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Effects of Some Climatic and Non–Climatic Factors on Sesame *Sesami indicum L.* Crop Production in Sheikan locality, North Kordofan State, Sudan

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ABSTRACT

The current study was carried out in Elobeid, Sheikan locality, North Kordofan State, covering the period 2006 - 2020. The objectives of the study were to compare the effect of some climatic and non-climatic factors on the production of sesame crop. The study relied on secondary data represented in time series data of three climatic factors: temperature, relative humidity and rainfall added to four non-climatic factors including the cultivated area per acre, price of the crop in (SDG), price of fuel in (SDG) and improved seeds per ton. Secondary data were collected from the reports of the Ministry of Agriculture, North Kordofan State, El-Obeid Crops Market and El-Obeid Airport's Meteorological station. Fuzzy and factor analysis were used to manipulate the data. The study results showed that groundnuts crop was more sensitive to non-climatic factors compared with climatic factors, as the most effective non-climatic factors on Groundnut production were humidity, temperature and rainfall with a correlation coefficient of (89.5%), (89.3%), (87.1%). Respectively, as for the non-climatic factors, they were fuel price, cultivated area, improved seeds and crop price with a correlation coefficient of (88.6%), (85.5%), (82.3%), (78.8%). Results of the fuzzy analysis depicted that the variables 55.9% was common in sesame production associated with the climatic factor and the non-climatic factor 32.7%. The study concluded that weather variables are among the basic features to support sesame farmers in using climate change information. From the above results, the study concluded that building awareness programs for farmers regarding climatic and non-climatic factors that affect crop production. Meteorological stations are to be established to obtain accurate climate forecasts that assist farmers to make the right decision about what to cultivate, committing to conducting more research on climatic and non-climatic factors in the study area to cover the remaining variables that were not included in the current study.

Keywords: Sesame, climatic and non-climatic factors, production, North Kordofan

1. INTRODUCTION

North Kordofan State, Sudan, where *Sheikan* locality is located, is endowed with immense natural resources viz. arable land, water, livestock, natural rangelands and minerals. The state population is about 2.76 million people, 52% of them are females. About 68% of the population lives in rural areas (Central Bureau of Statistics, North Kordofan State, 2020). The state is recognized as having high comparative advantage and international competitiveness with regard to most cash crops produced in the traditional rain-fed agricultural subsector, such as groundnuts, sesame, watermelon seeds and Roselle, in addition to the staple food crops such as millet and sorghum. The State is one of the most traditional subsistent agricultural areas in Sudan depending on amount, frequency and distribution of seasonal rainfall where smallholder farmers challenged by short rainy season and limited production inputs sources. Moreover, natural calamities, in terms of recurrent drought episodes and desert creeping coupled with unfavorable socioeconomic conditions, irrational use of natural resources due to poor natural resource management skills, have led to low crop productivity, food security gaps, and rural-urban migration. Poverty has aggravated among rural communities. Understanding the climatic factors and non-climatic production inputs helps the producer to make the right decision to reduce the risks and uncertainties when growing groundnuts and sesame as cash crops in *Sheikan* locality, North Kordofan State, Sudan.

.In the current study, the influence of climatic factors (annual rainfall/mm, annual mean temperature ^{0}C, and annual mean relative humidity %) coupled with non-climatic factors (land area/feddan, crop price SDG/M. tons., Fuel price SDG/ gallon and improved seeds) on productivity and production of Sesame were evaluated.

2. MATERIALS AND METHODS

2.1 Secondary data Collection

Data collection of the study including physical inputs such as land area, pesticides, machinery, fertilizing, improved seeds, labor, as well as climatic factors namely, annual temperature and rainfall that affect production of Sesame were obtained. Moreover, yearly production records of the crop were collected during the period from 2006 to 2020.

2.2 Set formation

Collected data were organized in form of sets as follows:

Xo = Mother factors

X1
X2
X3
X4
X5
X6
X7

} = Secondary factors

Where:

X0 = Total production of Sesame /Groundnut
X1 = Annual mean temperature (^{0}**C)**
X2 = Annual mean relative humidity (%)
X3 = Annual mean rainfall (mm)
X4 = land area (feddan)
X5 = Crop price tons (SDG)
X6 = Fuel price/ Gallon (SDG)
X7 = Improved seeds (tons)

2.3 Model Derivation

- Averages of the sets were calculated to transfer the quantities into pure number.
- Broad Matrix was build.
- The Matrix of unit values was determined to each column of the Matrix.
- The Grey coefficient [0-1] was determined.
- Grey correlation values were computed as well as Grey weight.
- The quantitative effects of secondary factors on mother factors were displayed to detect the most effective factor on the crop production.

2.4 Data statistical manipulation

2.4.1 Fuzzy analysis:

a. Description:

The study used Fuzzy relational analysis to analyze complicated uncertainty among the multi-responses in a given system and optimize it with the help of grey relational grade. Therefore, a multi-response optimization problem is reduced to a single response optimization problem called single relational grade.
The data is first to be normalized avoiding different units to reduce the variability. A suitable value was derived from the original value to make the array between 0 to 1 (NoorulHaq *et al*., 2008). In general, it is a method of converting the original data to a comparable data. Then next step is to calculate grey relational coefficient, ξi(k) from the normalized values, find out the grey relational grade (GRG). An optimal level of process parameters was determined using higher grey relational grade. To obtain this, average grade values for each level of process parameter was found out, which can be shown as mean response table. From, mean response table, higher values of average grade values were chosen as optimal parametric combination for multi-responses, after optimal combination was found out, the next step is to perform the analysis of variance (ANOVA) for judging the significant parameters affecting the multi-responses at 95% confidence level.

b. Technique & coding

To determine the most effective some climatic and input factors on Groundnut and Sesame production in *Sheikan* locality, Fuzzy analysis was used.
Fuzzy analysis model approaches:

i- Observed data of mother factor and sub-factors as follows

$X_1 \quad X_2 \ldots\ldots X_n$

$X_{21} \quad X_{22} \ldots\ldots X_{2n}$

…….. …… …….

$X_{m1} \quad X_{m2} \ldots\ldots X_{mn}$

Where X_i and X_{ij} are mother factor and sub-factors respectively.

ii. Data averaging:

The data were symbolized and averaged as follows:

$$X_0^{(0)}(k) = \frac{X_k}{\bar{X}_k}$$

$$X_1^{(0)}(k) = \frac{X_{1k}}{\bar{X}_1}$$

$$X_2^{(0)}(k) = \frac{X_{2k}}{\bar{X}_2} X_m^{(0)}(k) = \frac{X_{mk}}{\bar{X}_m} \mathrm{k} = 1,2,\ldots\ldots,\mathrm{n} \ldots\ldots\ldots\ldots (3.2.1)$$

The series can be denoted in form of sets:

$$X_0 = \{X_0^{(0)}(1), X_0^{(0)}(2), \ldots\ldots\ldots\ldots, X_0^{(0)}(n)\}$$
$$X_1 = \{X_1^{(0)}(1), X_1^{(0)}(2), \ldots\ldots\ldots\ldots, X_1^{(0)}(n)\}$$
$$X_2 = \{X_2^{(0)}(1), X_2^{(0)}(2), \ldots\ldots\ldots\ldots, X_2^{(0)}(n)\} \ldots\ldots\ldots\ldots (3.2.2)$$
$$X_m = \{X_m^{(0)}(1), X_m^{(0)}(2), \ldots\ldots\ldots\ldots, X_m^{(0)}(n)\}$$

Where,

X_0 = mother factor

iii. Determination of coefficients, Δ_1,Δ_2,$\Delta_3$and$d_{oi}(k)$

Assume that $M = \{1, 2, 3, \ldots\ldots, m\}$ and $N = \{1, 2, 3, \ldots\ldots, n\}$

Then,

$$\Delta_1 = \min_{i\in M}\left\{\min_{k\in N}\left|X_0^{(0)}(k) - X_i^{(0)}(k)\right|\right\} \ldots\ldots\ldots\ldots (3.2.3)$$
$$\Delta_2 = \max_{i\in M}\left\{\max_{k\in N}\left|X_0^{(0)}(k) - X_i^{(0)}(k)\right|\right\} \ldots\ldots\ldots\ldots (3.2.4)$$
$$\Delta_3 = \left|X_0^{(0)}(k) - X_i^{(0)}(k)\right| \ldots\ldots\ldots\ldots (3.2.5)$$

iv. Calculation of relative differences

The relative difference of X_i sub-factor and mother factor X0 at k-the point can be calculated as follows:

$$d_{0i}(k) = \frac{\Delta_1 + \lambda\Delta_2}{\Delta_3 + \lambda\Delta_2} \ldots\ldots\ldots\ldots (3.2.6)$$

Where,

$d_{0i}(k)$ = relative differences at different points

λ = distinguishing coefficient taken between 0 – 1.

v. Computation of the correlation degree coefficients:

In order to work out the comprehensive correlation degree coefficients, considering the importance of different observed points according to globally observed points. If the weight coefficients vector for n points is given by:

$W = (w_1, w_2, \ldots\ldots\ldots, w_n,)$

Satisfy,

$$\sum_{k=1}^{n} w_k = 1$$

$wk \geq 0$, $k \in N$

$$\text{then}, \gamma_{0i} = \sum_{k=1}^{n} w_k d_{0i}(k), \quad i \in M \ldots\ldots\ldots\ldots (3.2.7)$$

If all weight coefficients are equal each other as follows:

$$w_k = \frac{1}{n}, k = 1, 2, \ldots\ldots\ldots.., n$$

Then,

$$\gamma_{0i} = \frac{1}{n}\sum_{k=1}^{n} d_{0i}(k) \ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots\ldots\ldots\ldots.. (3.2.8)$$

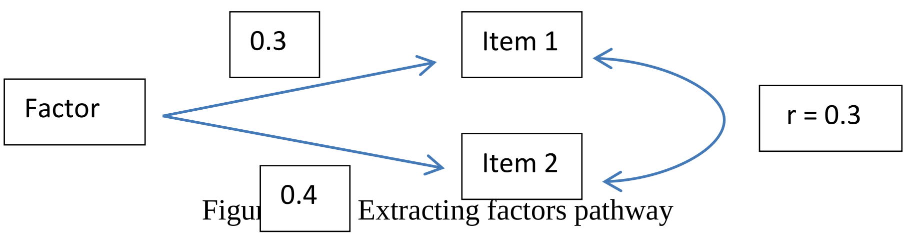
Applications of fuzzy mathematical approaches and models

2.2.2 Factor Analysis

It was used to determine if related subtests "cluster", traits "cluster and related items "cluster" are together

Extracting Factors

Factor analysis starts with a correlation matrix for all individual variables, subtests, or items. The algorithm initially assumes that only one underlying factor can adequately account for the association among variables, subtests, or items. In other words, it begins with the assumption that one-factor model can account for the correlations among item responses. To test this assumption, the algorithm must estimate the correlation between the underlying factor and each item to determine if the correlation between the items is equivalent to the product of the path coefficients.



Figu[illegible] Extracting factors pathway

Rotating Factors

- Typically, the raw un-rotated factors are difficult to interpret. For *m* uncorrelated factors, the relationship between inter-correlations and factor loadings is:
  jk m k ikij aa∑==ρ 1
  Where: i and j refer to the items, a refers to the factor loadings, and k refers to the particular factor

Orthogonal Rotations

Quartimax : This rotation tries to load each variable mainly on one factor to try and "clean up" the variables. The problem with this method is that most of the variables tend to load on a single factor

Varimax : This rotations tries to "clean up" the factors and is usually easiest to interpret (Gorsuch, 2014).

4. RESULTS AND DISCUSSIONS

Climate plays a dominant role in agriculture having a direct impact on the productivity of physical production factors (Abbas *et al*. 2021). Adverse climate effects can influence farming outputs at any stage from cultivation through the final harvest. Even if there is sufficient rain, its irregularity can adversely affect yields if rains fail to arrive during the crucial growing stage of the crops (Mowa and Lambi, 2006, Rudolf and Hermann 2009). Climatic and non-climatic factors presumably impact crops production, namely sesame, cultivated in rain-fed, dry land of North Kordofan as exemplified by *Sheikan* locality (Tables 4.1-4.6). In fact, the area has witnessed recurrent drought episodes coupled with variability in weather elements since the previous century in 1984/85 coupled with elevated magnitude of non-climatic factors such as price of inputs and land area. In fact, non-climatic factors comprise a wide range of environmental, economic, social and technological factors. The current study attempted to investigate the impact of these climatic and non-climatic factors on productivity/production of the main cash crops cultivated in the area, groundnuts and sesame. In this study, one of the goals of factor analysis is to create a smaller set of variables (the factors) that capture the original information nearly as well as the larger set of variables (the items). As demonstrated in Tables 4.1-4.5, sesame production was affected by annual mean relative humidity where correlation degree coefficient was 0.895 (89.5 %). Annual mean temperature effect on sesame production recorded 0.893 correlation degree coefficient (89.3 %) as second factor after humidity. It was found that sesame production was affected by fuel price with correlation degree coefficient of 0.886 (88.6 %), such factor was ranked as third one refer to its effect on production of the crop. In case of annual mean rainfall, the correlation degree coefficient found to be 0.871 (87.1 %). Therefore, rainfall was ranked as the fourth factor. Land area effect on sesame production recorded 0.855 correlation degree coefficient (85.5 %) as the fifth factor. Improved seeds effect on sesame production recorded 0.823 correlation degree coefficient (82.3 %) as the sixth factor. Nevertheless, it was stated that the use of improved seeds increases crop yields in a changing climate because they are resilient to both biotic and abiotic stresses (Kumar *et al*., 2019).

The lowest effect on sesame production was caused by crop price where correlation degree coefficient was 0.788 (78.8 %). It was worthy to mention that traditional agricultural sector is entirely rainfall-dependent, where smallholder farmers plow their land under climate change and rainfall variability using traditional technologies of low input and low output agricultural production practices (Baye. 2017) despite that, in this study, rainfall ranked number four in its influence on sesame production preceded by temperature and relative humidity. It seems plausible that amount and distribution of seasonal rainfall are more crucial for rain-fed agriculture than the annual amount. On the other hand, the most non- climatic factor that affects sesame production is fuel price with ever escalating prices to date. Figure (4.1): depicts the distribution of Eigen value for sesame crop. Three factors must be kept for their values more than one, while four factors should be dropped off and level out for they were less than one. That is why Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was used to check the fit of sample size. Table (4.6) shows: KMO measures of sampling adequacy and Bartlett's Test of sphericity which evaluates the null hypothesis that all of the correlations in analysis.0.002 which includes a probability less than 0.05. The null hypothesis rejected which indicate that sample size for sesame crop is mediocre; therefore, the sample size is considered sufficient.

Table (4.8), shows the communalities after extraction and reflect the common variables in the sesame production, explain about 75.9% of the variables associated with non-climatic factors 32.7% and climatic factor 55.9,thus the remaining 24.1% are related to other variables are not included in this model.

Table (4.1): Production of sesame, climatic and some inputs factors in North Kordofan during the period 2006 – 2020.

	Xo	**X_1**	**X_2**	**X_3**	**X_4**	**X_5**	**X_6**	**X_7**
Year	Production, ton	Temperature, ^{0}C	R.H, %	Rainfall, mm	land area, fed	Crop price, .SDG / quintal	Fuel price, SDG /gallon	Improved seeds ,tons
2006	46831	41	39	331.7	719625	35	4.5	14
2007	44451	34.5	43	647.2	201683	80	4.5	12
2008	50445	43.6	43	435.5	121019	105	4.5	11
2009	61379	35.6	38	494.7	194403	105.5	4.5	15
2010	62233	35.6	44	422.9	55002	115.5	4.5	17
2011	36661	34.9	40	304	73064	180	6.53	20
2012	65995	34.7	45	526.1	106321	245	8.018	10
2013	109134	35.5	40	384	124047	483	8.018	7.5
2014	103534	34.8	44	260	23045	515	18.5	5
2015	130041	34.9	40	276	209372	390	18.5	4.5
2016	60086	32.5	41	340	241710	402	18.495	4
2017	94919	34.9	41	319	294937	874	18.5	3.75
2018	139696	34.9	42	457	320566	2408	18.5	2
2019	21794	35	42	489.7	269079	3130	18.5	1.5
2020	11112	33.9	43	531.7	246775	8500	18.5	2

4.1 Sesame Production Fuzzy Analysis

4.1.1 Averaging sets of sesame and factors

Table (4.2): Sesame data aveagizing

Year	X_0	X_1	X_2	X_3	X_4	X_5	X_6	X_7
2006	0.677	1.1468	0.9361	0.8000	3.3725	0.0298	0.3869	1.6260
2007	0.642	0.9650	1.0321	1.5610	0.9451	0.0683	0.3869	1.3937
2008	0.729	1.2195	1.0321	1.0504	0.5671	0.0896	0.3869	1.2775
2009	0.887	0.9958	0.9121	1.1931	0.9110	0.0900	0.3869	1.7421
2010	0.899	0.9958	1.0561	1.0200	0.2577	0.0986	0.3869	1.9744
2011	0.530	0.9762	0.9601	0.7332	0.3424	0.1536	0.5614	2.3228
2012	0.953	0.9706	1.0801	1.2689	0.4982	0.2091	0.6894	1.1614
2013	1.577	0.9930	0.9601	0.9261	0.5813	0.4123	0.6894	0.8710
2014	1.496	0.9734	1.0561	0.6271	0.1080	0.4397	1.5902	0.5807
2015	1.879	0.9762	0.9601	0.6657	0.9812	0.3329	1.5902	0.5226
2016	0.868	0.9090	0.9841	0.8200	1.1327	0.3432	1.5902	0.4645
2017	1.371	0.9762	0.9841	0.7694	1.3822	0.7462	1.5907	0.4355
2018	2.018	0.9762	1.0081	1.1022	1.5023	2.0560	1.5907	0.2322
2019	0.315	0.9790	1.0081	1.1811	1.2610	2.6724	1.5907	0.1742
2020	0.161	0.9482	1.0321	1.2824	1.1565	7.2575	1.5907	0.2322

Table (4.3): Values of $\square_3$ for areas of Sesame and variables

X_1	X_2	X_3	X_4	X_5	X_6	X_7
0.4703	0.2596	0.1235	2.6960	0.6466	0.2896	0.9494
0.3228	0.3900	0.9188	0.3030	0.5738	0.2552	0.7515
0.4908	0.3034	0.3216	0.1615	0.6391	0.3418	0.5488
0.1090	0.0254	0.3064	0.0243	0.7966	0.4997	0.8554
0.0968	0.1571	0.1210	0.6412	0.8003	0.5120	1.0754
0.4462	0.4301	0.2032	0.1875	0.3763	0.0314	1.7928
0.0172	0.1267	0.3155	0.4551	0.7442	0.2639	0.2080
0.5836	0.6164	0.6504	0.9952	1.1642	0.8871	0.7055
0.5225	0.4398	0.8688	1.3879	1.0562	0.0942	0.9152
0.9024	0.9184	1.2129	0.8974	1.5456	0.2883	1.3559
0.0410	0.1161	0.0479	0.2647	0.5247	0.7222	0.4034
0.3950	0.3871	0.6018	0.0109	0.6250	0.2194	0.9357
1.0418	1.0099	0.9158	0.5157	0.0378	0.4274	1.7858
0.6642	0.6933	0.8663	0.9462	2.3576	1.2759	0.1405
0.7872	0.8711	1.1214	0.9955	7.0965	1.4297	0.0712

$\square_1$ = min {min = 0.0109
$\square_2$ = max {max = 7.0965

Table(4.4):Sesame: Relative differences of X_i sub-factor at k-th (2006 -2020)

No.	Years	Factors						
		X_1 (d_{01})	X_2 (d_{02})	X_3 (d_{03})	X_4 (d_{04})	X_5 (d_{05})	X_6 (d_{o6})	X_7 (d_{07})
1	2006	0.8856	0.9346	0.9693	0.5699	0.8484	0.9273	0.7913
2	2007	0.9194	0.9037	0.7967	0.9241	0.8634	0.9357	0.8277
3	2008	0.8811	0.9240	0.9197	0.9594	0.8499	0.9149	0.8687
4	2009	0.9731	0.9959	0.9233	0.9962	0.8191	0.8792	0.8082
5	2010	0.9764	0.9605	0.9699	0.8495	0.8184	0.8765	0.7697
6	2011	0.8910	0.8946	0.9487	0.9527	0.9068	0.9942	0.6663
7	2012	0.9982	0.9684	0.9211	0.8890	0.8291	0.9336	0.9475
8	2013	0.8613	0.8546	0.8476	0.7833	0.7552	0.8024	0.8367
9	2014	0.8743	0.8924	0.8057	0.7210	0.7729	0.9771	0.7974
10	2015	0.7996	0.7968	0.7475	0.8005	0.6987	0.9276	0.7257
11	2016	0.9916	0.9712	0.9897	0.9334	0.8738	0.8334	0.9006
12	2017	0.9025	0.9044	0.8576	1.0000	0.8528	0.9446	0.7937
13	2018	0.7754	0.7808	0.7972	0.8757	0.9924	0.8952	0.6672
14	2019	0.8449	0.8391	0.8062	0.7918	0.6026	0.7377	0.9648
15	2020	0.8209	0.8053	0.7621	0.7833	0.3343	0.7149	0.9833
	Average	0.8930	0.8951	0.8708	0.8553	0.7879	0.8863	0.8232
	%	**89.3**	**89.5**	**87.1**	**85.5**	**78.8**	**88.6**	**82.3**

Table (4.5): Correlation degree coefficient

Factor	Symbols	Ratio	%
Annual mean relative humidity (%)	X_2 (γ_{01})	0.895	89.5
Annual mean temperature (ºC)	X_1 (γ_{01})	0.893	89.3
Fuel price / gallon (SDG)	X_6 (γ_{06})	0.886	88.6
Annual mean rainfall (mm)	X_3 (γ_{03})	0.871	87.1
Land area (fed)	X_4 (γ_{04})	0.855	85.5
Improved seeds (tons)	X_7 (γ_{07})	0.823	82.3
Crop price / quintal (SDG)	X_5 (γ_{05})	0.788	78.8

Table (4.6) Factor analysis showing KMO and Bartlett's Test (Sesame crop)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.384
Bartlett's Test of Sphericity	Approx. Chi-Square	53.967
	df	28
	Sig.	.002

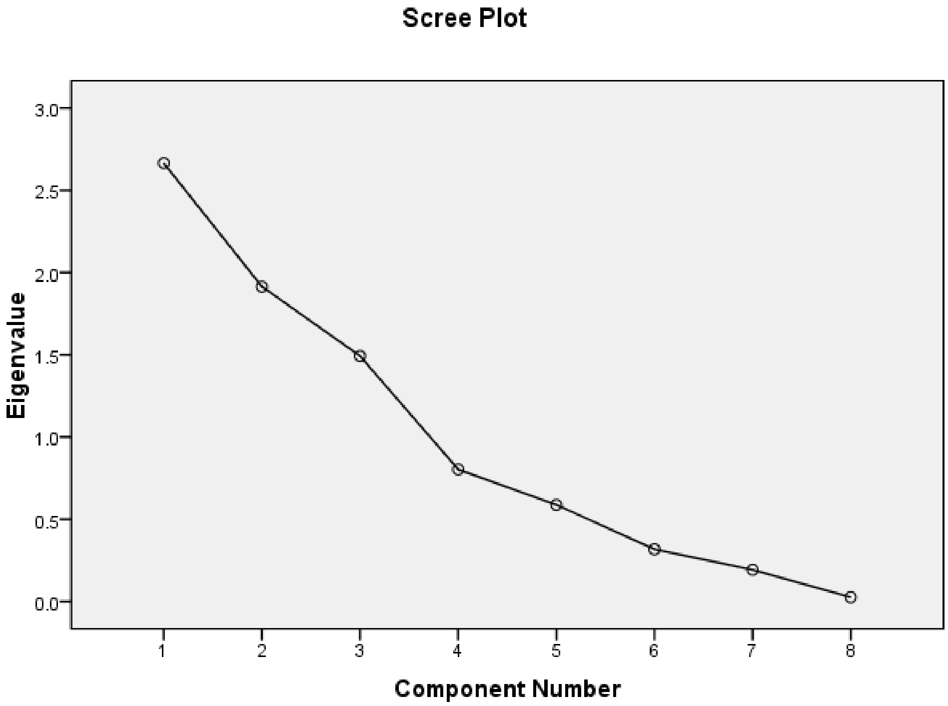


Figure (4.1): Sesame Eigenvalue

Table (4.7): Sesame's Total Variance Explained

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	2.666	33.320	33.320	2.666	33.320	33.320	2.617	32.711	32.711
2	1.914	23.927	57.248	1.914	23.927	57.248	1.856	23.197	55.908
3	1.493	18.660	75.908	1.493	18.660	75.908	1.600	20.000	75.908
4	.803	10.037	85.945						
5	.588	7.346	93.291						
6	.317	3.969	97.260						
7	.193	2.407	99.667						
8	.027	.333	100.000						

Extraction Method: Principal Component Analysis.

5.1 CONCLUSIONS

Based on the findings of the study; both climatic and non-climatic factors have their effects on crop production. Sesame is more sensitive to climatic factors. Better understanding and interpretation of weather variables such as relative humidity, temperature, and rainfall are essential features to support sesame growers to use climatic change information and weather forecasting information; farmers need to be aware of potential risks associated with the climatic factors changes.

5.2 RECOMMENDATIONS

- Awareness raising programs should be built up for farmers regarding climatic and Non-climatic factors affecting crop production.
- Agricultural extension administration should provide farmers with contribution importance of each factor in production process for the specific crop.
- Establishment of meteorological stations around agricultural area to obtain climatic forecasts that assist farmers to take the right decision for what to cultivate.
- Further researches needed for climate and non-climatic factors in study area to cover the remained variables that not included in current study.

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