Effect of moisture content on seed hardness of cowpea, [27].

In the case of aerodynamic properties of grain kernels, the terminal velocity of the kernels increases with the increase in the moisture content while the drag coefficient decreases with the increase in moisture content. Research conducted by [29] showed that the terminal velocity of paddy and white rice for each variety increased as the moisture content increased (Figure 3).

On the other hand, the drag coefficient of the rice varieties for paddy and white rice gradually decreased from 0.57 to 0.53°, 0.50 to 0.48°, 0.71 to 0.63° and 0.68 to 0.61°, respectively, as the moisture content level was increased from 5 to 37 % (w.b.) (Figure 4). According to [30], the terminal velocity of pistachio nut and its kernel was found to increase as the moisture content was increased from 4.10 to 38.10 % (w.b.).

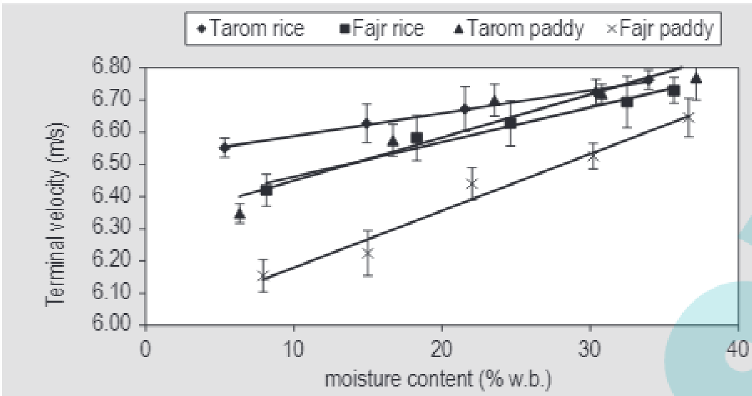

Figure 3. Effect of moisture content, % (w.b.) on terminal velocity of paddy and white rice grain kernels, [29].

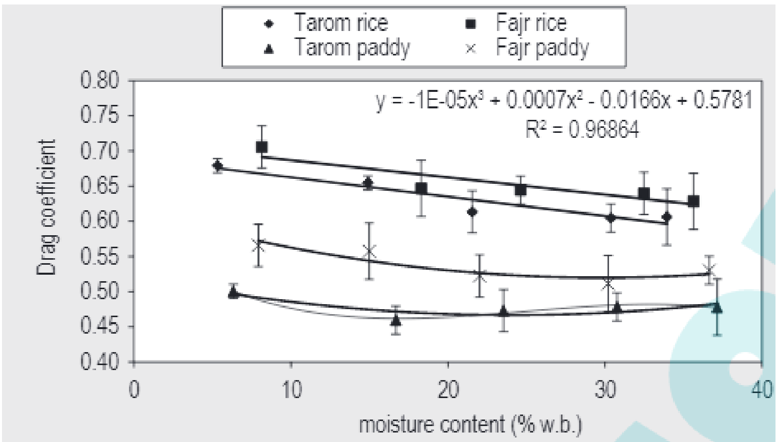

Figure 4. Effect of moisture content, % (w.b.) on drag coefficient of paddy and white rice grain kernels, [29].

INSTRUMENTATION AND EVALUATION OF PHYSICAL, MECHANICAL AND AERODYNAMIC PROPERTIES OF GRAIN SEEDS

Sample Preparation

The grains are cleaned to remove stones, dirt, dust, broken seeds, foreign and unwanted matters from the sample of the grain kernels.

Determination of Physical Properties

In order to obtain data on the physical properties of grain crops, parameters such as the moisture content, shape, size (geometric mean diameter, GMD), sphericity, roundness, surface area, roundness, volume, bulk density, specific gravity, true density, porosity, mass of products and friction against various surfaces have to be determined [31]; [1]. The knowledge of shape, size and density is valuable in designing the planting, threshing and grading process equipment. Size of the grains is determined by measuring the length, breadth, and thickness [21]; [32] and [33]. The frictional properties such as the angle of repose and the coefficient of friction are important properties in design of seed bins and other storage structures including the compressibility and flow behavior of materials [33]; [34]. Some convention designed and/or specially developed instruments/equipment are used by various researchers to determine the various engineering properties of grain crops.

Determination of Size

The venier caliper, micrometer screw gauge or a travelling microscope reading to an accuracy of ± 0.01 mm can be used to measure the three dimensions (major diameter, minor diameter and thickness) (Figure 5) of the grains selected randomly at same or different moisture content levels. Readings obtained are used to evaluate the size of the grains using Equation (1) [35]; [36], [22]; [21]

$$GDM = (abc)^{1/3} \quad \text{........ (1)}$$

Where: GMD = size, mm; a = major diameter, mm; b = minor diameter, mm and c = thickness, mm of the grain kernels.

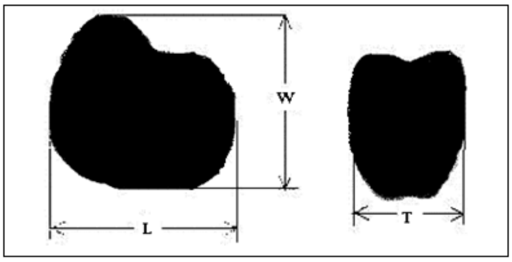

Figure 5. Three major dimensions of grain kernel, [13].

Note: L = a (major diameter), W = b (minor diameter) and T = C (thickness)

Determination of shape and sphericity

The shape of grain crops is assumed to approximate to a sphere. The sphericity is used to determine the shape.
Sphericity is a measure of how close a material is to being spherical.
It has to do with how round the grains are, and is determined using the expression given in equation 2 by [37].

$$Sphericity, \% = \frac{GMD}{a} \quad \text{…….. (2)}$$

Where: GMD = Geometric Mean Diameter, mm and a = major diameter, mm

According to [38], sphericity can also be calculated by using the following expression

$$\varphi = (LWT)^{0.333} \quad \text{…….. (3)}$$

Where, φ = sphericity, %, L = length, mm; W = width, mm; T= thickness, mm.

Determination of Mass

The mass of individual sample of the grain crops is measured using an electronic weighing balance of 0.00l g sensitivity [21].

Determination of Volume

The volume of the grains can be determined by using specific gravity method. In this method, the weight of the grains at different moisture content levels are determined in air using an electronic weighing balance of 0.001g sensitivity and in water using the specific gravity bottle and the volume computed using Equation (4) [13]; [1].

$$\text{Volume (cm}^3\text{)} = \frac{weight\ in\ air\ (kg) - weight\ in\ water\ (kg)}{weight\ density\ of\ water\ (kgcm^{-3})} \quad \text{…… (4)}$$

Alternatively, the volume of grains can be determined experimentally using water displacement method, as given by [39]. A displacement device may be constructed using a coated metal with a flow path created closer to the top. Water is poured into the device until it reaches the flow point. The excess water is being allowed to flow out until it stops. The grains is put inside water proof nylon and placed in the displacement device. An amount of water is displaced and is collected and its value read from a measuring cylinder. The volume of the displaced water is taken as the volume of the tuber.

According to [21], the volume of grains can also be calculated using Equation (5).

$$V = \frac{\pi B^2 X^2}{6(2X - B)} \quad \text{……….. (5)}$$

Where: $B = (YZ)^{0.5}$; X = a (Length or major diameter), mm;
Y = b (Width or minor diameter), mm; Z = c (Thickness), mm.

Determination of Surface Area

The surface area of grain seeds can be calculated using Equation (6) as suggested by [27]; [13] and [40].

$$S = \pi D_g^2 \qquad \text{.........} (6)$$

Where S = surface area (mm^2), D_g = geometric mean diameter (mm).

Determination of True Density

The true density of the grains can be determined by taking the ratio of the mass and the volume of the grain samples according to [6] and [41].

$$\rho_s = \frac{m}{v} \qquad \text{........} (7)$$

Where: ρ_s = True density (gcm^{-3}); m = mass of grains, g
v = volume of grains, cm^3

Determination of Bulk Density

The bulk density is the ratio of the mass of a sample of a seed to its total volume. Bulk density of the grains can be determined by weighing the grains filled in a container of known weight and volume. The grains are placed such that it fills the container to the brim and then it is weighed in an electronic weighing balance of 0.001g accuracy. The volume of the container is determined by filling a measuring cylinder of known volume with water and then pouring the water into the container until it fills the container. The volume of water poured into the container serves as the volume of that container. The bulk density of the grains is then calculated using Equation (8), according to [6].

$$\rho_b = \frac{M_b}{V_c} \qquad \text{........} (8)$$

Where: ρ_b =Bulk Density of the grains (gcm^{-3}); M_b =Bulk Mass of the grains (g)
V_c = Volume of the container (cm^3)

Determination of Porosity

Porosity can be calculated from the values of bulk density and true density based on the relationship stated by [6], [41] and [13].

$$P_o = 1 - \frac{\rho_b}{\rho_t} \times 100 \qquad \text{........} (9)$$

Where: P_o = Porosity of the grains, %; ρ_b= Bulk Density of the grains, gcm^{-3}
ρ_t = True Density, gcm^{-3}

Determination of Moisture Contents

The oven-dry method of moisture content determination can be used to determine the moisture content of the grain samples. The oven temperature was set at 105ºC for 24 hours [21]. The weight of initial samples of seeds and the weight of oven-dry samples of the same seeds are determined in the laboratory and the moisture content is evaluated from Equation (10) according to [12].

$$M_C = \frac{Ws - Ds}{Ds} \text{ x } 100\% \quad \text{..…….. (10)}$$

Where: M_C = moisture content of the seed grains, % (w.b);
W_S = weight of initial seed grain samples, kg and
D_S = Wight of oven-dry seed grains, kg.

To vary the moisture content of the sample, the randomly selected quantity of grain seeds is dried down to the desired moisture content. To obtain higher moisture content, calculated amount of distilled water is added using the following Equation [20]; [41]; [21].

$$Q = \frac{Wi\,(Mf - Mi)}{100 - Mf} \quad \text{………….. (11)}$$

Where: Q = quantity of water added (mL); WI = initial mass of sample (g);
Mi = initial moisture content, % (d.b.); Mf = final moisture content, % (d.b.)

Then the conditioned grain seeds are preserved in air tight and moisture resistant polyethylene bags; and stored at 5ºC in a refrigerator for 7 days to ensure homogeneous distribution of moisture all over the bulk grain seeds [34]; [11].

Determination of Angle of repose

The angle of repose is determined by using a known size of plywood box with a removable front panel. The box is filled with the sample, and then the front panel is swiftly removed, making the seeds to flow and assume a heap with regular slope (Figure 6). The angle of repose is calculated from the measurement of the height of the free surface of the sample at the centre, using Equation (12) [42]; [43]; [21]; [13].

$$Ø = \tan^{-1}\left(\frac{h}{b}\right) \quad \text{…….. ….(12)}$$

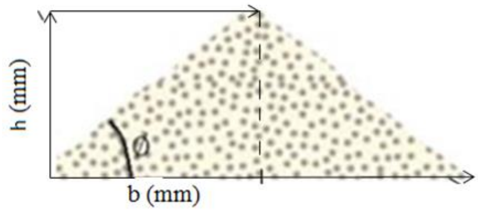

Figure 6. Angle of repose of grain seeds

Where: Ø = angle of repose, degrees; h = height of the grains, mm,
b = $\frac{1}{2}$ base covered by the grain samples, mm.

MECHANICAL PROPERTIES

Compression Test

The quasi-static plate compression tests can be performed using the Monsanto Tensometer (Plate 1) according to [44] to determine the force-deformation characteristics along the major, minor and intermediate axes of the seeds at the desired moisture content levels. In the method, grain seeds whose diameters are already determined are placed individually using a laboratory thumb on the compression jaws or grips, ensuring that the centre of the tool is in alignment with the peak of the curvature of the seed. Force is applied while turning the load arm of the testing machine at desired rate of speed (0.5 – 3.5 mms^{-1}) and the grain loaded to point of rupture. This is accompanied by the corresponding drop on the force-deformation graph (Figure 7), which is plotted concurrently by the cursor of the tool and its attached needle, which punctured the graph sheet at frequent intervals; thus recording the force produced by joining the successive punctures showing force-deformation curve of the seed. Bio-yield point and the rupture points are measured at different loading positions and moisture contents in the process.

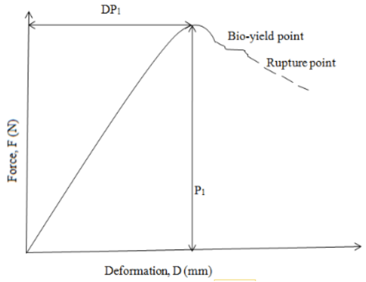

Figure 7. Force-deformation curve for biomaterials, [6].
P_1 = Inflection point; DP_1 = Deformation at inflection point

Plate 1. Honsfield Monsanto Tensiometer (Source: Civil Engineering Department, UNN)

Alternatively, the Instron universal testing machine with Load cell of 500 N to an accuracy of 0.5 N sensitivity can be used (Figure 8) ([27]; [45]. The seeds are placed between two aluminum jaws of the tool and pressed at 0.5 mms^{-1} speed until rupture point is reached.

The force-deformation curves are recorded by the computer and the rupture force is determined.

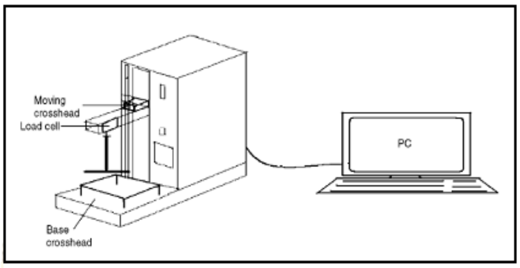

Figure 8. Universal test machine, [13].

Determination of compressive strength

The compressive strength of the seeds is computed using Equation (13)

$$\gamma_c = \frac{F_c}{A} \qquad \text{………. (13)}$$

Where: γ_c = compressive strength (Nmm^{-2}); F_c = maximum load at fracture (N)
A = cross sectional area of specimen (mm^2)

Determination of stiffness

Stiffness modulus is evaluated using equation 14 as given by [6]

$$S_M = \frac{F_{max}}{D_{max}} \qquad \text{………. (14)}$$

Where: S_M = Stiffness modulus, Nmm^{-2}; F_{max} = maximum breaking force, N and D_{max} = maximum deformation at breaking point, mm

Determination of Toughness

Toughness is the amount of work or energy required to bring about rupture in a material. It is determined by computation of the area under the force deformation curve before rupture, expressed as:

$$\beta = \frac{Rf}{Vm} \qquad \text{………. (15)}$$

Where: β = Toughness, kNmm^{-2}, R_f = rupture force, kN and
Vm = volume of material, mm^3

Determination of Deformation

Deformation which is the relative displacement of points within a body as a result of an applied force is determined by measuring the increase in the three characteristic dimensions of the seeds.

Determination of Static coefficient of friction

The static coefficient of friction for grain seeds may be determined with respect to three selected surfaces (plywood, mild steel and glass). A glass box of known dimensions (length, width and height) without base and lid is filled with sample and placed on an adjustable tilting plate, faced with test surface. The surface is raised gradually until cylinder started to slide down. The angle of inclination is read from graduated scale and the static coefficient of friction is evaluated based on Equation (16) [18]; [27]; [13].

$$\mu = \tan\alpha \qquad \text{.............. (16)}$$

Where: μ = Static coefficient of friction, α = angle of inclination, degree

In an alternative, the coefficient of friction of grain seeds maybe determined against four metallic surfaces, made of mild steel, galvanized iron, stainless steel and aluminum according to the method described by [32]; [46] and [21].

AERODYNAMIC PROPERTIES

The aerodynamic characteristics of grain seeds may be determined according to the methodology described by [47] as adopted by [22]

Determination of terminal velocity

Terminal velocity is determined experimentally following the method of [47] or mathematically using the relationship according to [48] and [49]

$$V_t = \sqrt{\frac{2mg}{\rho A C d}} \qquad \text{.............. (17)}$$

Where: V_t = terminal velocity ms^{-1}; m = mas of seeds, g;
g = acceleration due to gravity, ms^{-2}; C_d = drag coefficient;
ρ = density of the fluid through which the grain is falling, gcm^{-3} and
A = surface area of grain seeds, mm^2.

The drag coefficient, C_d is evaluated using the expression described by [48]

$$c_d = \frac{2F_d}{\rho \mu^2 A} \qquad \text{..................... (18)}$$

Where, F_d = drag force,N; ρ = mass density of the fluid, gcm^{-3},
μ = flow speed of the object relative to the fluid, ms^{-1} ,
A = reference area, cm^2.

CONCLUSIONS

Information of the engineering properties of grain crops and their characteristics under different moisture content levels are of considerable importance when designing tools to be used proficiently for sowing, post-harvest processes and handling of the grains.
Grain kernels are sensitive to moisture content.

Thus, the compressive force required to initiate grain kernel rupture decrease with the increase in moisture content. The terminal velocity of the kernels increases with the increase in the moisture content while the drag coefficient decreases with the increase in moisture content. Most physical properties increase with the increase in moisture content except the bulk density of the seeds.
The aerodynamic properties are basically applicable in the pneumatic separation, conveying and handling of biomaterials during processing. Proper cleaning during threshing operation requires the knowledge of some physicals and aerodynamic characteristics of grain crops, hulls and stalks.

RECOMMENDATIONS FOR FUTURE STUDIES

The following recommendations are made for future studies:

I. Differences exist in engineering properties among different types and varieties of grains seed crops; it is therefore recommended that studies should be conducted in every grain crop to obtain data on their engineering properties based on moisture content which will guide farmers, processors and manufacturers of machines in designing and/or selecting proper machines that would suit their production/processing process of grain crops for increased production at reduced damage/loss of the seeds.

II. Studies of the engineering properties of grain crops should be strictly based on moisture content since moisture content has great influence on the engineering properties of grain kernels and grain seeds are very sensitive to moisture.

III. Farmers, and users of the machinery should strictly use the engineering characteristics data of the seeds in selecting proper machines for their operations to avoid damage/ loss of the seeds during operation.

REFERENCES

[1] Oduma, O, Femi, P.O and Igboke M.E. 2013. Assessment of Mechanical Properties of pigeon pea (cajanus cajan (L.) Millps.) under compressive loading. *International Journal of Agricultural Science and Bio resource Engineering Research*, Vol. 2(2) pp.35-46.
[2] Nwuba, E.I.U 1988. Selected Physical and Mechanical Properties of Cowpea as Related to Mechanical threshing of Entire Plant Short. P.hD Thesis, Department of Agricultural Engineering, Ahmadu Bello University, Zaria.
[3] Oluka, S.I 1991. Some physical and Aerodynamic properties of cowpea as Related to Mechanical Cleaning of whole shoot. M.Eng. Thesis Anambra State University of Technology, Enugu.
[4] Akinso, A. and Lasis, I.M. 2013. Effect of Cooking Time on select physical and mechanical properties of Dried Pigeon pea (cajunus cajan). *The West Indian Journal of Engineering.* Vol.35, No2. pp.45-50.
[5] Mohsemin, N.N. 1986. *Physical properties of plant and Animal material*. Gardon and Bread series publication London. vol. 1, pp. 25- 837.
[6] Oluka S.I. 2000. Mechanical characteristics of Local Corn Kernels in Quasi-static compressive loading. *Journal of science and Technology,* Vol.6. pp.1-10.

[7] Ezeaku, C.A.1994. Fracture characteristics of Bambara Groundnut (Vigna subteranea verds) in compressive loading. M.Eng. Thesis, University of Nigeria Nskka.

[8] Oduma, O. Oluka, S.l. and Eze, P.C. 2013. Physical and mechanical properties of Sorghum grains (*Sorghum Vulgare*). Journal of Experimental Research. An Official publication of Enugu state University of science and Technology. Second Edition. Vol.1, pp. 95-102.

[9] Koya, O.A., Idowu, A. and Fabrode, M.O. 2004. Some properties of palm kernel and shell relevant in nut cracking and product separation. *Journal of Agricultural Engineering.* Vol.12. pp. 33 – 43.

[10] Oluka, S.I and Nwuba, E. I.U.2001 "Physical and Aerodynamic properties of cowpea seeds, Hulls and Stalks". *JEAS*, vol 1, No1. pp.35- 43.

[11] Altuntas E., E. Ozgoz and O. F. Taser. 2005. Some physical properties of fenugreek seeds. *Journal of Food Engineering,* 71(1): pp.37–43.

[12] Bahram, H.R., Hassan-Beygi, S.R., Kianmehr,M.H., Valaei, I., Mazraeh, H.M. 2014. The effectof moisture content, particle size and consolidation stress on flow properties of vermicompost. *Agric Eng Int: CIGR Journal,* 16(1): pp. 247ー252.

[13] Sarajeh, H., Mohammad, A., Majid Khanali,O. and Keyvan M. 2014. Effect of moisture content on some physical properties of Grass pea (*Lathyrussativus L.*). *Agric Eng Int: CIGR Journal,* 16(4): pp.261-267.

[14] Aviara, N. A., M. I. Gwandzang, and M. A. Haque. 1999. Physical properties of guna seeds. *Journal of Agricultural Engineering Research*, 73(2): pp.105–111.

[15] Deshpande, S. D., S. Bal, and T. P. Ojha. 1993. Physical properties of soya bean. *Journal of Agricultural Engineering Research,* 56: pp.89–98.

[16] Ogunjimi, L. O., N. A. Aviara, and O. A. Aregbesola. 2002. Some engineering properties of locust bean seed. *Journal of Food Engineering*, 55(2): pp.95–99.

[17] Altikat, S. and Yaşar, S. 2019. Differentiation in Gravimetrical and Frictional Properties of Phaseolus Vulgaris L. by a Partial Least Square Regression Model. *KSU J. Agric Nat* 22(4): 641-649, 2019 DOI:10.18016/ksutarimdoga.vi.515891

[18] Altuntas, E., and M. Yildiz. 2007. Effect of moisture content on some physical and mechanical properties of faba bean (*Viciafaba L.*) grains, *Journal of Food Engineering,* 78: pp.174–183.

[19] Seifi, M. R. and Alimardani, R. 2010. The Moisture Content Effect on Some Physical and Mechanical Properties of Corn (*Sc. 704*). *Journal of Agricultural Science.* Vol. 2, No. 4; pp. 125 – 134.

[20] Sahay, K. M., & Singh, K. K. 1994. *Unit Operations of Agricultural Processing*. 1st ed. Vikas Publishing House Pvt. Ltd., New Delhi, India

[21] Sharanagat, V. S. and Goswami, T. K., 2014. Effect of moisture content on physio-mechanical properties of coriander seeds (*Coriandrum sativum*). *Agric Eng Int: CIGR Journal*, 16(3): pp.166ー172.

[22] Oduma, O., Igboke, M. E and Ali, F.U. 2014. Physical and aerodynamic characterization of pigeon pea kernel, Hull and stalk materials, *IJASBER* vol 3 (1 & 2). Pp. 1 – 13.

[23] Baryeh, E. A. (2002). Physical properties of millet. *J. of Food Engineering,* 51, pp.39–46. http://dx.doi.org/10.1016/S0260-8774(01)00035-8.

[24] Kingsly et al. 2006. Moisture dependent physical properties of dried pomegranate seeds (Anardana). *Journal of Food Engineering,* 75(4): 492–496.

[25] Zewdu et al. 2007. Moisture-Dependent Physical Properties of Tef Seed. *Bio systems Engineering*, 96(1): pp.57–63.

[26] Selvi et al. 2006. Some physical properties of linseed. *Bio system Eng.*, 95(4): pp.607-612.

[27] Davies, R.M. Zibokere, D.S. 2011. Effect of moisture content on some physical and mechanical properties of three varieties of cowpea (*Vigna unguiculata (L) walp*). *Agric. Eng. Int:CIGR Journal*, 13(1).

[28] Henshaw, F. O. 2008. Varietal differences in physical and proximate composition of cowpea (*Vigna unguiculata*). *World Journal of Agricultural Sciences*, 4(3): pp.302-306.

[29] Gharekhani, M., Kashaninejad, M., Garmakhanyye, A. D. and Ranjbari, A. 2013. Physical and Aerodynamic Properties of Paddy and White Rice as a Function of Moisture Content. *Quality Assurance and Safety of crops & foods.* 5(3). pp.187 – 197.

[30] Kashaninejad, M., Mortazavi, A., Safekordi, A. and Tabil, L.G., 2008. Handling and Functional Properties of Pistachio (*Pistacia vera L.*) nut and its kernel. Journal of food Engineering. 72: pp.30 – 38.

[31] Murthy C. T., and S. Bhattacharya. 1998. Moisture dependant physical and uniaxial compression properties of black pepper. *Journal of Food Engineering,* 37(2): pp.193–205.

[32] Dutta et al. 1988. Physical properties of gram. *Journal of Agricultural Engineering Research*, 39(4): pp.259–268.

[33] Joshi et al. 1993. Physical properties of pumpkin seeds. *Journal of Agricultural Engineering Research*, 54(3): pp.219–229.

[34] Singh, K. K. and Goswami, T.K. 1996. Physical properties of cumin seed. *Journal of Food Engineering,* 64(2): 93–98.

[35] Kiani Deh Kiani, M., S. Minaei, H. Maghsoudi and M. Ghasemi Varnamkhasti. 2008. Moisture dependent (Anardana). *Journal of Food Engineering,* 75(4): pp.492–496.

[36] Simonyan K. J., and Ehiem J. C., (2012). Physical Properties of Wild Mango Fruit and Nut. *International Agrophysics,* 26, 95-98 DOI: 10.2478/v10247-012-0014-x

[37] Koocheki, A., Razari, S. M., Milani A., Abedin E., and Izadikhah. 2007. Physical Properties of Water Melon Seed as a function of Mooisture Content and Variety. *International Agro Physics*, 21: pp.349-359.

[38] Davies, R. M. 2010. Some physical properties of Arigo seed. *Int. Agrophysics,* 24: pp.89-92.

[39] Huges and Stephen W., 2005. *Archimedes Revisited:* A Faster, Better, Cheer Model of Accurately Measuring the Volume of Small Objects". Physiics Education 40(5): 468-474. Bibcode: 2005 Phy Ed.$0.46811. doi: 10.1088/0031-9120/40/008.

[40] Arthur, M.A. 2009. Moisture-dependent physical properties of cowpea. B. Sc. Thesis, Department of Agricultural and Environmental Engineering, Niger Delta University, Bayelsa State.

[41] Sacilink, K., R. Ozturk, and R. Kesikin. 2002. Some physical properties of hemp seeds. *Biosystems Engineering,* 86(2): pp.191– 198.

[42] Oje, K. and E. C. Ugbor. 1991. Some physical properties of oil bean seed. *Journal of Agricultural Engineering Research*, 50: pp.305–313.

[43] Oyelade, O.J., P.O. Odugbenro, A.O. Abioye, and N.L.Raji. 2005. Some physical properties of African star apple (*Chrysophyllumalibidum*) seeds.*Journal of Food Engineering,* 67: pp.435–440.

[44] Oluka, S.I, Oduma, O. and Eze, P.C. 2010. Physical and mechanical properties of sorghum Grains (*Sorghum vulgare*) . Book of proceeding of the 10th international conference and 31st Annual General meeting of Nigeria Institution of Agricultural Engineers, (NIAE). Enugu 2010.

[45] Tavakoli H., Rajabipour A., Mohtasebi S.S. 2009. Moisture Dependent Some Engineering Properties of Soybean Grains. *Agricultural Engineering International: CIGR Ejournal,* Manuscript 1110. Vol. 11.

[46] Khosltaghaza, M.H; and Mehdizadch, R. 2006. Aerodynamic properties of Wheat Kernel and straw materials. *Agricultural Eng. International: the CIGR Ejournal.* Vol. VIII. pp.1-9.

[47] Briens C.L. 1991. Correlation for direct calculation of the terminal velocity of spherical particles in Newtonian and pseodoplastic materials. *ELSEVIER.*Vol. 67. Issue 1. pp. 87 -91.

[48] Okeke C.G and Oluka S.I. 2021. A Study of Aerodynamic Properties of Yam Flour. *Journal of Agricultural Engineering,* University of Belgrade, Republic of Sebia. No.2, 2021. pp.11-18.

PREGLED ISPITIVANJA I PROCESA OCENE NEKIH INŽINJERSKIH KARAKTERISTIKA ZRNA ŽITARICA I PRIMENA ZA MEHANIZOVANU PROIZVODNJU I PRERADU U NIGERIJI

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Apstrakt: Urađen je pregled procesa ispitivanja i evaluacije rezultata nekih inženjerskih karakteristika zrna žitarica i korišćenje za mehanizovanu proizvodnju i preradu u Nigeriji. Različiti slični radovi koji su bili relevantni za studiju su istraženi i korišćeni za ovaj pregled. Pravilna procena i korišćenje inžinjerskih karakteristika žitarica bi unapredila dizajn i/ili razvoj opreme koja bi bez napora unapredila proizvodnju i proces ubiranja ili prerade žitarica posle žetve i minimizirala nepotrebno oštećenje/gubitak semena/zrna.

Ispitivanjme je utvrđeno da sadržaj vlage ima veliki uticaj na inženjerske osobine zrna. Rezultati istraživača su pokazali povećanje mase semena korijandera sa 8,89 na 9,826 g kada je sadržaj vlage povećan sa 8,5 % na 15,89 % (v.b.). Ugao trenja je povećan sa 25,5 ^{o} na 31^{o} uz povećanje sadržaja vlage sa 8,5 % na 15,89 % (v.b.).

Koeficijent trenja za različite površine je u porastu sa povećanjem sadržaja vlage (%), dok nasipna gustina (zapremina) opada sa povećanjem sadržaja vlage.

Sila kompresije potrebna za pojavu rupture (oštećenje) zrna opada sa povećanjem sadržaja vlage.

Dakle, deformacija kod oštećenja-rupture zrna se povećava sa povećanjem sadržaja vlage. Rezultati ispitivanja ukazuju na smanjenje sile loma u rasponu od 63 do 38N za uzorak sa oznakom IT86D-I0I0, 64 do 40N i 70 do 46 N, respektivno za sorte IAR-339-1 i Ife Brown pri sadržaju vlage u rasponu od 15 do 30% (v.b).

Istraživanje je dalje pokazalo da je većina studija bila fokusirana na nekoliko žitarica i da podaci o inžinjerskim osobinama dobijeni za različita semena (zrna) žitarica variraju od useva do useva i od sorte do sorte.

Ova varijacija zahteva studije inženjerskih svojstava različitih vrsta i varijeteta žitarica na različitim nivoima sadržaja vlage koje bi usmeravale poljoprivrednike, prerađivače i dizajnere/proizvođače mašina u razvoju i izboru odgovarajućih mašina za njihov rad na bilo kom nivou kako bi se povećao njihov učinak uz smanjen gubitak ili oštećenje semena (zrna).

Ključne reči: *Žitarice, inženjerska svojstva, ispitivanje, evaluacija, mašine, prerada.*

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DIFFERENT MECHANICAL CONTROL OF WEEDS UNDER VINES TO REDUCE ECOLOGICAL FOOTPRINT

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Abstract: The purpose of the study was to investigate the alternative methods of weed control in the vineyard under 'Sauvignon' vines to reduce ecological footprint in vineyard production. Weed control was performed at the experimental site with the mechanical weed control under vines with a grass cutter, a rotating star hoe (roll hoe) and a vine trunk cleaner, while at the same time additional mulching was carried out in the belts between the rows. The ecological footprint of each production operation was estimated by including environmental impacts related to fossil-C (kg CO_2/hm^2), air, water, soil, non-renewable, renewable, and area resources. While carrying out the mechanical control, we analysed the weed coverage, grape yield and yield loss. Grape yield was highest for weed-free control plots, followed by plots where ploughshare was used. Yield loss was lowest when using ploughshare. In addition to the weed-free plot, weed coverage was lowest when glyphosate was used. The maximum amount of CO_2 is released while using rotating star hoe. At the grass cutter and vine trunk cleaner less CO_2 was released. The same is with global warming potential (GWP).

Key words: *mechanical weed control, vineyard, ecological footprint*

INTRODUCTION

Weed control is one of the basic technological operations in vineyards to ensure the appropriate quantity and quality of crop yield [1]. For this purpose, weed control practices can be also achieved through cultural practices [2].

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EU policy for sustainable use of pesticides is aimed to reduce the use of pesticides for agricultural production in accordance with the guidelines of the new "Green deal" development strategy. Of all pesticides, herbicides are most frequently used chemicals, whereby stakeholders have the greatest public pressure and demand to achieve a significant reduction in seasonal rates applied to agricultural production areas.

The symbol of chemical agriculture is the herbicide glyphosate, used once or twice a year as the most frequent weed control practice that the EU policy wants to ban in the near future [3].

All countries are conducting research on the environmental and economic consequences of discontinuing the use of glyphosate and are testing alternative weed control methods (e.g. mechanical control, etc.) or alternative chemical control that implicates plant based organic herbicides (e.g. organic acids) or non synthetic products (e.g. vegetable oils, etc.) [4-5].

Research should take into account the economic and environmental aspects of different weed control techniques. Mechanical control increases energy consumption, farmer working time load as well as erosion risks in vineyards on slopes [6]. Hugh investment in new machines is needed. There are also some obstacles in using alternative chemical control. The effectiveness of alternative chemicals is often lower than the effectiveness of glyphosate and more applications are required annually.

When using alternative classical herbicides we increase the total annual in put of herbicides into the vineyard ecosystem. Furthermore, alternative organic herbicides are expensive and the annual cost of purchasing of weed control chemicals can increase 3 to 5times [4, 7].

There are several different methods for calculating the environmental footprint in the world, but each takes into account human behavior to a different extent. One of the calculation methods is the Sustainable Process Index® (SPI) or the sustainability index of the process. The environmental footprint can be expressed in gha (global hectares) per ha of area in ha or m^2 per kg of product per year. We call such a calculation the Ecological Efficiency Index EEI [8]. Environmental footprint is also measured in global hectares (gha). Global hectares represent the footprint of one hectare of production area [9].

The presented article shows the effectiveness of different weed control measures by comparing the three methods of mechanical weed control and one chemical method by analyzing the weed coverage (%), grape yield, yield loss, CO_2 emisions and ecological footprint.

MATERIAL AND METHODS

The experiment was conducted in the vineyard of the vineyard farm located in Plač, north-eastern region of Slovenia. The size of the vineyard experiment area was 2000 m^2, the GIS location of vineyard was 46°40'10.2" N, 15°35'57.7" E. Vines of cultivar ‘Sauvignon’ grown in an intensive 16-year old vineyard plantation were grafted on Kober 5BB rootstock and spacing was 2.3 m x 0.85 m. The height of vine stocks steam was 0.7 m and plants were fixed in vertical trellis and trained according to standard unilateral Guyot with single spawning (spar with up to ten buds) with a plug (one to two buds on the plug). In the past, weed management under nith the vines was always done by application of glyphosate based herbicides and by mulching the grass strip between the vine rows.

Weed community under wine rows was composed of the following species:
a) dominant species: *Lolium perenne, Elymus repens, Poa annua, Cirsium arvense, Taraxacum officionale, Urtica dioica, Glechoma hederacea*
b) species with medium abundance: *Setaria glauca, Digitaria sanguinalis, Aegopodiumpodagraria, Convolvolus arvensis, Daucus carota, Polygonum aviculare, Potentillareptans, Senecio vulgaris, Ajuga reptans, Veronica persica, Sonchus asper, Ranunculusrepens, Conyza canadensis, Achilea millefolium, Agrosits alba*

c) species with low abundance: *Bromus sp., Medicago lupolina, Cerastium sp., Stenactisannua, Trifolium repens, Galium verum, Galium aparine, Plantago sp., Stellaria media, Prunella vulgaris, Lisimachia nommularia.*

The research was carried out on site using the three mecahanical and one chemical methods overviewed in Table 1: herbicide glyphosate compared with mechanical control methods carried out with three different tractor attachments from BRAUN Maschinen bau GmbH: a grass cutter (llama), a rotating star hoe (roll hoe) and a vine trunk cleaner. The control plot was without any treatment.

Table 1. Overview of the chemical and mechanical treatments

Treatment	Application dose	Treatment date
Glyphosate	Taifun (glyphosate 36%) 6 L ha^{-1} Taifun (glyphosate 36%) 6 L ha^{-1}	May 5^{th} July 28^{th}
Star hoe	Tractor driven, operated at 5 km h^{-1}	April 24^{th}, June 30^{th}, August 26^{th}
Ploughshare	Tractor driven, operated at 5 km h^{-1}	April 24^{th}, June 30^{th}, August 26 th
Vine trunk cleaner	Tractor driven mulcher attached, 5 km h^{-1}	April 24^{th}, June 30^{th}, August 26^{th}

Individual plot represented a 0.5m wide and 10 m long stripe. Plots with mechanical weed control treatments were arranged in separate vine rows, whereby a 90 m row was managed by use of a specific tool. Rows were than devided in sections which were statistically considered as repetitions.

Description of viticultural tools for alternative mechanical weed control

We used three Braun tools (Figure 1) to control weeds under vines. Namely the Braun LUV Perfect grass trimmer (ploughshare blade under cuter; locally called Lama), rotating wheel or star hoe tiller and trunk cleaner mounted on side of mulcher. The Braun LUV Perfect trimmer is used for efficient and environmentally friendly cultivation in the vineyard. That is, to cultivate a strip of soil under nuth the vines. In fact the blade undercuts and lifts the weed and turf cover and facilities loosening of soil. Tool blade was equipped with lifting adopters that allow better "dissolution" of soil and grass turf.
In our case ploughshare trimmer was mounted at the side of tractor attached in the middle bracket with two hydraulic cylinders that allow the transverse movement of the tool in a row near the vine. This bracket is integrated bon the left and right bracket for various tools (working elements).
Above the working element– the grass trimmer, there is a sensor – a mechanical lever which is movable in parallel with respect to the grass trimmer.

When bumping into a trunk of a vine or tree or bumping into a pillar the mechanical lever activates the control valve and the hydraulic cylinder moves grass trimmer away from these obstacles. We need two hydraulic connections for operation pressure and return line. In front of the grass trimmer, a plate is also placed on a fixed bracket, which cuts the ground or grass. On the frame lifting system is also mounted, which with a hydraulic cylinder allows precise adjustment of the vertical position of the working element.

We always lowered the grass trimmer to the working depth while driving. In the experiment we worked shallower, that suggested by manufacturer between 7 and 10 cm deep, with the set working depth being maintained without difficulty. The grass trimmer was installed only on one side of the tractor and the rotating wheel on the other. For tool operation (grass trimmer) the oil flow was 7 to 12 L min^{-1}.

Another weeding tool was the rotating star hoe called in German Roll hack used for loosening the soil along the vine and for mechanical weed control in the row space. The principle of operation is the same as by disc plates. The circular star perch has two star plates, the teeth of these stars are curved. These teeth scrape small grooves from the surface during rolling. Compared to disc plates, circular star hoes achieves good performance even at low operating speeds (from 4.5 km h^{-1} onwards). It does not leave a flat cutting edge, which significantly reduces the risk of water erosion of the slope. Therefore, use of this tool is also recommended on steep vineyards. The inclination angle of the working elements is adjusted without tools, only by selecting the appropriate hole on the bracket. There are as many as 43of these holes. By selecting the setting angle, we also determine the aggressiveness of tool operation of the star plates.

The third tool was hydraulic driven vine trunck cleaner Braun RP mounted on side of Braun Alpha sensor thronic mulcher with primary function to remove water shoots – suckers from vine trunk. Rotating rubber paddles on single rotating shaft (30 cm long) cut away weed sand mulch them. In our case mulched stripe was 20 cm wide belt on each side of vine trunk.

Figure 1. Example of Braun tool to control weeds under vines

Herbicide application method and control method efficiency evaluation

Herbicide was applied in concentrations as shown in Table 1. They were applied with backpack sprayer Solo 425 equipped with nozzle Hypro VP 110 – 03 using 300 L of spray per hectare. Droplet VMD value was close to 240 µm. Herbicides were applied on 50 cm wide stripe under vines.

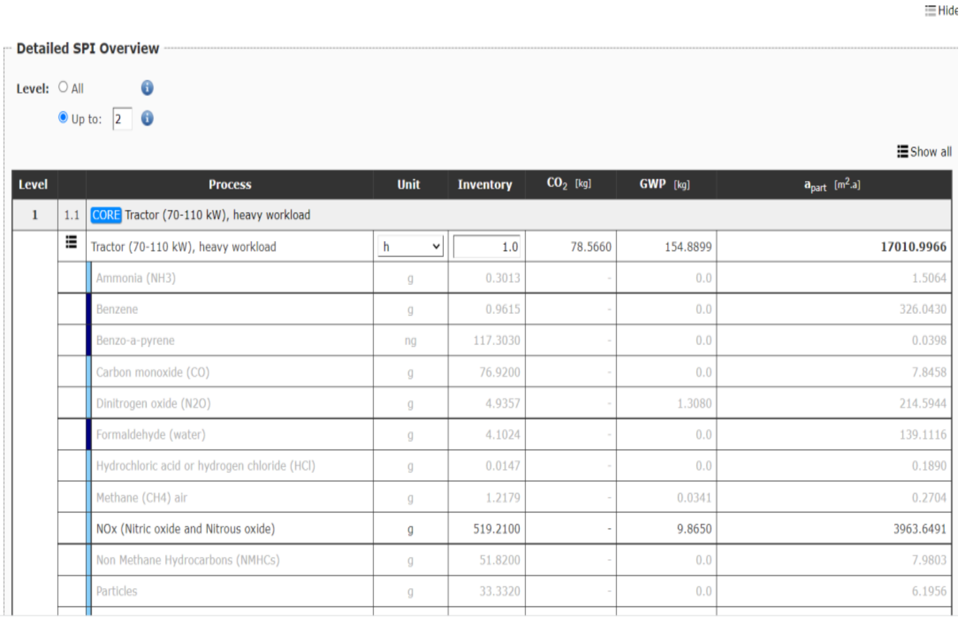
Efficacy of herbicides and of machine control measures was estimated by visual scoring of level of damage done to weeds.

In this publication we show just data on coverage values for 4 evaluations a season. Coverage % represents the share of soil area covered by living weeds.

Ecological footprint

We calculated the ecological footprint using the Spion Web program [10]. The ecological footprint of each production operation was estimated by including environmental impacts related to fossil-C (kg CO_2/hm^2), air, water, soil, non-renewable, renewable, and area resources. Calculation of fossil-C assumed sedimentation of carbon to ocean beds, which requires about 500 m² of sea ground per year to put 1 kg of carbon back into the long-term (fossil) storage on the sea bed. CO_2 (kg) emissions are calculated from the "Area for fossil carbon," where the extracted fossil carbon and carbon-based materials are assumed to be oxidized to CO_2 over the life cycle and finally end up as C sedimention in the oceans. GWP potentials are calculated on the basis of GWP factors, where material flows of GWP are calculated by multiplying the GWP factor of the components. The sum of CO_2 life-cycle-emissions and other GWP-relevant impacts is the total GWP estimated in kg of CO_2 equivalent. Global Warming Potentials (GWPs) are a quantified measurement of the globally averaged relative radiative forcing impacts of a particular greenhouse gas. It is defined as the cumulative radiative forcing – both direct and indirect effects – integrated over a period of time from the emission of a unit mass of gas relative to some reference gas [11].

Calculation of the environmental footprint (figure 2) was made in accordance with the guidelines by scientists research [9]. We used the SPI on Web program [10], in which we first assessed the life cycle of individual process chains. The obtained results were analyzed with the help of an online program for calculating the environmental footprint (SPI on Web). We obtained calculations of the ecological impacts of technical processes on the environment through the entire life cycle. In the SPI on Web program, we entered data on the machinery tools used in each soil treatment system. The point of our research is that the program provided a total environmental footprint.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Detailed SPI Overview

Level: All

Up to: 2

Show all

Level		Process	Unit	Inventory	CO_2 [kg]	GWP [kg]	a_{part} [m^2.a]
1	1.1	CORE Tractor (70-110 kW), heavy workload					
		Tractor (70-110 kW), heavy workload	h	1.0	78.5660	154.8899	**17010.9966**
		Ammonia (NH3)	g	0.3013	-	0.0	1.5064
		Benzene	g	0.9615	-	0.0	326.0430
		Benzo-a-pyrene	ng	117.3030	-	0.0	0.0398
		Carbon monoxide (CO)	g	76.9200	-	0.0	7.8458
		Dinitrogen oxide (N2O)	g	4.9357	-	1.3080	214.5944
		Formaldehyde (water)	g	4.1024	-	0.0	139.1116
		Hydrochloric acid or hydrogen chloride (HCl)	g	0.0147	-	0.0	0.1890
		Methane (CH4) air	g	1.2179	-	0.0341	0.2704
		NOx (Nitric oxide and Nitrous oxide)	g	519.2100	-	9.8650	3963.6491
		Non Methane Hydrocarbons (NMHCs)	g	51.8200	-	0.0	7.9803
		Particles	g	33.3320	-	0.0	6.1956

Figure 2. Example of SPI data calculation for tractor tractor Fendt 211V

RESULTS AND DISCUSSION

Weed control efficiency

Data from Table 2 show that weed coverage values were very high in all variants. Weeds always recovered quite fast after treatment. We had rainy summer what helped weeds to regenerate fast especially in plots with mechanical weed control. It is interesting that the level of correlation among weed coverage and yield loss is not tight (Table 3). Because of high variability in yield of individual vines, differences among tested variants were not statistically significant, despite quite notable differences in weed coverage.
In glyphosate treated plots the coverage was varied from 30 to 50% throughout most of the season. This was due the successive emergence of perennial weeds. Despite two treatments some weed cover was always present.

Table 2. Size of weed population expressed as the average rate of weed coverage (%) on a 0.5 m wide stripe under grapevine rows

Type of treatment	June 30th	July 28th	August 26th	September 30th
Glyphosate	29.25	44.5	62.25	38.75
Rotary hoe	86.0	76.25	82.0	76.75
Ploughshare lama	85.5	82.0	90.75	67.5
Vine trunk cleaner	82.75	92.75	94.5	94.25
Weedy control	95.75	98.75	100.0	99.75

The 2020 season was very favourable for the development of the grapevine and we had a high grape yield. We achieved a good result with mechanical tools. At a rotary hoe cultivated plots, the yield loss was only 14.9% and at plots cultivated with grass trimmer it was only 10.1%. Plots managed by use of trunk cleaner the loss was high and represents 25.3% compared to weed free control. On the other hand the lost of the crop yield was 38.1% in a weedy control when compared to weed free control. Trunk cleaner was attached to mulcher and it was not primarily designed for control of weeds but to remove shoots from the vine trunk. The rubber elements did not hit the weeds at the optimal angle and therefore and all the weeds were not damaged and cut off. Mechanical weed control does not differ a lot from most quality at weed free control parcel.

Table 3. Grape yield and yield loss in percentage

Type of treatment	Grape yield (kg h^{-1})	Yield loss (%)
Glyphosate	16,559.4	15.6
Rotary hoe	15,426.6	14.9
Ploughshare	16,647.2	10.1
Vine trunk cleaner	13,626.6	25.3
Weedy control	9,973.1	38.1

THE ECOLOGICAL FOOTPRINTS OF THE VINEYARD OPERATIONS

The ecological footprints of the vineyard operations are presented in Table 4.

Table 4. Footprint, CO_2 emissions and GWP under different processing types

Processing type	Footprint/$m^2 \cdot kg^{-1}$	CO_2/kg	GWP/kg CO_2eq
Rotating star hoe (roll hoe)	17011.0	78.57	154.89
Grass cutter	11016.3	51.90	122.6
Vine trunk cleaner	8239.6	36.4	105.6

The data represents annual amount of biologically productive land that necessary to assimilate the emissions produced in all processes needed for tillage of 1 ha field area (m^2/kg). The largest footprint is related to rotating star hoe (17011.0 m^2/kg). It is 35,2 % higher than ecological footprint using grass cutter. The lowest footprint was estimated at vine trunk cleaner. It is 51,6 % lower than rotating star hoe.

The maximum amount of CO_2 is released while using rotating star hoe. At the grass cutter and vine trunk cleaner loss CO_2 was released. The same is with global warming potential (GWP). In production in agriculture, a lot of carbon is released in the atmosphere, which can be confirmed by related research. Bravo studied the Chilean sweet cherry production. The average carbon footprint of the Chilean sweet cherry production is 0.41 kg CO_2-eq/kg of harvested fruit. Diesel and fertilizers are the most important contributors to the carbon footprint of sweet cherry cultivation [12]. Environmental impact of food production is very important, and carbon footprint served as an indicator to guide farmland management.

The conventional production system was found to have a Footprint value almost double than the organic production, mainly due to the agricultural and packing phases. These suggest that reducing the Ecological Footprint of wine production could include organic procedures, a decrease in the consumption of fuels and chemicals, and an increase in the use of recycled materials in the packing phase [13].

CONCLUSIONS

Even if mechanical weed control is carried out three times per season, it is not possible to guarantee comparable effectiveness to that achieved with the use of glyphosate-based herbicides.

Mechanical weed control should be started early in the season when the weeds are still small, and control should be repeated 4 to 5 times, resulting in 3 to 4 times higher costs of weed control than by using herbicide glyphosate twice. The tested tools did not work properly when used in wet soils at speeds below 6 to 7 km h^{-1}. The advantages of this tool are precise vertical lifting, changing settings without tools, efficient operation at high working speeds, reduced risk of erosion, easy handling, large range for tilt angle adjustment plates and environmentally friendly work [14-16].

The maximum amount of footprint, CO_2 emissions and GWP potential was achieved with tool rotating star hoe. This is because the tool must work at a higher working speed for adequate work efficiency, which increases fuel consumption, especially on slopes.

The tool grass cutter has a medium values of Footprint, CO_2 emissions and GWP potential. This tool works at a maximum working speed of 4 km/h and approximately at a working depth of up to 5 cm. Due lover working speed is needed and a little higher need of power the consumption of fuel for this tool was not so high compared with rotating star hoe. The smallest ecological footprint, CO_2 emissions and GWP potential has tool vine trunk cleaner. This tool is used at a low working speed, and the tool itself is working by the use of a hydro motor. As a result, the tractor also has a low fuel consumption. Therefore, from point of the ecological footprint, the most suitable tool for mechanical weed control is the most suitable vine trunk cleaner.

REFERENCES

[1] Cirujeda, A., Aibar, J., Anzalone, A., Martin-Closas, L., Meco, R., Moreno, M.M., Pardo, A., Pelacho, A.M., Rojo, F., Royo-Esnal, A., Suso, M.L., Zaragoza, C. 2012. Biodegradable mulch instead of polyethylene for weed control of processing tomato production. Agron. Sustain. Develop., 32, pp.889- 97.

[2] Balsari, P., Marucco, P., Vidotto, F., Tesio, F. 2006. Assessment of different techniques for weed control in vineyard. In Proceedings of Giornate Fitopatologiche, pp.529-534.

[3] Antier, C., Kudsk, P., Reboud, X., Ulber, L., Baret, P. V., Messéan, A. 2020. Glyphosate use in the European agricultural sector and a framework for its further monitoring. Sustainability, 12(14), [5682]. https://doi.org/10.3390/su12145682

[4] Tourte, L., Smith, R., Bettiga, L., Bensen, T., Smith, J., Salm, D. 2008. Post-emergence herbicides are cost effective for vineyard floor management on the Central Coast. California agriculture, 62(1), pp.19-23.

[5] Manzone, M., Demeneghi, M., Marucco, P., Grella, M., Balsari, P. 2020. Technical solutions for under-row weed control in vineyards: Efficacy, costs and environmental aspects analysis. Jour. Of Agric. Eng., 51(1), pp.36-42. https://doi.org/10.4081/jae.2020.991

[6] Tamagnone, M., Balsari, P., Manzone, M., Bozzer, C. 2011. Comparison of different spraying equipment used for weed control in vineyards and in orchards. In 11° Workshop SuProFruit 2011, pp.136-138.

[7] Shrestha, A., Kurtural, S.K., Fidelibus, M.W., Dervishian, G., Konduru, S. 2013. Efficacy and Cost of Cultivators, Steam, or an Organic Herbicide for Weed Control in Organic Vineyards in the San Joaquin Valley of California. Article in HortTechnology. DOI: 10.21273/HORTTECH.23.1.99

[8] Vukmanič T, Robačer M in Bavec M. 2017. Okoljski odtis jedi/obrokov. Zaključno poročilo za ministrstvo za gospodarstvo, razvoj in tehnologijo.

[9] Moidl S, Lenhart L, Pekny W. 2008. Footprint. Der Ökologischer Fußabdruck Österreich mit Unterstützung des Lebensministeriums, 3. Auflage, Wien, 16.
SPIonWeb, 2022. https://spionweb.tugraz.at/, 21.11.2022.

[10] Kettl K H. SPI on Web, 1996. Available online:
https://spionweb.tugraz.at/%20SPIonWeb_Stepbystep_eng. Accessed on [2020-06-13].

[11] Bravo G, Lopez D, Vasquez M, Iriarte A. 2017. Carbon Footprint Assessment of Sweet Cherry Production: Hotspots and Improvement Options. Polish Journal Environtal Studies 26(2): pp. 559-566.

[12] Galli, A., Kitzes, J., Pulselli, R., Borsa, S., Marchettini., N. 2008. Ecological Footprint Analysis Applied to the Production of Two Italian Wines. Agriculture, Ecosystems & Environment. 128(3): pp.162-166. DOI:10.1016/j.agee.2008.05.015

[13] Kehlenbeck, H., Saltzmann, J., Schwarz, J., Zwerger, P., Nordmeyer, H., Roßberg, D., Karpinski, I., Strassemeyer, J., Golla, B., Freier, B. 2015. Folgenabschätzung für die Landwirtschaft zum teilweisen oder vollständigen Verzicht auf die Anwendung von glyphosathaltigen Herbiziden in Deutschland. Julius Kühn-Institut, Bundesforschungsinstitut für Kulturpflanzen, Julius-Kühn- Archiv, 451, pp.1–150.

[14] Steinkellner, S. 2019. Nationale machbarkeitsstudie zum glyphosatausstieg, Endbericht zum forschungsprojekt nummer 101347. Universität für Bodenkultur Wien, pp.1–257. (https://www.bmlrt.gv.at/land/land-bbf/Forschung/machbarkeitsstudie.html).

[15] MacLaren, C., Storkey, J., Menegat, A., Metcalfe, H., Dehnen-Schmutz, K. 2020. An ecological future for weed science to sustain crop production and the environment. A review. Agronomy for Sustainable Development. DOI: https://doi.org/10.1007/s13593-020-00631-6

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RAZLIČITE KONTROLE MEHANIČKOG NAČINA UNIŠTAVANJA KOROVA U VINOGRADU ZBOG REDUKCIJE EKOLOŠKOG OTISKA

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Apstrakt: Cilj rada je ispitivanje alternativne metode suzbijanja korova u vinogradu pod sortom Sauvignon kako bi se smanjio ekološki otisak u vinogradarskoj proizvodnji. Suzbijanje korova je na oglednoj parceli obavljeno mehaničkim suzbijanjem korova kosačicom za travu, (rotirajući zvezdasti alat) i čistačem prostora oko stabala vinove loze. U isto vreme izvršeno dodatno malčiranje po trakama između redova vinove loze.

Ekološki otisak svake proizvodne operacije procenjen je uključivanjem uticaja na životnu sredinu povezane sa sadržajem fosilnog C (kg CO_2/hm^2), vazduhom, vodom, karakteristikama zemljišta, neobnovljivim, obnovljivim faktorima i površinskim resursima područja ispitivanja.

Prilikom obavljanja mehaničke kontrole analizirani su: zakorovljenost, prinos grožđa i gubitak prinosa.

Prinos grožđa bio je najveći na kontrolnim parcelama bez korova, a zatim na parcelama na kojima je korišćen kultivator.

Gubitak prinosa bio je najmanji kada se koristio kultivator sa raonikom. Pored parcele bez korova, pokrivenost korovom bila je najniža kada se koristio glifosat.

Maksimalna količina CO_2 se oslobađa dok se koristi alat rotirajuća zvezda. Kod kosilice za travu i čistača stabala vinove loze emitovano je manje CO_2.

Slično je i sa potencijalom globalnog zagrevanja (GVP).

Ključne reči: *Mehaničko suzbijanje korova, vinograd, ekološki otisak*

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ODREĐIVANJE USLUŽNE CENE ORANJA NA OSNOVU TROŠKOVA MEHANIZACIJE

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Sažetak: U radu je na primeru "Zlatiborskog Ekoagrara", mašinskog prstena "Agrotehnički centar", prikazana analiza troškova rada mehanizacije i obračunata uslužna cena oranja (bez PDV-a), a sve u cilju optimalnog korišćenja raspoložive poljoprivredne mehanizacije i rentiranja. Ukupni troškovi i cena oranja po radnom satu (€/h) obračunati su na osnovu fiksnih vlasničkih i varijabilnih operativnih troškova traktora Lamborghini Spire 80 Trend (58 kW) i dvobraznog obrtnog pluga Kuhn Master 103-3T. Godišnji troškovi traktora iznosili su 19.004 € i pluga 1.993 €. Na osnovu godišnjeg angažovanja traktora od 400 i pluga 120 sati obračunata je i cena rada traktorsko-mašinskog agregata pri oranju 64,12 €/h. Ovu cenu oranja čine troškovi traktora 47,51 €/h ili 74,09% i pluga 16,61 €/h ili 25,91%.

U strukturi obračuna ukupnih troškova traktora, varijabilni troškovi učestvuju sa 61,08%, fiksni troškovi 23,88%, plata radnika 6,54% i profitna marža 8,50%. Fiksni troškovi pluga čine 85,07%, a varijabilni 14,93% od ukupnih troškova, a u koje nisu uračunati troškovi goriva, maziva, plata radnika i profitna marža, jer su već obuhvaćeni varijabilnim troškovima traktora.

U radu je predstavljen jedan od načina izračunavanja, troškova rada traktorsko-mašinskog agregata u osnovnoj obradi zemljišta. Na osnovu kojeg farmeri mogu racionalno odlučiti da li im je isplativija nabavka novog traktora i pluga ili korišćenje usluga oranja drugih farmera i mašinskih prstenova.

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Ključne reči: *traktor, plug, cena oranja, fiksni, varijabilni, troškovi, mašinski prsten.*

UVOD

Pravilnom obradom zemljišta stvaraju se povoljni uslovi za klijanje semena, rast i razvoj gajenih biljaka. Pravovremenom obradom zemljišta poboljšava se vodno vazdušni i toplotni režim, podstiču se hemijski i mikrobiološki procesi. Oranjem treba obezbediti, optimalne uslove za rast i razvoj biljaka bez obzira na tip i stanje zemljišta kao i kultura koje se gaje.

Osnovna obrada zemljišta oranje, rastresanje i podrivanje obavlja se odgovarajućim mašinama u skladu sa postavljenim agrotehničkim zahtevima. Praktična iskustva u Srbiji pokazuju da se osnovna obrada zemljišta uglavnom obavlja na konvencionalan način primenom plugova ravnjača ili obrtača. Pored konvencionalnog načina obrade zemljišta u praksi se primenjuje i vertikalna, konzervacijska, redukovana, minimalna obrada zemljišta, primenom čizel plugova, podrivača, razrivača i poljskih kultivatora. U cilju smanjenja broja prohoda, gaženja, sabijanja zemljišta i uštede energije, sve više se koriste kombinovane mašine za obradu zemljišta.

U Srbiji ukupno ima 336.928 plugova, 14.440 podrivača i 3.364 razrivača. Na području Zlatiborske oblasti evidentirano je 11.272 plugova, 100 podrivača i 40 razrivača [1].

U procesu oranja se potroši velika količina energije, rada i vremena, pa se zbog toga smatra najskupljom agrotehničkom merom, jer zahteva veća finansijska ulaganja. Prema većini autora, na troškove obrade zemljišta u biljnoj poizvodnji potroši se oko 40% ukupne energije. Samo u oranju se potroši 50-55% ukupne potrošnje goriva za obradu zemljišta, što čini 38-42% ukupnih troškova u proizvodnji nekog useva. Na smanjenje troškova rada traktora i pluga uticalo je osavremenjavanje mehanizacije, povećanjem preciznosti, brzine rada i učinka, a smanjenjem potrošnje goriva, troškova održavanja i popravke [2].

Cilj istraživanja je prikazati metodologiju obračuna fiksnih i varijabilnih troškova rada traktora i pluga radi utvrđivanja cene uslužnog oranja. Obračunom i analizom troškova ukazuje se farmerima kako primenom navedene metodologije mogu da formiraju realne cene rada mehanizacije pri pružanju usluga. Upoređivanjem ovih troškova farmeri koji koriste usluge rada mehanizacije mogu ekonomski racionalno odlučivati šta im je isplativije, da nabave sopstvenu mehanizaciju ili da koriste usluge drugih farmera.

MATERIJAL I METODE RADA

Podaci za obračun troškova traktora Lamborghini Spire 80 Trend i dvobraznog pluga obrtača Kuhn Master 103-3T dobijeni su analizom rada u mašinskom prstenu „Agrotehnički centar” u Krivoj Reci „Zlatiborskog Eko-agrara”, za proizvodnu 2022. godinu.

U radu su obračunati fiksni, varijabilni kao i ukupni troškovi traktora i pluga na osnovu kojih je utvrđena cena koštanja oranja. Osnovi parametri za obračun amortizacije traktora i pluga i ostalih fiksnih troškova je njihova nabavna cena, optimalni radni vek, likvidaciona vrednost i godišnje angažovanje (Tabela 1).

Uzeti parametri za analizu troškova traktora i pluga obračunati su po metodi koju navode Autori [3], [4], [5], [6], [16], [18].

Tabela 1. Osnovni parametri za obračun troškova traktora i dvobraznog pluga
Table 1. Basic parameters for cost calculation for tractor and plough

Parametri Parametres	Traktor- Tractor Lamborghini Spire 80 Trend	Plug- Plough Kuhn Master 103-3T
Nominalna snaga traktora - Nominal power	58 kW	min 39 kW
Stepen korišćenja motora - Engine power utilization rate	80%	-
Specifična potrošnja - Specific fuel consumption	238 g/kWh	-
Odnos između kg i L goriva - Ratio between kg and L of fuel	1kg=1,176 L	-
Cena goriva - Price of fuel	1,85 €	-
Nabavna vrednost - Purchase value (Vo)	47.500 €	14.850 €
Kamatna stopa - Interest rate (Ks)	2% od Vs	3% od Vs
Vreme korišćenja - Number of years of tractor use (n)	12 god.	12 god.
Godišnje angažovanje traktora - Annual engagement of tractor work	400 h	120 h
Likvidaciona (očekivana) vrednost - Expected liquidation value (Vn)	15.600 €	4.500 €
Srednja vrednost - Mean value of the tractor (Vs)	31.550	9.675
Troškovi osiguranja - Insurance costs	1% od Vs	1% od Vs
Troškovi garažiranja - Garage costs	1 % od Vo	1 % od Vo
Troškovi popravke - Repair costs	0,8% odVo	2% od Vo

Godišnji iznos amortizacije po proporcionalnoj (linearnoj, konstantnoj) metodi izračunat je po formuli: $Ap = (Vo - Vn)/n$,

Ap - godišnji iznos amortizacije;
Vo - nabavna vrednost mašine;
Vn - likvidaciona vrednost (vrednost otpisa) mašine posle n godina;
n - broj godina korišćenja (radni vek korišćenja mašine).

Srednja vrednost za traktor i plug *(Vs)* obračunata je po formuli: $Vs= (Vo+Vn)/2$
Godišnji iznos kamate *(Ki)* za angažovana sredstva za nabavku traktora, pluga obračunat je: $Ki= (Vo+Vn)/2 \times Ks$,
Ks - Kamatna stopa na agažovana sredstva
Potrošnja goriva *(Pg)* je izračunata korišćenjem formule: $Pg= Sw \times Si \times Spg \times k$
Pg - Potrošnja goriva (L);
Sw - Snaga traktora na priključnom vratilu traktora (kW);
Si - stepen iskorišćavanje snage motora u % (80%)
Spg - Specifična potrošnja goriva (g/kWh), k- koeficijent za izračunavanje potrošnje goriva iz kg u L (1kg= 1,176 L).
Profitna marža izračunata je na osnovu formule: $Pm= (Ft+ Vt)/100 \times 10$,
Pm-Profitna marža;
Ft-Fiksni troškovi;
Vt-Varijabilni troškovi;
Troškovi kamate obračunati su na osnovu kamata kredita koje banke daju za nabavku traktora 2% i priključnih mašina 3%.

Ukupni troškovi i cena koštanja oranja po radnom satu (€/h) obračunati su na osnovu fiksnih, varijabilnih troškova traktora i pluga, plate rukovaoca traktora i profitne marže, pri angažovanju traktora od 400 sati i pluga 120 sati godišnje.

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Za brže i kvalitetnije obavljanje poljoprivrednih radova, povećanje obima proizvodnje i smanjenja troškova potrebna je savremena, precizna i efikasna mehanizacija [16], [17].[18], [19].

Nažalost, na porodičnim gazdinstvima mehanizacija je stara preko 20 godina, a farmeri su ograničeni finansijskim sredstvima da bi zastarelu mehanizaciju zamenili novom. Malim farmerima koji obrađuju manje površine zemljišta nije ekonomski isplativo da ulažu veliki novac za kupovinu savremene produktivne i kompjuterizovane, skupe mehanizacije, koja će godišnje na gazdinstvu biti vrlo malo korišćena. Troškovi traktora i mašina u R.Srbiji su često visoki zbog njihovog nedovoljnog angažovanja u proizvodnji u toku godine, kao i zbog visokih nabavnih cena. Da bi se nabavka nove skupe mehanizacije, traktora i poljoprivrednih mašina ekonomski isplatila, potrebno ih je što više angažovati u toku godine na svojoj farmi ili pružanjem usluga drugim farmerima. Zbog toga se mnogi farmeri odlučuju za korišćenje usluga mehanizacije drugih farmera ili mašinskih prstenova koji iznajmljuju svoje mašine i uslužno vrše obavljanje određenih poljoprivrednih radova po tržišnim cenama. Usled depopulacije sela, odlaska mladih u grad i nedostatka radne snage u poljoprivredi, iz godine u godinu, povećana je potražnja za pružanjem mašinskih usluga. U praksi se dešava da se cene rada mehanizacije određuju paušalno, neposredno u dogovoru između davaoca i primaoca usluga, ne vodeći pri tome računa o stvarnim troškovima. Često se dešava da su cene usluga daleko veće od realnih cena, jer ih određuju uslovi tržišta u zavisnosti od broja farmera koji pružaju i koji traže usluge mašina. Najbolje je odluku o ekonomskoj opravdanosti nabavke i posedovanju ili korišćenju usluga mehanizacije doneti na osnovu obračuna fiksnih i varijabilnih troškova. Nakon utvrđivanja elemenata troškova koji se odnose na troškove posedovanja i troškove iznajmljivanja mehanizacije može se doneti najpovoljnija odluka sa ekonomskog aspekta. Pravilnim obračunom cene rada usluga mehanizacije mogu se planirati troškovi, što je posebno važno u kriznoj 2022. godini, kada su drastično porasli troškovi dizel goriva, održavanja i popravke mehanizacije, kao i troškovi radne snage.

U sastavu "Zlatiborskog Ekoagrara" privrednog društva za razvoj poljoprivrede čiji je osnivač lokalna samouprava u Čajetini formiran je mašinski prsten "Agrotehnički centar". Za potrebe rada "Agrotehničkog centra" lokalna samouprava je nabavila 7 traktora i 29 priključnih mašina koje treba da pružaju usluge poljoprivrednim proizvođačima. Planirano je da mašinski prsten pruža usluge poljoprivrednim proizvođačima i široj zajednici po regresiranim cenama. Pored poljoprivredne mehanizacije i pružanja usluga poljoprivredncima, mašinski prsten poseduje i mašine i uređaje koji su namenjeni obavljanju komunalnih poslova (za održavanje lokalnih puteva zimi, čišćenje snega, uređenje poljskih puteva, kanala, uklanjanje samoniklog rastinja na međama i dr).

Formiranje uslužne cene rada traktora i priključnih mašina najviše zavisi od njihove nabavne cene, dužine radnog veka, godišnjeg angažovanja, brzine rada i učinka.

U obračun troškova rada mehanizacije za osnovnu obradu zemljišta uzeti su fiksni i varijabilni troškovi traktora i pluga obrtača, profitna marža i plata rukovaoca mehanizacijom. Fiksne troškove čine troškovi: amortizacije kamata, osiguranja, garažiranja, registracije, popravke traktora i pluga. Varijabilne troškove čine: troškovi goriva, podmazivanja, popravke i održavanja traktora i pluga.

Nabavne cene traktora od 47.500€ i pluga 14.850€ su preuzete sa računa dobavljača mehanizacije po kome su plaćene (Tab.1). Linearnom metodom obračunati su godišnji troškovi amortizacije traktora u iznosu od 2.658 € i pluga od 862 €. Izračunati godišnji iznos amortizacije, radi otpisa stare i nabavke nove mehanizacije, ravnomeran je za svaku godinu planiranog radnog veka traktora i pluga bez obzira na godišnji obim rada. Najveće učešće u fiksnim troškovima traktora imaju troškovi amortizacije 58,56%, zatim troškovi kamate 13,91%, garažiranja 10,46%, popravke 8,37%, osiguranja 6,94% i registracije 1,76% od ukupnih fiksnih troškova. Obračunati ukupni godišnji fiksni troškovi traktora iznose 4.539 € i pluga 1.695 € (Tab. 2).

Rezultati o procentualnom učešću amortizacije u ukupnim troškovima navedeni u radu su u saglasnosti sa rezultatima (57,59 %) autora [5]. U istraživanjima [4]**,** [7], [6] [16], [18], Autori navode da troškovi amortizacije traktora iznose 41%, 48,26% i 50,24% od ukupnih fiksnih troškova traktora, što je manje od vrednosti obračunatog procentualnog učešća u ovom slučaju.

Tabela 2. Obračun godišnjih fiksnih troškova traktora i pluga u zavisnosti od angažovanja (u €)
Table 2. Calculation of annual fixed costs for tractor and plough depending on use (in €)

Godišnji fiksni troškovi Annual fixed costs	Za 400 h rada traktora 400 hours of tractor work	Učešće u % Share in %	Za 120 h rada pluga 120 hours of plough work	Učešće u % Share in %
Troškovi amortizacije -Depreciation costs	2.658	58,56	862	50,86
Troškovi kamate - Interest costs	631	13,91	290	17,11
Troškovi osiguranja - Insurance costs	315	6,94	97	5,72
Troškovi garažiranja - Garage costs	475	10,46	149	8,79
Troškovi popravke - Repair costs	380	8,37	297	17,52
Troškovi registracije - Registration costs	80	1,76	-	
Ukupno godišnji fiksni troškovi Total annual fixed costs	4.539	100	1.695	100
Fiksni troškovi €/h rada Fixed costs per working hour €/h	11,35		14,13	

Ukupni iznos fiksnih troškova je 9,56%, a amortizacije 5,6% od nabavne cene traktora. Procentualno učešće troškova amortizacije u odnosu na nabavnu cenu traktora je u saglasnosti sa amortizacijom od 5,8% nabavne cene traktora koju navode drugi autori [9]. U istraživanju [6] učešće amortizacije u nabavnoj ceni traktora je manje (4,88%), a kod autora [10] i [5] je veće (6,24%) od vrednosti navedenih u ovom radu.

Troškovi kamate su obračunati na osnovu kamata kredita koje banke daju za nabavku traktora 2 %, i priključnih mašina 3% od srednje vrednosti mehanizacije i iznose 631 € i 290 €.

U saglasnosti sa metodama autora [3], [10], [11], [12], [5], [6] [16], [18] obračunati su troškovi garažiranja u vrednosti od 1% od nabavne cene i iznose za traktor 475 € i plug 149 €. Isti autori navode, da ukoliko nisu poznati stvarni troškovi osiguranja onda se obračunavaju u iznosu od 1% od srednje vrednosti traktora (315 €) i pluga (97 €).

Troškovi održavanja i popravke su vrlo bitni za siguran i pouzdan rad traktora i priključnih mašina, i zavise od časova njihovog angažovanja u toku godine. Prethodno navedeni autori predlažu da se za održavanje i popravku izdvaja iznos u vrednosti od 0,8% od nabavne vrednosti traktora i 2 % nabavne cene priključnih mašina.

Na osnovu ovog obračuna troškovi popravke i održavanja traktora iznose 380 €, a pluga 297 €. Ovi troškovi su namenjeni za održavanje i zamenu delova pluga (raonika, crtala, predplužnjaka i dr), a kod traktora za periodično održavanje u cilju postizanja pouzdanosti mehanizacije tokom rada. Troškovi popravke i održavanja iznose 8,37% od fiksnih i 1,99% od ukupnih troškova traktora, što je u saglasnosti sa rezultatima objavljenim u radovima [7], [8], [13]. Prema istraživanjima autora [5], [6] učešće ovih troškova je niže u odnosu na fiksne i ukupne troškove traktora.

U varijabilnim troškovima najveće učešće imaju troškovi goriva i ulja. U okviru ovih troškova obračunat je još i rad radnika, profitna marža, kao i troškovi podmazivanja i održavanja (ulja, maziva, filtera i dr.). U zavisnosti od angažovanja mehanizacije varijabilni troškovi rastu sa povećanjem obima rada u toku godine. (Tab. 3).

Tabela 3. Obračun godišnjih varijabilnih troškova traktor i pluga u zavisnosti od angažovanja (u €)
Table 3. Calculation of annual variable costs for tractor and plough depending on use (in €)

Godišnji varijabilni troškovi Annual variable costs	Za 400 h rada traktora 400 hours of tractor work	Učešće u % Share in %	Za 120 h rada pluga 120 hours of plough work	Učešće u % Share in %
Troškovi goriva - Fuel costs	8.880	76,51	-	-
Troškovi podmazivanja - Lubrication costs	1.776	15,30	-	-
Troškovi održavanja - Maintenance costs	950	8,19	297	-
Ukupno godišnji varjabilni troškovi Total annual variable costs	11.606	100	297	100
Varjabilni troškovi €/h rada Variable costs per working hour €/h	29,02		2,48	

Prosečna potrošnja goriva traktora zavisi od snage motora, režima rada traktora, uslova rada, a utvrđena je sondom koja se nalazi u rezervoaru goriva i obračunata po formuli datoj u metodu rada. Potrošnjom goriva od 12 L/h po cenama goriva od 1,85 €/L obračunati su troškovi goriva za 400 sati godišnjeg rada traktora u iznosu od 8.880 € ili 46,73 % od ukupnih troškova (Tab.3). Navedeni rezultati su u saglasnosti sa rezultatima prikazanim u radovima [7], [8], a niži od rezultata datih u istraživanju [5]. Prema istraživanjima [14], [15],[9], [5], [6] troškovi goriva imaju najveće učešće u varijabilnim troškovima, a što su potvrdila i istraživanja prikazana u radu (76,51%).

Od ukupnih godišnjih troškova traktora više od polovine čine varijabilni troškovi, što je potvrđeno u našim istraživanjima i iznose 61,08% (Tab.4.) Kako navodi autor [10],

[16], [17] na porodičnim poljoprivrednim gazdinstvima procentualno učešće varijabilnih troškova kod novih traktora iznosi 46,52% od ukupnih troškova.

Prema dobijenim rezultatima (Tab. 4.) ukupni troškovi oranja su 64,12 €/h (bez PDV-a). Troškovi traktora 47,51 €/h ili 74,09 % i pluga 16,61 €/h ili 25,91%, od ukupnih troškova. Navedeni rezultati su niži u odnosu na istraživanja koja navode autori [4], [13].

U cenu usluge oranja obračunata je profitna marža od 4,04 €/h ili 10% od ukupnih fiksnih i varijabilnih troškova.

Ukupna cena rada pluga je 16,61 €/h, a formirana je na osnovu fiksnih (14,13 €) i varijabilnih troškova (2,48 €) koji se odnose na troškove popravke i održavanja pluga po času rada. Ostali varijabilni troškovi kao što su gorivo, podmazivanje i rad, već su obračunati u varijabilnim troškovima traktora.

Tabela 4. Ukupni troškovi i cene usluga oranja u zavisnosti od angažovanja traktora i pluga (€/h)
Table 4. Total costs and prices of plowing services depending on use tractor and plough (€)

Vrste troškova Types of costs	Za 400 h rada traktora 400 hours of tractor work	Učešće (%) Share (%)	Za 120 h rada pluga 120 hours of plough work	Učešće (%) Share (%)
Fiksni troškovi - Fixed costs	11,35	23,88	14,13	85,07
Varijabilni troškovi - Variable costs	29,02	61,08	2,48	14,93
Bruto plata radnika - Salary of worker	3,10	6,54	-	-
Profitna marža - Profit margin	4,04	8,50	-	-
Cena usluge (u €/h)* Price of service (in €/h)	47,51	100	16,61	100
Ukupni godišnji troškovi (u €)* Total annual costs (in €)	19.004	/	1.993	/

**obračunate vrednosti su bez PDV*

U procentualnim iznosima fiksni troškovi pluga čine 83,60 %, a varijabilni troškovi 16,40 %, koji se odnose samo na troškove popravke i održavanja, a koji su niži od rezultata u radu [4]**,** a veći od vrednosti koje navodi autor [8]**.**

Obračunati rezultati troškova traktora u našim istraživanjima ne mogu u potpunosti biti u saglasnosti sa rezultatima drugih istraživača, zbog nabavne cene traktora, kao i zbog obračuna varijabilnih troškova usled razlike u ceni goriva u pojedinim zemljama što potvrđuju istraživanja drugih autora [4].

ZAKLJUČAK

U radu je prikazan jedan od načina izračunavanja troškova radi određivanja realne cene rada mehanizacije u cilju optimizacije i unapređenja korišćenja traktora i priključnih mašina.

Cena rada mehanizacije za osnovnu obradu zemljišta formirana je na osnovu fiksnih i varijabilnih troškova traktora i pluga obrtača, kao i troškova rada rukovaoca traktora i profitne marže.

Od ukupnih troškova oranja 64,12 €/h, troškovi traktora su 47,51 €/h ili 74,09 %, a troškovi pluga 16,61 €/h ili 25,91%.

Najveće učešće u fiksnim troškovima traktora i pluga imaju troškovi amortizacije 58,56% i 50,86%, a slede troškovi kamate 13,91% i 17,11%, garažiranja 10,46 % i 8,79%, popravke 8,37% i 17,52%, osiguranja 6,94 % i 5,72% i registracije 1,65% od ukupnih fiksnih troškova. U analizi varijabilnih troškova traktora najveće učešće imaju troškovi goriva 76,51%, zatim troškovi podmazivanja 15,30 % i redovnog održavanja 8,19 % za 400 sati godišnjeg anagažovanja traktora.

U procentualnim iznosima fiksni troškovi pluga čine 83,60 %, a varijabilni troškovi 16,40 %, koji se odnose samo na troškove popravke i održavanja pluga po času rada, a koji su ujedno i jedini varijabilni troškovi. Ostali varijabilni troškovi, kao što su gorivo, podmazivanje i rad već su uračunati u varijabilne troškove traktora.

Uzimajući u obzir obračunate fiksne vlasničke i varijabilne operativne troškove traktora i pluga realno se mogu formirati uslužne cene oranja.

ZAHVALNOST

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LITERATURA

[1] Koprivica, R., Marić, M., Zečević, S., Veljković, Biljana, Gavrilović, Marija, Terzić, D. 2022. Korišćenje savremene mehanizacije u brdsko-planinskom području. Zbornik radova, Naučni skup "Nove tehnologije i prakse u poljoprivredi i šumarstvu". AIN Odeljenje biotehničkih nauka. Beograd 24.11. 2022, pp. 91-105.

[2] Taha, S. Y., Taha, F. J., Nekolayevech, Z. A. 2016. Estimating economical costs for operating agricultural machines and equipment during plowing operations. *The Iraqi Journal of Agricultural Sciences*, *47*(1): pp.385-390.

[3] Khairo, S., Davies, L.2009. Guide to machinery costs and contract rates.

[4] *Primefacts* 913: pp.1-12.

[5] Goyal, R., Singh, S. 2020. Farm Power and Machinery Management. *Cost of Operation of Farm Equipment* 67-69. http://online.kmsdasuya.in/wp-content/uploads/2020/09/FMP-Farm-Power-and-Machinery-Management-Rajesh-Goyal-Surinder-Singh.pdf

[6] Veljković, Biljana, Koprivica, R., Gavrilović, Marija, Đokić, D., Muhović, A., Terzić, D. 2022. Calculation price of tractor operation based on costs, Proceedings of the XIII International Scientific Agricultural Symposium Agrosym 2022, pp.1163-1168, http://agrosym.ues.rs.ba/article/showpdf/BOOK_OF_PROCEEDINGS_2022.pdf

[7] Gavrilovic, Marija, Koprivica R., Veljkovic Biljana, Muhovic A., Djokic D., Terzic D.2022. Determining the price of tractor operation depending on the annual engagement, 4th ISAF,12-14 October 2022 Ohrid North Macedonia Book of apstract pp.31 https://isaf2022.isaf.edu.mk/wp-content/uploads/2022/10/ISAF-2022_DetailedProgramme.pdf

[8] Stiles, S., Stark, R. 2021. Estimating Farm Machinery costs. *Agriculture and natural resources*, Division of agriculture research and extension, University of Arkansas System, https://www.uaex.uada.edu/publications/PDF/fsa-21.pdf

[9] Lazarus, W. 2021. Machinery cost estimates. 1-9. https://wlazarus.cfans.umn.edu/william-f-lazarus-farm-machinery-management

[10] Altintas, N., Ozcelik, A. 2014. The Determination of Cost Components Regarding Tractor Use in Farms in Eskisehir Province. *Alinteri Journal of Agriculture Science,* 27(2): pp.1-9.

[11] Zimmer, D., Šumanovac, L., Jurić, T., Jurišić, M., Ranogajec, Ljubica, Plaščak, I. 2018. Analiza troškova sata rada traktora na obiteljskim gospodarstvima. *Agronomski glasnik* 3/2018: pp.149-162.

[12] Edwards, W.2015. Estimating farm machinery costs. *Ag. Decision Maker*, File A3-29: 1-11. https://www.extension.iastate.edu/agdm/crops/pdf/a3-29.pdf

[13] Molenhuis, J. 2020. Guide to Custom Farmwork and Short-Term Equipment Rental. *Factsheet* 20-005: 1-16. http://www.omafra.gov.on.ca/english/busdev/facts/16-035.pdf

[14] Lattz, D., Schnitkey G. 2021. Machinery Cost Estimates for 2021. *Farmdoc daily* (11): 143, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign.https://farmdocdaily.illinois.edu/2021/10/machinery-cost-estimates-for-2021.html

[15] Vasiljević, Zorica, Todorović, S., Popović, N. 2008. Uticaj promene cene goriva na optimatizaciju ukupnih troškova upotrebe poljoprivredne mehanizacije za obradu zemljišta. Poljoprivredna tehnika godina XXXIII, 4: pp. 69-77.

[16] Ercegović, Đ., Pajić, M., Raičević, D., Oljača, M., Gligorević, K., Vukić, Đ., Radojević R., Dumanović, Z., Kolčar, D. 2010. Efekti primene sistema meliorativne obrade na zemljištima teškog mehaničkog sastava u proizvodnji ratarskih kultura. Poljoprivredna tehnika, Godina XXXV, No2: pp. 55-64.

[17] Pajić Miloš, Dumanović Zoran, Ercegović Đuro, Gligorević Kosta, Oljača Mićo, Dragičević Vesna. 2012. Efekti produženog dejstva primene meliorativnog sistema obrade zemljišta teškog mehaničkog sastava u proizvodnji ratarskih kultura. Poljoprivredna tehnika, vol. 37, br. 4, str. 59-67.

[18] Koprivica Ranko, Veljković Biljana, Gavrilović Marija, Šiljić Aleksandar, Rašković Vera, Stošić Nemanja, Terzić Dragan, Đokić Dragoslav. 2021. Opremljenost i angažovanost mehanizacije na porodičnom poljoprivrednom gazdinstvu, Poljoprivredna tehnika, vol. 46, br. 4, str. 74-83.

[19] Živković Milovan, Oljača Mićo V., Komnenić Vaso, Gligorević Kosta, Dražić Milan, Pajić Miloš . 2019.Osnovna obrada zemljišta u višegodišnjim zasadima sa rotacionom ašovom. Poljoprivredna tehnika, vol. 44, br. 3, str. 34-43.

DETERMINATION OF THE SERVICE PRICE FOR PLOWING BASED ON THE COST OF MECHANIZATION

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Abstract: In the paper, using the example of "Zlatibor Ecoagrarian", in the machinery ring "Agrotechnical Center", the analysis of the operating costs of mechanization and the calculated service price of plowing (without VAT) are shown, all with the aim of optimal use of existing agricultural machinery and renting.

The total cost and price of plowing per working hour (€/h) were calculated based on the fixed ownership and variable operating costs of the Lamborghini Spire 80 Trend tractor (58 kW) and the Kuhn Master 103-3T double-row plow. The annual cost for the tractor was €19,004 and for the plough €1,993.

Based on an annual use of the tractor of 400 hours and the plough of 120 hours, the price of the tractor-machine unit for plowing was calculated to be 64.12 €/h. This price for plowing is composed of the cost of the tractor 47.51 €/h or 74.09% and the plough 16.61 €/h or 25.91%.
In the calculation structure of the total cost of the tractor, variable costs account for 61.08%, fixed costs account for 23.88%, workers' wages account for 6.54%, and profit margin accounts for 8.50%. The fixed cost of the plough accounts for 85.07% of the total cost and the variable 14.93%, excluding the cost of fuel, lubricants, wages and profit margin, as they are already included in the variable cost of the tractor.
The paper presents one of the ways to calculate the operating costs of a tractor-machine unit in basic tillage. On this basis, farmers can rationally decide whether it is more profitable for them to buy a new tractor and plough or to use other farmers' plowing services and machinery rings.

Keywords: *Tractor, plough, price of plowing, ownership and operating costs, machinery ring*

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PREDICTION OF TOMATO YIELD AND WATER PRODUCTIVITY UNDER DEFICIT IRRIGATION SCENARIOS USING AQUACROP MODEL IN AFAKA, KADUNA, NIGERIA

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Abstract: Improving water productivity through deficit irrigation has become a major goal for sustainable agriculture amidst global decline in water availability. The study evaluated the yield, crop water use and water productivities of field-grown drip-irrigated tomato in response to regulated deficit irrigation, and subsequent simulation under different deficit and irrigation method scenarios, using AquaCrop model, in Afaka, Nigeria. The field experiment, laid in randomized complete block design, comprised three deficit irrigation levels (80, 60 and 40% of reference evapotranspiration, ETo) imposed at the vegetative, flowering and maturity growth stages, with 100% ETo at the three crop growth stages as the control. The highest fresh fruit yield (19.0 t/ha) was obtained irrigating with 100% ETo value at all growth stages but the highest water productivity of fresh fruit (4.94 kg/m^3) was obtained irrigating with 60% ETo at maturity stage, then full irrigation at vegetative and flowering stages. On fruit dry yield basis, the highest simulated crop water productivity (0.46 kg/m^3) for the deficit scenarios was obtained irrigating with 80% ETo at all the three growth stages, having the highest fruit dry yield (1.67 t/ha) and the lowest seasonal water applied (447 mm). Under the scenarios of irrigation methods (drip, basin and furrow), the fruit dry yield was similar in each treatment, but water productivity was highest (0.53 kg/m^3) under drip irrigation system.

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Irrigating with 80% ETo at all the entire crop growth cycle of UC 82B tomato is recommended for the highest crop water productivity.

Key words: *Prediction, tomato yield, water productivity, deficit irrigation, scenarios, AquaCrop, Nigeria*

INTRODUCTION

Global freshwater is becoming increasingly scarce, due to improper management, indiscriminate use and a changing climate. Water requirements for agriculture is expected to increase by fifty percent to meet increasing food demands of a growing population all over the world [1]. For a better water resources utilization at the crop farm level, it is essential to apply an irrigation scheduling criterion such that the crop is watered at the right time and in the right volume. Hence, on condition of limited water supply, a so called 'regulated water deficit' can be conveniently applied [2]. Deficit irrigation aims at supplying lower irrigation volumes compared to the estimates required by the crop during the whole crop cycle but in coincidence with some particular stages that are the most sensitive to water stress [3]. Deficit irrigation is thus, a management strategy aimed at avoiding irrigation when it has a scarce influence on yield, in this way maximizing the productive result with smaller water amounts [4]. In deficit irrigation, the crop is subjected to a certain level of moisture stress either during a particular growth stage or throughout the entire crop growth stages, without significant reductions in yields [5], with the expectation that the yield reduction induced by the controlled moisture stress will not be significant in comparison with the benefits derived by diverting the saved water to irrigate additional cropped area [3], [6].

The challenge for researchers today is to develop viable irrigation scheduling methodologies, that are simple to implement, easy to understand from the farmer and project management standpoints, and profitable. Studies on deficit irrigation scheduling of tomato within the Northern Guinea Savanna of Nigeria are rarely available, and research outcomes on deficit irrigation are generally few for the sub-Saharan Africa [7]. Studies on the impacts of methods of administering growth-stage deficit irrigation on yield and soil water balance of a maize crop in Samaru, Nigeria, has been reported [8]. Also, investigators have studied the effects of deficit irrigation and mulch on yield and water use efficiency of watermelon in Samaru, Nigeria [9], while research on the effect of irrigation regimes on growth and yield of tomato under high water-table conditions in Kadawa, Nigeria was also reported [10]. Yet, knowledge gaps still remain with respect to the regulated deficit irrigation effects on the yield, and water productivity of tomato in Kaduna, Nigeria.

The approach of conducting field experiments has been described as being expensive, time consuming, subject to uncontrolled environmental conditions and difficult for long term analyses [11]. To overcome this problem crop simulation models have been developed as easier options, which can simulate field results [12]. The models help researchers to describe the dynamics of a crop in relation to its environment, understand the interactions of the various components and extend results beyond experimental sites and years [13].

Advances in software technology has enabled development of models (software) which can be used for simulating crop production. This is an excellent strategy for conducting tests and experiments, availing data already collected, wrapping few people, low cost, speed, creation and guessing of ideal scenarios to assist in decision making for public and private sectors [14], [15]. Hence, modeling becomes a valuable tool to study and develop promising deficit irrigation strategies as it allows a combination of different factors affecting yield under different scenarios [16].

The objective of this study, therefore, is to evaluate the effects of various deficit irrigation scheduling scenarios on the yield and water productivity of tomato using the AquaCrop model.

MATERIALS AND METHODS

Description of the AquaCrop Model

The AquaCrop model (Figure 1.), developed by the Food and Agriculture Organization of the United Nations (FAO) is a dynamic menu-driven crop model with a well-developed user interface for simulating the attainable yield of herbaceous crops as a function of water consumption [17]. Its major advantages over other models lie in its accuracy, simplicity and robustness [17]. The main menu provides access to a whole set of menus where input data is displayed and can be updated. Input data comprise those of weather, crop, irrigation, field management, soil, groundwater characteristics, planting or transplanting date, simulation period and conditions at the start of the simulation period. The simulations were carried out with AquaCrop model, version 6.0.

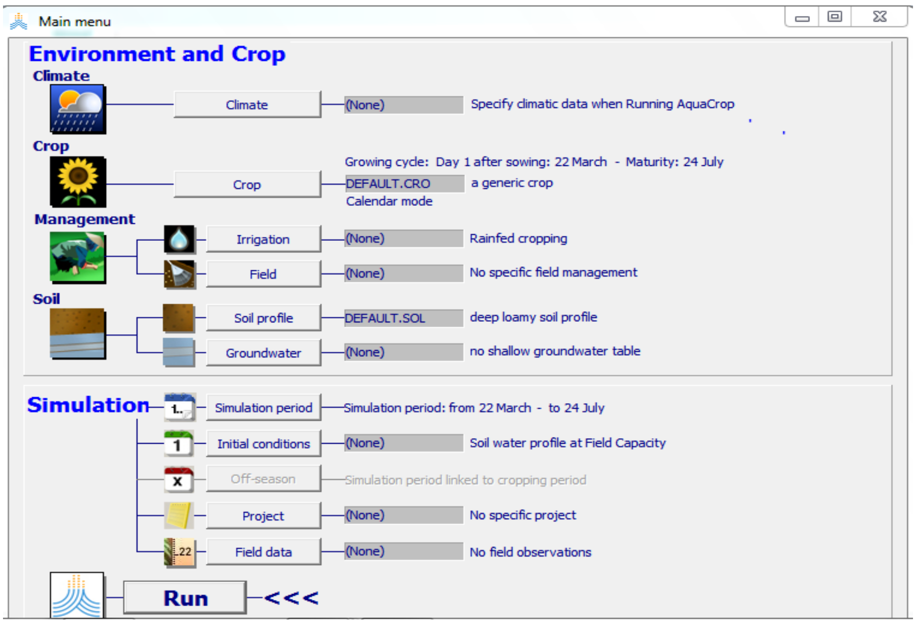

Figure 1. AquaCrop start menu

Study Area

The study was carried out at the experimental farm of the Federal College of Forestry Mechanization, Afaka, Kaduna, Nigeria, on latitude 10º36'N and longitude 07º25'E.

The rainy season lasts from mid-April to early October. Kaduna has an annual mean rainfall of 1206 mm and its temperature range is 31^0C to 33^0C for the maximum scale and 14^0C to 19^0C for the minimum scale [18].

Description of the Field Experiment

The research was carried out as growth-stage based deficit irrigation trials in the 2017/2018 and 2018/2019 irrigation seasons. The field trial spanned from 12^{th} December to 11^{th} March, in both seasons. The experiment was preceded by the nursery stage, which lasted for thirty days. The experiment was laid in randomized complete block design (RCBD) and replicated three times. The treatment factors are three deficit irrigation levels (80, 60 and 40% of reference evapotranspiration, ETo) and three crop growth stages, namely, vegetative stage (V), flowering stage (F) and maturity stage (M). Full irrigation (100% ETo) at the three growth stages is the control. A fixed 3-day irrigation interval was used throughout the experiment as recommended by [19]. Table 3.1 describes the field treatments.

AquaCrop Prediction of Yield and Water Productivity under Different Scenarios

Consequent upon satisfactory simulation of yield, crop water use and water productivity of UC 82B tomato in Afaka, Kaduna, Nigeria [20], the model was used for scenario analyses to evaluate the management practices for drip-irrigated tomato in the study area. The scenario analyses explain the implication of using the model under varied irrigation conditions. The following scenarios were considered: irrigation depths at one of three growth stages; irrigation depths at two of three growth stages; irrigation depths at all three growth stages and irrigation methods (drip, basin and furrow).

Scenario 1: Deficit application at one of three growth stages, in successions

Scenario 1 was created based on the field treatment which gave the highest water productivity in the field trials of 2017/18 and 2018/19. The treatment, designated as T_7 (Table 1) gave the highest water productivity of 0.45 kg/m^3, with a corresponding fruit dry yield of 1.59 kg/m^3 and crop water use of 369 mm. T_7 was described as the irrigation schedule where the crop was fully irrigated at the vegetative and flowering stages but 60% ETo at the maturity stage. Hence, T_7, tagged $V_{100}F_{100}M_{60}$ was selected. The water productivities of T_7 were 4.94 kg/m^3 and 0.45 kg/m^3 on fruit fresh and dry yield basis, respectively. The scenarios hence created are with respect to varied irrigation depths during the maturity growth stage as described in Table 2.

Scenario 2: Deficit application at two of three growth stages, in successions

Scenario 2 comprises four irrigation depths, and deficit application at two of three growth stages in successions. The irrigation depths were 100, 80, 60 and 40% of the mean ETo of the study area.

Each irrigation depth was successively imposed at two crop growth stages, the third stage being fully irrigated (Table 3).

Scenario 3: Deficit application at all three growth stages

In scenario three, each irrigation depth is applied all through the entire crop growth stages (Table 4). The irrigation interval was fixed at 3 days.

Table 1. Treatment descriptions of the field experiment

Treatment Number	Treatment Tag	Treatment Description
T_1	$V_{100}F_{100}M_{100}$	Full irrigation (100% ET_o) at all crop growth stages (control)
T_2	$V_{80}F_{100}M_{100}$	Irrigating with 80% ET_o at vegetative stage, full irrigation at flowering and maturity stages
T_3	$V_{100}F_{80}M_{100}$	Irrigating with 80% ET_o at flowering stage, full irrigation at vegetative and maturity stages
T_4	$V_{100}F_{100}M_{80}$	Irrigating with 80% ET_o at maturity stage, full irrigation at vegetative and flowering stages
T_5	$V_{60}F_{100}M_{100}$	Irrigating with 60% ET_o at vegetative stage, full irrigation at flowering and maturity stage
T_6	$V_{100}F_{60}M_{100}$	Irrigating with 60% ET_o at flowering stage, full irrigation at vegetative and maturity stage
T_7	$V_{100}F_{100}M_{60}$	Irrigating with 60% ET_o at maturity stage, full irrigation at vegetative and flowering stage
T_8	$V_{40}F_{100}M_{100}$	Irrigating with 40% ET_o at vegetative stage, full irrigation at flowering and maturity stage
T_9	$V_{100}F_{40}M_{100}$	Irrigating with 40% ET_o at flowering stage, full irrigation at vegetative and maturity stages
T_{10}	$V_{100}F_{100}M_{40}$	Irrigating with 40% ET_o at maturity stage, full irrigation at vegetative and flowering stages

Table 2. Treatment descriptions for deficit irrigation at maturity stage

Treatment Number	Treatment Tag	Treatment Description
$T_{7(30)}$	$V_{100}F_{100}M_{30}$	Full irrigation (100% ET_o) at vegetative and flowering stages, 30% ETo at maturity stage
$T_{7(40)}$	$V_{100}F_{100}M_{40}$	Full irrigation at vegetative and flowering stages, 40% ETo at maturity stage
$T_{7(50)}$	$V_{100}F_{100}M_{50}$	Full irrigation at vegetative and flowering stages, 50% ETo at maturity stage
$T_{7(60)}$	$V_{100}F_{100}M_{60}$	Full irrigation at vegetative and flowering stages, 60% ETo at maturity stage
$T_{7(70)}$	$V_{100}F_{100}M_{70}$	Full irrigation at vegetative and flowering stages, 70% ETo at maturity stag
$T_{7(80)}$	$V_{100}F_{100}M_{80}$	Full irrigation at vegetative and flowering stages, 80% ETo at maturity stage
$T_{7(90)}$	$V_{100}F_{100}M_{90}$	Full irrigation at vegetative and flowering stages, 90% ETo at maturity stage

Table 3. Irrigation depth – growth stage based scenario (deficit at two of three growth stages, full irrigation at one growth stage)

Treatment Number	Treatment Tag	Treatment Description
$T_{2,3}$	$V_{80}F_{80}M_{100}$	Irrigating with 80% ET_o at vegetative and flowering stages, full maturity stage
$T_{2,4}$	$V_{80}F_{100}M_{80}$	Irrigating with 80% ET_o at vegetative and maturity stages, full irrigation at flowering stage
$T_{3,4}$	$V_{100}F_{80}M_{80}$	Irrigating with 80% ET_o at flowering and maturity stages, full irrigation at vegetative stage
$T_{5,6}$	$V_{60}F_{60}M_{100}$	Irrigating with 60% ET_o at vegetative and flowering stages, full irrigation at maturity stage
$T_{5,7}$	$V_{60}F_{100}M_{60}$	Irrigating with 60% ET_o at vegetative and maturity stages, full irrigation at flowering stage
$T_{6,7}$	$V_{100}F_{60}M_{60}$	Irrigating with 60% ET_o at flowering and maturity stages, full irrigation at vegetative stage
$T_{8,9}$	$V_{40}F_{40}M_{100}$	Irrigating with 40% ET_o at vegetative and flowering stages, full irrigation at maturity stage
$T_{8,10}$	$V_{40}F_{100}M_{40}$	Irrigating with 40% ET_o at vegetative and maturity stages, full irrigation at flowering stage
$T_{9,10}$	$V_{100}F_{40}M_{40}$	Irrigating with 40% ET_o at flowering and maturity stages, full irrigation at vegetative stage

V: Vegetative, F: Flowering, M: Maturity

Table 4: Irrigation depth – growth stage based scenario (deficit irrigation at all growth stages)

Treatment Number	Treatment Tag	Treatment Description
$T_{2,3,4}$	$V_{80}F_{80}M_{80}$	Irrigating with 80% ET_o at V, F and M stages.
$T_{5,6,7}$	$V_{60}F_{60}M_{60}$	Irrigating with 60% ET_o at V, F and M stages.
$T_{8,9,10}$	$V_{40}F_{40}M_{40}$	Irrigating with 40% ET_o at t V, F and M stages.

V: Vegetative, F: Flowering, M: Maturity

Scenario 4: Deficit irrigation across three irrigation methods

Drip and surface (basin and furrow) irrigation methods were considered under this scenario, the latter representing the irrigation practice of most of the tomato farmers in the area.

Drip irrigation wets a fraction of the soil surface (30%), basin irrigation wets the entire soil surface (100%) and furrow (every furrow, narrow bed) wets an average of 80% of the soil surface [21].

RESULTS AND DISCUSSION

Effects of Irrigation Depths on Fruit Dry Yield, crop Water Use and Water Productivity

The effects of varied irrigation deficits at one growth-stage (maturity) on the fruit dry yield (Y_{dry}), crop water use (CWU) and water productivity (WP) are presented in Table 5. The highest simulated Y_{dry} and CWU were 1.71 t/ha and 375.3 mm, respectively, and these occurred in $T_{7(90)}$ while the least Y_{dry} and CWU were 1.06 t/ha and 287.9 mm, respectively. The Y_{dry} range is about 50% lower than that obtained in a similar study in Harare, Zimbabwe, using galina and shanty varieties [21]. The yield differences are attributable to a number of factors ranging from environmental to agronomic; yield and water productivity can vary substantially among species and genotypes (cultivars) [23] and also in response to location, stress patterns, planting dates, and other factors [24].

The WP ranged between 0.37 and 0.46 kg/m^3 in the treatments examined with $T_{7(70)}$ having the highest value (WP=0.46 kg/m^3) and $T_{7(30)}$ having the least (WP = 0.37 kg/m^3). Hence, it can be implied from the model that tomato fruit yield is more productive when irrigated with 70% ETo value at the maturity stage than 60% ETo at maturity as observed in the field. Compared to the full irrigation treatment about 69 mm of seasonal water applied (equivalent to 13% of full irrigation) was saved in $T_{7(70)}$ and this can be used to cultivate additional 0.15 ha, with the potential to produce additional 0.25 t/ha. Total derivable dry yield from $T_{7(70)}$ will be 1.89 t/ha which is well above the yield of the fully irrigated treatment.

Table 5. Effects of deficit irrigation at one of three growth stages (Scenario 1)

Treatment	SWA, mm	Y_{dry}, t/ha	CWU, mm	WP, kg/m^3
$T_{7(30)}$	355	1.06	288	0.37
$T_{7(40)}$	370	1.10	277	0.40
$T_{7(50)}$	408	1.31	325	0.40
$T_{7(60)}$	481	1.5	369	0.45
$T_{7(70)}$	461	1.64	361	0.46
$T_{7(80)}$	488	1.65	324	0.44
$T_{7(90)}$	515	1.71	375	0.45

Effects of deficit application at two of three growth stages, in successions

The effects of irrigation depths on simulated fruit dry yield, crop water use and water productivity for scenario 2 are presented in Table 6. The highest simulated Y_{dry} and CWU were obtained as 1.69 t/ha and 373 mm, respectively in $T_{2,3}$ while the least Y_{dry}, CWU and WP were obtained in $T_{9,10}$ as 1.02 t/ha, 254 mm and 0.40, respectively.

The highest crop water productivity was obtained in $T_{5,6}$, with Y_{dry} value of 1.62 t/ha, CWU of 357 mm and WP of 0.46. Water saved in $T_{5,6}$ was 72 mm, which is 13.6% of the water applied in the fully irrigated treatment.

The amount of water hence saved can be used to cultivate additional 0.157 ha, with the potential to produce additional 0.255 t/ha. The additional yield adds up to give a yield potential of 1.875 t/ha which is an advantage over the yield obtained from the fully irrigated treatment.

Effects of deficit application at all three growth stages

The simulated fruit dry yield, crop water use and water productivity as affected by irrigation depths and growth stage based deficit irrigations for scenario 3 are presented in Table 7. The highest simulated Y_{dry}, CWU and WP were obtained in $T_{2,3,4}$ as 1.67 t/ha, 365 mm and 0.46 kg/m^3, respectively in while the least were obtained in $T_{8,9,10}$ as 0.97 t/ha, 233 mm and 0.41, respectively. $T_{2,3,4}$ is the treatment with the highest water productivity, and hence, the recommended deficit water application strategy across the entire crop growth cycle. Irrigation water saved in $T_{2,3,4}$ is 83 mm, which is 13.7% of the water applied in the fully irrigated treatment. Potentially, this can be applied to cultivate additional 0.19 ha to produce additional 0.31 t/ha. The additional yield adds up to give a yield potential of 1.98 t/ha which is greater than the yield from the full irrigation.

Table 6. Effects of deficit irrigation at **two** of three growth stages (Scenario 2)

Treatment	SWA, mm	Y_{dry}, t/ha	CWU, mm	WP, kg/m^3
$T_{2,3}$	500	1.69b	373b	0.45b
$T_{2,4}$	471	1.66c	367c	0.45b
$T_{3,4}$	464	1.66c	368c	0.45b
$T_{5,6}$	458	1.62d	357d	0.46a
$T_{5,7}$	401	1.59e	351e	0.45b
$T_{6,7}$	386	1.53f	337f	0.45b
$T_{8,9}$	417	1.32g	301g	0.44b
$T_{8,10}$	330	1.20h	289h	0.41c
$T_{9,10}$	308	1.02i	254i	0.40c
SE±		0.080	14.00	0.0069
Significance		*	*	*

Table 7. Effects of deficit irrigation at **all three** growth stages (Scenario 3)

Treatment	SWA, mm	Y_{dry}, t/ha	CWU, mm	WP, kg/m^3
$T_{2,3,4}$	447	1.67a	365a	0.46a
$T_{5,6,7}$	351	1.50b	333b	0.45b
$T_{8,9,10}$	257	0.97c	233c	0.41c
SE±		0.19	35.31	0.013
Significance		*	*	*

Generally, the fruit yields and crop water use decreased with increase in moisture deficit (percentage water withheld) and growth stage progression (vegetative to flowering to maturity). This confirms the findings that yield reduction increases as deficit levels increase, especially at the reproductive growth stages [8], [25], [16].

The yield reduction due to moisture stress was evident from observed reduction in plant growth and development in the moisture stressed plots. In moisture stressed plants, there is reduction of the photosynthetic process as the stomata close to reduce transpiration [26].

Also, translocation of assimilates are known to be affected by water stress which hence limits photosynthesis.

Comparison of deficit irrigation scenarios

The irrigation treatments with the highest irrigation water productivities among the deficit scenarios were compared among themselves as depicted in Table 8. The highest crop water productivity value of 0.46 was obtained in $T_{7(70)}$, $T_{5,6}$ and $T_{2,3,4}$ among the three deficit irrigation scenarios examined. However, $T_{2,3,4}$ should be the most preferred deficit treatment, having the least seasonal water applied (SWA = 447 mm) and highest fruit dry yield (1.67 t/ha). The results showed that while the highest yield may be obtained under full irrigation, the highest water productivity may occur under deficit irrigation. Similar results were obtained in the deficit irrigation on tomato (Galila 555) in Silte Zone, Rift Valley, Ethiopia [27]. The water saved under the deficit irrigation would translate into additional cultivated land, the latter being the opportunity cost of the water saved during deficit irrigation. The increase in water productivity justifies the use of regulated growth deficit irrigation under the condition of limited water availability.

Table 8. Comparison of deficit irrigation scenarios

Treatment	SWA, mm	SWs, mm	Y_{dry}, t/ha	CWU, mm	WP, kg/m^3	Y_e, t/ha
T_1	530	0	1.72	384	0.45	1.72
$T_{7(70)}$	461	69	1.64	361	0.46	1.89
$T_{5,6}$	458	72	1.62	357	0.46	1.88
$T_{2,3,4}$	447	83	1.67	365	0.46	1.98

SWs = Seasonal water saved (mm), Ye = expected yield (t/ha)

Effects of Deficit Irrigation across Three Irrigation Methods

The effects of irrigation methods on the model outputs are presented in Table 9. The irrigation method scenarios comprise the drip irrigation system, which was used in conducting the field study and surface irrigation (basin and furrow) systems, which are the farmers' practice in the study area.

Table 9. Effect of irrigation methods on yield, crop water use and water productivity

Irrigation methods	Fruit dry yield, t/ha					
	T_1	T_7	T_1	T_7	T_1	T_7
Drip	1.69	1.53	322.8	290.0	0.52	0.53
Basin	1.69	1.53	365.3	337.2	0.46	0.45
Furrow	1.69	1.53	366.2	328.3	0.47	0.47

The simulation results showed that the fruit dry yields were similar irrespective of the irrigation method for each of T_1 (1.69 t/ha) and T_7 (1.53 t/ha).

Under field conditions, however, studies have shown that irrigation methods have effect on the yields of crops. [28], [29] reported that drip irrigation yielded 19% and 50% more fruit yield, respectively, than furrow irrigation. Hence, the model response to the effects of different irrigation methods for the same irrigation depth is inadequate with respect to the fruit dry yield.

The model however, showed different crop water use and crop water productivity values in response to the irrigation methods. For each treatment the lowest crop water use was obtained under drip irrigation compared to the basin and furrow systems.

This corroborates the reports for off-season vegetables under drip and furrow irrigation systems [30]. In $T_{1,}$ the drip system was 12% more efficient than both basin and furrow. Also, in T_7, the drip system was 14% and 12% more efficient than the basin and furrow systems, respectively. The differences are attributable to the percentage of soil surface wetted under irrigation. It has been indicated that 30%, 80% and 100% of soil surfaces are wetted under drip, furrow and basin irrigation systems, respectively [21]. On the average, water productivity was highest under drip irrigation system (0.53 kg/m^3) compared to both basin and furrow systems (0.46 kg/m^3). This is because under the surface systems more seasonal water application is required without a significant improvement in the crop yield. Hence, under water-limiting conditions drip irrigation should be preferred to the surface systems for more efficient irrigation water management and higher water productivity.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The conclusions made from this study are as follows:

1. The application of the validated AquaCrop 6.0 is innovative as it was able to adequately simulate the effects of varied irrigation depths at different growth stages on fruit yield, crop water use and water productivity in both seasons. The model is found to be valuable in aiding decision making for effective irrigation management strategies and prediction of tomato yield in the study area and other areas of similar environmental conditions.
2. The three deficit irrigation scenarios evaluated showed that irrigation water productivity was highest when deficit irrigation was applied at 80% ETo value across the three growth stages than when applied at either one or two of the growth stages. Hence, an appropriate deficit irrigation strategy can proceed through the entire crop growth stages to achieve the highest irrigation water productivity of UC 82B tomato.

Recommendations

1. The model scenario study under varied irrigation depths showed that the tomato yield decreased as the deficit levels increased, with the highest water productivity occurring when the crop was irrigated with 80% ETo amount across the entire crop growth cycle.

This is, therefore, the recommended regulated deficit irrigation schedule for UC 82B tomato under water limiting condition in the study area.

2. In comparison to surface methods, drip irrigation is recommended for improvement of water productivity as crop water use was found to be lower under the drip method.

REFERENCES

[1]. IAEA. 2017. Agricultural water management, *International Atomic Energy Agency publication.* https://www.iaea.org/topics/agricultural-water-management

[2]. English M.J., Musick J.T. and Murty V.V. 1990. Deficit irrigation. In: Management of farm irrigation systems, Hoffman, G.J., Towell T.A.and Solomon K.H. (eds.), St. Joseph, Michigan, USA, ASAE.

[3]. Kirda C. 2002. Deficit irrigation scheduling based on plant growth stages showing water tolerance. In: Deficit Irrigation Practice, FAO (ed.), Rome, Italy, pp. 3-10

[4]. Mannini P. 2004. Le buone pratiche agricole per rispamiare acqua. A cura di Pirani P., Regione Emilia-Romagna. *Agricultura*, 5, suppl. 18, 177 pp.

[5]. FAO 2000. Socio- Economic Impact of Smallholder irrigation Development in Zimbabwe, Food and Agr. Organization (FAO) Sub-Regional Office for East and Southern Africa, Harare.

[6]. Kirda, C., Kanber, R. and Tulucu, K. 1999. Yield response of cotton, maize, soybean, sugar beet, sunflower and wheat to deficit irrigation. The Netherlands, Kluwer Academic Publishers.

[7]. Oiganji E., Igbadun H.E., Mudiare O.J. and Oyebode M.A. 2017. Water use efficiency of maize crop under deficit irrigation scheduling using gravity drip system in Samaru, Nigeria. *Global J. of Science Frontier Research: (D) Agriculture and Veterinary*. 17(1), pp. 74-82

[8]. Igbadun H.E. 2012. Impact of methods of administering growth stage deficit irrigation on yield and soil water balance of maize crop (SAMAS TZEE). *Nigerian Journal of Basic and Applied Sciences*, 20(4), pp. 357-367

[9]. Halilu, A. G., Othman M.K., Ismail H., and Shanono N.J. 2014. Effects of deficit irrigation and mulch on yield and water use efficiency of watermelon in Samaru, Nigeria. *Nigerian Journal of Soil and Environmental Research*, 12, pp. 13–17.

[10]. Ismail, H., Abubakar, S.Z., Oyebode, M.A., Halilu, A.G., and Shanono, N.J. 2014. Effect of irrigation regimes on growth and yield of tomato under high water-table conditions. *Journal of Soil and Environmental Research*, 12, pp. 43–57

[11]. Oiganji, E., Igbadun H., Mudiare O.J., and Oyebode M.A. 2016. Calibrating and validating AquaCrop model for maize crop in Northern zone of Nigeria. *Agricultural Engineering International: CIGR Journal*, 18(3), pp. 1-13

[12]. Igbadun, H.E. 2008. A model for generating water management responses indices use in assessing impact of irrigation scheduling strategy. *Nigerian Journal of Engineering*, 14(2)

[13]. Kumar, V., and Ahlawat I.P.S. 2004. Carry-over of bio-fertilizers and nitrogen applied to wheat and direct applied nitrogen in maize in wheat-maize cropping system. *Indian Journal of Agronomy*, 49(4), pp. 233-236.

[14]. Jones J.W., Antle J.M., Basso B., Boote K.J., Conant R.T. 2017. Brief history of agricultural systems modeling. *Agricultural Systems*, 155, pp. 240-254

[15]. Souza J.L.M., Oliveira C.T., Rosa S.L.K. and Tsukahara R.Y. 2020. Calibration and validation of the AquaCrop model to estimate maize production in Campos Gerais, Paraná State,Brazil.*Revista Brasileira de Meteorologia*, 35(2), pp. 243-253.

[16]. Liu, J., Wiberg, D., Zehnder, A., Yang, H., 2007. Modeling the role of irrigation in winter wheat yield, crop water productivity, and production in China. *Irrig. Science,* 26, pp. 21–33.

[17]. Steduto P., T.C. Hsiao, E. Fereres and D. Raes (2012). Crop yield response to water. Irrigation and Drainage Paper No. 66, FAO Rome

[18]. NIMET 2015. Climate of Kaduna, Nigeria, 1986 – 2015, Nigerian Meteorological Agency.

[19]. Zhai Y.M., Shao X.H., Xing W.G. and Wang Y. 2010. Effects of drip irrigation regimes on tomato fruit yield and water use efficiency. *Journal of Food, Agriculture and Environment*, 8(3), pp. 709-713.
[20]. Onwuegbunam D.O., Oyebode M.A., Igbadun H.E. and Ismail H. 2022. Simulation of response of field-grown drip-irrigated tomato to water stress using Aquacrop model, Unpublished PhD. Thesis, Department of Agricultural and Bio-resources Engineering, Ahmadu Bello University, Zaria, Nigeria.
[21]. Raes D., Steduto P., Hsiao T.C. and Fereres E. 2018. Annexes: AquaCrop 6.0 - 6.1 Reference Manual, Food and Agriculture Organization of the United Nations, Rome, May 2018
[22]. Muroyiwa G., Mhizha T., Mashonjowa E. and Muchuweti M. 2022. Evaluation of FAO Aquacrop model for ability to simulate attainable yields and water use for field tomatoes grown under deficit irrigation in Harare. *African Crop Science Journal*, 30(2), pp. 245 – 269.
[23]. Sheshshayee, M.S., Bindumadhava, H., Shankar, A.G., Prasad, T.G. and Udayakumar, M. 2003. Breeding strategies to exploit water use efficiency for crop improvement. *Journal of Plant Biology*, 30(2), pp. 253-268.
[24]. Fereres E. and Soriano M.A. 2007. Deficit irrigation for reducing agricultural water use, *Journal of Experimental Botany.* 58(2), pp. 147-158.
[25]. Jiang, X., Zhao, Y., Wang, R., & Zhao, S. 2019. Modeling the Relationship of Tomato Yield Parameters with Deficit Irrigation at Different Growth Stages. Hortscience, 59(4), pp. 1492-1500
[26]. Singh V., Sasode S., Patel R., Kumar S. and Ahirwal A. 2020. Moisture stress and their effects on crops. Kirshi Science, eMagazine for Agricultural Science, 1(6), pp. 1-4, December, 2020, www.krishiscience.in/storage/app/finalpdf/rDxQlkd0ONjIgIXDhH
[27]. Bekele T., Wabela K. and Abebo M. 2022. Effect of deficit irrigation on tomato (Galila 555) yield and water productivity in Silte Zone, Rift Valley, Ethiopia. *International Journal of Plant Biotechnology*, 8(1), pp. 1-7.
[28]. Pruitt W.O., Fereres E., Henderson D.W. and Hagan R.M. 1984. Evapotranspiration losses of tomatoes under drip and furrow irrigation. California Agriculture, May-June 1984, pp. 10-11. www.calag.ucanr.edu/download_pdf.cfm?article=ca.v038n05p10
[29]. Kahlon M.S., Josan A.S. Khera K.L. and Choudhary O.P. 2007. Effect of drip and furrow methods of irrigation on tomato under two irrigation levels. *Indian Journal of Agricultural Research*, 41, pp. 282-286.
[30]. Musa M., Iqbal M., Tariq M., Sahi F.H., Cheema N.M. and Jahan F.N. 2014. Comparative water use efficiency of drip and furrow irrigation systems for off-season vegetables under plastic tunnel. *SAARC J. Agric.*, 12(1), pp. 62-71.

PREDVIĐANJE PRINOSA PARADAJZA I POTROŠNJE VODE PO SCENARIJU SA DEFICITOM NAVODNJAVANJA UPOTREBOM MODELA AQUACROP, U AFAKI, KADUNA, NIGERIJA

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Apstrakt: Poboljšanje potrošne vode za navodnjavanje kod deficita postalo je glavni cilj za održivu poljoprivredu zbog globalnog pada pristupačnosti vode.

Studija je procenila prinos, upotrebu vode za useve i potrošnju vode kod paradajza gajenog u polju navodnjavanjem sistemom kap po kap kao odgovor na regulisano navodnjavanje u slučaju deficita vode, i naknadnu simulaciju pod različitim scenarijima deficita i metoda navodnjavanja, koristeći AquaCrop model, za uslove pokrajine Afaka, Nigerija.

Eksperiment na terenu, postavljen u randomizovanom kompletnom blok dizajnu, sastojao se od tri različita nivoa deficita navodnjavanja (80, 60 i 40% referentne evapotranspiracije, ETo) postavljenih u fazama vegetativnog razvoja: cvetanja i zrelosti, sa 100% ETo u tri faze porasta useva, kao kontrole.

Najveći prinos svežeg paradajza (19,0 t/ha) dobijen je navodnjavanjem sa 100% ETo vrednošću u svim fazama rasta, ali je najveća potrošnja vode svežeg paradajza (4,94 kg/m^3) dobijena navodnjavanjem sa 60% ETo u fazi zrelosti, zatim puna navodnjavanje u vegetativnim i cvetnim fazama.

Na osnovu prinosa paradajza (slučaj kada nije navodnjavano), najveća simulirana potrošnja vode kod (0,46 kg/m^3) za scenarije deficita dobijena je navodnjavanjem sa normom od 80% ETo kod sve tri faze rasta, sa najvećim (ne navodnjavano) prinosom paradajza (1,67 t/ha) i najmanja sezonska primena vode (447 mm).

Kod scenarija metode navodnjavanja (kap po kap, nalivanje i brazda), prinos paradajza (ne navodanjavano) je bio sličan za svaki tretman, ali je potrošnja vode bila najveća (0,53 kg/m^3) kod sistema kap po kap.

Navodnjavanje sa 80% ETo tokom celog ciklusa rasta useva paradajza sorte UC 82B preporučuje se za najveću produktivnost navodnjavanja.

Ključne reči: *Predviđanje, prinos paradajza, produktivnost vode, deficit navodnjavanja, scenariji, AkuaCrop, Nigerija*

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PERFORMANCE OPTIMIZATION OF DRAFT AND POWER REQUIREMENT FOR SOME TILLAGE IMPLEMENTS IN A LOAMY SOIL: A RESPONSE SURFACE APPROACH

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Abastract: Tillage is the basic operation in agriculture and its energy requirements represent a considerable portion of the energy utilized in crop production. A field experimental data were optimized using central composite rotatable design of response surface method for draft and power requirement for 3-bottom disc plough, spring tine cultivator and offset disc harrow in a loamy soil. Optimum draft for 3-bottom disc plough, spring tine cultivator and offset disc harrow on a loamy soil were 2.80; 0.20 and 1.82kN, respectively while optimum power requirements for 3-bottom disc plough, spring tine cultivator and offset disc harrow were 3.93; 0.30 and 2.42 kW, respectively. Optimum tillage depth and tractor speed for 3-bottom disc plough, spring tine cultivator and offset disc harrow were 22.03 cm and 10.84 km/hr, 14.07 cm and 10.80 km/hr, 17.70 cm and 10.24 km/hr, respectively. It is therefore recommended that tillage operation should be carried out at the specified optimum values at the study location in order to increase the efficiency of the operation.

Keywords: *Draft, power requirement, tillage, loamy soil, optimization*

INTRODUCTION

Authors [5] and [7] stated that by combining statistical and mathematical tools, Response Surface Methodology (RSM) is considered to be an effective methodology to develop, modify and optimize several operations.

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RSM has shown to be a valuable tool for the detailed examination of the problem during which a particular response of interest is usually influenced by several reaction variables with the idea of optimizing a defined response of concern. Author [7] reported that the first aim of using RSM was to model experimental responses, but as time went on, RSM applications were advanced to develop models for the optimization of numerical experiments.

Author [5] stated that the main objective of RSM is to have a topographical knowledge of response surfaces and region where optimal responses can be found.

Agricultural sustainability depends on farm profitability. Thus, farmers are under constant pressure to produce more with less and to reduce production costs through improved operating efficiency. Tractor-implement operation efficiency depends heavily on how well the tractor and implement are matched. When ideally matched, there is less power loss, improved operation efficiency, reduced operation cost, and optimum utilization of capital on fixed costs [3].

Determination of the draft and the power requirement play a vital role in the design and development of agricultural tools and the selection of the suitable tractor. The soil type and condition, moisture content, ploughing depth, and speed etc, are essential factors which affect the draft and power requirements of agricultural tools. The energy which is needed for agricultural activities is the power needed to overcome the draft and the energy to pull implements [8]. Draft required during tillage is a function of soil properties, working depth, tool geometry, travel speed, and width of the implement. It is an essential factor to measure and evaluate the performance of an implement for energy requirements. Moisture content, bulk density, penetration resistance texture of the soil and its strength are the soil properties that contribute mostly to tillage energy [4], [6] and [9].

Tillage is a process which mechanically modifies or manipulates the soil by cutting, pulverizing and inverting in order to provide conditions favorable to crop growth [1].
It is a physical, chemical or biological process which manipulates the soil to optimize conditions for seed germination and seedling emergence and establishment.
Tillage is an integral part of the crop production system and usually account for a high proportion of total energy spent in crop production [2].

MATERIALS AND METHODS

Study location

The study was conducted at Use Offot located in Uyo local government area of Akwa Ibom state, Nigeria.

Optimization of the different parameters

Response surface methodology was applied to the experimental data using a commercial statistical package, design – expert 11.0.1 (Stat-Ease Inc., Minneapolis, USA). The same software was utilized for generating the response surface plots, superimposition of contour plots and optimization of the variables. The response surface and contour plots were generated for various interactions for the two independent variables. Desirability, a mathematical method was utilized to select the optimum values.

RESULTS AND DISCUSSION

Soil analysis test for the study location

Analysis of soil test carried out at the study location for the three tillage implement is presented in Tab. 1

Table 1. Mechanical properties of the soil at the study location for the tillage implements

Soil Parameter	Values		
	3-Bottom Disc Plough	Spring Tine Cultivator	Off-set Disc Harrow
Soil Composition	%	(%)	(%)
Sand	41	41	41
Silt	35	35	35
Clay	24	24	24
Classification	Loam	Loam	Loam
Average Bulk density	(g/cm^3)	(g/cm^3)	(g/cm^3)
	1.32	1.32	1.32
Average Moisture content	(%)	(%)	(%)
	13.9	16.2	15.0

Experimental test results

The average summary of the experimental results for the two-factor, five levels factorial Central Composite Rotatable Design (CCRD) of the response surface methodology (RSM) for draft and power requirement are presented in Tabs. 2 and 3

Table 2. Experimental results for draft using three implements on loamy soil

S/N	Factor 1	Factor 2			
	D_T (cm)	S_T (km/hr)	D (kN)-3BDP	D (kN)-STC	D (kN)-ODH
1	10	7.2	1.19	0.12	1.02
2	15	5.4	1.78	0.20	1.53
3	15	9.0	1.91	0.22	1.68
4	20	3.6	2.53	0.28	2.16
5	20	7.2	2.69	0.30	2.27
6	20	7.2	2.67	0.30	2.27
7	20	7.2	2.69	0.30	2.28
8	20	7.2	2.69	0.30	2.27
9	20	7.2	2.68	0.30	2.27
10	20	10.8	2.77	0.31	2.34
11	25	5.4	3.46	0.40	3.04
12	25	9.0	3.65	0.42	3.16
13	30	7.2	4.64	0.54	3.97

D_T = Tillage Depth (cm); S_T = Tractor Speed (km/hr); D = Draft (kN);
3BDP = 3-Bottom Disc Plough; STC = Spring Tine Cultivator; ODH = Offset Disc Harrow

Table 3. Experimental results for power requirement using three implements on loamy soil

S/N	Factor 1	Factor 2			
	D_T (cm)	S_T (km/hr)	PR(kW)-3BDP	PR(kW)-STC	PR(kW)-ODH
1	10	7.2	2.28	0.20	1.88
2	15	5.4	2.24	0.28	2.09
3	15	9.0	3.55	0.47	3.52
4	20	3.6	1.94	0.18	1.49
5	20	7.2	4.19	0.39	3.10
6	20	7.2	3.97	0.38	3.06
7	20	7.2	4.11	0.39	3.14
8	20	7.2	4.16	0.39	3.04
9	20	7.2	4.02	0.38	3.08
10	20	10.8	5.04	0.48	3.81
11	25	5.4	3.52	0.49	4.25
12	25	9.0	5.98	0.73	5.59
13	30	7.2	6.58	0.66	4.92

D_T = Tillage Depth (cm); S_T = Tractor Speed (km/hr); PR = Power Requirement (kW); 3BDP = 3-Bottom Disc Plough; STC = Spring Tine Cultivator; ODH = Offset Disc Harrow

Optimization of the tillage operation for the draft at the study location

The draft for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location was optimized with Design Expert (version 11.0.1) software to obtain optimal tillage conditions. The optimum tillage operating conditions; predicted and measured values for draft for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location are presented in Tab. 4. Figs. 1, 2 and 3 show the response surface plots of the optimum draft with optimal factors combination of tillage depth and tractor speed of 20.85 cm and 6.66 km/hr; 14.55 cm and 7.42 km/hr; and, 17.00 cm and 6.12 km/hr with optimum predicted draft of 2.80, 0.20 and 1.82 kN for 3-bottom disc plough, spring tine cultivator and offset disc harrow respectively.

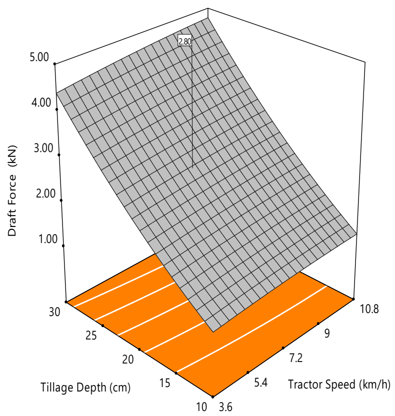

Figure 1. The 3D plot of response surface for optimization of tillage operation for optimum Draft for 3-bottom disc plough (3-BDP) at the study location

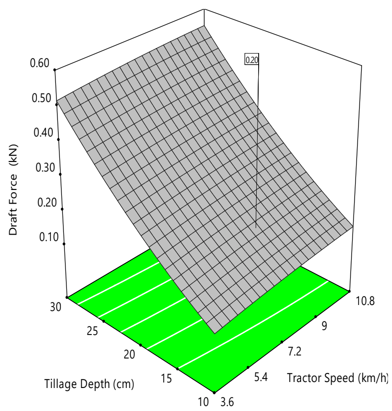

Figure 2. The 3D plot of response surface for optimization of tillage operation for optimum Draft (kN) for spring tine cultivator (STC) at the study location

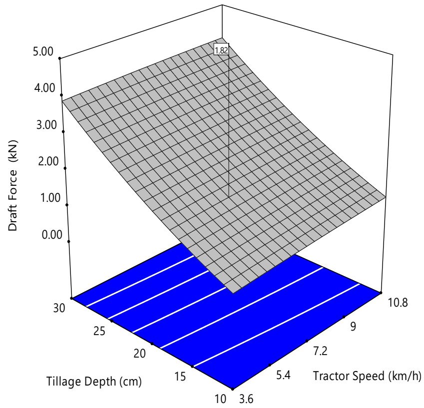

Figure 3. The 3D plot of response surface for optimization of tillage operation for optimum Draft (kN) for offset disc harrow (ODH) at the study location

Table 4. Optimum operating parameters for the draft for the three implements at the study location

Implement	Tillage depth (cm)	Tractor speed (km/hr)	Predicted draft (kN)	Measured draft (kN)	Desirability
3-bottom disc plough	20.85	6.66	2.80	2.79	0.978
Spring tine cultivator	14.55	7.42	0.20	0.19	0.892
Offset disc harrow	17.00	6.12	1.82	1.83	0.891

Optimization of the tillage operation for power requirement at the study location

The power requirement for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location was optimized with Design Expert (version 11.0.1) software to obtain optimal tillage conditions. The optimum tillage operating conditions; predicted and measured values for power requirement for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location are presented in Tab. 5. Figs 4, 5 and 6 show the response surface plots of the optimum predicted power requirement with optimal factors combination of tillage depth and tractor speed of 20.85 cm and 6.66 km/hr; 14.55 cm and 7.42 km/hr; and, 17.00 cm and 6.12 km/hr with optimum predicted power requirement of 3.93, 0.30 and 2.42 kW for 3-bottom disc plough, spring tine cultivator and offset disc harrow respectively.

Table 5. Optimum operating parameters for power requirement for the three implements at the study location

Implement	Tillage depth (cm)	Tractor speed (km/hr)	Predicted power requirement (kW)	Measured power requirement (kW)	Desirability
3-bottom disc plough	20.85	6.66	3.93	3.81	0.978
Spring tine cultivator	14.55	7.42	0.30	0.22	0.892
Offset disc harrow	17.00	6.12	2.42	2.86	0.891

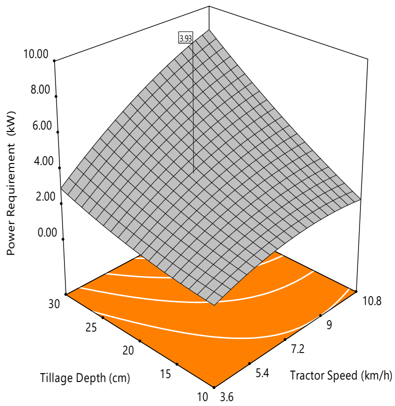

Figure 4. The 3D plot of response surface for optimization of tillage operation for optimum Power requirement (kW) for 3-bottom disc plough (3-BDP) at the study location

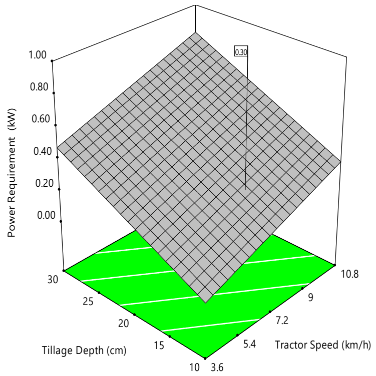

Figure 5. The 3D plot of response surface for optimization of tillage operation for optimum Power requirement (kW) for spring tine cultivator (STC) at the study location

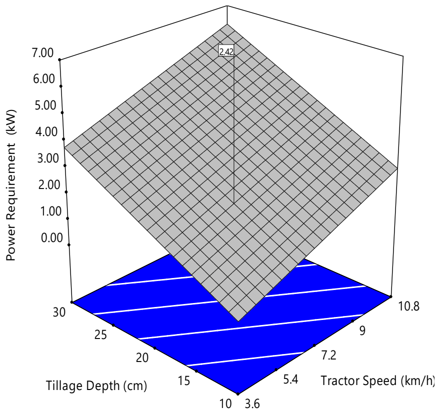

Figure 6. The 3D plot of response surface for optimization of tillage operation for optimum Power requirement (kW) for offset disc harrow (ODH) at the study location

CONCLUSION

Optimum draft and power requirement at optimum tillage depth and tractor speed for 3-bottom disc plough, spring cultivator and offset disc harrow in a loamy soil were obtained. Tillage operation at the obtained optimum values in the study location will increase the efficiency of the tractor and the tillage implements performance which will in turn improve the economic significance of the farming community. Techniques of optimization guide farmers in the selection of appropriate tillage parameters which can improve the efficiency of the tillage systems.

REFERENCES

[1] Anazodo, U. G. N. 1982. Mechanization of family farms in Nigeria. *Agricultural Mechanization in Asia, Africa and Latin America*. 8(3): pp.59 – 65.

[2] Anazodo, U. G., Horrio, H. and Sign, G. 1986. Agricultural machinery uses in Nigeria, the experience of Decades. *Proceedings of Nigerian Society of Agricultural Engineers*. 2: pp.406 – 429.

[3] Grissor, R. D., Perumpral, J. V. and Zoz, F. M.2007. Spreadsheet for matching tractor and drawn implements. *American Society of Agricultural and Biological Engineers,* 23(3): pp. 259 – 265.

[4] Grissor, R. D., Yasin, M. and Kocher, M. F. 1994. Tillage implements forces operating in silty clay loam. *American Society of Agricultural and Biological Engineers,* 94: pp.15 – 32.

[5] Montgometry, D. C. 2005. Design and analysis of experiments. Response surface method and designs. John Wiley and Sons, Inc.: Hoboken, NY, USA. pp.1-757.

[6] Palmer, A. L. and Kruger, I. R. 1982. Comparative drafts of six tillage implements. Proceeding of Conferences on agricultural engineering, Armidale, NSW, Australia. pp.163 – 167.

[7] Raymond, H. M. and Douglas, M. C. 2002. Response surface methodology: Process and product optimization using designed experiments, and ed.; John Wiley and Sons, Inc.; Hoboken, NY, USA. pp.1-705.

[8] Smith, L. A. and Barker, G. L. (1982). Equipment to monitor field energy requirement. *Transactions of the ASAE*. 26(6): pp.1556 – 1559.

[9] Upadhyaya, S. K., Williams, T. H., Kemble, L. J. and Collins, N. E. (1984). Energy requirements for chiselling in coastal plain soils. *Transactions of ASAE,* 28(8): pp.1643 – 1649.

OPTIMIZACIJA PERFORMANSI SILE VUČE I ZAHTEVA ZA SNAGU NEKE OPREME U OBRADI ILOVASTOG ZEMLJIŠTA: PRISTUP PREMA OSOBINAMA POVRŠINE ZEMLJIŠTA

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Sažetak: Obrada zemljišta je osnovna radna operacija u poljoprivredi i njene energetske potrebe predstavljaju značajan deo energije koja se koristi u biljnoj proizvodnji.

Eksperimentalni podaci na terenu su optimizovani korišćenjem metode centralnog rotabilnog kompozitnog dizajna sa karakteristikama osobina površine zemljišta (ilovasti tip) za potrebnu silu vuče i snagu za: diskosni plug sa tri radna tela, kultivator sa opružnim motičicama i disk (offset) tanjiraču na ilovastom tipu zemljišta.
Optimalna sila vuče za diskosni plug sa tri (3) radna tela, kultivator sa opružnim tipom motičica i disk tanjiraču na ilovastom tipu zemljišta iznosio je 2,80; 0,20 i 1,82 kN, respektivno, dok su optimalni zahtevi za snagom traktora za iste navedene mašine bili 3.99; 0,30 i 2,42 kW, respektivno.
Optimalna dubina obrade zemljišta i brzina traktora za diskosni plug sa 3 radna tela (diska), kultivator sa oprugom i diskosnu (offset) tanjiraču iznose: 22,03 cm i 10,84 km/h, 14,07 cm i 10,80 km/h, 17,70 cm i 10,24 km/h, respektivno.
Zbog toga je preporučljivo da se obrada zemljišta izvede sa specificiranim navedenim optimalnim vrednostima na lokaciji proučavanja kako bi se povećala efikasnost operacije obrade zemljišta.

Ključne reči*: Sila vuče, potrebna snaga, obrada, ilovasti tip zemljišta, optimizacija.*

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PROXIMATE COMPOSITION AND ORGANOLEPTIC PROPERTIES OF OVEN-DRIED ABA KNIFE FISH (*Gymnarchus Niloticus*)

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Abstract: This study investigates the quality composition of Aba knife fish (*Gymnarchus Niloticus*) predominant in South-eastern Nigeria. The fish sample require proper processing techniques to preserve their organoleptic qualities for a substantial period. The objective of the study was to investigate the influence of oven-drying process on the proximate and organoleptic qualities of *Gymnaruchus Niloticus*. The studied fresh fish fillets were rinsed in clean water, brined and spread in trays before taken for oven drying. An oven drier (FALC STF-F-52) was used for the oven-drying process. Analyses of proximate compositions (moisture content, crude lipid, crude protein, ash content and crude fiber) were carried out on the fresh and oven dried fish samples. The study showed that oven drying decreases the moisture content to a safe level of 38.13 $\pm$ 0.01% dry basis(d.b), and increase the crude protein content (18.23$\pm$0.01), fat content (4.34$\pm$0.01), ash content (3.40$\pm$0.01), carbohydrate content (35.96$\pm$0.01) of the investigated fish samples. There were no crude fibre contents (0.00) in the fresh fish samples. Therefore, the oven drying process had no noticeable effect on the fibre content. The oven dried fish samples were rated high in terms of taste, aroma, colour, texture and general acceptability by the panel of assessors. The significance of the obtained results as well as recommendations for further studies were offered.

Keywords: *Fish, drying process, quality composition, fillets, oven drier.*

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INTRODUCTION

Fish are major source of food for humans, providing a significant portion of protein, fats and vitamins in the meals of a vast proportion of the people and a key food commodity [1].

This is one of the world's most crucial source of animal protein preferred by most people due to the nutrients it has which are all vital for human health and growth [2,3]. Fish has nutrients such as omega-3 long chain polyunsaturated fatty acids (n-3 LC-PUFAs) calcium, iodine, vitamin D, zinc and iron [4]. It is also the cheapest source of animal protein, however, fresh fish spoil so easily and therefore requires adequate preservation and storage [5]. It is susceptible to microbial spoilage, tissue decomposition and the development of rancidity [6]. Fish oven-drying is a process of preserving fish by exposing it to high temperature in a drying chamber and this is more necessary when there is poor infrastructure in handling and processing fresh foodstuffs [7].

In Nigeria, oven-drying is a common practice in fish processing as it preserves its quality for an extended time and offers several advantages such as insignificant alterations and minimum deterioration of the product. This process is usually characterized by a combination of salting, drying and heating in an oven drying chamber [8].

Fish oven-drying is a simple method of preserving fish as it does not require highly sophisticated equipment or expertise [9]. Oven drying as a method of preservation produces acceptable products due to the desirable flavor and colour it imparts. The shelf-life of the oven-dried fish sample is usually extended basically due to the reduction in water activity. In order to ensure a short storage duration of dried fish that is safe from molds and bacteria infestation, the percentage moisture content must be less than 30 [10; 11].

Oven-drying is known to affect the weight, aroma, colour, texture, flavour and general acceptability of the finished products [12; 7]. Oven-drying results in weight loss in the final product due to both the effect of dehydration and leaching of lipids from the fish sample. The weight loss can be about 10-25% depending on the origin of the material, final product characteristics, drying method, size and shape of the fish [13]. Oven-drying affects the quality of fish in numerous ways, however, this depends mainly on the quality of the raw material used. A quality raw material will definitely yield a quality oven-dried product that ensures a good market demand and profit [14].

Aba knife fish (*Gymnarchus Niloticus*) is a fish found in swamps, rivers and lakes in the Nile, Niger, Chad and Nigeria. The fish is normally found in slow-moving streams and densely vegetated swamps [15]. In its natural habitat the fish feeds on insects, crustaceans, snails and frogs [10]. Deterioration of fish quality begins immediately after harvest, so therefore requires adequate preservation and storage.

Hence, oven-drying as a method of preservation which has been known to impart desirable proximate and organoleptic qualities of finished products was applied in this study to determine the influence of oven drying on the proximate and organoleptic qualities of the fish sample [16].

Gymnaruchus Niloticus is rich in protein which makes it command a high price in Nigerian market. It has an average price of $10 per fish which is due to its high value and usually relished when dried [1].

Various researches has been carried out on the breeding, life cycle, feeding, nutritive value and storage of *Gymnarchus Niloticus* species but there's limited information on the oven-drying process and the influence of oven-drying on the proximate values and organoleptic properties.

This research therefore, aims to determine the effect of oven-drying on the proximate composition (moisture content, crude protein, crude fibre, fat, ash, carbohydrate) and organoleptic qualities (taste, texture, aroma, colour and general acceptability) of *Gymnarchus Niloticus*.

MATERIALS AND METHODS

The materials used to determine the proximate and organoleptic properties of Aba knife fish sample were 25kg capacity, oven dryer, fresh Aba knife fish, salt, water, plastic containers, digital weighing scale, thermo-hygrometer and digital stop watches (PGE DSTP2).

The instruments used for this research were soxhlet reflux flask (CG 1368), electronic balance (model XY200L), muslin cloth, digital thermometer (HVAC IP69K), trays, measuring cylinders (100ml boro-silicate glass), petri dish (pyrex), whiteman filter paper, kjeldahl distillation apparatus (MGD 1000X), porcelain crucible, muffle furnace and thimble (STD 9612). The reagents used are concentrated sulphuric acid (H_2SO_4), boric acid, selenium powder, sodium hydroxide (NaOH), petroleum ether hydrogen chloride (HCl), and distilled water (H_2O).

Sample collection and preparation

Fresh Aba knife fish were purchased from local fishermen at Atani fish market in Anambra State of Nigeria. Fresh samples were preserved in ice to prevent deterioration while some samples were taken to the oven for drying. Then the samples were taken for proximate composition analysis at the Laboratory of the National Root Crops Research Institute (NRCRI), Umudike, Nigeria.

Experimental procedure

The methodology prescribed by [18] was used for the production of the oven-dried Aba fish. The fresh fish samples were measured in length (cm) and mass (kg) and the average length of the fresh samples was 61.85cm with a range of 58.9 - 64.8 cm while the average mass was 12.9 kg with a range of 7.8 – 10.2 kg. The dimensions of the fillet samples were taken as follows. The average yield length of the fillet was 12.37cm with a range of 11.78 – 12.96 cm while the average mass of fillet was 1.77 kg with a range of 1.1 – 2.4 kg and was cut into twenty-one fillets and clean water was used to wash the fillets. Brining was done by dipping the fillets into 75% saturated brine solution which was made by dissolving 27g of salt solution (NaCl) in 100ml of water.

The fillets were rinsed in fresh clean water and sprayed in trays while seven fillets were taken to the laboratory for proximate analysis of the fresh sample and the other fourteen fillets were taken for oven drying. The mean temperature of the oven during the drying process was 105^{o}C. The fish fillets were loaded on the oven tray and the temperature was taken hourly until a constant weight was achieved when the fish fillet was properly dried.

The oven-dried sample was divided into two, seven fish fillets were used for the organoleptic analysis and the other seven were taken to the laboratory to conduct the proximate analysis of the oven-dried samples. The oven drying process of the fish sample is shown in Fig. 1 below.

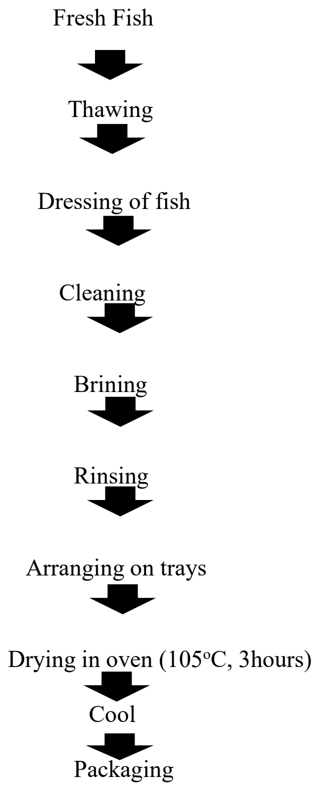

Figure 1. Flow chart of Aba Knife fish oven drying process

Proximate analysis

The proximate composition of the fresh and oven-dried samples were determined using the prescribed method described by Association of Official Analytical Chemists [19].
The procedures for the determination of the proximate properties of the fresh and oven-dried fillet samples are as follows:

Determination of moisture content

A mass of 10g of the sample was poured into a previously weighed moisture can. The sample in the can was dried in the oven at 105^0C for three hours.

It was cooled in a desiccator and weighed, returned to the oven for further drying after which it was left to cool and weighed repeatedly at hour intervals until a constant weight was obtained. The weight of the moisture lost was calculated as a percentage of the mass of the sample analyzed. It was given by the expression as shown in Equation (1):

$$\text{Moisture content} = \frac{100}{1} \times \frac{W_1 - W_3}{W_2 - W_3} \quad \text{................(1)}$$

Where: W_1 = mass of empty moisture can,
W_2 = mass of moisture can + weight of sample before drying,
W_3 = mass of moisture can + weight of sample dried to constant mass (g).

Determination of ash content

A mass of 3g of the processed sample was poured into a previously weighed porcelain crucible. The sample was burnt to ashes in a muffle furnace at 550°C. When it was completely ashed, it was cooled in a desiccator and weighed. The weight of the ash was expressed in percentage of mass of sample analyzed as shown in the Equation (2):

$$\%_{ash} = \frac{100}{1} \times \frac{W_2 - W_1}{W3} \quad \text{...................... (2)}$$

Where: W_1 = mass of empty crucible (g), W_2= mass of crucible + ash (g),
W_3=mass of sample (g).

Determination of crude fiber content

A mass of 3g of the processed sample was boiled in 150ml of 1.25% H_2SO_4 solution for 30mins under reflux. The boiled sample was washed in several portions of hot water using a two-fold muslin cloth to trip the particles which were returned back to the flask and boiled again in 150 ml of 1.25% NaOH for another 30 mins under the same condition.

After washing in several portions of hot water, the sample was allowed to drain dry before being transferred to a weighed crucible where it was dried in an oven at 105^0C to a constant mass. It was burnt to ashes in a muffle furnace. The mass of fiber was calculated as a percentage of weight of sample analyzed. It was given by the expression as shown in Equation (3):

$$\%_{\text{crude fiber}} = \frac{100}{1} \times \frac{W_2 - W_3}{\text{Mass of sample}} \quad \text{..................... (3)}$$

Where: W_2 = mass of crucible + sample after boiling, washing, and drying (g);
W_3 = mass of crucible + sample as ash (g).

Determination of fat content

A mass of 3g of the processed sample was wrapped in a porous paper (Whiteman filter paper) and put in a thimble. The thimble was placed in a soxhlet reflux flask and mounted in a weighed extraction flask containing 200 mls of petroleum ether.

The upper end of the reflux flask was connected to a water condenser. The solvent (petroleum ether) was heated. It boiled, vaporized and condensed into the reflux flask. The reflux flask filled up and symphonized over carrying its oil extract down to the boiling flask. The process was allowed to go on repeatedly for 4hours before the defatted sample was removed, the sample recovered and the oil extract was left in the flask.

The flask containing the oil extract was dried in the oven at 60°C for 30minutes (to remove the residue solvent) cooled in a desiccator and weighed.

By difference the weight of fat extract was determined and expressed as a percentage of the weight of the analyzed sample and is given by Equation (4):

$$\%\text{Fat} = \frac{100}{1} \text{ x} \frac{\text{W2} - \text{W1}}{\text{weight of sample}} \qquad \text{...................... (4)}$$

Where: W_1= mass of empty extraction flask and

W_2 = mass of extraction flask + fat extract (g)

Determination of protein content

This was done by the Kjeldahl method. The total N_2 was determined and multiplied with a factor of 6.25 to obtain the protein content. 1.0g of processed sample was mixed with 10ml of concentrated H_2SO_4 in a digestion flask. A tablet of selenium catalyst was added to it before it was heated in a fume cupboard until a clear solution was obtained (i.e., the digest) which was diluted to 100ml in a volumetric flask. 10mls of the digest was mixed with an equal volume of 45% NaOH solution in a Kjeldahl distillation apparatus. The mixture was distilled into 10mls of 4% boric acid containing 3 drops of mixed indicator (bromoseressol green/methyl red). A total of 50mls of distillates was collected and titrated against 0.02N. The N_2 content and hence the protein content was calculated using Equation (5):

$$\% \text{ Protein} = \% \text{ } N_2 \text{ x } 6.25$$

$$\% \text{ } N_2 = \left(\frac{100}{\text{W}} * \text{ N} * \frac{14}{1000} * \frac{\text{Vt}}{\text{Va}}\right) \qquad \text{.................. (5)}$$

Where: W = mass of sample (g),

N = normality of titrant (0.02 H_2So_4),

Vt = Total digest volume (100ml)

Va = Volume of digest analyzed (10ml),

T = Titre value of sample (40ml) and

B = Titre value of blank (50 ml).

Determination of carbohydrate content

It was estimated using the Equations (6) – (7):

%carbohydrate=100% (protein+lipid+ash+crude fibre+moisture content+dry matter) ..... (6)

$$\%_{CHO} = P_c + L_c + A + F_c + MC_{db} \quad \text{.....................} \quad (7)$$

Where: CHO = carbohydrate, L_c = crude lipid,

F_c = crude fat,

MC_{db}= moisture content dry basis,

A= ash and

P_c = crude protein.

Organoleptic Evaluation

The organoleptic evaluation of the oven-dried fillet samples was carried out using a 5-point hedonic scale [20] analyzed by a panel of 10 persons from the Bioprocess and Food Engineering option of the Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Nigeria. The quality attributes evaluated include taste, colour, aroma, texture and general acceptability. The panel scores were analyzed using Duncan's Multiple Range Test to check for samples' treatment that differ significantly from each other. From the score sheet used (Table 1). The fresh and oven-dried fish samples used for the experiment are shown below in Figs 2 and 3, respectively

Table 1. Indexes adopted by the panel for accessing the characteristics of the Oven-dried fish

Colour	Rating	Taste/Aroma	Rating	Texture	Rating
Golden (Dark lustre)	5	Excellent	5	Very dry	5
Golden (Lustre)	4	Very good	4	Dry	4
Brown (Normal)	3	Good	3	Fairly dry	3
Brown (Slightly)	2	Fair	2	Spongy	2
Silvery (Normal)	1	Poor	1	Wet	1
Mean value					

Fig. 2. Fresh Aba knife fish

Fig. 3. Oven-dried Aba knife fish

RESULTS AND DISCUSSION

The result of the proximate analysis carried out on the fresh and oven-dried fish samples is presented in Table 2. The mean crude protein content of the oven-dried samples increased by 3.55% when dried, whereas moisture content was grossly reduced to a mean safe level of 38.13% for storage. Similar results were obtained by [17]. Because there was no crude fiber content in the fresh fish sample, the crude fiber value remained 0.0% after drying. The mean ash and carbohydrate content of the oven-dried sample increased 2.17% and 31.52% respectively. More so, the fat content and energy increased 3.02 and 167.53%, respectively.
The result obtained from the study indicated weight loss as presented in Table 2, this shows that the fresh fish sample lost moisture content due to dehydration during the oven-drying process which took 3 hours before the final weight was obtained, these findings is in line with [2] and [11]. The loss in moisture of oven dried fish samples is as a result of the application of heat which decreases water activity in fish tissue, while high moisture content provides a conducive environment for spoilage by microbes [18].

Table 2. Mean proximate composition (mean± SD)
n=3 of the fresh and oven dried Aba Knife Fish

Proximate Property	Fresh Sample	Oven dried Sample
Moisture Content (%)	78.34 ± 0.03	38.13 ±0.02
Protein Content (%)	14.68 ± 0.01	18.23 ±0.01
Fat (%)	1.32 ± 0.02	4.34 ±0.03
Crude Fibre (%)	0.00	0.00
Ash Content (%)	1.23 ±0.01	3.40 ±0.01
Carbohydrate (%)	4.44 ±0.005	35.96 ±0.05
Energy (Cal/100g) (%)	88.29 ±0.08	255.82 ±0.02

The recorded lowest moisture content in dried fish samples entails a longer shelf life of the product. It has been reported by [12] that the principle of fish oven-drying is the removal of moisture content as a result of heat application from an oven. The quality of fish protein is superior to that which could be obtained from milk, meat and eggs. The increase in protein content of oven-dried sample as shown in Table 2 may be due to product dehydration which concentrated the protein during drying thereby increasing the nutritive value of the fish. A Similar findings was reported by [21] who compared the crude protein level of *Clarias Gariepinus* to the processed oven-dried sample.

The result obtained in Table 2 shows that fresh Aba knife fish has a high moisture content (78.34%) with a low fat content (1.32%) after drying there was a significant increase in fat content (Table 3). [10] reported that as the water content decrease in a fish, the fat increases and vice-versa. The increase in fat content could also be as a result of the heat generated by the oven which increases the concentration of nutrient in the mass of fat due to lipid oxidation. This finding is in line with [9] who reported that during drying fish losses its moisture content which result in increase in the concentration of nutrient in the remaining mass of fats.

Ash is the inorganic residue that remains after matter has been burnt off which was found in little non-significant traces in the fish sample. Ash is the measure of the mineral content of any food including fish [22]. Oven-drying increase significantly (≤ 0.05) the ash content of *Gymnarchus Niloticus* (Table 3) which could be attributed to the fish species, season and food availability. Similar findings was reported by [8] who observed significant difference in ash content of some oven dried C*larias Gariepinus*. The ash content of the dried sample increased 1.23% to 3.40% (Table 2) which is similar to the works of [6] on Bonga Spp, Sardinella Spp and *Heterotis Niloticus*.

Carbohydrate content in the fresh fish sample is 4.44% which is minimal and practically minute [23]. From Table 2, after drying it was observed that the carbohydrate value of the oven-dried fish sample increased from 4.44% to 35.96%. Fresh fish generally do have very low levels of carbohydrates because glycogen does not contribute much to the reserves in the fish body tissue [24].

Author [2] also observed that increase in carbohydrate of dried fish could be due to the fish consumption, absorption capacity and conversion potentials of essential nutrients from their diet or local environment into such biochemical attributes needed by the organism.

Table 3. Analysis of Variance (ANOVA) of the Mean proximate composition of Oven Dried Fish Sample.

Parameters	Source of Variation	Sumof Squares	df	Mean Square	F	Sig.
Moisture Content	Between Groups	2425.266	2	2425.266	247526	0.0001
	Within Groups	0.0004	1	235.02		
Protein Content	Between Groups	44.04	2	18.7974	751896	0.0004
	Within Groups	54.66	1	18.001		
Fat Content	Between Groups	3.95	2	13.7182	822649	0.0008
	Within Groups	13.02	1	0.00167		
Ash Content	Between Groups	3.66	2	7.19415	179853	0.0002
	Within Groups	10.23	1	0.0004		
Carbohydrate	Between Groups	13.29	2	1490.26	149265	0.0002
	Within Groups	107.85	1	0.0001		
Energy	Between Groups	264.89	2	4212.12	538864	0.0001
	Within Groups	767.61	1	0.7817		

Organoleptic characteristics of oven-dried Aba knife fish fillet

The result of the organoleptic analysis carried out on the oven-dried fish samples is presented in Table 4. The mean texture and aroma of the dried samples increased by 3.1 and 2.0, also there was increase in the mean colour, taste and general acceptability of the oven dried samples which is 2.9, 3.5 and 2.2 respectively. Similar results were obtained by [12]. The organoleptic qualities of a processed fish sample are of great importance due to the fact that every consumer wants good qualities from fish consumption. The organoleptic qualities of a fish are what normally attract consumers to it [21]. The high temperature in the oven (105^{o}C) contributes to the loss of amino acids as a result of millard reaction which involves amino group of amino acids with sugars and carbonyls. It is this reaction that necessitates the characteristic golden brown colour of the oven dried fish.

Table 4. Mean scores of the ratings of respondents on fresh and oven dried fish sample

Organoleptic Property	Mean Score of Fresh Sample	Mean Score of Oven-dried Sample
Texture	1.2	4.2
Aroma	2.4	4.4
Colour	1.5	4.5
Taste	1.0	4.5
General Acceptability	2.2	4.4

The concentration of nutrients and the denaturation effect of drying increases the taste of oven-dried fish. The influence of the high temperature is important in chemical reactions in the fish samples leading to the production of the flavour, colour, and other properties of oven dried fish [12]. Results from Table 5 show the statistical analysis carried out to ascertain the level of significance of the organoleptic qualities of the oven-dried fish sample. The texture mean score of 4.3 shows that the oven dried fish sample dry (Table 1) was statistically significant (≤ 0.05) with P-value of 0.010. It can also be seen that the mean aroma score of 4.4 indicates very good taste (Table 1) is statistically significant (≤ 0.05) with P-value of 0.005. A mean score of 4.4 rating was given by the respondents on colour of the samples. This implies that the colour of the oven dried samples is equated to a golden lustre (Table 1). In terms of taste and general acceptability, the respondents rated a mean score of 4.5 and 4.4 indicating very good taste and general acceptance, more so they are both statistically significant (Table 5).

Table 5. Analysis of variance (ANOVA) of the mean scores of respondents rating on oven dried Aba knife fish

Parameters	Source of Variation	Sum of Squares	Df.	Mean Square	F-value	Sig.
Texture	Between groups	36.45	1	36.45	46.532	0.010
	Within groups	14.10	8	0.783		
Aroma	Between groups	12.80	1	12.80	12.659	0.005
	Within groups	18.20	9	1.011		
Colour	Between groups	4.05	1	4.05	2.632	0.100
	Within groups	27.70	8	1.539		
Taste	Between groups	22.05	1	22.05	22.424	0.010
	Within groups	17.70	8	0.983		
General acceptability	Between groups	8.45	1	8.45	24.934	0.002
	Within groups	6.10	8	0.339		

CONCLUSION

In this experimental study, the proximate composition and organoleptic qualities of oven dried *Gymnaruchus Niloticus* were investigated. Considering the results established from this work, the following conclusions are drawn:

I. Oven drying increases the crude protein content, ash content, fat content, and carbohydrate content of Aba knife fish.
II. There was no crude fiber content in the fresh Aba knife fish. Hence, oven drying did not affect the fiber content.
III. The oven dried Aba knife fish was rated high in texture, aroma, colour, taste, and general acceptability.

The result of the current study may be useful in determining the influence of oven drying on the qualitative (nutritional) and quantitative (organoleptic) characteristics of local fish species in the tropical climates. Future empirical studies will consider the optimization of the proximate composition and organoleptic qualities at varying pretreatment conditions and oven drying techniques. It will be expedient to establish prediction relations for the energy demand and shrinkage influence of the different sizes of the *Gymnarchus Niloticus* species.

REFERENCES

[1] Effiong B.N and Fakunle J.O.2011. Proximate and mineral composition of some commercially important fish in Kainji Lake, Nigeria. *Journal of Basic Applied Science Resources*. 5: pp.2497-2500.

[2] Chukwu, O. 2009. Influences of drying methods on the nutritional properties of tilapia fish (*Oreochromis Niloticus*) World Journal of Agricultural Science 5: pp.256-258.

[3] Centre of Excellence Science Seafood Health.2011. Sea food, nutrition and human health. A synopsis of the nutritional benefits of consuming seafood. *Chemists Washington DC.* pp 1-5.

[4] Mcmanus, A. and Newton, W. 2011. Seafood, nutrition, and health: A synopsis of the nutritional benefits of consuming seafood. Center for excellent seafood and health. *Curtin Health Innovation Research Institute, Curtin University of Technology,*
Perth Australia. pp. 1-8.

[5] Mojisola O. 2014. The Effect of Different Processing Methods on the Nutritional Quality and Microbiological Status of Cat Fish (*Clarias lezera*). *Journal of Food Processing and Technology*, 5(6). pp.54-60.

[6] Akinneye, J.O., Amos, A. and Arannilewa, S.T.2010. Effect of drying methods on the nutritional composition of three species of fish (Bonga spp, Sardinella spp and Heterotis niloticus). *Journal of Fishery International*. 2(1): 99-103.

[7] Nwakuba, N.R., Okafor, V.C., Abba, E.C. and Nwandikom, G.I. 2018. Thin-layer drying kinetics of fish in a hybrid solar dryer. *Nigerian Agricultural Journal*, 49 (1): pp.46-56.

Kumolu-Johnson, C.A., Aladetohun, N.F., and Ndimele, P.E.2010). The effects of drying on the nutritional qualities and shelf life of *Clarias Gariepinus*. African Journal of Biotechnology 9: pp.73-79.

[9] Olayemi F.F., Adedayo, M.R., Bamishaiya, E.I., and Aagu, E.F.2011. Proximate composition of catfish (*Clarias Gariepinius*) smoked in Nigeria stored product research institute (NSPRI) developed Kiln. *International Journal of Fisheries Aquaculture*. 3(5): pp.96-98.

[10] Eyo, E.O. 2010. Fish processing technology in the tropics. National Institute for fresh water fisheries research. *University of Ilorin Press*. pp. 10-70.

[11] Egbal, O., Mohammed, E., Regian, A., Hana, M., Asgad, A. (2010). Investigation of the quality change of raw and oven dried *Oreochromis Niloticus* and *Clarias Lazera*. *Park Journal of Nutrition*. 5: pp.481-484.

[12] Abolagba, O.J and Osifo, S.J.2008. The effect of oven on the chemical composition and keeping qualities of cat fish (*Heterobranchus bidorsalis*) using two energy sources. *Journal of Agricultural Forestry Fish*. 51:27-30.

[13] Tawari, C.C and Abowei, J.F.2011. Traditional fish handling and preservation in Nigeria. *Asian Journal of Agricultural Science*. 3: pp.427-436.

[14] Cardinal, M.; Knockaert, C.; Torrissen, O.; Sigurgisladottir, S.; Mørkøre, T.; Thomassen, M. and Vallet, J. L. 2001. Relation of drying parameters to the yield, colour and organoleptic quality of dried Atlantic salmon (*Salmo salar*). *Food Research Internat.*, 34, pp.537-550.

[15] Paul,T., Nwakuba, N.R. and Simonyan, K.J .2021. Proximate composition and organoleptic properties of smoked *Gymnarachus Niloticus*. *J. of Experimental Research*. 9(2): pp.23-32.

[16] Emere, M.C and Dibal, D.M .2013. A survey of the methods of fish processing and preservation employed by artisanal fishermen in Kaduna city. *Journal of Food Science and Quality Management.* 1:16-22.

[17] Ogbonnaya, C. 2009. Influences of drying methods on nutritional properties of tilapia fish (*Oreochromis Niloticus*). *World Journal of Agricultural Science*. 5(2): pp.256 – 258.

[18] Akintola, S.L., Brown, A., Osowo, O. D. and Bello B.O. 2013. Effect of hot smoking and oven drying process on the nutritional composition of Giant Tiger shrimp (*Penaeus monodon, fabricius*). *Poland Journal of Food and Nutritional Science.* 63: pp.227-237.

[19] Association of Official Analytical Chemist. 2000. Official Method of Analysis of the *Association of Official Analytical Chemist*. (15th edition). AOAC Internat., Washington DC.

[20] Iwe, M.O.2002. Handbook of organoleptic method and analysis. *Rojoint Commercial services Ltd.* Enugu, Nigeria.

[21] Adebowale B.A, Dongo L.N, Jayeola C.O, and Orisajo S.B.2008. Comparative quality assessment of fish (*Clarias Gariepnius*) dried with three different drying methods. *Journal of Food Technology*. 6: pp.5-8.

[22] Omotosho, O.E., Oboh, G. and Iweah, E.E.2001. Comparative effects of local coagulants on the nutritive value, invitro multi-enzyme protein digestibility and organoleptic properties of *Clarias Gariepinius*. *Southampton Area Council for Educational Advance.* 3: pp.85-89

[23] Osibiona, A.O., Kusemeju, K. and Akande, G.R.2009. Proximate composition and fatty acid profile of the African catfish (*Clarias Gariepinius*). *J. of Fish Aquatic Science*. 9: pp.13-17.

[24] United State Department of Agriculture, USDA .2010. National nutrient database for standard reference. *Agricultural Research Service*, Release 23, Nutrient *Laboratory.*

PRIBLIŽAN SASTAV I ORGANOLEPTIČKE OSOBINE SUŠENE RIBE ABA (*Gimnarchus Niloticus*)

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Apstrakt: Ova studija istražuje kvalitet uređenja (obrade) Aba ribe nožastog oblika (*Gimnarchus Niloticus*) koja dominira u jugoistočnoj Nigeriji. Uzorci ribe zahtevaju odgovarajuće tehnike obrade da bi se očuvale organoleptičke osobine tokom značajnog perioda.

Cilj rada je ispitivanje uticaja procesa sušenja u sušari (pećnici) na približne i organoleptičke kvalitete ribe *Gimnaruchus Niloticus*.

Fileti sveže ribe su isprani u čistoj vodi, salamureni i rašireni (položeni) na metalnu površinu pre nego što su uneti zbog sušenja u pećnicu (sušaru). Proces sušenja je obavljen u pećnici (sušari) sa oznakom modela FALC STF-F-52.

Analize približnih sastava sadržaja vlage, sirovih lipida, sirovih proteina, sadržaja pepela i sirovih vlakana su obavljene na uzorcima sveže i sušene ribe.

Studija je pokazala da sušenje ispitivanih uzoraka ribe u navedenom modelu sušare smanjuje sadržaj vlage na bezbedan nivo od 38,13±0,01% suve materije, a povećava sadržaj sirovih proteina je 18,23±0,01; sadržaj masti je 4,34±0,01; sadržaj pepela je 3,40±0,01 i sadržaj ugljenih hidrata bio je 35,96±0,01.

U uzorcima sveže ribe nije bilo sadržaja sirovih vlakana (0,00). Proces sušenja u pećnici nije imao primetan uticaj na sadržaj vlakana.

Uzorci ribe sušene u sušari su visoko ocenjeni u pogledu ukusa, arome, boje, teksture i opšte prihvatljivosti od strane panela ocenjivača.

Značaj dobijenih rezultata ima preporuke za dalja istraživanja.

Ključne reči: *Riba, proces sušenja, kvalitetni sastav, fileti, sušara.*

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