

Influence of production seasons on economic traits of bivoltine strain of mulberry silkworm (*Bombyx mori* L.) in Melkassa Agricultural Research Center

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Abstract

Production seasons play a crucial role in the silkworm, *Bombyx mori* L., growth, reproduction, as well as silk yield and quality. This experiment was conducted with an objective to know the degree of phenotypic difference of the economic traits and the productivity of different breeds in Melkassa Agricultural Research Center under different production seasons based on different response variables measured from one mulberry silkworm strain. In this study, a Chinese (Black Plain, bivoltine) strain was taken as the study unit. In this study, three production seasons, namely wet rainy, cold dry, and hot dry, were evaluated for their effect on the rearing performance of mulberry silkworm strains. In this experiment, characters of the tested silkworm strains reared during the wet rainy season were superior as compared to cold dry and hot dry seasons. The data revealed that the Chinese bivoltine silkworm strain reared under wet rainy production season showed higher fecundity (356.4 ± 40.7), a lower incubation period (8.3 ± 1.29), lower larval mortality (5.7 ± 3.8), a higher larval weight (1.8 ± 0.12), a high effective rate of rearing (83.2 ± 7.97), a high number of cocoons harvested per 300 worms (247.7 ± 23.8), cocoon weight (1.55 ± 0.08), pupal weight (1.28 ± 0.068), shell weights (0.26 ± 0.032), and shell ratio percentage (21.9 ± 1.9). As a result, this finding proved that rearing silkworms during a wet, rainy season will make silk producers more productive. Hence, the study also suggests that silkworm rearing under cold dry season and hot dry season can be enhanced by simulating the environmental conditions of the wet rainy season.

INTRODUCTION

Sericulture is the science of rearing silkworms for the commercial production of raw silk and includes the operations that are required to produce silk fiber (Ishfaq et al. 2007). Being poikilothermic organisms, silkworms are subjected to temperature and humidity-mediated embryonic and postembryonic development. The seasonal differences in the environmental components affect the genotypic expression in the form of phenotypic output of silkworm characters. The silkworm is sensitive to environmental fluctuations and unable to survive naturally due to continuous domestication since the dawn of sericulture (Hussain et al. 2011).

The optimum temperature for normal growth of silkworms is between 20°C and 28°C, and the desirable temperature for maximum productivity ranges from 23°C to 28°C. Temperature above 30°C directly affects the health of the worm, while temperature below 20°C retards all the physiological activities, especially in early instars. The adverse environmental conditions at egg stage result in a variety of embryonic disorders leading to the deterioration of quality leading to the death of the embryo (Singh, 2022). The combined effect of both temperature and humidity largely determines the satisfactory growth of the silkworms and production of quality cocoons (Gupta and Dubey, 2021). The early-stage instars are resistant to high humidity with relatively little or no effect of change in the moisture. On the contrary, the late-age instars are weak against high humidity, suffering badly from the damage of humidity (Gupta and Dubey, 2021).

Moreover, the cocoon formation process is greatly influenced by fluctuating environmental conditions, particularly temperature and humidity (Ramachandra et al., 2001). The cocoon weight and reproductive characters were greatly influenced by different temperature regimes (Onaga, 2012). Therefore, the aim of the study is to find out the effect of seasonal differences on the rearing performance of selected mulberry silkworms and to suggest remedial measures to reduce the adverse impact of seasonal differences on silkworm rearing.

MATERIALS AND METHODS

This experiment was conducted in the Melkassa Agricultural Research Center, sericulture research laboratory. The center lies at 8o 24' N latitude and 39o 21' E longitude, with an altitude of 1550 meters above sea level.

As per the rearing recommendations of silkworms by Rajan and Himantharaj (2005), the silkworm rearing room and equipment were cleaned, washed, and disinfected with 2% formalin solution at the rate of 800 ml per 10 m² area before the commencement of the experiment. Mulberry silkworm breeds were reared following shelf rearing techniques in the same laboratory as per appropriate recommendations, starting from brushing till cocoon spinning. Silkworm management practices like bed cleaning, bed spacing (Abiy et al., 2017), feeding amount and frequency (Ahmed et al., 2017), and so forth were done as per the recommendation. Sexually matured silkworm moths were collected from the sericulture research laboratory of the Melkassa Agricultural Research Center. Male and female adult silkworm moths that emerged on the same date were put together to get mating for subsequent studies. The mating pairs remained for about 24 hours, and males were separated from females after 24 hours. Individually sexed females were placed on egg laying newspapers for one day to lay eggs. After hatching, a silkworm larval population was established in the rearing trays under the same laboratory conditions as the Melkassa Agricultural Research Center.

Silkworms at the larval stage were fed on mulberry leaves four times a day with tender leaves until the larvae ended the II instar stage and semi tender leaves to III instar larvae, while more mature leaves were fed to IV and V instar larvae. Equal amounts of feed from the same feed plant variety were given. Mulberry was cultivated and used as a feed source for these silkworm strains. The grown-up worms, after completing feeding during late fifth instar at their ripened stage (ready to spin silk), were picked and transferred on the mountages (equipment to provide support for cocoon formation) for spinning silk cocoons, pupation, and adult moth emergence. After six to eight days of spinning, cocoons were harvested from the mountages.

Observations on daily temperature and relative humidity, number of days required for hatching period (incubation), hatchability%, larval duration, larval mortality rate, effective rearing rate, number of eggs laid per female (fecundity), and qualitative characters of the cocoon (fresh cocoon weight, cocoon shell weight, pupal weight, and shell ratio) were recorded. A silkworm strain used for this study was a Chinese bivoltine strain. Under this experiment, three production seasons, namely wet rainy, cold dry, and hot dry,

were considered as treatments. A complete randomized design with three replications was used for each treatment, and 300 silkworms were brushed in each replication and allowed to complete the larval period. Statistical analysis of R programming at 5% level of significance was used to analyze the data using the analysis of variance (ANOVA) procedure. Least significant difference (LSD) was used for mean separation (Gomez & Gomez 1984). The following formulas were used for analysis of egg hatchability (%), effective rearing rate (%), and shell ratio (%) calculations.

$$\text{Egg hatchability to } = \frac{\text{Number of normal eggs} - \text{Number of none hatched eggs}}{\text{Number of normal eggs}} \times 100$$

$$\text{Effective rearing rate} = \frac{\text{Number of survived larva}}{\text{Number of larvae brushed}} \times 100$$

$$\text{Silk ratio} = \frac{\text{weight of the cocoon shell}}{\text{weight of fresh cocoon}} \times 100$$

RESULTS

Temperature and relative humidity

The year of the study area was classified into three seasons: wet rainy season (June-September), cold dry season (October-January), and hot dry season (February-May). The temperature and humidity under the study laboratory conditions were recorded. Accordingly, the maximum temperature of 28.7 °C was recorded in the hot dry season, and the minimum temperature of 18.6 °C was recorded in the cold dry season. Whereas the maximum humidity of 79.5 was recorded in the wet rainy season and the minimum humidity of 61.3 was recorded in the hot dry season (Fig. 1).

The effect of seasonal difference on egg production and productivity parameters

In this study, the number of eggs laid per female moth was significant in the wet rainy season, and the average number of eggs in the wet rainy season, cold dry season, and hot dry season were 356.4 ± 40.7 , 290.9 ± 41.4 , and 315.5 ± 23.3 days, respectively. In this study, the incubation period along different production seasons was recorded, and it was higher in the cold dry season than the wet season and the hot dry season. The average incubation period in wet rainy season, cold dry season, and hot dry season was 8.3 ± 1.29 , 12.2 ± 1.28 , and 8.5 ± 0.53 days, respectively. Statically, it showed a highly significant difference in the cold dry season and no statically difference in the wet rainy and hot dry seasons. In the present study, the hatchability percentage was varied among production seasons, and it had a lower percentage in the cold, dry season. The hatchability percentages for wet rainy season, cold dry season, and hot dry season were 92.8 ± 6.67 , 88.17 ± 5.93 , and 95.8 ± 0.47 days, respectively (Table 1).

Table 1
The effect of seasonal difference on egg production and productivity parameters

Production seasons	No of egg laid per female moth	Incubation period (days)	Hatchability %
Wet rainy season	356.4 ± 40.7a	8.3 ± 1.29b	92.8 ± 6.67a
Cold dry season	290.9 ± 41.4b	12.2 ± 1.28a	88.17 ± 5.93b
Hot dry season	315.5 ± 23.3b	8.5 ± 0.53b	95.8 ± 0.47a
LSD	2.7	2.1	3.5
CV %	14.62	21.79	6.77
P-value	0.000	0.000	0.0024

The effect of seasonal difference on larval productivity parameters

The average total larval period recorded in wet rainy, cold dry season and hot dry season were $25.8 \pm 0.86b$, $28.85 \pm 2.2a$ and $25.0 \pm 0.0b$ days respectively (Table 2). The lower larval period ($25 \pm 0.08a$) was observed in hot dry season and there was a significant difference among the production seasons. The percentages of larval mortality at young stage in wet rainy, cold dry season and hot dry season were $10.5 \pm 5.3b$, $17.3 \pm 5.17a$ and $11.3 \pm 2.04b$ respectively. And the percentages of larval mortality at late stage for wet rainy, cold dry season and hot dry season were $5.7 \pm 3.8b$, $9.3 \pm 3.1a$ and $8.6 \pm 2.9a$ respectively. The higher larval mortality was recorded in wet rainy season for both young stage mortality ($17.3 \pm 5.17a$) and late-stage mortality ($9.3 \pm 3.1a$). Statically it was significant difference among season.

The single larval weight (g) across in the study treatments was determined and it was $1.8 \pm 0.12a$, $1.6 \pm 0.15b$, and $1.64 \pm 0.11b$ larval weight for wet rainy season, cold dry and hot dry seasons respectively. In the present study the numbers of larvae spinning cocoons were $249.5 \pm 23.9a$, $216.1 \pm 17.5c$ and $233.7 \pm 4.9b$ for wet rainy season, cold dry season and hot dry season respectively and it was significant difference among production seasons. The effective rearing rate were also determined and it were $83.2 \pm 7.97a$, $72.0 \pm 5.85c$ and $77.9 \pm 1.63b$ in wet rainy season, cold dry season and hot dry season respectively. The maximum (83.2 ± 7.97) effective rearing rate was recorded under wet rainy season.

Table 2
The effect of seasonal difference on larval productivity parameters

Production seasons	Total larval period in days	Mortality at young stage by percent	Mortality at late stage by percent	Larval weight (g)	No of larvae spinning cocoons	ERR (%)
Wet rainy season	25.8 ± 0.86b	10.5 ± 5.3b	5.7 ± 3.8b	1.8 ± 0.12a	249.5 ± 23.9a	83.2 ± 7.97a
Cold dry season	28.85 ± 2.2a	17.3 ± 5.17a	9.3 ± 3.1a	1.6 ± 0.15b	216.1 ± 17.5c	72.0 ± 5.85c
Hot dry season	25.0 ± 0.0b	11.3 ± 2.04b	8.6 ± 2.9a	1.64 ± 0.11b	233.7 ± 4.9b	77.9 ± 1.63b
LSD	2.7	3.5	3.7	6.61	7.5	7.5
CV %	7.30	24.68	25.01	8.22	9.93	9.93
P-value	0.000	0.0003	0.01124	0.001	0.000	0.000

The effect of seasonal difference on cocoon, pupae and shell production parameters

In this study, the number of normal cocoons harvested was determined and it was $247.7 \pm 23.8a$, $232.4 \pm 21.7a$, $213.7 \pm 17.7b$ number of cocoons in wet rainy season, cold dry and hot dry seasons respectively. The number of cocoons harvested during wet rainy season and hot dry season were significantly higher compared to the cold dry season. The mean weight for fresh single cocoon was $1.55 \pm 0.08a$, $1.43 \pm 0.076b$ and $1.42 \pm 0.051b$ mean weight in grams for wet rainy season, cold dry and hot dry seasons respectively. The mean weight for fresh single cocoon during wet rainy season was higher significant compared to the cold dry season and hot dry season (Table 3).

In this study, a single pupa weight in wet rainy season, cold dry season and hot dry season were $1.28 \pm 0.068a$, $1.20 \pm 0.056b$ and $1.20 \pm 0.041b$ g and the maximum single pupal weight ($1.28 \pm 0.068a$) was recorded during wet rainy season. In this study, highest single shell weight value $0.26 \pm 0.032a$ g was recorded during wet rainy season and there was no significant difference between cold dry season and hot dry season (Table 3). In this study the shell ratio was measured to estimate the quality of each individual based on the raw silk content in its cocoon accordingly shell ratio percentage in wet rainy season, cold dry season and hot dry season were $21.9 \pm 1.9a$, $19.3 \pm 1.4b$ and $18.6 \pm 1.2b$ percent respectively. The higher percentage of shell ratio ($21.9 \pm 1.9a$) was recorded in wet rainy season.

Table 3
The effect of seasonal difference on cocoon, pupae and shell production parameters

Production seasons	No of normal cocoons harvested out of 300 sample	Fresh single cocoon weight(g)	Single pupa weight (g)	Fresh single shell weight(g)	Shell ratio percentage (%)
Wet rainy season	247.7 ± 23.8a	1.55 ± 0.08a	1.28 ± 0.068a	0.26 ± 0.032a	21.9 ± 1.9a
Cold dry season	213.7 ± 17.7b	1.43 ± 0.076b	1.20 ± 0.056b	0.23 ± 0.038b	19.3 ± 1.4b
Hot dry season	232.4 ± 21.7a	1.42 ± 0.051b	1.20 ± 0.041b	0.21 ± 0.019b	18.6 ± 1.2b
LSD	2.7	7.5	8.4	26.6	2.6
CV %	10.91	6.21	5.58	12.22	8.19
P-value	0.011	0.000	0.008	0.017	0.001

DISCUSSION

In this study the number of eggs laid per female moth was showed a significant difference in wet rainy season and the average number of eggs laid in wet rainy season, cold dry season and hot dry season were 356.4 ± 40.7 , 290.9 ± 41.4 and 315.5 ± 23.3 days respectively. The number of eggs laid per female moth in wet rainy season was higher than egg laid in cold dry season and hot dry season. This result was in agreement with reports by Ishfaq et al. (2007) who reports that each female moth lays 300 to 500 eggs. On the other hand, this result was less than the finding by (Almojuela. C M and et al. 2022) who studies on silkworm hybrid DMMMSU 225 significantly produced the highest fecundity of 562.60.

Incubation is an important process by which the activated silkworm eggs are maintained under proper environmental conditions to get better hatching. In the current study the average incubation length for wet rainy season, cold dry season and hot dry season were 8.3 ± 1.29 , 12.2 ± 1.28 and 8.5 ± 0.53 days respectively and statically it showed significant difference in cold dry season. This may be due to low temperature and low humidity during cold dry season. These results were comparable with the reports by (Singh, 2022) low temperature prolongs the incubation period and many eggs do not hatch at all and hatching is very irregular.

In this finding the hatchability percentage in wet rainy season, cold dry season and hot dry season were 92.8 ± 6.67 , 88.17 ± 5.93 and 95.8 ± 0.47 days respectively. The lower hatchability percentage was recorded in cold dry season. This result was in agreement with the previous results of (Singh, 2022) at lower temperature results in a large proportion of eggs laying or becomes weak and some do not hatch at all.

The average larval period recorded in wet rainy season, cold dry season and hot dry season were 25.8 ± 0.86 , 28.85 ± 2.2 and 25.0 ± 0.08 respectively (Table 2). The lower larval period (25 ± 0.08 days) was observed in hot dry season and there was a significant difference in hot dry season. This may be due optimum temperature and relative humidity during this season. This result was almost in agreement with the previous reports of Mohammed and Ayoub (2022) who reports that the average the total larval period was 26.17 ± 1.50 days. also, this was in line with the findings of (Shriya Singh et al. 2023) who studies the highest larval duration (24.43 days) was recorded in untreated control.

The percentages of larval mortality at young stage in wet rainy, cold dry season and hot dry season were 10.5 ± 5.3 , 17.3 ± 5.17 and 11.3 ± 2.04 percent respectively. And the percentages of larval mortality at late stage for wet rainy, cold dry season and hot dry season were 5.7 ± 3.8 , 9.3 ± 3.1 and 8.6 ± 2.9 respectively. The higher larval mortality was recorded during cold dry season both at young stage (17.3 ± 5.17) and late stage (9.3 ± 3.1) (Table 2). This result also agrees with the finding by (Singh et al., 2020) who reported 24.07% larval mortality at early stage and 11.81% at late larval mortality were reported. Also, this was agreed with the ideas of (Hussain et al. 2011) who reports that the rate of development and physiology of larvae may be influenced by high temperature which results in alteration in metabolism causing reduced egg yield, increased mortality and enhanced disease incidence due to the production of apyrene sperm which results in the production of unfertilized eggs.

In this study the single larval weights (g) in all treatments were determined and it were 1.8 ± 0.12 , 1.6 ± 0.15 , and 1.64 ± 0.11 larval weight in wet rainy season, cold dry and hot dry seasons respectively. This result was higher than the previous results of (Ponmurugan, M. Karthikeyan, A. and Vinotha, M. 2019) who reported that on the last day of the fifth instar the weight of the larva was 1.52 g in larval feed on mulberry leaf.

In the present study the numbers of larvae spinning cocoons were 249.5 ± 23.9 , 216.1 ± 17.5 and 233.7 ± 4.9 for wet rainy season, cold dry season and hot dry season respectively and the highest number of larvae spinning cocoon was recorded in wet rainy season (249.5 ± 23.9) while the lower number of larvae spinning cocoon (216.1 ± 17.5) was reported in cold dry season. These results are in agreement with findings of (Hosamani and Chandrashekar 2022) who reports the attribute to availability of optimum climatic condition particularly humidity and temperature throughout the larval and mounting periods during winter increase the number of larvae spinning cocoon when compared to other seasons.

Effective rearing rate (ERR) indicates the survivability of silkworm during the silkworm crop (Rahmathulla et al. 2007). In this study the effective rearing rate in wet rainy season cold dry season and hot dry season were 83.2 ± 7.97 , 72.0 ± 5.85 and 77.9 ± 1.63 percent respectively. The maximum (83.2 ± 7.97) effective rate of rearing was recorded under wet rainy season. It may be due to favorable seasonal condition for silkworm rearing in wet rainy season. The result of these studies was agreed with the report by Caccam and Mendoza (2013) who reports that silkworms raised in rainy season were significantly heavier, had higher effective rearing rates and cocoon yield per box than those raised in dry season.

In the current study fresh single cocoon weight in wet rainy season, cold dry season and hot dry season were 1.55 ± 0.08 , 1.43 ± 0.076 and 1.42 ± 0.051 g respectively. The highest value (1.55 ± 0.08) of fresh single cocoon weight was obtained in wet rainy season. These results were higher than the reports of Hosamani and Chandrashekar, (2022) who reported that single cocoon weight 1.233g. and it was less than the reports of Lakshmi et al. (2014) who reports that the newly evolved hybrids over the three seasons indicates that maximum (1.812 g) and minimum (1.560 g) cocoon weight.

In the current study the maximum single shell weight 0.26 ± 0.032 g was recorded under wet rainy season was recorded. These results are in agreement with findings of Khursheed et al. (2022) who reported that shell weight for chinese races reared on local mulberry under controlled conditions was $0.203b \pm 0.003$ g. Also, this was in line with the findings of (Almojuela. C M and et al. 2022) who reported in the control group the heaviest cocoon shell of 0.246 g was reported.

In this study the shell ratio was measured to estimate the quality of each individual based on the raw silk content in its cocoon accordingly shell ratio percentage in wet rainy season, cold dry season and hot dry season were $21.9 \pm 1.9a$, $19.3 \pm 1.4b$ and $18.6 \pm 1.2b$ percent respectively. The higher percentage of shell ratio ($21.9 \pm 1.9a$) was recorded in wet rainy season. This result was higher than the previous reports by (Almojuela. C M and et al. 2022) who reported that 17.23% shell ratio in the control group for silkworm hybrid DMMMSU 225. Also, it was higher than the reports by (Paramita Das, et al., 2020) who reports that for the N×NB4D2 silkworm race shell ratio % (17.084%) was reported.

CONCLUSION AND RECOMMENDATION

In this study the grainage, larval and cocoon characters treated in wet rainy season providing supportive evidence for good rearing condition, also statistically significant compared to other production seasons on all parameters. Rearing silkworms in wet rainy season was superior to get significant results in all the tested important variables for bivoltine silkworm strain. It has showed better results in reducing incubation period, larval mortality, larval period and good effective rearing rate which could enable to obtain more production and productivity. It was also found superior in increasing number of eggs laid per female, hatchability, larval weight, cocoon weight, pupal weight, shell weight and silk ratio. Out of these variables short incubation period and duration of larval period were also significantly recorded in hot dry seasons like results were obtained in wet rainy season while all the tested variables were significantly less performed in cold dry season. Although wet rainy season was a better performer than other seasons, silk worm rearing can also be possible in cold dry and hot dry seasons. However least performing variables in hot and cold dry seasons requires appropriate management practices by regulating the temperature and relative humidity in the silkworm rearing period to achieve better results like wet rainy season. Finally, the study suggests that silkworm rearing under cold dry season and hot dry season can be enhanced by avoiding temperature and humidity fluctuations during these seasons and/or by applying simulated environmental conditions of the wet rainy season.

DECLARATIONS

Author Contribution

Author Contribution Statements
Beshada Taye The principal investigator, led the analysis and writing of the paper. Metasebia Terefe led the project and oversaw the project progress. Aynalem Tsegaw contribution was through data collection. Kedir Shifa was led the analysis, writing, and interpretation. All other authors Ahmed Ibrahim and Abiy Tilahun were instrumental in acquiring the observations or contributed relevant scientific expertise to the project.

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Figures

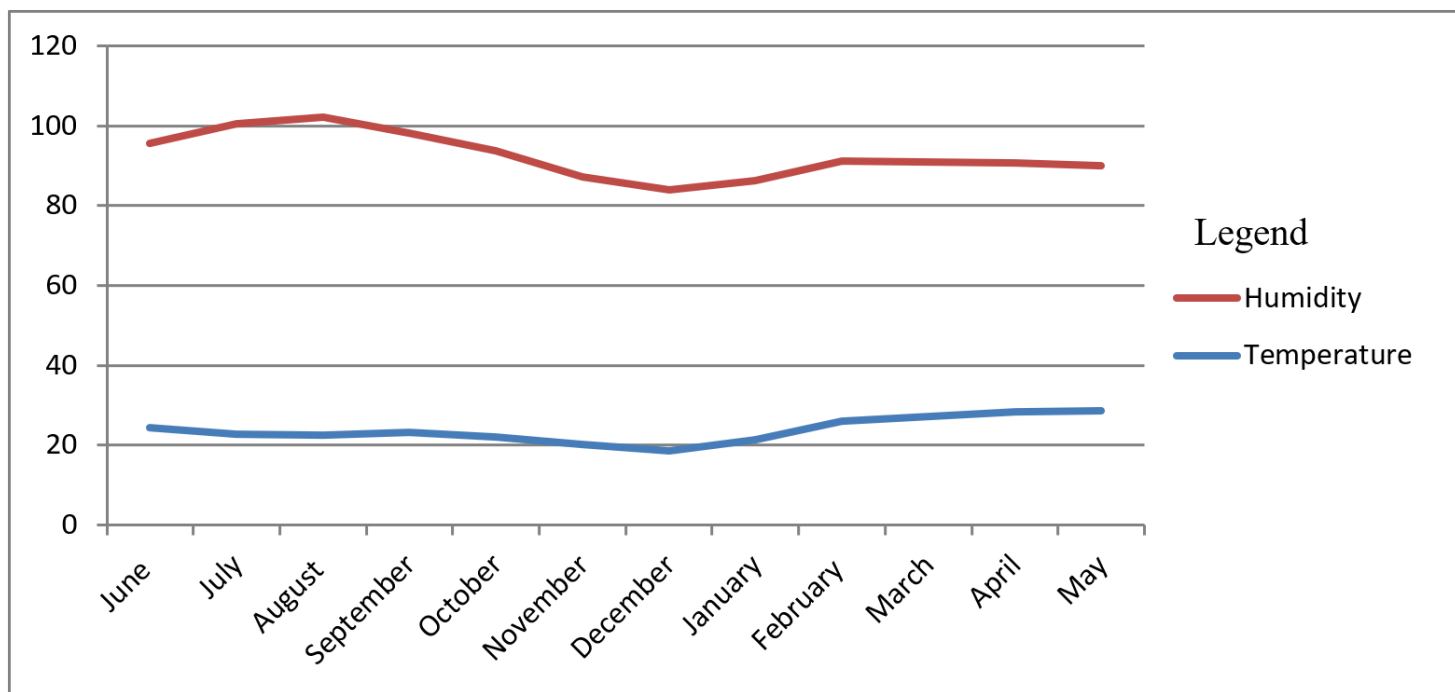


Figure 1

The average temperature and relative humidity across the season in the study laboratory (2011-2014 E.C)