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RESEARCH ARTICLE

Effect of climate variability on Sorghum productivity at Qena, Egypt.

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Abstract

Climate changes and global warming represented by increasing temperature and the significant variations in precipitation are the most important factors affecting the distribution and production of food grains worldwide. The present study focused on the effect of climatic change indicators (temperature and relative humidity) on sorghum productivity in Qena Governorate, Egypt. The results show that there was an increasing trend rate (0.05 °C/year) in the annual mean temperature during the period from 2001 to 2021. In addition, the results show a decreasing trend rate (-0.45% /year) in the annual mean of relative humidity. On the other hand, the results indicate a decreasing trend equal to (-**6**1.9 kg /year) in the annual mean of sorghum productivity during this period. The statistical analysis illustrates a negative correlation between temperature (R^2=0.45). The results show that the productivity of hectare decreases by about -538.9 kg if the annual mean temperature increases by 1 ˚C. In addition, the statistical analysis indicates a positive correlation between productivity and humidity. The results show a decrease in the hectare productivity by about 72.5kg if the annual mean relative humidity decreases by 1 %. The results concluded that the increase in temperature with the condition of low relative humidity led to a decrease in Sorghum productivity in Qena Governorate.

Keywords: Climate Changes; Temperature; Relative humidity; Productivity of Sorghum; Qena.

1. Introduction

Climate change is defined as any change in climate over time, due to natural fluctuations or human activities (Solomon *et al.*, 2007). Climate change is negatively impacting food security (FAO, 2018). The latest Intergovernmental Panel on Climate Change (IPCC) report highlighted rising temperatures, changing rainfall patterns, and an increased frequency of extreme events such as heatwaves, tropical cyclones, and the occurrence of agricultural and ecological droughts (Allan *et al.*, 2023). As the main drivers that put food security at risk in light of escalating climate change. As a result, yields of staple crops such as maize have declined across Africa, widening food insecurity gaps (Macauley and Ramadjita, 2015). According to the sorghum [*Sorghum bicolor* (L.) Moench] is the world's fifth-most important cereal for food, feed, fuel, and fiber, after wheat, rice, maize, and barley. It is especially well-suited to hot, dry climates (Paterson *et al.*, 2009). Sorghum was 40.7 million hectares of cultivated land worldwide, yielding 57.6 million tons of grain. However, around 147961 ha in Egypt were used to produce up to 727648 tons of grain (FAOSTAT, 2017). Crop productivity is impacted by temperature. there might be a favorable or negative impact on crop growth depending on the temperature (Affoh *et al.*, 2022). This suggests that crops suffer at particular development stages from higher

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temperatures. Due to the intolerant nature of maize plants, prolonged exposure to heat causes a sharp decline in the crop's production (Schauberger *et al.,* 2017). The booting and physiological maturity phases of sorghum proved harmful to its production (Prasad *et al.,* 2015; Sunoj *et al.,* 2017). Relative humidity is an important climatic factor and refers to the ratio of air vapor pressure to saturated vapor pressure. There is a negative relationship between relative humidity and the growth stages of the sorghum crop (Ohsumi *et al.,* 2008). Low relative humidity increases evaporation and transpiration, causing water stress to the crop (Ferrante and Mariani, 2018). High relative humidity makes the plant unable to evaporate water or extract nutrients from the soil, and if this happens for a long time, it causes plant rot and insect pests. High humidity and high temperature cause the appearance of fungal diseases, which leads to a decrease in the productivity of the sorghum crop (Romero *et al.,* 2022). Therefore, this study amid to the effect of temperature and Relative humidity on the productivity of Sorghum using the measurements of the temperature study in the Qena Governorate and the productivity of Sorghum during the period from 2001 to 2021.

2. Materials and methods

2.1. Description of the study area

The climate of Qena is very hot and dry in summer and cold in winter. In summer, the average daily maximum temperature is 40°C, and the average daily minimum relative humidity is 17%, while in winter the average daily maximum temperature is 25°C and the average daily minimum RH = 26% It rarely rains. Also, it receives a large quantity of solar radiation, especially in summer. The prevailing wind directions are North, Northeast, and East. Also, Qena City is characterized by low traffic density and no industrial activities (Hassan, 2015). Qena City (26°10' N, 32°43' E, 82 masl lies within the subtropical region, and its terrain is semi-desert (El-Nobi, 2012). It is situated in Upper Egypt, about 600 kilometers south of Cairo. It is mostly found within the narrow Nile valley, which divides Egypt into two desert regions: the western and eastern deserts. Figure (1) illustrates the geographical location of Qena. According to the Köppen climate classification, the climate of Qena like Egypt's climate has a Hot desert climate (BWh) with a hot season from March to September and a cold season from October to February (Adam, M. E. N., 2013). That is, the climate of Qena is very hot and dry in summer and cold in winter. Also, it rarely rains and receives a large quantity of solar radiation, especially in summer (Mahmoud, 2018).

2.2. Database and data quality

As mentioned above in the aim of the study, this study begins with a summary of the mean trend of temperature and relative humidity across Qena. However, the monthly temperature in Qena from 2001 to 2021 was obtained from the Meteorological Research Station (MRS) at the South Valley University (SVU), Egypt (Adam, M. E. N., & El-Nobi, E. F. (2017). The daily temperature in Qena from 2001 to 2021 was obtained from the SVU- MRS (Adam, M. E. N., & El-Nobi, E. F. (2017); Adam, M. E. N. (2013). SVU- MRS is located in Qena, Upper Egypt (26°20ˈN, 32°77ˈE, 82 m asl) and can be defined as an urban site (Hassan, et al. 2018). The Egyptian Meteorological Authority (EMA) is responsible for scientific advice, calibration, and quality systems for the Egyptian Monitoring Network. Data quality control is a necessary step before using these data. Data analysis was undertaken using software, such as Excel (version 2016) (Fouad *et al.,* 2022). The productivity data of the sorghum crop was collected from Periodic statistical reports from the Egyptian Ministry of Agriculture, to identify the types of sorghum cultivated, the cultivated area, and the total productivity during the study period.

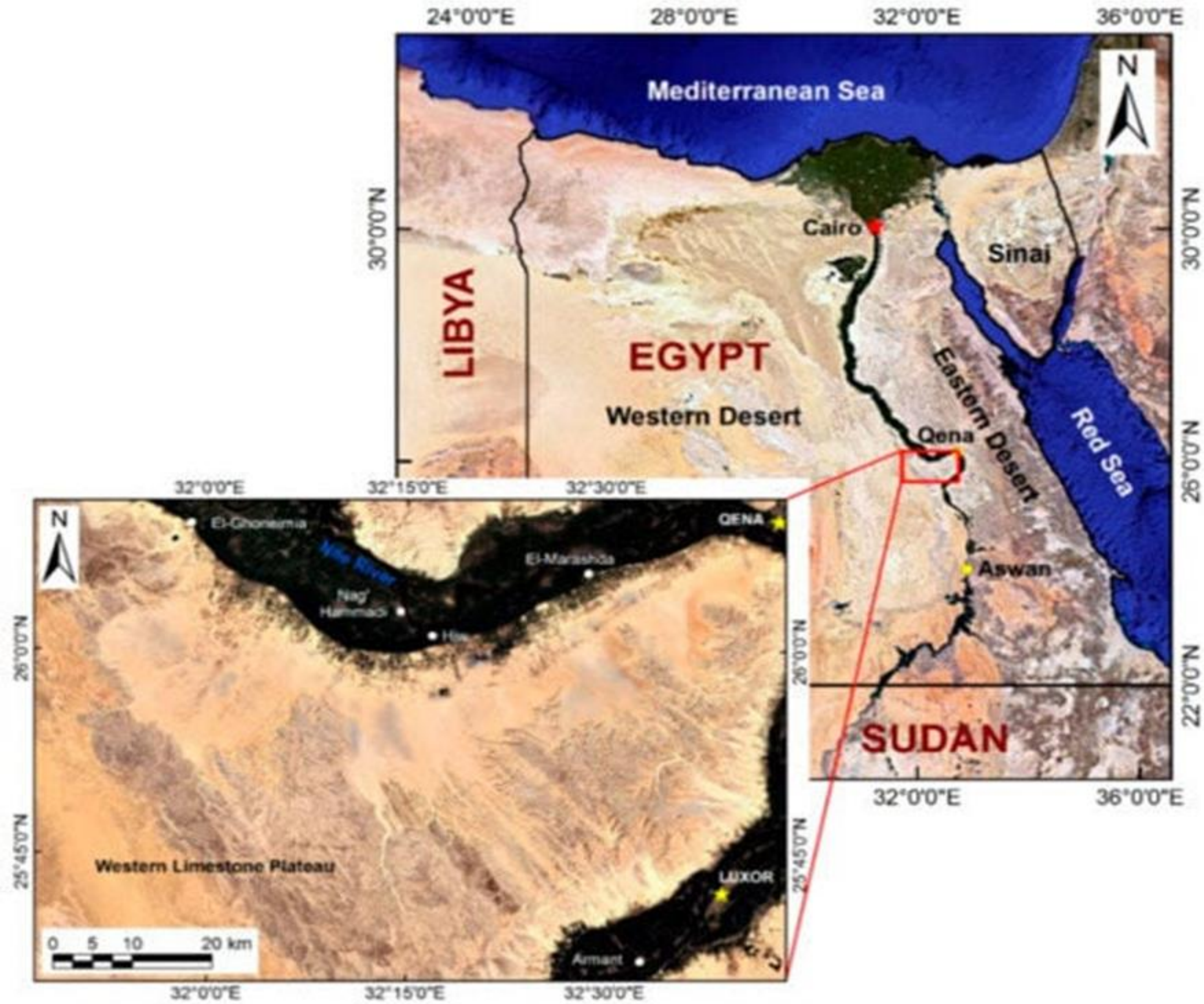

Figure 1. The geographical location of Qena, Egypt (Gaber, Ahmed, *et al.,* 2020).

3. Results and discussion

3.1. Statistical description and annual trend of productivity of Sorghum over Qena

Table (1) shows the data of annual mean values of Sorghum productivity, temperature, and relative humidity calculated during the growing season (May and August) in qena during the period from 2001 to 2021. The statistical analysis shows that the mean productivity is 3377.2 ± 425.4. The annual maximum productivity was 3948 kg/ha in 2004. The annual minimum productivity of Sorghum was 2744 kg/ha in 2017. Figure (2) illustrates that the average variation of Sorghum productivity had a decreasing trend. The trend rate is equal to -61.9 kg/year. Said et al. (2016) stated that sorghum productivity took a general decreasing trend during the period from 1997 to 2014. Its results showed that productivity reached its minimum in 2013 and its maximum in 1999 in Asyut. Sandeep et al. (2018) mentioned that during the past two decades, sorghum production decreased by 1%.

Table 1. Annual mean of Sorghum productivity, temperature, and relative humidity in Qena.

Years	Productivity (Kg/ha)	T_{mean} (C˚)	RH_{mean} (%)
2001	3766	33.0	30.6
2002	3766	33.1	30.2
2003	3780	33.1	28.6
2004	3948	32.4	29.3
2005	3794	32.3	30.0
2006	3794	32.5	28.3
2007	3766	32.7	24.2
2008	3710	32.6	20.5
2009	3696	32.0	22.0
2010	3262	33.3	***
2011	3290	32.3	21.9
2012	3304	32.9	21.2
2013	3304	32.7	21.7
2014	3290	32.9	21.1
2015	2744	32.9	21.9
2016	2744	33.4	21.4
2017	2744	33.6	17.1
2018	2758	33.4	23.8
2019	2772	33.8	30.2
2020	3304	33.4	***
2021	2814	34.3	***
Max	3948	34.3	30.6
Min	2744	32.0	17.1
Mean	3377.2	33.0	24.7
SD	425.4	0.5	4.3

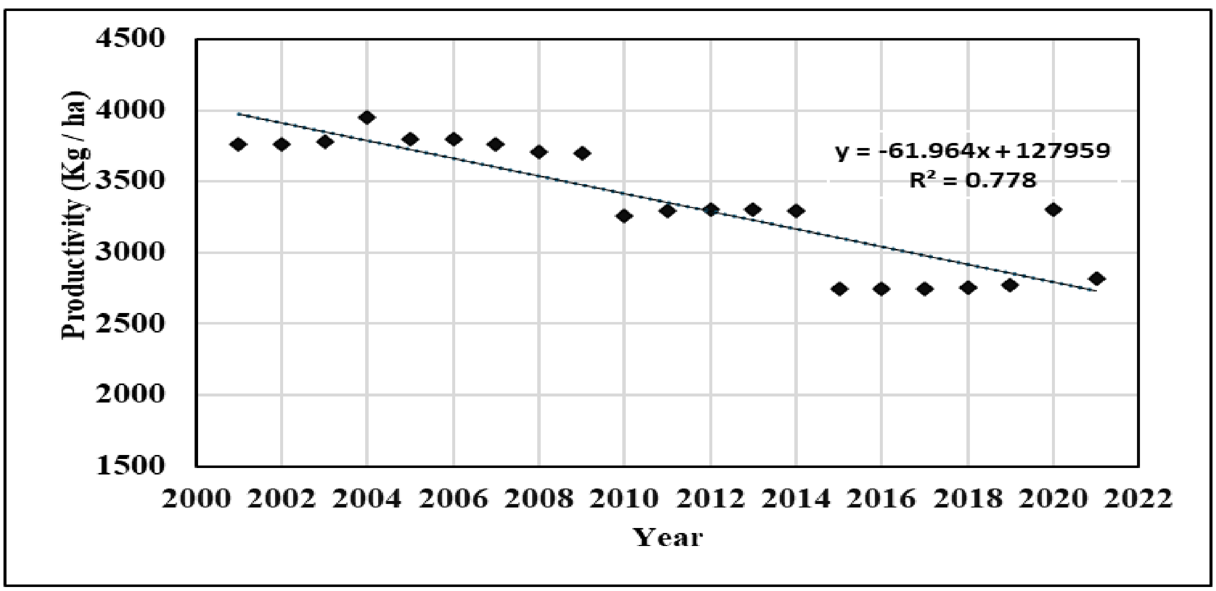

Figure 2. Annual trend of mean productivity of sorghum in Qena from 2001 to 2021.

3.2. The relationship between temperature and productivity of Sorghum

The data of annual mean values of temperature calculated during the crop season (May-August) illustrated in Table (1) show that the year with the highest temperature was 2021, where the maximum annual temperature reached (34.3˚C), in other hand the average productivity reached the value (2814 kg/ha). While we find that the year with the lower average temperature was 2009, where the minimum annual temperature reached (32˚C), in this year the average productivity reached (3696 kg/ha).

Figures (3) show the annual variation of temperature during the crop season of Sorghum in Qena from 2001 to 2021. The results showed that there was an increasing trend rate of about (0.05°C/year) in the annual mean temperature during the crop season. Figures (4) show the effect of temperature on Sorghum productivity. The results indicate that there was a negative correlation between temperature and productivity (R^2 = 0.45). The results show that the productivity decreases by about -538.6 Kg/ha if the annual mean temperature increases by 1 ˚C.

The results concluded that the increase in temperature leads to a decrease in Sorghum productivity and these results agree with results reported by previous studies (Sandeep *et al.*, 2018). Milleret concluded Sorghum Yield drops sharply with Exposure to temperatures over 33° C (Miller *et al.*, 2021).

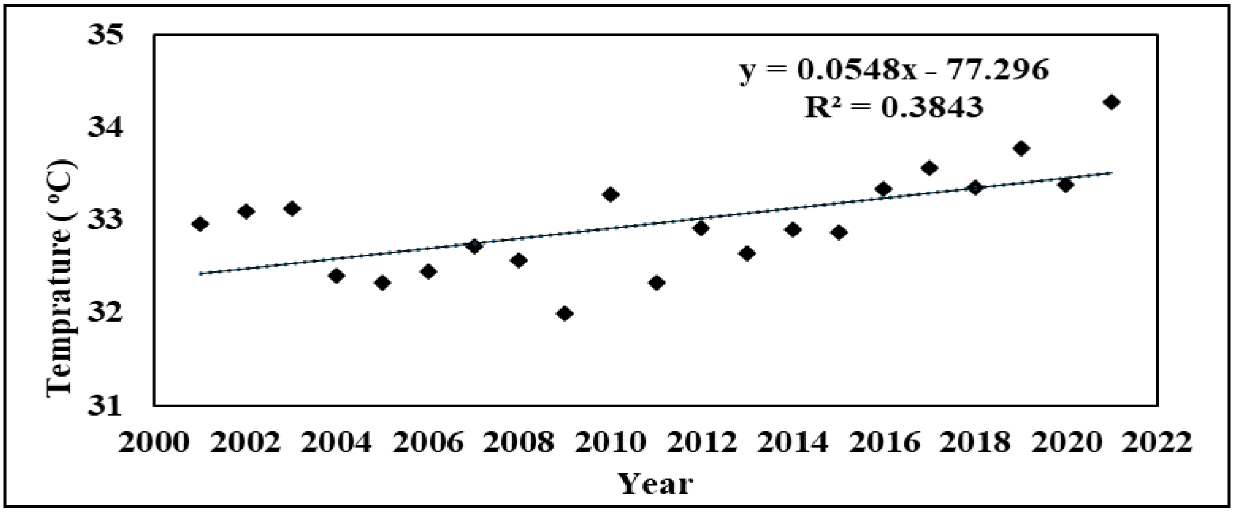

Figure 3. Annual trend of mean temperature in Qena from 2001 to 2021.

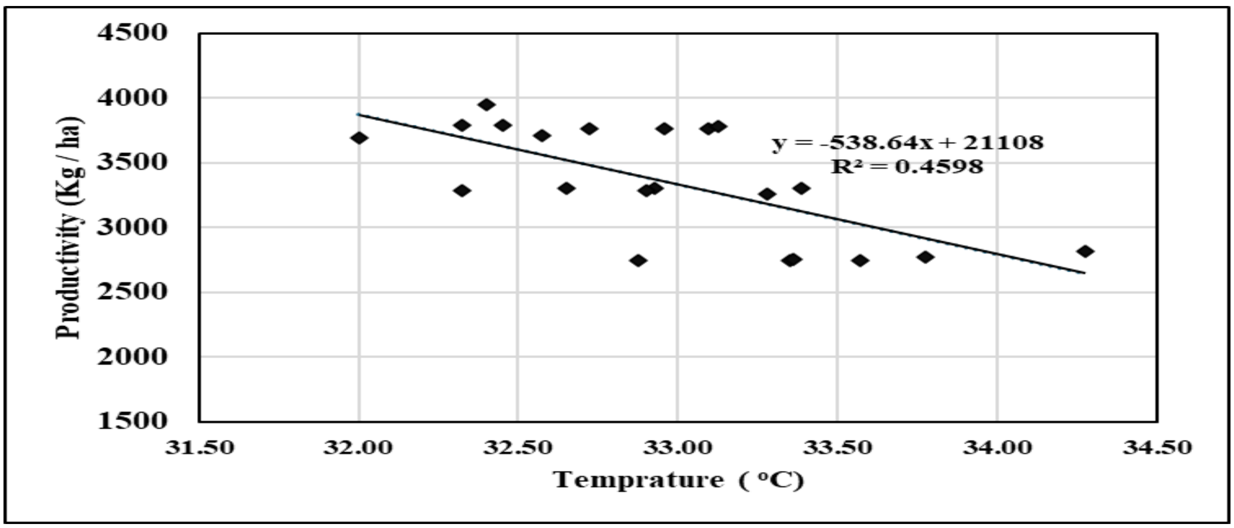

Figure 4. The relationship between mean temperature and productivity of Sorghum in Qena from 2001 to 2021.

3.3. The relationship between relative humidity and productivity of Sorghum

Table (1) shows that the year with the highest mean relative humidity was 2001, where the average annual relative humidity reached

(30.56%), on the other hand, the average productivity was (2744 Kg/ha). We find that the year with the most decrease in relative humidity is 2017, where the average annual relative humidity reaches (17.1%), and the average productivity decreases to (3766 Kg/ha). Figures (5) show the annual variation of relative humidity during the growing season of Sorghum in Qena from 2001 to 2021. The results show a decreasing rate of (-0.45°C/year) in the annual mean relative humidity during the growing season. Figures (6) show the effect of relative humidity on Sorghum productivity. The results show a positive correlation between relative humidity and productivity (R^2 =0.85). The results show a decreasing rate of about -72.55 Kg/year in the Sorghum productivity if the annual mean of relative humidity decreases by 1%. The results concluded that the decrease in relative humidity leads to a decrease in Sorghum productivity in the Qena region. These results agree with previous study reported by Affoh concluded that relative humidity affected Sorghum yield in the Plateau region (Affoh *et al.*, 2022). High temperature coupled with low relative humidity affects the final yield. Climate variability affects grain quality, The effects of restricted water on grain yield and quality were linearly related to soil moisture and drought stress (Gooding *et al.*, 2003).

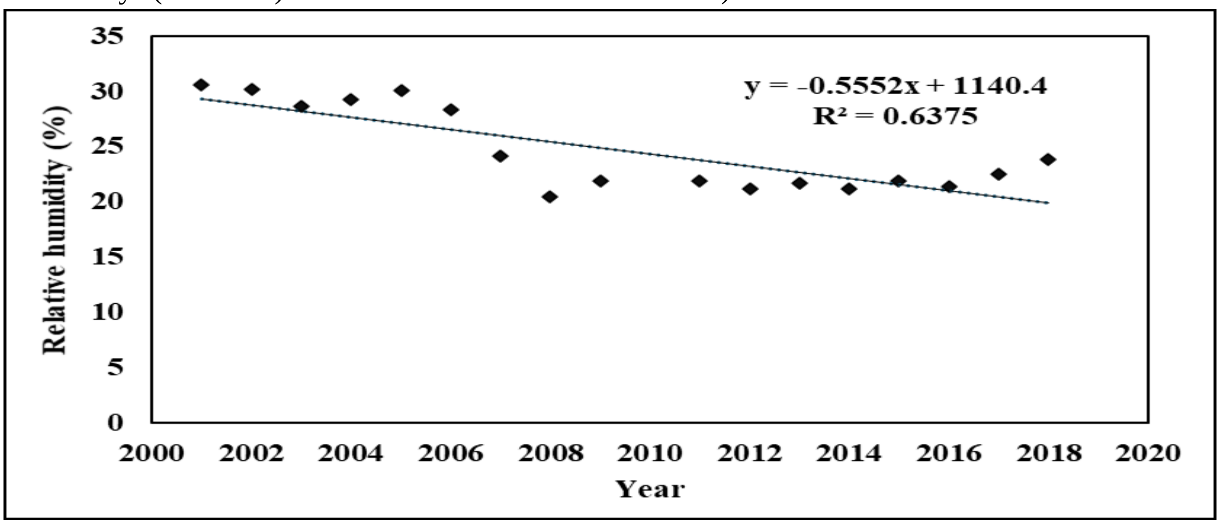

Figure 5. Annual trend of mean relative humidity in Qena from 2001 to 2019.

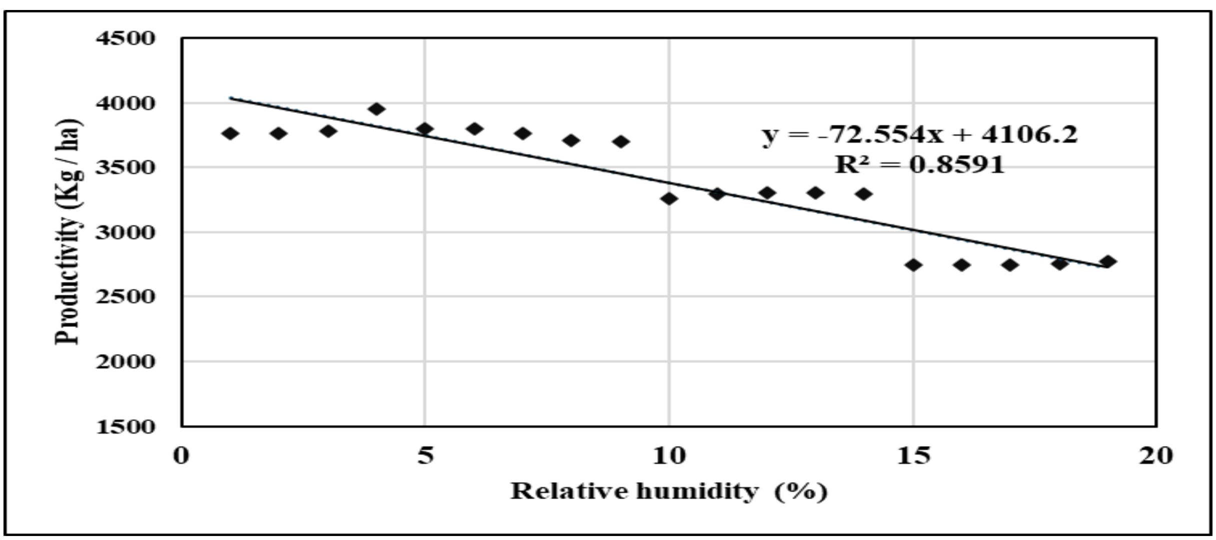

Figure 6. The relationship between the mean relative humidity and Sorghum productivity.

4. Conclusion

Sorghum represents a staple food in Asia and Africa, and although it is tolerant of climate change, heat stress, and droughts reduce the crop yield significantly sorghum (Promkhambut *et al.*, 2011; Zhang *et al.*, 2016). According to studies, corn productivity may decrease by 7% in 2020 and 32% in 2080 (Srivastava *et al.*, 2010). The optimum temperature for germination of fine grains is 21-35 degrees Celsius and for vegetative growth 26-34 degrees. The study explored the impacts of climate change on Sorghum yield in Qena, Egypt during the 2001-2021 period, the results show a decreasing trend rate of about (-61.9 / year) in acre productivity. The climate variability in Qena exhibit increasing in air temperature during growing season of Sorghum within (0.02°C/year) and decreasing in relative humidity within a rate of (0.37 % per year). The results show that temperature negatively impacted (R= 0.45) the Sorghum yield. The study shows that there is a positive correlation (R=0.85) between relative humidity and productivity, but unfortunately, the results show a decreasing trend rate in relative humidity during the growing season which leads to drought stress and affects the soil quality which decreases Sorghum productivity.

Authors' Contributions
All authors are contributed in this research

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Institutional Review Board Statement
All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement
Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate
Not applicable

Consent for Publication
Not applicable.

Conflicts of Interest
The authors disclosed no conflict of interest.

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