Wisdom at the source of the Blue Nile

Volume 7, Number 2
December, 2022

Journal of Agriculture and Environmental Sciences (JAES)

Publication of the College of Agriculture and Environmental Sciences
Bahir Dar University, Ethiopia
http://www.bdu.edu.et/caes
ISSN: 2616-3721 (Online); 2616-3713 (Print)

About the Journal

Journal of Agriculture and Environmental Sciences (JAES) is a publication of the College of Agriculture and Environmental Sciences, Bahir Dar University. JAES is a multidisciplinary open access journal, publishing scientifically sound peer-reviewed research results as well as literature review in all aspects of agriculture and environmental sciences and related fields. This journal is issued two times per year.

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Length-Weight Relationship, Fulton's Condition Factor and Sex Ratio of Nile Perch (*Lates niloticus,* Linnaeus- 1762) in Lake Abaya, Ethiopia

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Received: June 11, 2022 Accepted: October 21, 2022

Abstract: *The length-weight relationship of fish is an important fishery management tool. The objectives of the study were to determine the length-weight relationship, Fulton's condition factor and the sex ratio of Lates niloticus in Lake Abaya. Total length (TL), total weight (TW), and sex data were collected from 755 fish samples (377 females and 378 males) for one year (January to December 2021) from the commercial fishery of Lake Abaya. The collected data were summarized by using descriptive statistics and analyzed with the application of Microsoft Excel 2010 and SPSS software. There was no significant deviation in sex ratio (M: F) from hypothetical 1:1 ratio (χ^2 = 0.00; P > 0.05). The length-weight relationship was calculated using power function and obtained as $TW = 0.0077*TL^{3.1176}$, (R^2 = 0.8834), $TW = 0.0078*TL^{3.1372}$, (R^2 = 0.8548) and $TW = 0.0098*TL^{3.0723}$, (R^2 = 0.8713) for females, males and combined sexes, respectively. The regression coefficient "b" was significantly different from the cubic value "3" (P<0.05) and implied that L. niloticus of Lake Abaya follows a positive allometric growth pattern. The one-way ANOVA (P > 0.05) revealed that Fulton's condition factor between sexes was insignificant but highly significant by month's interaction (ANOVA, P < 0.05). The t-test also revealed a highly significant difference in a month's interaction (t-test, P = 0.000) indicating the seasonal variation in the mean monthly condition factor. The average value of Fulton's condition factor was higher than one and indicates that L. niloticus in Lake Abaya was in good health condition. The present study was focused only on L. niloticus and recommends that similar studies including feeding and reproductive biology should be conducted to determine the status of other fish species in Lake Abaya.*

Keywords: Allometric growth pattern, Commercial fishery, Fishery management, freshwater fish, Lake Fishery

1. Introduction

The growth of fish is a mathematical function of length and weight which varies due to biological changes and seasonal dynamics (Das, 2004). The length-weight relationship of fish is an important fishery management tool. The relationship is pronounced in estimating the average weight at a given length group and assessing the relative well-being of a fish population (Abowei *et al*., 2009). Length-weight relationships of freshwater fishes are useful in determining weight and biomass when only length measurements are available and are required in fishery management and conservation (Froese, 1998; Oscoz *et al*., 2005). Knowledge of the sex ratio of fish is important to ensure proportional fishing of two sexes and provides information necessary for assessing the reproductive potential of a population (Vazzoler, 1996).

The condition factor (K) is a method by which the physical condition and seasonal variation in the well-being of an individual fish could be known (King, 1995). The condition factor is a quantitative parameter of the well-being and state of the fish that reflects recent feeding conditions (Le cren, 1951). The growth of any fish is related to the prevailing environmental conditions. Many authors have explained the importance of the condition factor as a useful tool for assessing fish growth rate, age and feeding intensity (Abowei, 2006; Kumolu-Johnson and Ndimele, 2010; Oribhabor *et al*., 2011; Onimisi and Ogbe, 2015; Abu and Agarin, 2016). The well-being of fish is considered a good indicator of various water bodies' health in relation to water pollution due to its cheapest means of determining the stress of water pollution on the fish's body condition (Gupta and Tripathi, 2017).

The *L. niloticus* is one of the four commercially important fish species in Lake Abaya. Lakes Abaya and Chamo are the main sources of *L. niloticus*. It is a widely accepted fish species as a food commodity and is economically important for the fishing societies in Lake Abaya. The biology of fish from different water bodies in Ethiopia has been studied by various scholars. But such important information in Lake Abaya is null or little. Therefore, the present study aimed to generate crucial information on length-weight relationships, sex ratios and Fulton's condition factor of *L. niloticus* in the lake to provide the necessary scientific information for proper utilization and management of the lake fishery.

2. Materials and Methods

2.1. Description of the study area

Lake Abaya is one of the two southernmost Rift Valley lakes in Ethiopia. It is the second largest lake in the country next to the highland lake, Lake Tana. It is located between 5˚55'9"N to 6˚35'30"N latitude and 37˚36'90"E to 38˚03'45"E longitude. The lake, including its islands, has a total area of 1108.9 km^2. It is located at an average altitude of 1235 meters above sea level (Bekele, 2007). It has a maximum length of 79.2 km with a maximum width of 27.1 km. The mean and the maximum depths are 8.6 m and 24.5 m, respectively (Arne, 2013).

2.2. Methods of sampling and data collection

Samples of *L. niloticus* were collected from the three commercial fisheries that are actively practicing fishing in Lake Abaya. Fishes were randomly collected for three days a week at four landing sites of the commercial fisheries from January to December 2021. The trained fishermen were involved in data collection with regular following-up of the researcher. The total length and total weight of fresh fish samples were measured to the nearest 1 mm and 1 g using a measuring board and sensitive electronic and hanging balances, respectively. Small-sized fish was weighed with sensitive electronic balance while the larger sized was weighed with hanging balance. Sex determination was made visually based on external sexual characteristics as well as dissecting the abdomen and observing the gonads.

2.3. Data analysis

The length-weight relationship was calculated using the power function described by Le Cren (1951).

$$TW = aTL^b \qquad [1]$$

Where

- TW = total weight (g)
- TL = total length (cm)
- a = the intercept
- b = the slope of length-weight regression

The Fulton's condition factor (K) is often used to reflect the nutritional status or well-being of an individual fish and was calculated by using the formula described by Fulton (1904) which is indicated below.

$$K = \left(\frac{TW}{TL^3}\right) * 100 \qquad [2]$$

Where

- TW = total weight of fish in gram (g)
- TL = total length of fish in centimeter (cm)

The data analyses were done using Microsoft Office Excel (2010) and SPSS (Version 16.0) software. A chi-square test (χ^2 test) was employed to determine if the sex ratio varies between the male and female *L. niloticus*.

3. Results and discussion

3.1. Sex ratio

About 755 samples of *L. niloticus* were collected. Among these samples, 377 (49.93%) were females and 378 (50.07%) were males (Table 1). The monthly sex ratio (M: F) was statistically insignificant between males and females except for August, October and December. But the total sex ratio (M: F) was 1:1 and statistically insignificant (χ^2 = 0.00; P > 0.05). The finding indicates the presence of a normal and expected sex ratio of one male to one female of *L. niloticus* in Lake Abaya. Sex ratio is one of the reproductive parameters to determine the availability of mature males and females expected to spawn. In normal conditions, the male-to-female ratio is indicated as a 1:1 ratio. It is therefore evident that the *L. niloticus* in Lake Abaya tends to have an equal population of males and females. Unlike the present study, the sex ratio of *L. niloticus* was dominated by males in Lake Chamo (Dadebo *et al*., 2005) and in Lake Victoria (Edwine *et al*., 2017).

Table 1: Sex ratio of *L. niloticus* in Lake Abaya

Month	Female	Male	Total	Expected frequency	Sex ratio (M: F)	Chi-square (χ^2)	P-value
January	20	18	38	19	1:1.11	0.05	0.75
February	20	20	40	20	1:1	0.00	1.00
March	17	24	41	20.5	1:0.70	0.60	0.27
April	37	31	68	34	1:1.19	0.26	0.47
May	43	41	84	42	1:1.05	0.02	0.83
June	48	57	105	52.5	1:0.84	0.39	0.38
July	20	17	37	18.5	1:1.18	0.12	0.62
August	72	106	178	89	1:0.69	3.25	0.01*
September	25	23	48	24	1:1.09	0.04	0.77
October	27	10	37	18.5	1:2.7	3.91	0.01*
November	28	22	50	25	1:1.27	0.36	0.40
December	20	9	29	14.5	1:2.22	2.09	0.04*
Total	377	378	755	377.5	1:1	0.00	0.97

* Significant value

3.2. Length-weight relationship

The values of the regression coefficient "*b*" for females, males and combined sexes were 3.1176, 3.1372, and 3.0723, respectively, where the relationships are presented in Figures 1, 2, and 3, respectively. Based on the analysis of variance (one-way ANOVA), there was a significant difference between the regression coefficient "*b*" and the expected cubic value of "*b*" ($P < 0.05$). The t-test revealed the presence of a significant difference between the regression coefficient "*b*" in female, male and combined sexes ($P < 0.05$). According to the results of this study, the growth patterns of *L. niloticus* was positive allometric and curvilinear in Lake Abaya. The positive allometric growth patterns implied that the fish became relatively stouter and deep-bodied as they increased in length.

A similar relationship has been reported by Edwine *et al*. (2017) for *L. niloticus* in Lake Victoria and Pendjari River (Simon *et al*., 2009). Fishes can attain an isometric, negative or positive allometric growth pattern. In isometric growth, the fish does not change the shape of its body as it continues to grow while negative allometric growth shows the fish becomes thinner as its body length increases as opposed to a positive allometric growth that implies the fish becomes relatively broader and fatter as its length increases (Riedel *et al*., 2007). The variation in the value of *b* takes place due to season, habitat, gonad maturity, sex, diet, stomach fullness, health, preservation techniques and annual differences in environmental conditions (Bagenal and Tesch, 1978; Arslan *et al*., 2004; Froese, 2006; Yilmaz *et al*., 2012; Ali *et al*., 2016). Furthermore, variations in fish growth patterns could also be related to the condition of the species itself, its phenotype, specific geographic location, and its environment (Tsoumani *et al*., 2006).

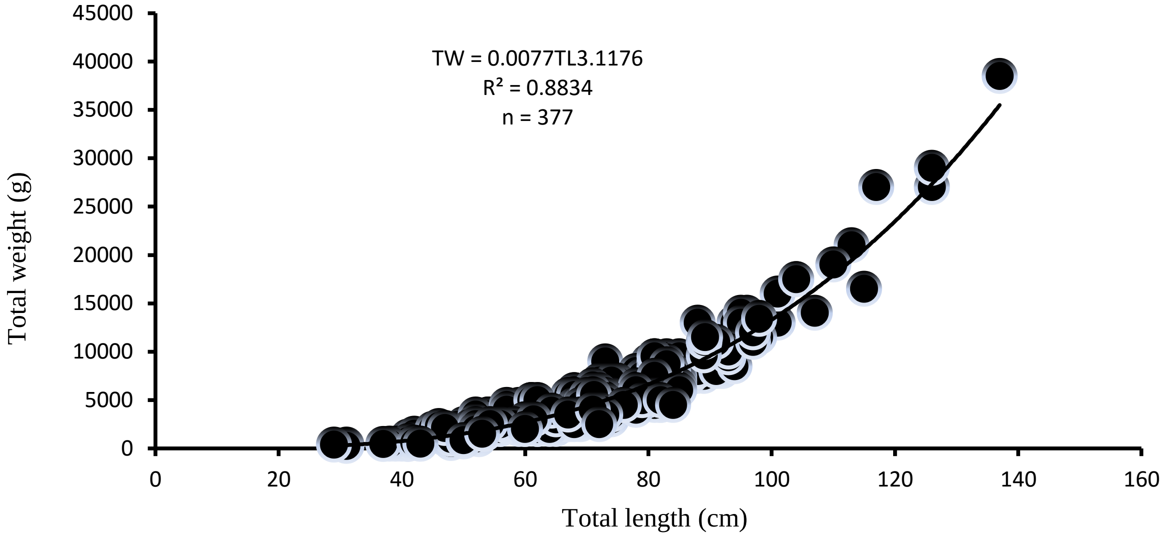

Figure 1: Length-weight relationship of female *L. niloticus* from Lake Abaya

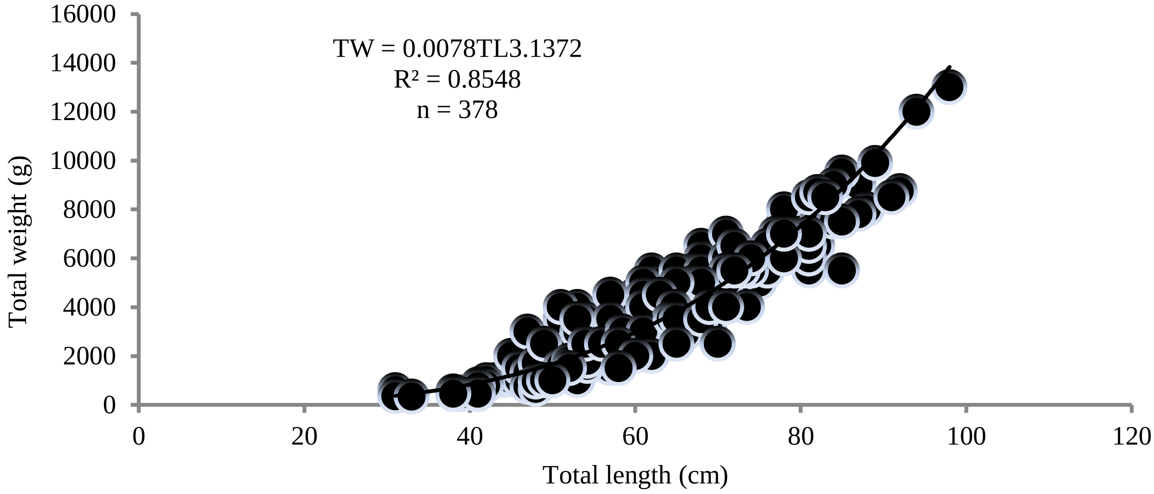

Figure 2: Length-weight relationship of male *L. niloticus* from Lake Abaya

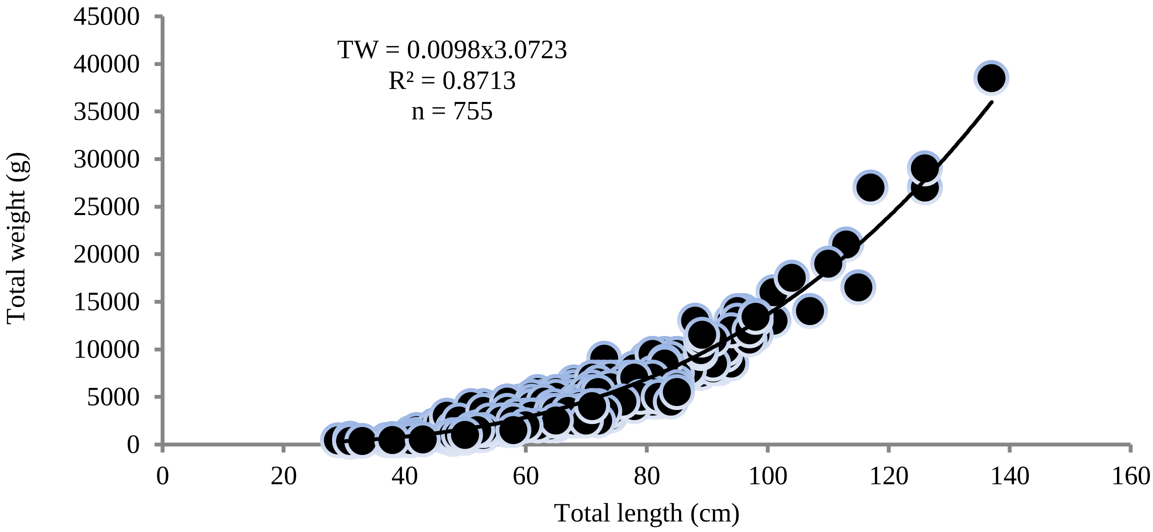

Figure 3: Length-weight relationship of combined sex *L. niloticus* from Lake Abaya

3.3. Fulton's condition factor

The monthly mean Fulton's condition factor ranged from 0.92 to 1.47 for females, 0.89 to 1.56 for males and 0.93 to 1.53 for combined sexes (Table 2). The average K value for females, males and combined sexes were 1.29, 1.34 and 1.31, respectively. The lowest condition factor for females (0.92) was recorded in October, and the highest (1.47) was in August. For males, the lowest value, 0.89 was recorded in December and the highest value (1.56) was in August. For combined sexes, the lowest value (0.93) was recorded in December and the highest (1.53) in August. The results indicated that there was no significant difference between the mean condition factor of males and females *L. niloticus* ($P > 0.05$; Fig. 4). But the mean condition factor by month's interaction in Lake Abaya was significantly different ($P < 0.05$). The t-test also revealed a highly significant difference in a month's interaction (t-test, $P = 0.000$) indicating the seasonal variation in the mean monthly condition factor.

In the study of fish, the condition factor is used in comparing its condition, size or well-being (Ndimele *et al*., 2010). Condition factor is also important in the monitoring of feeding intensity, age and growth rates in fish (Anene, 2005). Related studies had also shown that the condition factor is strongly influenced by both biotic and abiotic environmental conditions, and can be used to assess the ecological habitat of fish species (Ayoade, 2011; Onimisi and Ogbe, 2015; Abu and Agarin, 2016). Morton and Routledge (2006) divided the K values into five categories very bad (0.8–1.0), bad (1.0–1.2), balance (1.2–1.4), good (1.4–1.6) and very good (> 1.6). On the other hand, Ayoade (2011) suggests that a condition factor higher than one is a good fish health condition.

It was observed in the present study, that the average condition factor of *L. niloticus* in Lake Abaya was 1.29, 1.34 and 1.31 for females, males and combined sexes, respectively. Variations in condition factors are influenced by many biotic and abiotic factors such as phytoplankton abundance, predation, and water temperature and dissolved oxygen concentrations among others (Ahmed *et al*., 2011). Morton and Routledge (2006) state that the fish with condition factor values ranging from 1.2-1.4 is considered to be in balance condition; while Ayoade (2011) suggests the condition factor higher than one is in good health condition. Hence, the condition factor in the present study was higher than one and *L. niloticus* in Lake Abaya was in good health condition.

The average condition factor of the fish species in the current study was similar to the condition factors reported by Edwine *et al*. (2017) in Lake Victoria, Olapade, *et al*. (2019) in River Jong, and Simon *et al*. (2009) in the Pendjari River for the same fish species. The condition factor of fish can vary based on the species type, prevailing environmental conditions, and food availability in their occupied habitats (Okach and Dadzie, 1988; Wanyanga *et al*., 2016). The condition factor of fish can also be affected by season, reproductive cycles and water quality parameters (Khallaf *et al*., 2003).

Table 2: Mean monthly condition factor of females, males and combined *L. niloticus* in Lake Abaya during 2021

Months	Female	Male	Combined sex
January	1.20	1.20	1.2
February	1.42	1.47	1.44
March	1.43	1.49	1.47
April	1.37	1.37	1.37
May	1.23	1.27	1.25
June	1.46	1.53	1.5
July	1.39	1.45	1.42
August	1.47	1.56	1.53
September	1.18	1.43	1.3
October	0.92	1.02	0.95
November	1.41	1.36	1.39
December	0.95	0.89	0.93
Average	1.29	1.34	1.31

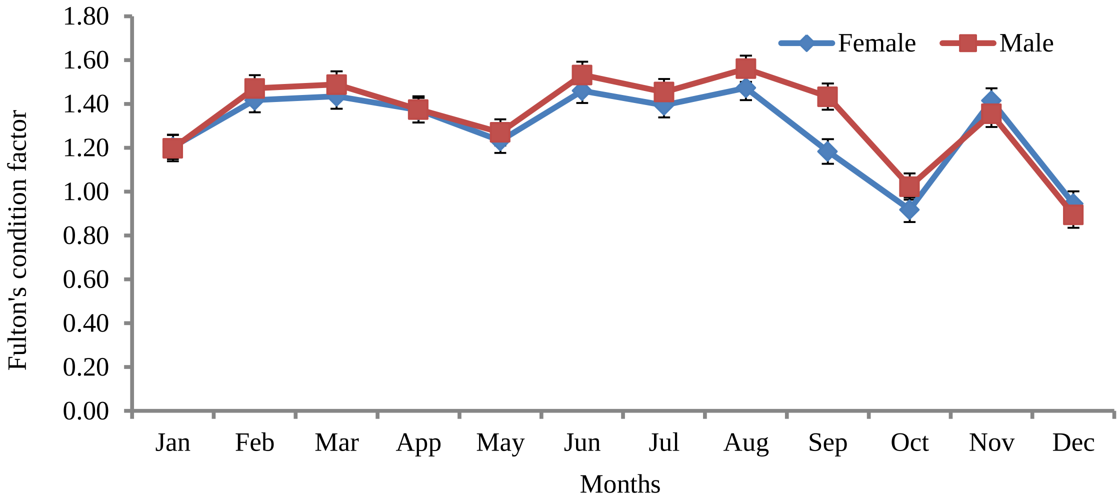

Figure 4: Monthly Fulton's condition factor (FCF) between females and males *L. niloticus* in Lake Abaya

4. Conclusion

The sex ratio of *L. niloticus* did not deviate from the expected sex ratio of one male to one female and the length-weight relationship follows a positive allometric growth pattern. The body condition of *L. niloticus* was showing seasonal variability in the monthly condition factor and it was generally good in health condition. The present study was focused only on *L. niloticus* and recommends that similar studies including feeding and reproductive biology should be conducted to determine the status of other fish species in Lake Abaya.

Conflict of interest

The author declares that there is no conflict of interest in publishing the manuscript in this journal.

Acknowledgment

The author would like to acknowledge the Ethiopian Institute of Agricultural Research (EIAR) for the financial support and Arba Minch Agricultural Research Center for accessing the necessary facilities.

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Determinants of adoption of improved panicum forage by agro- pastorals in Dasenech District, Southern Ethiopia

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Received: August 24, 2022 Accepted: September 21, 2022

Abstract: *Adoption of improved forage remains vital in combating feed shortages and reducing livestock deaths in pastoral and agro-pastoral areas of Ethiopia. However, it depends on household characteristics, institutional and socioeconomic factors, and the perception of the community. Thus, this study examined the determinants of adoption and intensity of improved panicum forage technologies in the Dasenech district. A multistage sampling technique was employed to select 140 forage-producing agro-pastoral households. A double hurdle model was used to analyze the data. The results indicated that agro-pastoralists' adoption and intensity of adoption of panicum forage production in the Dasenech district is high. However, more than 60% of agro-pastoralists who had adopted and cultivated panicum forage claimed problems in accessing irrigation water, which was associated with high fuel for operating irrigation water pumps. Moreover, the probability of adoption of panicum forage production in the district is influenced by access to irrigation water, forage production experience, cooperative membership, and distance to the training center. The intensity of adoption of panicum forage production was also influenced by the sex of the respondent, credit access, distance to market, production experience, price of seed, and livestock holdings. Working on issues related to the improvement of access to irrigation water, establishing cooperatives of agro-pastoralists, and provision of credit opportunities and market information by respective stakeholders is proposed to enhance the adoption and production of panicum forage in the study area.*

Keywords: Adoption intensity, Agro-pastoral, Double hurdle, Panicum forage

1. Introduction

Livestock farming in Ethiopia is economically and socially very important and generates a large amount of export income both at the domestic and international levels. The entire livestock industry, which includes cattle, sheep, goats, equines, and poultry, contributes 15–17% of the GDP, 47.7% of the agricultural GDP, and 37–87% of household incomes (ILRI, 2010; Behnke and Metaferie, 2011). Despite playing a range of roles in both the domestic and global economies of the nation, the contribution of the livestock sub-sector is now below its potential due to several technical and non-technical issues. The most pressing technical problem is the lack of cultivated and wild feed, both in terms of quantity and quality (CSA, 2016).

In Ethiopia, cattle perform poorly because feed quality and quantity are inconsistent, especially during the dry seasons of the year (Ayantunde et al., 2005). This requirement necessitates the use of improved forage, which has various advantages over currently available traditional feed resources. In different parts of Ethiopia, the government of Ethiopia has introduced various improved forages that are utilized as animal feed and to conserve soil and water. However, little is known about how farmers feel about growing and using such forages. Regarding the types of improved forages grown in natural resource conservation areas of an agro-ecological zone and institutional barriers preventing individual farmers from using feed resource management technology, farmer perceptions of technology were one of the factors that could support or hinder the adoption of improved forage technology (Gecho and Punjabi, 2011).

Moreover, the main livestock feed resources accessible in Ethiopia are natural pastures, crop residues, and grazing (Tolera, 2008; Assefa, 2012).

However, these feed resources are very low in quality, having high fiber, low to moderate digestibility, and low levels of nitrogen (Habte, 2000), which might be linked with a low voluntary intake, thus resulting in inadequate nutrient supply, low productivity, and even weight loss. On the other hand, the organic matter content of the soil diminishes as a result of keeping feed supplies within the fields, which worsens the topsoil structure and speeds up erosion (Alemayehu et al., 2016). This situation calls for the inclusion of improved forages, which could provide several advantages over the currently available traditional feed sources or overgrazing in the field.

Adoption of those improved forages refers to a business, a farmer, or a reflection of a farmer's decision to employ a new technology of improved forages, method, and practice in the farming system's production process. Farmers will then only use the technologies that are appropriate for their needs. This may present a chance for smallholder farmers to increase their income and output (Zakarias, 2016).

Forage development strategies have been used for a long time in Ethiopia, but their uptake by the farming community has been very low due to several factors, including a lack of and inability to adopt forage technologies; weak extension services; a lack of and high cost of planting materials; resistance on the part of most smallholder farmers; and the size of livestock ownership and farm size (Othill, 1986; Assefa and Kebede, 2012; Beshir, 2014). Lack of sufficient land is one of the key obstacles to the adoption of new technologies in the Ethiopian farming system. This is a limitation that farmers are reluctant to plant forage and allocate their land for food crops. As a result, adopting specialization or intercropping forage with other crops has little effect on land allocation and optimizes land for both forage and food crops (Teshome, 2014).

Numerous researchers have been identified that lack of knowledge as a constraint for adoption of technology by farmers. After having forages on their hands they do not know what is best to do with them or how to use them efficiently. Lessening the problem can be possible with the help of good extension services. It is well recognized that extension service is an important pillar in the transformation of subsistence agriculture to market-oriented agriculture (Gebremedhin et al., 2006). Lack of funds for covering the costs of creating specific forage technologies is the other significant reason preventing many Ethiopian farmers from adopting new forage technologies. Primary variables that influenced farmers' adoption of forage technology were their physical and social capital holdings, educational accomplishments, household parameters, and income level (Cramb, 2000; Shelton et al., 2005; Mapiye et al., 2006; Gillah et al., 2012).

Many previous studies conducted on the adoption of improved forage technologies and its intensity of usage as well as the impact on livestock productivity suggested that adoption did not result in higher income for beneficiaries of the technology as a result of different socioeconomic and institutional factors of production among others (Njarui et al., 2017; Beshir, 2014; Gebremedhin et al., 2003; Mwangi and Wambugu, 2003; Kumwenda and Ngwira, 2003). These studies evaluated the intensity and rate of adoption of better fodder technologies. However, they were unable to evaluate the specific panicum forage technologies that have recently been made available to farmers and agro-pastoralists.

Therefore, this study is aimed at identifying determinants of adoption decisions and the intensity of adoption of improved panicum forage technologies in pastoral/agro-pastoral areas of Southern Ethiopia. Furthermore, South Omo is one of the zones in southern Ethiopia with total area coverage of 108ha for panicum forage production (SOZLFO, 2020). However, the information regarding how many pastoralists or agro-pastoralists grow panicum forages on their farm, the knowhow about what is best to do with panicum forages or how to use them efficiently, and what associated social, economic, household, and institutional constraints of production or determinants of adoption decision and adoption intensity of panicum forage production has not yet been seen in the study site.

2. Research Methodology

2.1. Description of the study area

Dasenech district is one of the ten districts in the South Omo zone of Southern Ethiopia. The economic activity in the district is mainly based on livestock, crop, and fishing production. Crop production is mainly dependent on irrigation from the Omo River and Omo overflow. In the district, rainfall is both low and irregular, making the pastoralists and agro-pastoralists vulnerable to famine and drought. Flood-recession agriculture along the banks of the Omo River is considered more reliable than rain-fed shifting cultivation. However, this system of production is limited in extent and contributes little to the overall subsistence needs of the local agro-pastoral groups. Major crops grown are sorghum, maize, and bananas. Major livestock types kept in the district are cattle, sheep, and goats. In terms of livelihood patterns of households, the district is under the South Omo Pastoral Livelihood, distinguished by its semi-arid climate, with low and erratic rainfall, low altitudes, and warm temperatures. According to the Central Statistical Agency projection, the estimated population in the district is about 66,000. The district is administratively divided into 39 kebeles, of which 28 kebeles are along the Omo River practicing flood-recession agriculture in addition to cattle rearing and recently practicing forage production, particularly panicum, Rhodes, and elephant grass.

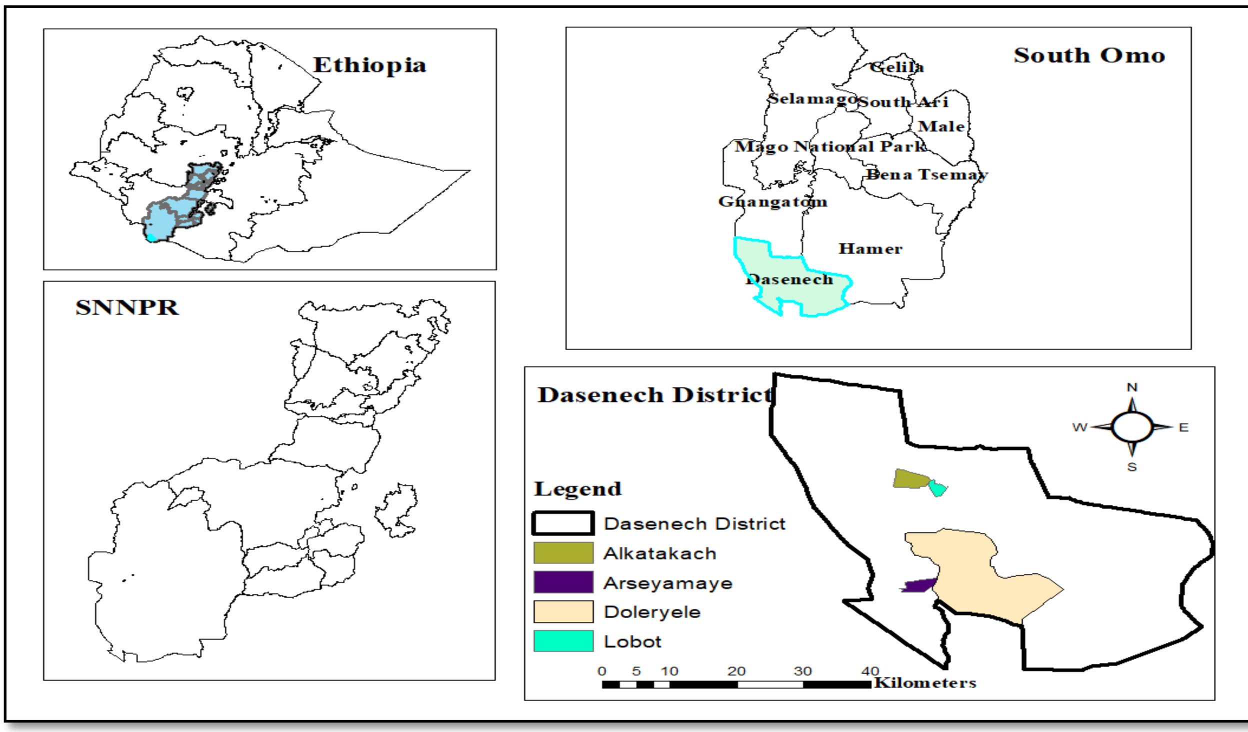

Figure 1: Map of the study area

2.2. Research design, data types and sources

The study employed a cross-sectional survey research design. Primary data was collected from the study population at a single point in time to examine the relationship between variables of interest. Both qualitative and quantitative data types were collected from primary and secondary data sources. The primary data collected from households includes information on household households, socioeconomic, land characteristics, institutional factors, and other factors that are supposed to explain smallholder improved panicum forage producers. Secondary data sources used for this study were journals, relevant textbooks, government and non-government reports, and South Omo zone agricultural office and district agricultural office reports.

2.3. Sampling procedure, sample size determination, and method of collection

The study site was purposefully selected based on improved panicum forage production and availability. Multistage stage sampling techniques were employed to draw sample household heads. In the first stage, potential kebeles in panicum forage production were identified based on district information and consequently, five kebeles were randomly selected. In the second stage, the number of sample households from each sample kebele was determined from the recent lists of households using a proportional size. In the third stage, given the relative homogeneity of households in terms of their socioeconomic characteristics and livelihood styles, samples of households were drawn using a simple random sampling method from each kebele. To determine sample size the formula described by Yemane (1967) was used [1]. Accordingly, the sample size was 154, which was adjusted to 140 pastoral households during data cleaning to be consistent and reliable for the analysis.

$$n = \frac{N}{1+N(e)2} \quad [1]$$

Where

- n is sample size for the study
- N is the population of interest (14895)
- e is the precision level, which was 0.08

Formal and informal methods of data collection were implemented to acquire primary data. A key informant interview and focus group discussion with pre-defined social groups (3 elderly, 3 agro-pastoralists, 2 youth, 2 women, and 2 development agents) were conducted before the formal survey to collect general information about the study site and improve panicum forage production. A checklist was used to guide the informal discussion conducted to generate data that could not be collected from individual interviews. Formal data collection was employed with the help of a pre-tested structured questionnaire. With the help of local enumerators, researchers collected data during the 2021 production season.

2.4. Descriptive analysis and Double hurdle model

The descriptive statistics employed were mean, standard deviation, frequency distribution, percentages, chi-square tests (for categorical variables), and t-tests (continuous variables) and were used to describe and examine adopters and non-adopters of panicum forage technology.

2.4.1. *The adoption decision of smallholder agro-pastoralists and the intensity of improved panicum forage production*

The intensity of increased panicum forage production and the decision to adopt it were examined using the Double Hurdle Model. This concept presupposes that farmers must overcome two obstacles when making agricultural decisions (Cragg, 1971; Sanchez, 2006; Humphreys, 2013). According to Cragg (1971), there are two stages of adoption challenges. The first stage involves deciding whether or not to embrace the technology, while the second stage has to do with the adoption level. It is believed that there is a connection between the two layers (Berhanu and Swinton, 2003). Therefore, this proposed association has been examined in a number of recent studies (Gebremichael and Gebremedhin, 2014; Katengeza et al., 2012; Akpan et al., 2012; Mal et al., 2013).

Therefore, a double hurdle model was chosen because it allows for the distinction between the determinants of adoption and the level of adoption of improved panicum forage production through two separate stages. This model estimation procedure involves running a probit regression to identify determinants of adoption decisions in the activity using all of the sample population in the first stage, and a truncated regression model on the adopting households to analyze the adoption intensity in the second stage. In our case, the first stage of the double hurdle model examined the determinants of the adoption decision to panicum forage and was analyzed by means of the probit.

Burke (2009) claims that the double hurdle model (DHM) is helpful because it enables a subset of the data to accumulate at a certain value without introducing bias in the second stage's estimation of the determinants of the continuous dependent variable, allowing you to collect all the data from the participant's remaining sample. Therefore, there are no limitations on the components of explanatory variables in each decision stage in the double hurdle model. Therefore, the factors influencing the decision to use improved panicum forage and the degree of adoption can be studied individually.

As a result of this, estimates for adoption decisions can be generated using probit regression, and truncated regression can be used to investigate the number of adoption decisions. Burke (2009) asserts that the separable in estimates should not be confused with the possibility of separability. We start in the first stage (adoption decision), where households are classified according to whether they are adopters or not by using probit analysis, and from there we calculate the likelihood function. To do so, let Pi denote a binary indicator function, taking the value "1" if agro-pastoralists adopted panicum forage in the 2021 production year and "0" otherwise. Further, let Qi denote the proportion of area covered by panicum forage of the total land owned in the specified production year. We can then derive the likelihood function for the standard double hurdle model as follows:

$$logLprobit = L(\alpha,\beta) = [1-\phi(pi\alpha)\phi\frac{xi\beta}{\sigma} \quad [2]$$

$$\text{Log}\, truncate = [\, [[\frac{\phi(pif)}{\sigma}][\frac{Q(Q1-x\prime L\beta}{\sigma}]]\,] \quad [3]$$

Where

- Φ denotes the standard normal CDF, is the univariate standard normal PDF
- σ is the variance of error terms
- logLprobit is the log-likelihood for a probit
- Log truncate is log-likelihood for a truncated regression with truncation at zero value of the continuous dependent variable in the second stage (proportion of area covered by panicum forage from the total land owned).

The log-likelihood from the Cragg-type double hurdle model is therefore the sum of the log-likelihood from probit and a truncated regression.

The fact that these two component parts can be completely separated and used individually to estimate, reduced regression is more beneficial (Ground and Koch, 2008; Aristei and Pieroni, 2008; Burke, 2009). Then the log-likelihood function for the double hurdle model was:

$$LogL = L(\alpha,\beta) = [1-\phi(pi\alpha)\phi\frac{xi\beta}{\sigma}] + [\, [[\frac{\phi(pif)}{\sigma}][\frac{Q(Q1-x\prime L\beta}{\sigma}]]\,] \quad [4]$$

Where

- Φ and ϕ were the standard normal cumulative distribution function and density function, respectively.

The maximum likelihood estimation (MLE) method was used to estimate the log-likelihood function. The test statistics double hurdle model was used as described by Greene (2000).

$$LR = -2[logLLT - (logLLP + logLLTR)] \approx x^2 \; or$$

$$LR = -2[LLTobit - LLHurdle] \quad [5]$$

Where:

- LT, LP and LTP are the log-likelihoods of the Tobit, probit and truncated regression models, respectively.

Rejecting the null hypothesis indicates that the choices regarding adoption and level adoptions are made at two different phases and support the double-hurdle model's superiority over the Tobit model.

2.4.2. *Constraints on the production of improved panicum forage*

Kendall's coefficient of concordance was used to rank constraints associated with the use of improved panicum forage production. The respondents mentioned and ranked constraints they faced on the production of improved panicum forage using the five-point Likert scale, where +1 = most important constraints, 1 = more important constraints, 0 = important constraints, -0.5 = less important and -1 = least important. The values of Kendall's coefficient of concordance were calculated using the formula below [6].

$$W = \frac{n[\Sigma T^2 - (\Sigma T)^2 / n}{nm^2(n^2\text{-}1)} \quad [6]$$

Where

- W stands for Kendall's coefficient of concordance
- m stands for the number of respondents
- n stands for the number of constraints
- T stands for the sum of rankings for the constraints being ranked

2.5. Variable definition and measurement as well as prior expectations

This section illustrates the variable description, measurement of variables, and prior expectations as indicated in Table 1.

Table 1: Variables, their measurements and expectations in the Double Hurdle Model

Variables	Measurement	Expected sign
Dependent variables		
Adoption	1 if agro pastoralist has adopted panicum forage, 0 if agro pastoralist has not adopted	
Intensity of adoption	Proportion of area covered by improved panicum forage from the total land owned	
Explanatory variables		
Sex	1 if male, 0 if female agro pastoralist	-/+
Age	Years	-/+
Education level (formal)	Years of schooling	+
Farm size	The total area of land managed by a household head	-/+
Family size	Number of family members in a household living for more than 6 months	+
Livestock holding	Number of livestock owned by a household head(TLU)	+
Price of forage seed	Market price of a forage seed (ETB)	+
Extension contact	1 if agro pastoralist contact with extension agents in a month, 0 otherwise	+
Credit access	1 if agro pastoral get credit services, 0 otherwise	+
Feed shortage	1 if feed shortage is a problem for agro pastoral, 0 otherwise	-
Irrigation to access	1 if access to irrigation, 0 otherwise	+
Member of cooperative	1 if member of panicum forage production cooperative, 0 otherwise	+
Experience in forage production	Number of years, agro pastorals cultivated panicum forage	+
Distance to market center	Distance to nearest market center in hours/minute	-
Distance to training center	Distance to nearest agro pastoral training center in hours/minute	-

3. Results and Discussion

3.1. Socioeconomic, institutional, and household characteristics of respondents

3.1.1. *Sex, age, education level, and family size of the respondent*

Male household heads made up 75% of adopters and more than 74% of panicum growers in the pooled sample. The average age of panicum forage growers was 37 years, showing that panicum forage growers in the research area are in their productive age category. On average, both adopters and non-adopters have less than one year of formal education. As a result, neither adopters nor non-adopters of panicum forage producers have completed primary school, suggesting that both groups had limited access to formal education and a low level of education overall in the research area. The average family size is nearly seven in pooled data, indicating family size for both adopters and non-adopters of panicum forage.

3.1.2. *Experience of forage production, feed shortage and extension visit*

Panicum forage growers at the study site had an average of 4 years and a maximum of 8 years of experience in growing forage, indicating that some of them had good knowledge of forage production. On average, an adopter of panicum forage has been working in forage production for two more years than a non-adopter. Major feed resources for livestock in the study site are free grazing, crop residue, panicum forage, and elephant grass. However, about 51% of the agro-pastoralists in the pooled sample faced feed shortages and did not produce improved forages due to lack of irrigation water access and limited supply of improved seed; and more than half (51%) of the adopters have faced feed shortages for livestock. Thus, the lack of improved feed and forage limits the productivity of livestock production in the study site, and the study by Galmessa *et al.* (2013) reported that an inadequate supply of quality feed is the major factor limiting dairy productivity. In 2021, 88% of adopters had visits by extension agents regarding forage cultivation, including panicum forage, whereas 54% of non-adopters did not. The aggregate data suggests that around 81% of the respondents had extension contacts. This demonstrates that extension work regarding forage cultivation is relatively good in the area.

3.1.3. *Access to irrigation water and credit services, and cooperative membership*

About 91% of adopters had access to irrigation water for panicum forage production, compared with 67% of non-adopters at survey time. The aggregate data reveals that about 77% of the respondents had access to irrigation water. Only 9% of adopters and 3% of non-adopters had access to credit services. In the pooled sample, 8% of the panicum growers had used credit services. This demonstrates that the agro-pastoralists in the study area are less experienced in obtaining financial services. Additionally, the absence of financing has frequently been mentioned as a productivity problem, particularly for small-scale farmers and pastoral herders (O'Lakes, 2010). About 37% of the panicum producers in the pooled sample were involved in panicum forage production cooperatives. This shows that agro-pastoralists in the study site are less involved in panicum forage production cooperatives. About 47% of adopters were involved in cooperatives for panicum forage production, compared with 3% of non-adopters at survey time.

3.1.4. *Distance to agro-pastoral training and nearest market center, and market price of panicum forage*

Both adopters and non-adopters have nearly the same walking distance to a knowledge and experience sharing center or agro-pastoral training center. This might be due to agro-pastorals being settled in certain common places in a group manner as a government strategy to settle them rather than their previous experience of mobile nature in the area. The distance between adopters and non-adopters to the nearest market is only one to two minutes-walking distance. The aggregate data indicates that agro-pastorals have an average of a 15-minute walking distance to the nearest market to sell or buy either panicum seed or other agricultural inputs or products. Awareness about the current market price of panicum forage stimulates the adoption decision to grow panicum forage. Adopters reported that the current market price of panicum forage seed is 240 ETB per kilogram, whereas non-adopters reported 119 ETB per kilogram. But during survey time, the market price of panicum forage in the district market was 350 ETB per kilogram. This implies that adopters have slightly better information regarding panicum forage seed than non-adopters in knowing the real market prices

3.1.5. *Livestock holding and farm size*

The mean tropical livestock unit (TLU) for adopters is about one unit higher than that of non-adopters. This means the adopters have more livestock holdings than non-adopters. The mean TLU for adopters and non-adopters was 9 and 8, respectively. The mean landholding for adopters is about 0.81 hectares, which is higher than that of non-adopters (0.77 hectares). This suggests that adaptors with higher land holdings could allocate land for panicum forage compared to non-adopters with lower land holdings. The average proportional area covered by panicum forage for adopters was 0.22 hectares.

As per the key informant discussion, panicum forage production has been started in 2018 by PCDP and the district livestock and fishery office. Following a slow initial rate of uptake in the first few years, the adoption rate accelerated and almost 150 households had adopted and planted panicum forages at the individual farm level by 2021. Planted forages had also spread in the area and were incorporated into development plans by local governments, NGOs, and development projects. Planting panicum forage is now becoming the 'normal practice' in the district and currently, about 28 kebeles are producing panicum forage. Various stakeholders such as the office of livestock and fishery resource, Jinka Agricultural Research center, RPLRP, FAO, PCDP, and others were engaged in the promotion of different forages mainly grass types such as panicum, Buffelgrass, Rhodes, elephant grass; legumes type lablab, cowpea and tree type like Pigeon pea, Sesbania sesban, and Leucaena. The different varieties of forage have varying levels of adoption rates. As revealed in key informant discussions with experts and focus groups discussions with agro-pastoralists the two major forages that have relatively been expanded and grown in the study sites included panicum and elephant grass. The others forage types mentioned were less adopted forage by agro-pastoralists. The reasons behind the less adoption rates of forage are associated with the interest of the agro-pastoralists to give priority to cash forage like panicum and less managed forage like elephant grass.

Table 2: Descriptive statistics of socioeconomic, institutional and household characteristics

Variables	Adopters (n=109)					Non-adopters (n=31)					All (n=140)					
	N	*Mean*	*Std. dev.*	*Min*	*Max*	*N*	*Mean*	*Std. dev.*	*Min*	*Max*	*t-test*	*N*	*Mean*	*Std. dev.*	*Min*	*Max*
Sex (1=male)	109	0.75	0.43	0	1	31	0.68	0.48	0	1	-0.83	140	0.74	0.44	0	1
Age (years)	109	37.97	9.11	19	65	31	34.58	7.89	22	55	-1.88*	140	37.22	8.95	19	65
Education (years)	109	0.19	0.09	0	8	31	0.48	1.39	0	6	1.32	140	0.26	1.09	0	8
Family size (number)	109	6.73	2.44	1	15	31	6.94	3.13	2	14	0.38	140	6.78	2.59	1	15
Feed shortage (1=yes)	109	0.51	0.50	0	1	31	0.48	0.51	0	1	-0.29	140	0.51	0.50	0	1
Experience of forage production (years)	109	4.18	1.81	0	8	31	1.58	2.20	0	6	-6.72***	140	3.61	2.18	0	8
Panicum forage production cooperative membership (1=yes)	109	0.47	0.50	0	1	31	0.03	0.18	0	1	-4.74***	140	0.37	0.48	0	1
Market price of panicum forage (ETB)	109	240.3	91.2	0	350	31	119.4	145.3	0	350	-5.64***	140	213.5	116.4	0	350
Access to credit service (1=yes)	109	0.09	0.29	0	1	31	0.03	0.18	0	1	-1.08	140	0.08	0.27	0	1
Distance market center(minute)	109	15.32	12.02	0	45	31	14.19	13.86	0	40	-0.44	140	15.07	12.41	0	45
Extension visit (1=yes)	109	0.88	0.33	0	1	31	0.54	0.51	0	1	-4.38***	140	0.81	0.39	0	1
Access to irrigation water (1=yes)	109	0.91	0.42	0	1	31	0.67	0.52	0	1	-2.58**	140	0.77	0.41	0	1
Livestock holding (TLU)	109	8.67	15.9	0	159	31	7.79	5.58	1.25	20.53	-0.29	140	8.45	14.28	0	159
Distance to agro pastoral training center (minute)	109	20.01	10.40	0	70	31	20.23	10.45	0	50	0.72	140	20.06	14.1	0	70
Farm size (ha)	109	0.81	0.33	0.5	2	31	0.77	0.36	0.25	2	0.43	140	0.78	0.35	0.25	2
Adoption (1=yes)	-	-	-	-	-	-	-	-	-	-	-	140	0.78	0.42	0	1
Proportion of area covered by panicum forage	109	0.22	0.20	0	1.25	-	-	-	-	-	-	-	-	-	-	-

3.2. Constraints of panicum forage production

Table 3 shows the major constraints prioritized by the respondents on panicum forage production including problems in irrigation water pump or breaking down of primary canals, informal seed suppliers/sellers harvesting of immature seeds due to awareness problems, insufficient seed provision by the government and weak extension support and training. Insufficient irrigation water pump and or break down of primary canals harvesting immature seeds were the 1st and 2nd main constraints in panicum forage production. On the other hand, the involvement of informal seed suppliers/sellers and fluctuations in seed supply by governments and NGOs to agro-pastoralists were mentioned as the third and fourth main constraints in panicum forage production. The absence of sufficient planting material as well as limited extension provision on forage management and harvesting has been indicated as a hindering factor to the adoption of improved forage (Ndah *et al.*, 2022). These constraints could lead to less adoption of panicum forage, reduced economic benefits and incomes from the production of improved forages. Kendall's coefficient of concordance shows that there was a low (31.7%) level of agreement among smallholder agro-pastoralists in ranking of constraints.

Table 3: Major constraints of agro-pastoralists in panicum production

Constraints	Level of agreements (frequency/percent)					Mean rank	Ranking
	Strongly agree	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*		
Informal seed suppliers/sellers	38(27.1)	29(20.7)	51(36.4)	10(7.1)	12(8.6)	3.88	3rd
Fluctuation of seed provision by government and support	8(5.7)	10(7.1)	54(38.6)	50(35.7)	18(12.9)	2.92	4th
Market access problem	8(5.7)	8(5.7)	63(45)	18(12.9)	43(30.7)	2.47	6th
Awareness problem of harvesting un matured seed	53(37.9)	28(20)	35(25)	11(7.9)	13(9.3)	4.18	2nd
Irrigation water pump problems or breaking of primary cannels	71(50.7)	49(35)	15(10.7)	3(2.1)	2(1.4)	4.88	1st
Weak extension support	14(10)	36(25.7)	21(15)	33(23.6)	36(25.7)	2.58	5h
Test statistics							
Number of observations	140						
Kendall's coefficient of concordance	0.317						
Chi-square	221.595						
Degree of freedom	5						
Asymptotic significance	0.000						

Source: own result, 2021

3.3. Determinants of adoption decision and intensity of adoption of improved Panicum forage

3.3.1. *Sex of the respondents*

The sex of the respondents is negatively related to the adoption intensity of improved panicum forage production (Table 4). This means that male agro-pastorals allocate a lower proportion of area to improved panicum forage production as compared to their female counterparts. The reason for this is that male agro-pastorals might compare many alternatives to growing either forage or crops while allocating land because of their access to more agricultural information than their female counterparts. Female agro-pastorals in the study site cut and carry panicum forage to feed cattle and shoat, sell fresher biomass than their male counterparts, and want to allocate more land for panicum forage production. The marginal effect indicates that the proportion of area allocated to improved panicum forage production by male forage producers decreases by 5.6% compared to their female counterparts. However, the study by Gebremedhin *et al.* (2003) disclosed that the gender of the household head had no impact on forage adoption.

3.3.2. *Experience in panicum forage production*

It is positively related to agro-pastoral adoption decisions (Table 4). The likelihood that agro-pastoralists will adopt improved panicum forage likewise rises as years of forage planting and gaining advantages grow. When all other conditions are maintained constant, the marginal effect shows that one additional year of growing panicum forage improves the likelihood of adoption and intensity by 3.1%. This might be due to agro-pastoralists getting more benefits from panicum production and being willing to expand the production. Because they can access information from a variety of sources, more experienced agro-pastoralists are more likely to have access to forage value and seed price information than less experienced ones. This is because households have already been exposed to technologies and realized their importance. An analogous result was stated by Van Den Berg (2013) on the adoption of improved farming practices.

3.3.3. *Access to irrigation water*

Access to irrigation water had a direct relationship with the adoption of improved panicum forage production. Agro-pastoralists who had access to irrigation water in the 2021 production season had about 0.59% more probability of adopting panicum forage than those with no access to irrigation water. Access to irrigation water enables agro-pastoralists to plant panicum seeds, irrigate them and get more benefits from them than those who have no access to irrigation water. The result is consistent with the study by Asmera and Yidnekachew (2021), which indicated that agro-pastoralists who are nearby the water source may have more access to water for their household consumption, livestock, and crop watering than those who are distant from water sources. Irrigation access offers the chance for forage production to the farmers, and those farmers who have good access to irrigation grow forage three times a year (Shiferaw *et al.*, 2018).

3.3.4. *Cooperatives in panicum forage production*

The forage production cooperative was positively related to the adoption decision of the improved panicum forage production (Table 4). When all other factors are held constant, being a member of a panicum-growing cooperative enhances the adoption of panicum forage by 6.1% as compared to non-members of cooperatives. This is because agro-pastoralists in groups have easier access to financing, agricultural inputs, capacity-building programs, success stories from other agro-pastoralists, and extension services since a group can access these resources more easily than individuals. Amfo and Ali (2020) assert that farmers in cooperatives are more likely to exchange ideas and learn from one another over time, increasing the adoption of agricultural technologies. Cooperative membership of beneficiaries to introduced technologies could enhance individual farmers' bargaining power and reduce transaction costs, hence creating an opportunity for extremes that could be used to announce improved forages for dairy cows (Kassie *et al.*, 2013).

3.3.5. *Distance to training center*

Distance to the training center was negatively related to the adoption decision of improved panicum forage production. The marginal effect indicates that as the distance from the agro-pastoral home to the agro-pastoral training center increases by one more minute, the adoption of panicum forage decreases by 2.1%. This is because the adoption process may be aided by being close to the training facility and receiving knowledge about various agricultural inputs. Growers of panicum forage who were closer to the training center and those who received information were more likely to adopt the panicum forage than those who were farther away. According to Zekarias (2016), farmers who live a long distance away from a farmer's training center have less access and utilization opportunities for forage technology, which lowers the adoption probability of improved forages. Similarly, findings by Mwakaje (2012) and Kassie *et al.* (2013) reported that access to training centers and information plays a key role in the adoption of introduced forage technologies.

3.3.6. ***Market price of panicum forage***

Market price was positively related to the intensity of the adoption of panicum forage. Agro-pastoralists who sell panicum biomass and seed and get a high price advantage have a higher probability of allocating more areas for panicum forage than those who do not get income or sell panicum seed or biomass. From the marginal effect, a unit increase in a panicum seed price increases the area allocated to panicum forage by 0.03%, other factors being held constant. The positive result of the market price of panicum forage, either to sell or to buy to grow, is an essential factor in deciding the allocation of land. Previous findings by Wandji *et al.* (2012) noted that the positive perception and knowledge of the price of characteristics of new technology have a significant effect on their adoption. The high price of forage seeds and farm inputs is one of the reasons for the non-adoption of some improved forages in Africa (Gebremedhin *et al.,* 2003; Mwangi and Wambugu, 2003; Kumwenda and Ngwira, 2003; Morris *et al.*, 2015).

3.3.7. ***Distance to marketing center***

It had a negative relationship to the intensity of adoption of improved panicum forage. The marginal effect suggests that a one-minute increase in walking distance from the agro-pastoral home to the market center decreases the tendency of the area allocated to panicum forage production by 11.4%, all other things being constant. This implies that the panicum forage growers who were further away from the market center were less likely to allocate an area to panicum forage than those who were closer to the market center. This might be due to less access to market information like the price of panicum seed and its importance. Similar findings by Beshir (2014) reported that distance from farmers' homes to the market center has a negative effect on the adoption of improved forages as farmers get different inputs from nearby markets. Proximity to markets usually encourages market participation by reducing transaction costs, thereby enhancing the adoption of improved forages (Gebremedhin *et al.,* 2003).

3.3.8. ***Access to credit service***

Credit access was positively related to the adoption intensity of panicum forage production (Table 4). The marginal effect indicates that agro-pastoralists who have access to credit services have a higher adoption intensity of panicum forage production compared to their counterparts by about 9.9%, other factors held constant. This means that agro-pastoralists who have access to credit services allocate more land for panicum forage production than those who have no access. This is because it enhances the opportunity to get additional income, and its accessibility reduces the transport cost, and farmers may learn more about the technology by observing; this furthers its adoption (Dehinenet *et al.*, 2014). The study by Adicha and Mada (2020) revealed that the accessibility of credit facilities is a prerequisite for a technology to be adopted and promoted properly. According to earlier research, having access to financial services gives farmers a strong chance to build up assets and buy various agricultural technologies, such as panicum forage technologies (Yehuala *et al*., 2013; Muzari *et al*., 2012; Akudugu *et al.*, 2012; AE *et* al., 2017; and Quddus, 2012).

3.3.9. ***Livestock holding***

It had positively related to the allocation of the area to grow panicum forage. Other factors held constant, a one-unit increase in total tropical units increases the area allocated to panicum forage by 0.3%. This indicates that agro-pastoralists with a great number of livestock were more likely to allocate land and grow panicum forage for their livestock feed as well as have a chance to sell biomass and seed. Similar findings by Beshir (2014) suggest that livestock holding in tropical livestock units has a positive effect on the probability of adoption of improved forages due to the availability of cash to buy the technology, as livestock in agro-pastoral areas is considered an asset that could be used either in the production process or in exchange. Njarui *et al.* (2017) reported that a large herd of cattle requires a large amount of feed and an area allocation to grow forage.

Table 4: Determinants of adoption decision and intensity of adoption of improved panicum forage

Explanatory variables	Coefficients (standard error)		
	Adoption	Intensity of adoption	Average marginal effects
Sex (1=male)	0.630(0.404)	-0.180(0.069)***	-0.056(0.030)*
Age (years)	0.009(0.024)	-0.002(0.004)	-0.0005(0.002)
Education (years)	-0.196(0.109)*	0.018(0.023)	0.001(0.010)
Family size (number)	-0.038(0.065)	0.014(0.012)	.0049(0.0052)
Feed shortage (1=yes)	-0.413(0.336)	0.109(0.058)*	0.033(0.031)
Panicum forage production experience (years)	0.372(0.101)***	0.041(0.018)**	0.031(0.008)***
Panicum forage production cooperative membership (1=yes)	1.913(0.452)***	-0.016(0.061)	0.061(0.018) ***
Market price of panicum forage (ETB)	0.0016(0.0015)	0.0006(0.0003)**	0.0003(0.0001)**
Access to credit service (1=yes)	-	0.229(0.136)*	0.099(0.046)**
Distance to market center(minute)	-	-0.264(0.120)**	-0.114(0.032)***
Extension visit (1=yes)	0.008(0.013)	0.002(0.002)	0.001(0.001)
Access to irrigation water (1=yes)	0.054(0.017)***	0.003(0.002)	0.003(0.001)**
Livestock holding (TLU)	0.010(0.011)	0.005(0.0006)***	0.003(0.0006)***
Distance agro pastoral training center (minute)	-0.335(0.108)***	-0.021(0.017)	-0.021(0.008)***
Farm size (ha)	-0.529 (0.364)	0.111(0.089)	0.029(0.031)
Constant	-.677(0.961)	-0.017(0.187)	-
Number of observations	140		
Wald chi-squared (15)	163.55		
Probability chi-squared	0.0000		
Log pseudo likelihood	23.158		
Lnsigma			
Constant	-1.534(0.165)*		
/sigma	0.216(0.036)		
Model variance-covariance matrix of the estimators (VCE)		Robust	

Note: Selection and intensity models must differ at least in one explanatory variable in order to use Cragg hurdle regression. Thus, selection model did not include access to credit services or the distant market center. Significant levels at 1%, 5%, and 10% are indicated by ***, **, and *, respectively.

4. Conclusions and Recommendations

Improved panicum forage production is becoming an important vendor in livestock feed production systems and a source for income generation of agro-pastorals. Understanding how household characteristics and institutional and socioeconomic factors affect the adoption and intensity of improved panicum forage production in the area was very important. Access to irrigation water, market distance, and membership in cooperative were major factors for the production of the feed in the study site. According to the study results adoption decision for panicum forage production is influenced by access to irrigation water, the education level of household heads, experiences in panicum forage production, cooperative membership and distance to the training center. The intensity of adoption is influenced by feed shortage, sex of the respondents, credit access, distance to market or market information, experience in panicum forage production, prices of biomass and seed, and the number of livestock holdings. Working towards the improved accessibility of irrigation water, the establishment of cooperatives of agro-pastoralists, provision of credit opportunities and market information by responsible stakeholders are recommended to enhance the adoption and production of panicum forage in the study area.

Competing interests

Authors declare that there is no conflict of interest.

Acknowledgment
The authors would like to acknowledge Southern Agricultural Research Institute and Jinka Agricultural Research Center for financial support.

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Association of some weather factors with fish assemblage in Asejire Lake, South-western Nigeria

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Received: August 20, 2022 **Accepted:** November 5, 2022

Abstract: *With the increasing human population, it is important to investigate the condition of Asejire Lake for sustainability. To this end, the effects of some weather factors were investigated on the fish assemblage, so as to provide necessary information to complement the dearth of reports about weather factors on the Lake. The study area was partitioned into three stations (upper, middle and lower) with fortnight collection of water samples, fish sampling and weather parameters for a period of 12 months (November 2017 – October 2018). Water samples were measured in situ using appropriate kits for pH, ammonia, nitrite and nitrates, dissolved oxygen and water temperature. Monofilament gill nets (40 mm and 60 mm) were used for fish sampling and were sorted and identified using appropriate monographs. The mean values across the sampling stations for temperature, pH, dissolved oxygen, ammonia, nitrates and nitrites were 18.36 ± 0.41°C, 7.30 ± 0.06, 2.37 ± 0.10 mg/L, 1.25 ± 0.05 mg/L, 1.34 ± 0.33 mg/L and 0.31 ± 0.03 mg/L, respectively. Across the months, mean values were 17.94 ± 0.48 °C, 2.67 ± 0.21 mg/L, 7.22 ± 0.21, 0.23 ± 0.02 mg/L, 0.13 ± 0.02 mg/L and 3.03 ± 0.03 for temperature, DO, pH, ammonia, nitrite and nitrates, respectively, with significant values ($P < 0.05$) among some parameters. A total of 1443 individual fishes (720 in the dry and 723 in the wet season) belonging to 27 species were encountered. March had the highest overall relative abundance of fish (23.77%) with Chrysichthys nigrodigitatus being the most abundant species (39.32%). March (47.64%) and April (32.78%) recorded the highest fish abundance in the dry and wet seasons respectively. Rainfall (540 mm) and temperature (35.50 °C) were highest in the month of September. The trend of rainfall and temperature was observed to increase over the months with t-values of 1.77 and 1.64 respectively. A negative relationship was observed between fish abundance with temperature (b_1= -1.08) and rainfall (b_1 = -0.26). It was observed that temperature values increased and rainfall values varied. Therefore, activities must be geared towards environmental management and consciousness of aquatic resources because of sustainability.*

Keywords: Anthropogenic activities, Asejire Lake, Fish diversity, Water quality parameters

1. Introduction

Weather describes the day-to-day state of atmospheric conditions of an area and it can be influenced by interacting factors such as latitude, elevation, nearby water, ocean currents, topography, vegetation, prevailing winds and human activities. When such conditions are above or below recommended limits, it may alter the physiological processes in the fish such as spawning, survival, rate of recruitment into the exploitable phase of the population, population size, production, yield, food composition and availability (Obot *et al.*, 2016). Fish are connected with their immediate environment and are therefore highly vulnerable to changes in weather patterns. These impacts can vary from the coastal areas to the drier northern parts of the country (Froese *et al.*, 2022). The effects of rainfall and temperature have been reported to pose a significant impact on Nigeria's freshwater and marine aquatic systems and hence on the country's fisheries resources (Gaines *et al.*, 2018). The interplay of rainfall and temperature governs other environmental factors and they can predict the state of the atmosphere (Sixth Assessment Report, 2021). The availability of water in its right quality and quantity plays an essential role in the existence of all living organisms. This valued resource is increasingly being threatened due to its use for various economic, domestic and industrial uses by the increasing human population (Froese *et al*., 2022).

Conversely, the fish species which make these water bodies their haven are affected by water pollution which may be due to the resultant discharge of wastes directly or indirectly into the water bodies. In such areas, fish may be affected in terms of abundance, and biodiversity, migration can occur when water quality is not tolerable and death is imminent in extreme cases. Asejire Lake is encompassed with various domestic and industrial activities; a prominent one is the Nigerian Bottling Company (NBC) plant which manufactures soft carbonated drinks. The bottling plant extracts portable water from the lake for manufacturing activities and releases various solid and liquid wastes into the environment. A constant discharge of fumes was observed from the manufacturing plants which releases carbon monoxide gases and its derivatives into the atmosphere.

Another activity observed on the lake was the intensive fish cage culture system by Triton Company which releases all wastes from the fecal and uneaten feed directly into the lake. Other activities such as crop production, washing of clothes by community inhabitants, water extraction by tankers for domestic supply, dredging, bathing and human defecation were also observed around the lake. However, several studies on the effects of various human activities on the water quality and fisheries resources of the Lake have been reported (Obot *et al*., 2016; Ipinmoroti *et al*., 2018), but there is limited documented information on the effects of weather patterns (rainfall and temperature) on the fish biodiversity in the lake. It is pertinent to study these at this time because of the current concerns of global warming resulting from human activities and the noticeable vulnerability of Nigeria to climate change which has posed a major challenge to fisheries (Omitoyin, 2009).

This study therefore proposes necessary management procedures as elaborated by the Agenda 2030 of the United Nations Sustainable Development Goal number 14 (Life underwater). These measures incorporate adaptation and mitigation procedures towards climate resilience by human activities as elaborated by SDG 13 (Climate resilience). This study also seeks to investigate the effects of rainfall and temperature on fish assemblage in the Lake.

2. Materials and Methods

2.1. Description of the study area

Asejire Lake is a man-made lake that is created on Osun River and is geographically located on 7.3669^o N, 4.1333^o E (Aladesanmi *et al*., 2013). It was impounded in 1970 and supplies about 80 million liters of water per day to Asejire and Osegere water treatment plants. About 80% of the water is used for domestic purposes and the use of chemicals around the lake is banned. Diverse human activities such as agricultural activities, laundry activities, and water withdrawals for domestic uses were observed around the lake catchment. Despite the ban on farming activities, it was observed to be the predominant activity. The lake has a mean depth of 11 m^2, a length of 11.2 km, a surface area of 526 ha and a catchment area of 7242 km^2. The lake was partitioned based on accessibility and logistical characteristics into three sampling stations and sampled fortnightly from November 2017 to October 2018.

Upper station (US): It was located about 300 m away from the middle station and 750 m from the dam wall. This station was located in the North Eastern part of the Lake and characterized by floating aquatic Macrophytes and a dense population of vegetation around the catchment. A few human activities such as washing and farming were observed in this area.

Middle station (MS): It was located about 300 m away from the upper station and 250 m away from the lower station. This area was some wart in the middle of the lake and human activities were intense in this area. The Triton cage culture system was located in this area, as well as increased fishing activities because of the aggregation of fish species around the cage area which feed on the remains and escape of feed from the cages.

Lower station (LS): It was located towards the Southern part of the Lake at 250 m away from the middle station and 250 m away from the dam wall. This area was close to the dam wall which received all forms of waste flowing from the upper region of the lake. Floating wastes such as plastics, nylon, and floating aquatic Macrophytes were observed on the water surface within this area. The spillway which is used to regulate the lake water level was located in this area (Figure 1).

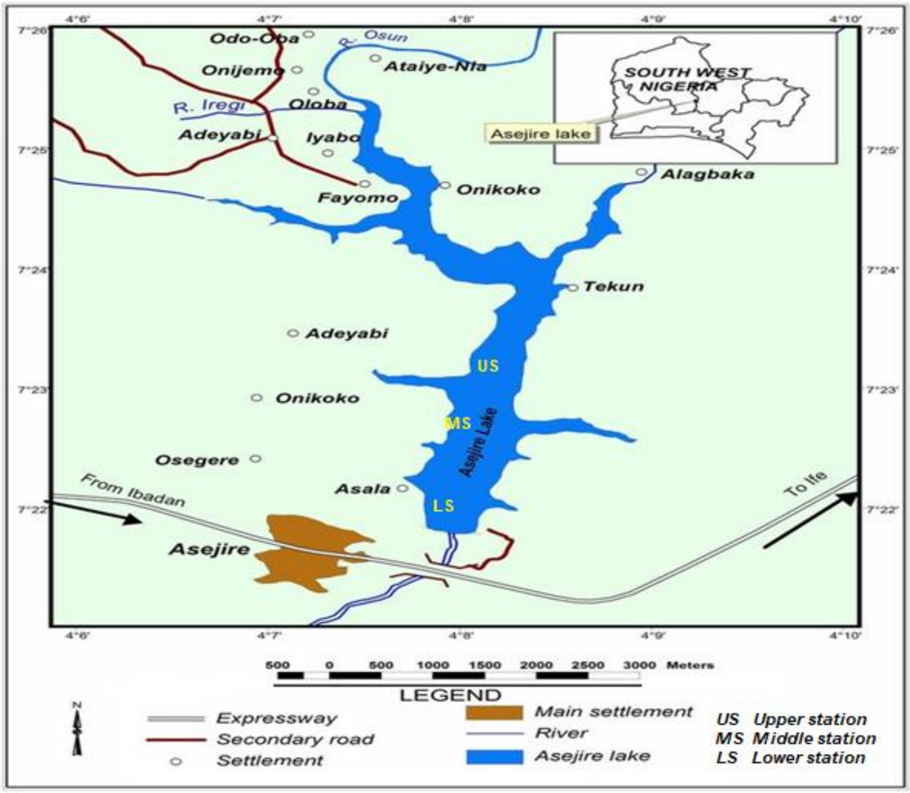

Figure 1: Map of Asejire Lake

2.2. Assessment of water quality

Water samples were collected fortnightly from each station using 10 ml sterilized sampling bottles between the hours of 0700 and 0900 GMT. The samples were measured *in situ* for Dissolved Oxygen (DO) concentration, temperature, pH, ammonia, Nitrite and Nitrates from November 2017 – October 2018.

2.2.1. *Dissolved oxygen*

Dissolved oxygen (DO) was measured using a DO meter manufactured by Lutron, United Kingdom (Model DO-5509) as described by the manufacturer. The meter was first calibrated and the probe was inserted into about 10 cm of the sample water so the water can cover the entire sensor on the probe. Readings were taken on the digital screen of the meter when it was steady and recorded in milligrams per liter (mg/L). The probe was rinsed after each measurement with tap water.

2.2.2. *Water temperature*

It was measured using a mercury-in-glass thermometer which was dipped into the water sample to a depth of 10 cm for about two minutes. Readings were taken when the mercury level in the thermometer was steady and recorded in degrees Celsius (°C).

2.2.3. *Ammonia*

It was measured using API Freshwater Master Test kit manufactured by MARS Fish care, United States of America. Water samples were poured into a 5 ml container and 2 drops of ammonia reagent A were added to the sample. It was allowed to stand for 30 seconds after which 1 drop of ammonia reagent B was added to the mixture. It was later left to stand for 10 seconds and the final colour of the mixture was compared with the ammonia colour chart provided by the manufacturer. Readings were taken from the corresponding colour on the chart and recorded in mg/L.

2.2.4. *pH*

The pH was measured using API Freshwater Master Test kit manufactured by MARS Fish care, United States of America. Water samples were poured into a 5 ml container and 2 drops of the pH reagent was added. The solution was left to stand for 30 seconds and the final colour of the mixture was compared with the colour chart so as to know the corresponding pH value of the sample.

2.2.5. *Nitrite*

They were measured using API Freshwater Master Test kit manufactured by MARS Fish care, United States of America. Water sample were poured into a 5 ml container and 2 drops of nitrate reagent was added to the sample. The solution was left to stand for 15 seconds and the final colour of the mixture was compared with the colour chart provided by the manufacturer. The corresponding value of the final colour was read and recorded in mg/L.

2.2.6. *Nitrates*

They were measured using API Freshwater Master Test kit manufactured by MARS Fish care, United States of America. The sample water was poured into a 5 ml container and 2 drops of nitrate reagent was added to the sample. The mixture was left to stand for 30 seconds and the final colour of the mixture was compared with the nitrate colour chart provided by the manufacturer. Readings were taken and recorded in mg/L.

2.3. Assessment of fish abundance and distribution

Fish species were collected fortnightly from the sampling stations using monofilament gill nets of mesh sizes 40 mm and 60 mm. These nets were set at each sampling stations between the hours of 1900 GMT and retrieved at 0700 GMT the next day as described by Kareem *et al.* (2015). The gears were retrieved, fish species collected and identified using monographs by Holden and Reeds (1978); Olaosebikan and Raji (2013), and their numerical abundance and distribution in each station were recorded.

2.4. Weather parameters

2.4.1. *Rainfall*

It was measured fortnightly from November 2017 – October 2018 using a standardized Stratus rain gauge (Model 6330), manufactured in the United States of America. It has a capacity of 280 mm, a weight of 0.9/1.8 kg and a size of 102 mm x 356 mm. It was placed in an open area so as to prevent obstruction from trees and ensure direct collection of water from the atmosphere into the rain gauge. The amount of rain collected was recorded in millimeters (mm).

2.4.2. *Atmospheric temperature*

It was measured fortnightly from November 2017 – October 2018 using Mason's Hygrometer (wet and dry bulb Thermometer) manufactured by Eisco labs, United States of America. It is usually wall-mounted and was placed around the Lake. It was used to measure atmospheric temperature as described by Camuffo (2019). The readings were taken on the tube when the mercury level was steady and values were recorded in degrees Celsius.

2.5. Statistical analysis

Descriptive statistics, such as numeric counts, percentages, means and standard deviations were used on data for fish assemblages, water quality parameters, and weather parameters. Turkeys' pairwise comparison was used to determine the level of significance among water quality parameters across the months and sampling stations. Linear regression analysis was used to determine the association between fish abundance and weather parameters (Equation 1). Linear trend analysis was used to observe the trends of rainfall and temperature over time (Equation 2). R-Statistical software was used for all statistical analysis at a 95% confidence level (P<0.05).

$$Y = bo + b1X \quad [1]$$

$$Yt = bo + b1 * t \quad [2]$$

Where:

Y = Fish abundance

b_o = Constant

b_1 = Regression coefficient/trend coefficient

X = Rainfall/temperature

Yt = Trends in rainfall/temperature

t = Time

3. Results and Discussion

3.1. Water quality parameters

The mean value of water quality parameters measured from the sampling stations and across the months during the study is presented in Tables 1 and 2 respectively. Across the sampling stations and months, the mean values were highest in the Middle station (18.44 ± 0.41 °C) and in February (22.00 ± 0.68 °C). Most of the mean values recorded from this study were below the recommended limits of 20 – 30 ºC for aquatic biota (FAO, 2022), except for February and April. The temperature results deviated from the mean value reports of 23.1°C and 25 °C from a Lake within the region (Olanrewaju *et al*., 2017; Sunday and Jenyo-Oni, 2018). Temperature is a very important parameter because it regulates the internal processes and body temperature of fish. Significant differences ($P<0.05$) in mean values were observed in December, July, August and September.

Most of the mean DO values across the sampling stations and months were below the recommended limits of 3 mg/L for aquatic biota (FAO, 2022), with the highest mean values in the upper station (2.71 ± 0.10 mg/L) and in June (3.64 ± 0.09 mg/L). An overall mean value of 2.37 ± 0.10 mg/L was measured across the sampling stations and it was lower than the recommended limit for aquatic biota (FAO, 2022). The DO concentration was observed to be high at the onset of the wet season and low at the end of the wet season. A possible reason could be due to the low temperature and turbulence of water by high winds. The DO level measured was low in the dry season, which may be due to the high metabolic rate and limited water turbulence. The low mean values were expected because of the increased levels of ammonia which inhibited DO in the lake thereby affecting fish species distribution (Beggel *et al*., 2021). The mean DO values in May – September were observed to be slightly above the recommended limits with significant monthly differences ($P<0.05$) observed in February, April, June, August and September. Across the sampling stations, the mean value in the middle section was observed to be significantly different ($P<0.05$) from other sections during the study. A possible reason for this may be the presence of the cage culture system which involves the intensification of supplementary feed and increased waste generation (Beggel *et al*., 2021).

Across the sampling months and stations, all the pH values were above the recommended limits of 6.5 – 8 for aquatic biota (FAO, 2022). Across the sampling stations, the highest pH was measured in the upper station (7.32 ± 0.06) with an overall mean value of 7.30 ± 0.06. For the sampling months, February had the highest mean monthly value (7.8 ± 0.00), and an overall mean monthly value was 7.29 ± 0.21. Significant monthly differences ($P < 0.05$) in mean pH values were observed in January, February, March, June, August and September. The pH value recorded from this study suggested that the condition of the water is between neutral to a slightly alkaline condition and is a tolerable level for the survival of fish species (Farombi *et al*., 2014; Obot *et al*., 2016).

Ammonia, nitrite and nitrates are products of decomposition. Nitrites are produced from a combination of Nitrosomonas bacteria and nitrates by Nitrobacter bacteria. The ammonia values across the sampling stations and months were extremely high when compared with recommended levels for aquatic biota (FAO, 2022). The highest mean value across the sampling stations was recorded at the middle station (1.96 ± 0.05 mg/L), and an overall mean value of 1.96 ± 0.05 mg/L was measured during the entire study. This was expected because the location of the cage culture system was in this area and it releases huge wastes from uneaten feed, excretory products and organic decomposition from the intensive culture system carried out (Beggel *et al*., 2021; Makori *et al*., 2017). This activity influenced the low dissolved oxygen as observed from the mean values in this station (Beggel *et al*., 2021).

Across the sampling months, the mean concentration of ammonia was highest in August (0.50 ± 0.03 mg/L) and September (0.50 ± 0.00 mg/L), and an overall mean of 0.21 ± 0.02 mg/L was measured during the entire study. These values were also higher than the recommended limit of 0.05 mg/L for aquatic biota (FAO, 2022), and significant monthly differences ($P<0.05$) were observed in the mean values measured in May and June. Elevated ammonia levels are not tolerable to fish because it can cause gill damage and inhibit DO, therefore its levels should be minimized (Sunday and Jenyo-Oni, 2018). Significant differences ($P<0.05$) were observed in mean ammonia levels measured in the middle and lower stations.

Table 1: Mean water quality parameters measured across the sampling stations

Parameters	Upper Station	Middle Station	Lower Station	Mean values	Recommended (FAO, 2022)
Temperature (°C)	18.30 ± 0.39	18.44 ± 0.41	18.33 ± 0.42	18.36 ± 0.41	20 – 30
DO (mg/L)	2.71 ± 0.10[b]	2.00 ± 0.10[a]	2.41 ± 0.10[b]	2.37 ± 0.10	3
pH	7.32 ± 0.06	7.29 ± 0.05	7.30 ± 0.06	7.30 ± 0.06	6.5 – 8
Ammonia (mg/L)	0.26 ± 0.06[b]	1.96 ± 0.05[a]	1.53 ± 0.05[a]	1.25 ± 0.05	0.05
Nitrite (mg/L)	0.07 ± 0.03 [b]	0.67 ± 0.03[a]	0.19 ± 0.03 [b]	0.31 ± 0.03	0.25
Nitrate (mg/L)	0.02 ± 0.33 [b]	2.27 ± 0.34[a]	1.72 ± 0.32 [b]	1.34 ± 0.33	250

± = the Standard Error of Mean; mean values with different superscripts are significantly different across the rows

Nitrite which occurs from the breakdown of ammonia was high in the middle station with a mean value of 0.67 ± 0.03 mg/L and an overall mean total of 0.31 ± 0.03 mg/L (Table 1). The mean values measured in the middle station were the only value above the recommended limit of 0.25 mg/L for aquatic biota (FAO, 2022). Across the sampling months, July had the highest mean value with 0.25 ± 0.09 mg/L and an overall mean of 0.12 ± 0.02 mg/L. Nitrite values were not detected in January, February and March with recorded mean monthly values (0.13 ± 0.02 mg/L) within the recommended limit of 0.25 mg/L (Table 2). The results from this study deviated from the reported mean values of 0.21 mg/L for aquatic biota (FAO, 2022) and 0.23 mg/L (Farombi *et al*., 2014). Nitrates are less toxic and mean values measured across the months (3.03 ± 0.03 mg/L) and sampling stations (1.34 ± 0.33 mg/L) were within the recommended levels of 250mg/L for aquatic biota (FAO, 2022), with similar values reported by Farombi *et al*. (2014).

Table 2: Mean water quality parameters measured across the sampling months

Season	Months	Temperature (°C)	DO (mg/L)	pH	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)
Dry	November	18.30 ± 0.26[b]	2.80 ± 0.04[b]	7.10 ± 0.01[b]	0.13 ± 0.01[b]	0.19 ± 0.02[b]	5.29 ± 0.00[a]
	December	17.30 ± 0.33[a]	2.91 ± 0.04[a]	7.00 ± 0.02[b]	0.33 ± 0.00[b]	0.21 ± 0.00[b]	5.02 ± 0.00[a]
	January	19.67 ± 0.21[b]	2.00 ± 0.00[b]	7.73 ± 0.04[a]	ND	ND	ND
	February	22.00 ± 0.68[b]	1.77 ± 0.00[a]	7.8 ± 0.00[a]	ND	ND	ND
	March	19.68 ± 0.33[b]	2.00 ± 0.05[b]	7.73 ± 0.04[a]	ND	ND	ND
Wet	April	20.0 ± 0.26[b]	2.1 ± 0.04[a]	7.2 ± 0.06[b]	0.25 ± 0.00[b]	0.20 ± 0.04[b]	ND
	May	18.00 ± 0.51[b]	3.5 ± 0.16[b]	7.10 ± 0.02	0.08 ± 0.05[a]	ND	ND
	June	18.00 ± 0.26[b]	3.64 ± 0.09[a]	7.27 ± 0.04[a]	0.13 ± 0.08[a]	0.17 ± 0.05[a]	5.67 ± 1.05[a]
	July	14.33 ± 0.21[a]	3.23 ± 0.11[b]	7.00 ± 0.00[b]	0.43 ± 0.05[b]	0.25 ± 0.09[b]	5.20 ± 0.00[a]
	August	15.00 ± 0.00[a]	3.00 ± 0.00[a]	6.90 ± 0.00[a]	0.50 ± 0.03[b]	0.22 ± 0.01[b]	5.00 ± 0.00[a]
	September	15.00 ± 0.00[a]	3.00 ± 0.00[a]	6.90 ± 0.03[a]	0.50 ± 0.00[b]	0.22 ± 0.03[b]	5.00 ± 0.00[a]
	October	18.00 ± 0.51[b]	2.10 ± 0.04[b]	7.00 ± 0.03[b]	0.13 ± 0.02[b]	0.20 ± 0.01[b]	5.02 ± 0.00[a]
	Mean Total	17.94 ± 0.48	2.67 ± 0.21	7.22 ± 0.21	0.23 ± 0.02	0.13 ± 0.02	3.03 ± 0.03

± is the Standard Error of Mean (SEM); ND – Not Detected; values with different superscripts across each column are significantly different ($P<0.05$)

3.2. Assessment of fish abundance and distribution

A total of 1443 individuals belonging to 27 species were identified with the highest abundance and distribution in the lower section (36.04%) which was close to the dam wall (Table 3). This was expected because the dam wall had created an obstruction which allowed aggregates of food materials and the abundance of fish species was eminent. The cage culture system was located in the middle section of the Lake and it recorded fish abundance (32.08%) which was close to the abundance encountered in the lower station. This was expected because fish species will aggregate around the cages to consume uneaten feed which finds its way out of the cages.

Despite the huge ammonia load (1.96 ± 0.05 mg/L), fish were abundant and must have devised means of survival in the middle section. Ipinmoroti *et al*. (2018) studied the abundance of fish species in the lake and reported an abundance of 1780 belonging to 19 species, which was higher than the abundance during this study but fewer species. Similarly, 27 species were reported by Ipinmoroti (2013) in the Lake. In the dry season (November 2017 – March 2018), a total of 720 individuals were encountered with March recording the most abundant fish species (47.64%). In the wet season (April – October 2022), a total of 723 individuals were encountered, with April recording the most fish species abundance (32.78%). It was observed that these two periods mark the transition between the dry and wet seasons and the natural instincts of fish species are expectant for a change in condition during this period (Negi and Mangin, 2013).

Table 3: Relative abundance and monthly fish distribution in the stations

Seasons	Months	US	MS	LS	Total	Total (%)	T/Sn	T/Sn(%)
Dry	November	11	14	11	67	4.64		9.31
	December	9	10	9	68	4.71		9.44
	January	66	44	66	145	10.05	720	20.14
	February	40	34	40	97	6.72		13.47
	March	92	144	92	343	23.77		47.64
Wet	April	76	85	76	237	16.42		32.78
	May	24	39	24	79	5.47		10.93
	June	105	47	105	234	16.22		32.37
	July	16	11	16	44	3.05		6.09
	August	4	6	4	36	2.49	723	4.98
	September	8	18	8	35	2.43		4.84
	October	9	11	9	58	4.02		8.02
	Total	460	463	520	1443	100	1443	
	Total (%)	31.87	32.08	36.04	100			

US – Upper section, MS – middle section, LS- lower section, T/Sn – total per season, T/Sn (%) – relative abundance of fish per month season

Across the sampling months, March had the highest relative abundance (23.70%) with *Chrysichthys nigrodigitatus* the most abundant (39.32%) fish species (Table 4). The dominance of *C. nigrodigitatus* have been reported in Owalla and Eko-Ende reservoirs (Taiwo, 2010) and Aiba Reservoir (Iyiola *et al*., 2019) which are located within the Osun river system. In contrast, Ipinmoroti *et al*. (2018) reported the dominance of *Tilapia marie* in the Lake. The fish abundance fluctuated over the months with the abundance higher in the dry season (47.20%). This was expected because breeding activities for most fish species had ceased due to reduced rainfall and limited food availability, therefore fish species will aggregate in open waters (Negi and Mangin, 2013). The total fish abundance recorded from the Lake during the study was low (1443) when compared to the reported results of 1780 individuals comprising 19 species (Ipinmoroti *et al*., 2018), and was lower than the number of species identified in this study.

Table 4: Relative abundance of fish species across the months

S/N	Fish species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	Total (%)
1	*Alestes baremoze*	0	8	57	3	3	10	0	0	0	0	3	0	84	5.81
2	*Alestes dentex*	12	0	0	0	0	0	0	0	0	2	0	0	14	0.97
3	*Brycinus longipinis*	0	3	21	0	0	0	0	0	0	0	0	0	24	1.66
4	*Chrysichthys nigroditatus*	39	43	213	63	18	125	38	0	4	5	10	11	569	39.32
5	*Citharinus citharus*	0	1	0	0	0	0	0	0	0	5	2	9	17	1.17
6	*Clarias gariepinus*	0	1	0	0	0	0	0	0	0	1	0	0	2	0.14
7	*Clarias macromystax*	0	0	0	0	0	0	0	0	1	1	1	0	3	0.21
8	*Coptodon mariae*	0	0	0	2	15	7	0	0	0	11	8	18	61	4.22
9	*Coptodon zilli*	0	0	0	86	0	32	0	0	0	0	12	2	132	9.12
10	*Cromeria occidentalis*	0	0	0	0	0	13	0	0	5	4	0	0	22	1.52
11	*Distichodus rostratus*	11	5	0	2	0	0	0	0	0	2	4	0	24	1.66
12	*Hepsetus odoe*	0	0	0	0	1	0	0	0	0	2	0	7	10	0.69
13	*Hemichromis fasciatus*	0	1	0	0	0	0	0	0	0	0	0	2	3	0.21
14	*Hydrocynus forskahlii*	18	0	5	1	8	7	0	0	0	1	0	0	40	2.76
15	*Hyperopisus bebe*	0	1	0	0	0	0	0	0	0	3	0	2	6	0.41
16	*Lates niloticus*	0	0	0	0	1	1	1	0	0	1	1	0	5	0.35
17	*Mormyrups aguilloides*	0	2	0	0	0	0	0	3	4	9	2	1	21	1.45
18	*Mormyrus rume rume*	14	6	6	0	0	0	0	0	0	0	8	0	34	2.35
19	*Oreochromis aureus*	0	2	3	0	0	0	0	0	1	2	3	1	12	0.83
20	*Oreochromis niloticus*	13	3	5	2	22	8	1	11	0	7	8	0	80	5.53
21	*Parachanna obscura*	7	6	0	0	0	0	0	0	0	0	0	2	15	1.04
22	*Polypterus senegalensis*	0	1	0	0	0	0	0	0	0	0	0	1	2	0.14
23	*Synodontis batensoda*	0	0	0	1	0	1	0	11	0	8	2	1	24	1.66
24	*Sarotherondon galilaeus*	0	2	0	1	0	10	0	4	0	0	0	0	17	1.17
25	*Synodontis marophthalamus*	0	0	0	1	0	0	0	0	0	2	0	8	11	0.76
26	*Schilbe mystus*	23	4	23	63	4	11	1	7	2	2	7	4	151	10.44
27	*Synodontis budgetti*	0	5	9	11	7	9	3	0	8	0	5	3	60	4.15
	Total	137	94	342	236	79	234	44	36	25	68	76	72	1443	
	Total (%)	9.49	6.51	23.70	16.35	5.47	16.22	3.05	2.49	1.73	4.71	5.54	4.71		

3.3. Weather distribution

3.3.1. *Weather condition parameters*

The mean rainfall and atmospheric temperature measured during the study are presented in Table 5. The wet season is often characterized by high rains and reduced temperature while the dry season is characterized by low rains and elevated temperature regimes (NiMET, 2019). For both parameters, a fluctuating trend was observed with mean values scattered along the line of trend fit. Total rainfall of 2940 mm was recorded throughout the study, with the highest in September (540 mm) and the least in January (70 mm). The highest and least mean rainfall values recorded from this study were as expected and corroborated by reports of NiMET (2019).

With relation to fish abundance, September which had the least fish abundance (2.0%) recorded the highest value for mean rainfall (540 mm) and atmospheric temperature (35.50 °C) during the study. The possible reason for this may be the response of fish species to increased rainfall and breeding activities in which they migrate to shallow regions for breeding activities (Negi and Mangin, 2013).

Conversely, December which is the peak of the dry season recorded the least rainfall (45 mm) and was expected to record the highest abundance of fish species (Table 5). However, December recorded a relative small abundance of 4.71% and the highest abundance was recorded in March (23.77 %), which denotes the end of the dry season. This occurrence may be due to the expectance of the rains by fish species in April which is the onset of wet seasons breeding activities may commence. Negi and Mangin (2013) reported similar occurrences in Tons River, India. The results on mean temperature from this study deviated from the statements of NiMET (2019) because the wet season which is supposed to be characterized by low temperatures had the highest monthly temperatures (Table 5) and the dry season had the least monthly temperatures instead of measuring the highest monthly temperature ranges. This clearly expresses a change in weather pattern from the normal deviation in characteristics of wet and dry seasons (Omitoyin, 2009; NiMET, 2019; Sixth Assessment Report, 2021).

Table 5: Mean rainfall and temperature and total fish abundance

Month	Mean Rainfall (mm)	Atmospheric Temperature (°C)	Total fish abundance
November	87	34.10	67
December	45	32.11	68
January	70	20.20	145
February	110	24.50	97
March	150	25.50	343
April	170	29.00	237
May	510	29.00	79
June	430	28.00	234
July	360	32.00	44
August	500	33.00	36
September	540	35.50	35
October	218	33.20	58
Total	3190	29.68	1443

3.3.2. *Linear trend analysis*

The linear trend analysis of rainfall and atmospheric temperature over time is presented in Table 6. Statistically, a positive trend that fluctuated across the months was observed over time. This indicated that the mean rainfall (t = 1.77) and average atmospheric temperature (t = 1.65) presented an increasing trend over the months. It explains that for a unit increase in time (months), mean rainfall has increased by 1.77 units and the average atmospheric temperature has increased by 1.645 units. Therefore, it may be said that the weather parameters measured during the study has increased over the months of the study.

3.4. Association between weather conditions and fish abundance

The association between fish abundance and weather factors is presented in Table 7. Statistically, the relationship was observed between fish abundance and weather parameters was not significant (P>0.05), but negative. The negative value implies that as one increases, the other decreases; as rainfall (b_1 = -0.27) and temperature

(b_1= -1.08) increased by one unit, fish abundance reduced by 0.27 units and 1.08 units respectively. It may therefore be said that the observed increase in temperature (Table 6) has declined the fish abundance over the time of study thereby posing negatively on the sustainability of fish species in the reservoir. With these effects, the supply of fish to the rural and urban populace is affected and measures to promote sustainability through management procedures are essential.

Table 6: Linear trend analysis for rainfall and temperature over time

Parameters	b_o	b_1	Relationship	Model $Y_t = b_o + b_1*t$
Rainfall (mm)	32.50	1.77	Positive	Yt = 3.25 + 1.77*t
Temperature (°C)	20.30	1.65	Positive	Yt = 20.30 + 1.65*t

Yt = Rainfall/Temperature, b_o= constant, b_1 = trend coefficient, t = time

Table 7: Regression coefficients between weather factors and fish abundance

Parameters	b_o	b_1	P-value	Relationship	Model $Y_t = b_o + b_1X$
Rainfall (mm)	224.3	-0.27	0.24^a	Negative	Y = 224.3 – 0.27 X
Temperature (°C)	480.4	-1.08	0.16^a	Negative	Y = 480.4 – 1.08X

Y = Fish abundance; b_o= constant, b_1 = regression coefficient, X = Mean rainfall/ average atmospheric temperature; P-value with different superscript are significant at $P<0.05$.

4. Conclusions

It was observed that the Lake was affected by the prevailing water conditions indicated by the low dissolved oxygen and high ammonia and nitrite concentrations. This affected the fish species distribution and abundance in the Lake. Temperature values were observed to have increased across the months while mean rainfall values were variable. These patterns were observed to have a negative effect on the fish species by reducing their abundance, and if it persists their sustainability in the lake is questionable. To address this issue, measures must be in place to ensure a healthy environment in terms of waste discharge into the Lake and gases to the atmosphere from industries within the catchment. These approaches will contribute to the sustenance of aquatic resources and reduction in greenhouse gases.These measures can also ensure the constant supply of fish species which is a major protein source for the human populace.

Conflict of Interest

The authors declare no conflict of interest exists.

Acknowledgment

The authors appreciate the journal editor and anonymous reviewers for their painstaking efforts towards reviewing this manuscript.

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Effect of *Jatropha curcas* seed meal inclusions in the diet of Lohmann Brown Layers on egg production and its quality

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Received: September 9, 2022 **Accepted:** December 11, 2022

Abstract: *Most of the protein source feedstuffs for poultry like soybean and soybean meal are expensive. Thus alternative and cheaper non-conventional feedstuffs should be assessed in order to broaden sources of ingredients. Jatropha curcas seed meal is one of the non-conventional feed ingredients that can be used for poultry feed. Therefore, the objectives of this study were to investigate the effect of dietary inclusion of treated and untreated Jatropha seed meal on feed intake, feed conversion ratio, egg production and egg quality traits. A feeding trial was carried out for eight weeks at Hawassa University, with 250 Lohmann Brown commercial layers (42 weeks old). Chicken were allotted to five treatment diets replicated five times with 10 hens per replication in a completely randomized design. The control treatment (T1) represents the standard poultry feed that contained 42% white maize, 15% wheat bran, 7% noug cake, 25% soybean, 4% bone and meat meal, 4% limestone, 2.5% Premix and 0.5% salt. In the treatments T2 to T5, 5% of soybean seed in T1 was replaced by 1.25% untreated and treated Jatropha seed meal where T2, T3, T4 and T5 contained untreated, heat-treated, NaOH-treated and T5 yeast treated Jatropha seed meal, respectively. There were significant variations in daily feed intake, food conversion rate, hen-day egg production, hen-housed egg production and mortality among treatment groups. Chicken receiving T2 had reduced daily feed intake compared to hens that were fed on all other diets (p<0.05). Chickens reared under T1 had lower values of food conversion rate and mortality than chickens kept on all other diets (p<0.05). There was no significant differences among all treatment groups in egg shape index, egg weight and shell thickness. Substituting 5% soybean with untreated jatropha seed meal influences most of the tested parameters in the present study. On the other hand, the replacement of 5% quantity of soybean with treated jatropha seed meal had no effects on hen-daily egg production, hen-house egg production, Egg shape index, Egg weight, Shell thickness, Albumin height, Yolk height, Yolk weight and Haugh Unit compared to the standard poultry diet (T1). Accordingly, 1.25% heat, NaOH and yeast-treated jatropha seed meal could be used to replace 5% of the soybean seed in the Lohmann Brown layers diet.*

Keywords: Dietary feed intake, Egg production, Egg quality, Jatropha seed meal

1. Introduction

Feed ingredients used in poultry production in Ethiopia are cereal grains, protein-rich oil seed cake (meal) and meat & bone meal. Most of the protein source feedstuffs like soybean and soybean meal are expensive. Thus, alternative and cheaper feedstuffs should be assessed in order to broaden sources of ingredients for the poultry feed industry (Annongu *et al*., 2010). Jatropha curcas seed meal is one of the non-conventional feed ingredients that may have the potential for both nutritional and medicinal uses (Goel *et al*., 2007).

Jatropha curcas, commonly known as physic nut, belongs to the euphorbiaceous family and is cultivated primarily for bio-fuel production (Barros *et al*., 2015). It grows quickly and survives in poor stony soil, is resistant to drought and disease, and can be grown on marginal agricultural land where no irrigation facility is available. Jatropha curcas seed meal is produced after the shells have been removed and has high nutritive value. The protein content of detoxified jatropha kernel meal 665g/kg was better than soybean meal 471g/kg and has a great potential to complement and substitute soybean meal as a protein source in livestock diets as it was reported by (Kumar *et al*., 2010).

However, Jatropha seed meal contains anti-nutritive compounds, such as lectin, trypsin inhibitor (anti-trypsin), saponin, phytate, and phorbol esters (Makkar and Becker, 1998). Of all the compounds, phorbol ester is considered as the most toxic compound. Anti-nutritional factors are harmful to humans and animals and limit the nutrient availability. Therefore, inactivation of such ingredients may be necessary to avoid damages.

The removal of phorbol esters would transform the Jatropha meal into a highly nutritious and high-value feed ingredient for monogastric, fish, and ruminants (Hass and Mittelbach, 2000). According to Martinez-Herrera *et al*. (2006) the meal could be detoxified and the residual protein-rich seed cake or meal, remaining after extraction of the oil, could form a protein-rich ingredient in feeds for poultry, pigs, cattle and even fish.

The nutrient compositions of ingredients in the ration of poultry affect the egg production performances and internal and external egg qualities. When nutrients are in excess and deficient in the ratio it affects and interferes with the absorption of other nutrients and causes deficiency disease. Calcium deficiency will lead to a weaker eggshell with a decrease in eggshell weight and eggshell strength (Bar *et al*., 2002). Eggs are one of the most important sources of animal proteins. Eggs are used in various food industries to produce different products, cosmetics and vaccines (Oluyemi and Roberts, 2007).

As egg is used for various purposes including for consumption in human diets quality means different for many people. Egg quality is a general term that refers to several standards, which define both internal and external qualities. Kramer (1951) defined quality as "the sum of characteristics of a given food item which influence the acceptability or preference for that food by the consumer". Evaluation of the internal and external qualities of a chicken egg is an important index in commercial egg production (Parmer *et al*., 2006).

Consumers are concerned about its quality, especially the yolk color. The quality of egg could be affected by many factors such as dietary nutrients, environmental factors, and diseases. Dietary nutrients like vitamin A and minerals influence both internal and external egg quality.

Earlier work shows that jatropha seed meal treated with 4% sodium hydroxide and heat achieved the best-reduced percentage of phytic acid and there was no reduction in body weight gain in comparison to the control groups of rats (Nabil *et al*., 2011). The heat treatment in combination with the chemical treatment of sodium hydroxide and sodium hypochlorite has also been reported to decrease the phorbol ester level in Jatropha seed meal to 75% (Goel *et al*., 2007).

However, there is little information regarding the effect of feeding jatropha seed meal on egg production performance and egg quality traits in layer hens in Ethiopia. Therefore, the aim of this research was to investigate the effect of Jatropha seed meal on egg production performance and internal and external egg quality of the Lohmann Brown chicken breed.

2. Materials and Methods

2.1. Description of the study area

The study was carried out at the poultry farm of the School of Animal and Range Sciences, Hawassa University, Hawassa, Ethiopia, which lies between 7° 5′ N latitude and 38°29′ E longitude. Hawassa lies at an altitude of 1650 m above sea level having an average rainfall ranging from 700 mm to 1200 mm. The mean minimum and maximum temperatures in the area are 13.5 °C and 27.6 °C, respectively (NMA, 2013).

2.2. Feeding trial

2.2.1. *Experimental treatments and design*

The diet was prepared out of white maize, wheat bran, soybean (roasted), noug cake (*Guizotia abyssinica*) meal, bone & meat meal, and from untreated, physically treated, chemically treated and biologically (Baker's yeast) treated jatropha seed meal (JSM), limestone, salt, and vitamin/mineral premixes.

Five treatments, which contain different feed mixes, were used in the present study (Table 1). The first feed mix (T1 = control) was the standard diet in the poultry farm of the School of Animal and Range Sciences at Hawassa University In the second, third, fourth and fifth diets 5% of soybean in the treatment one (T1) was replaced by 1.25% of untreated, heat treated, sodium hydroxide treated and Baker's yeast treated (24 hours fermented) JSM. The treatments were replicated five times and ten hens were randomly assigned to each treatment in a completely randomized design. The diets used in the present experiment were prepared at Hawassa University, College of Agriculture feed processing unit and formulated using FeedWin

InterActive vo. 24 computer software packages from Holland.

2.2.2. *Experimental animals and feeding management*

The experiment was conducted for eight weeks using 250 hens from Lohmann brown commercial layers, which were purchased from Debre Zeit Alema poultry farm (Ethiopia). The hens were reared in a deep-litter house system for eight months by feeding them with the standard feed (T1) in Hawassa University College's poultry farm.

The pullets were fed commercial grower diets in the company before they were brought to the university farm. After the 8th month of age (three months after they started laying eggs) the chicken was shifted to the experimental pens. They were allotted into five treatment diets, in which 5% of soybean in the control diet was replaced by 1.25% untreated, heat, NaOH and yeast (Baker's yeast) treated jatropha seed meal in treatments 2, 3, 4, and 5, respectively (Table 1). Chicken were fed ad-libtum daily at a refusal rate of not less than 10%. Feed was offered twice a day at 8:00 AM and 4:00 PM. The refusal was collected daily in the morning before the feed was offered. Feed offered and refusals were recorded daily.

Table 1: Proportion of the experimental diets used in the study

Ingredients (%)	Treatment diets				
	T1	T2	T3	T4	T5
White maize	42	42	42	42	42
Wheat bran	15	15	15	15	15
Noug cake	7	7	7	7	7
Soy bean (roasted)	25	23.75	23.75	23.75	23.75
Bone & meat meal	4	4	4	4	4
JSM	------	1.25	1.25	1.25	1.25
Limestone	4	4	4	4	4
*Premix	2.5	2.5	2.5	2.5	2.5
Salt	0.5	0.5	0.5	0.5	0.5
	100	100	100	100	100
Calculated nutritional composition					
Crude protein	18.7	18.75	18.7	18.6	18.7
Crude fiber	5.22	5.45	5.5	5.56	5.57
Crude fat	7.97	7.86	7.85	7.76	7.85
ME(kcal/kg DM)	3202.6	3177.94	3173.53	3164.63	3166.12
Calcium	2.37	2.37	2.37	2.37	2.37
Available phosphorous	0.64	0.64	0.64	0.64	0.64

DM= Dry matter, ME= metabolizable energy, T1 = control (42% white maize + 15% wheat bran + 7% noug cake + 25% soybean + 4% bone and meat meal + 4% limestone +2.5% Premix+ 0.5% salt), 5% of soybean seed in T1 was replaced by 1.25% untreated (T2), heat treated (T3), NaOH treated (T4) and yeast treated (T5) Jatropha seed meal

2.3. Data on feed consumption

The chicken feed consumption and feed conversion ratio was computed. Feed intake was determined by subtracting the weight of feed refused from that of feed offered for each replication and the average was taken for the group. The feed conversion ratio was determined as the ratio of the amount of feed consumed per kg of an egg. Mortality was recorded as it occurred. Chickens were offered tap water free of choice and water was changed daily. Chickens were reared in deep litter pens placed in ventilated and aerated rooms. A laying box was provided in each replication in which one box was for seven layers.

2.4. Egg production performance

Eggs were collected daily at 1400 h and 1600 h. Broken eggs were recorded in each replication. The cumulative average egg production percentage was calculated every week for eight weeks of production starting from the 21th week of production until the 28th week's production period (42 weeks to 49 weeks of age).

The laying percentage of the hens was estimated as hen-day egg production (HDEP) and hen-housed egg production (HHEP) using the formulas below as indicated by North (1984.

$$HDEP\ (\%) = \left(\frac{\text{Total egg laid}}{\text{No. alive birds x No. days in laying period}}\right) x\ 100 \qquad [1]$$

$$HHEP\ (\%) = \left(\frac{\text{Total egg laid}}{\text{No. birds initialy housed x No. days in laying period}}\right) x\ 100 \qquad [2]$$

$$FCR = \frac{\text{Amount of feed consumed}}{kg\ of\ egg} \qquad [3]$$

2.5. Egg quality

2.5.1. *External quality*

External quality traits were evaluated at the end of every week for eight weeks from the 21st week of production to the 28th week's production period. A total of 50 eggs two from each replication were randomly selected at each evaluation period. Egg weight, Egg mass (number of eggs times average egg weight), egg shape, and eggshell were assessed to look into the external quality of the five treatment groups. Eggs were marked using a pencil and weighed using a battery-operated electronic digital balance. The average egg weight was considered from the replications.

Egg shape index: The shape index was expressed as the ratio of the width to the length of the egg. The length (mm) and width (breadth) (mm) of each egg were measured using a digital caliper meter and the egg shape index was calculated using the following formula by Anderson *et al*. (2004).

$$Egg\ shape\ index\ (\%) = \left(\frac{egg\ width(mm)}{egg\ length(mm)}\right) x100 \qquad [4]$$

Eggshell thickness: The shell was broken and cleaned using tissue paper. The removed shell membrane was air dried at room temperature. After drying, three pieces of shells were taken from the narrow side (sharp end), the middle side (equatorial region), and the broad end side (blunt end). Each piece shell was measured using a digital caliper meter. An average shell thickness of three pieces was then calculated.

2.5.2. *Internal quality*

Haugh Unit: After completing measuring the external characters, the egg was broken out on a glass surface to measure the albumen and yolk heights. The height of the thick albumin and yolk were measured using an Ames tripod stand micrometer as described by Haugh, (1937). The height of the thick albumen was measured on the moth sides opposite to the chalazae then the average was taken. Haugh Unit was calculated as the ratio between egg weight and albumen height (mm) following the formula below (Haugh, 1937).

$$HU = 100 \log(AH + 7.57 - 1.7EW) \qquad [5]$$

Where

- AH = Albumen height in mm
- EW = egg weight in grams7.57 and 1.7 are correction factors

Yolk index: The yolk index was expressed as the ratio of yolk height to yolk diameter. The measurement was done after the egg was broken on a glass surface using an Ames tripod stand micrometer as described by Haugh (1937). The height of the yolk was determined by measuring the distance between the glass plate and the top of the yolk. The yolk diameter was measured horizontally by a digital caliper meter. The yolk index was then calculated using the following formula.

$$Yolk\ index = \frac{Yolk\ height\ (mm)}{Yolk\ diameter(mm)} \qquad [6]$$

Yolk and albumen weight: The yolk was carefully separated from the albumen and placed in two different Petri dishes. Both Petri dishes used in weighing the egg contents were initially weighed and the difference in the weights of the petri dish after and before the egg component was taken as the weight of the egg components. After each weighing, the Petri dishes were washed in clean water and wiped dry before the next weighing.

Yolk color: The yolk color was determined using a Roche color fan (RCF) using 1 to 16 scale where 1 = very pale and 16 = deep orange (Ashton and Fletcher, 1962).

2.6. Statistical analysis

The data collected on egg production, egg weight, and internal and external egg quality was analyzed using General Linear Models Procedure (SAS

Institute, 2002, ver. 9.2). Mean separation was performed using Multiple Range test (Duncan, 1955).

Single-factor ANOVA model was used to evaluate the effect of JSM on egg production (number of eggs, rate of laying (Hen-day egg production (HDEP), Hen-housed egg production (HHEP)), and internal and external egg quality.

3. Results and Discussion

3.1. Feed consumption and Production performance

The effect of JSM on daily feed intake (DFI) and egg production performance is presented in Table 2. Chicken that fed with T1 (control) had higher ($p<0.05$) DFI than chicken that fed with treated and untreated JSM. Chicken that fed on the T2 diet (untreated JSM) had lower DFI than chickens that fed on T3 T4, and T5, which were statistically similar when compared to each other ($p>0.05$). The possible reasons for higher DFI in the standard diet compared to other diets could be associated with the anti-nutritional elements present in diets that affect palatability. A combination of the negative effect of anti-nutritive and toxic compounds in the diet decreased feed consumption which then inhibited chicken growth (Barros *et al*., 2015). The concentration of 0.13 mg/g phorbol esters present in the Jatropha curcas has been reported as having a significant adverse effect on food intake and growth rate of rats (Aregheore *et al*., 2003). The decrease in DFI in chicken receiving the rations with JSM in the current study is in line with the work of Sumiati *et al*. (2012) who reported that feeding fermented 7.5% Jatropha curcas meal decreased the feed consumption of the laying hen.

The food conversion rate (FCR) of the hen was influenced by the treatment groups. Accordingly chicken reared using the control diet (T1) had lower FCR than chicken kept on treated and untreated JSM ($p<0.05$). The results revealed that chickens that fed on T2 had higher ($p<0.05$) FCR than chickens receiving T4 and T1 diets. No significant difference in FCR was observed between chicken getting T3 and T5 experimental diets. The reason for a decrease in FCR in the control and an increase in other diets with treated and untreated JSM could be associated with better nutrient utilization in the control and poor utilization of JSM due to the anti-nutritional elements and toxic substance (Tiurma *et al*., 2010).

Mortality was also influenced by the diet groups used in the present study (Table 2). A higher mortality rate was recorded in chicken that fed on diets containing treated and untreated JSM than the control diet. Chicken that fed on T5 had the highest mortality percentage of 5% compared to other experimental diet groups ($p<0.05$), while the chicken in the control ratio had the lowest mortality percentage 1.25%. The reason for high mortality rate of hens that fed on rations containing untreated and treated JSM could be due to the toxic substances found in jatropha. Ojediran *et al.* (2014) reported a high mortality rate ranging from 43.3 to 83.3% in broilers that fed on both treated and untreated JSM. In this study, mortality has occurred only during the first three weeks of the experimental period and there was no mortality afterward. This could be partly associated with the change of environment related to the house.

Table 2: Daily feed intake, feed conversion ratio, and egg production of Lohmann brown commercial layers as influenced by jatropha seed meal

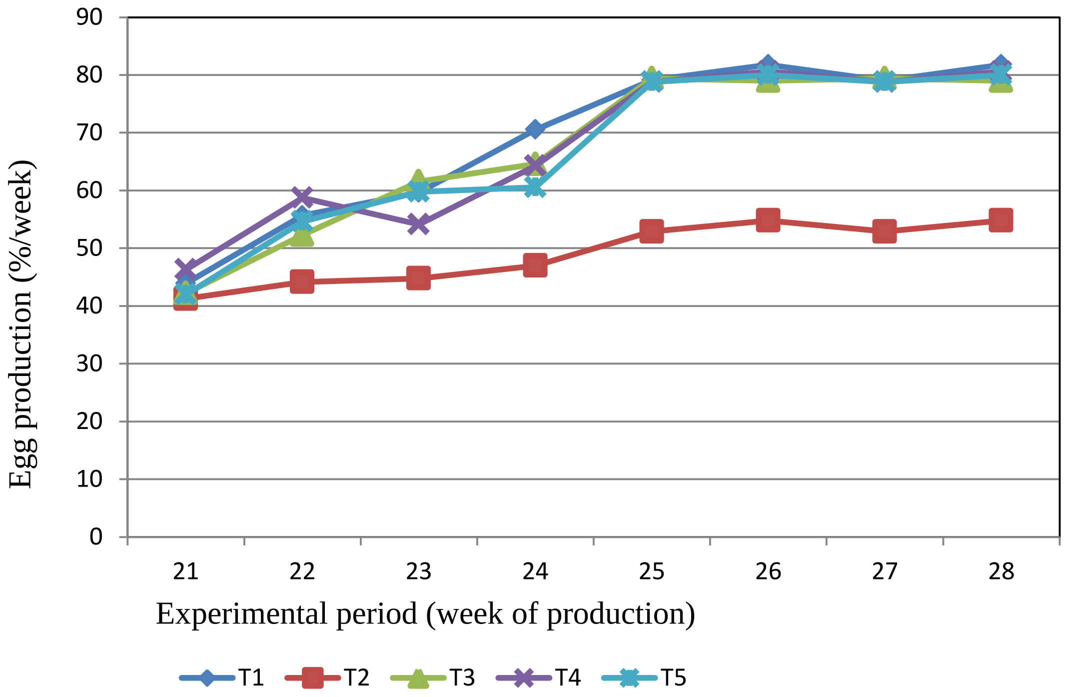
Performance	Treatments						
	T1	T2	T3	T4	T5	SEM	P-value
DFI g/b/d	122^{a}	116^{c}	120^{b}	120^{b}	120^{b}	0.297	0.0001
FCR	3.4^{d}	4.6^{a}	4.4^{b}	4.1^{c}	4.3^{b}	0.046	0.0001
HDEP (%)	69.4^{a}	49.0^{b}	67.2^{a}	67.8^{a}	66.8^{a}	1.05	0.0001
HHEP (%)	61.7^{a}	45.3^{b}	61.0^{a}	62.0^{a}	61.0^{a}	0.97	0.0001
Mortality (%)	1.25^{d}	2.50^{c}	3.75^{b}	3.75^{b}	5.0^{a}	0.33	0.0001

Row means with different superscript letters differ significantly at $p< 0.05$. SEM = standard error of the mean, T1 = control (42% white maize + 15% wheat bran + 7% noug cake + 25% soybean + 4% bone and meat meal + 4% limestone +2.5% premix + 0.5% salt), 5% of soybean seed in T1 was replaced by 1.25% untreated (T2), heat treated (T3), NaOH treated (T4) and yeast treated (T5) Jatropha seed meal; DFI = Daily feed intake, FCR = feed conversion ratio, HDEP = hen day egg production, HHEP = hen housed egg production

The trend of egg production during the experimental period is presented in Figure 1 below. Chicken that fed on T4 showed an irregular pattern of HDEP in which there was a decrease in egg production from the 22nd week to the 23rd week of production and went up from the 24th week of production. Chickens on T2 showed a smaller increment of egg production up to the 26th week of production and slightly dropped from the 26th week of production to 27th and then showed an increment at a lower rate compared to other treatments. Except for hens fed on the T2 diet the 26th week of production was the pick production period with values of 81.8, 80.6, and 80% for T1, T4, T3, and T5 respectively.

The values of HDEP and HHEP were low for hens getting T2 than the control and other treatment diets because of the low feed intake due to the anti-nutritional element that could affect protein consumption.

The result of HDEP in the current study is comparable to the work earlier reported by Fasuyi *et al.* (2007); but higher than the earlier finding by Sumiati *et al.* (2012).



T1 = control (42% white maize + 15% wheat bran + 7% noug cake + 25% soybean + 4% bone and meat meal + 4% limestone +2.5% vit. Premix + 0.5% salt), 5% of soybean seed in T1 was replaced by 1.25% untreated (T2), heat treated (T3), NaOH treated (T4) and yeast treated (T5) Jatropha seed meal

Figure 1: Pattern of HDEP of Lohmann Brown commercial layer during the experimental period (21 to 28 weeks of production)

3.2. Egg quality Parameters

3.2.1. *External egg quality*

Effects of feeding diets on egg quality parameters of Lohmann Brown commercial layers are presented in Table 3. There were significant variations in egg mass among the treatment groups. Hens that on fed T1 had the highest $p<0.05$) egg mass compared to hens that fed on all other treatment diets. Similarly, hens that received the T2 diet produced eggs with the lowest egg mass compared to those that fed on all other groups. On the other hand, no variations in egg weight, egg shape index, and eggshell thickness were recorded from all treatment groups ($p>0.05$). ()

Higher egg mass and production in chicken fed T1 than the other treatment diets could be associated with the higher amount of feed consumed resulting in higher egg production. A decrease in energy and protein intake resulted in decreasing egg production (Leeson and Summers, 2005). The similarity in egg weight in all experimental groups indicated that the inclusion of 5% treated and untreated JSM to replace the soybean meal had no adverse effect on egg weight. Similar results were observed by Sumiati *et al*. (2012) who reported that there was no variation in the egg weight among the treatment groups that were fed fermented Jatroph curass meal. The egg weight in this study is relatively lower than the values observed in previous research (62.67 to 68.30 g) as indicated by Fasuyi *et al*. (2007).

The shape of the egg is a very important trait in handling during incubation and packaging for transport. Eggs having Irregular shapes will be broken in packaging because they may not fit into the tray or containers. The treated and untreated JSM inclusion in chicken diets had no influence on the egg shape index compared to the control diets. The egg shape index in this study is slightly higher than the values observed in earlier research (71.5 to 73.3%) as reported by Welelaw *et al*. (2018). The possible reasons for the difference between the earlier report and the present study could be breed and feed source differences. Based on the classification of Sarica and Erensayin (2009) the shape index observed in the present study is categorized as normal or standard (SI = 72–76), which is important to reduce damages during transportation.

The eggshell thickness is an important indicator of the specific gravity (relative density) of eggs. The shell thickness and porosity help to regulate the exchange of carbon dioxide and oxygen between the developing embryo and the air during incubation (Roque and Soares, 1994). Shell thickness also has a significant effect on moisture loss during incubation and shortage. Thin-shelled eggs lose more moisture than thick-shelled eggs, causing the chicks to have difficulty in hatching (Roque and Soares, 1994). Eggshell thickness and strength are very important to handle the egg during transportation from the time of laying up to consumption (Aberra *et al*., 2005). In the present study, the replacement of soybean by 5% treated and untreated JSM in the diet did not affect the shell thickness of eggs. The eggshell thickness observed in the present study was however lower than the values in the previous study (Fasuyi *et al*., 2007) which reported values in the range of 0.39 to 0.47 mm. On the other hand shell thicknesses obtained in this study were relatively higher than those observed by Welelaw *et al*. (2018).

Table 3: External egg quality parameters of Lohmann brown commercial layers as influenced by jatropha seed meal

Egg Quality	Treatments						
	T1	T2	T3	T4	T5	SEM	P-value
Egg shape index	75.1	75.66	74.95	75.75	74.89	0.22	0.043
Egg mass (g/h)	29.9^{a}	20.3^{d}	22.2^{c}	22.^{5bc}	23.1^{b}	0.34	0.00
Egg Wt. (g)	60.0	59.7	58.7	59.3	59.7	0.2	0.002
Shell thickness (mm)	0.39	0.39	0.39	0.40	0.40	0.002	0.76

Row means with different superscript letters differ significantly at ($p< 0.05$). SEM= standard error of the mean. T1=control (42% white maize + 15% wheat bran + 7% noug cake + 25% soybean + 4% bone and meat meal + 4% limestone +2.5% + 0.5% salt), 5% of soybean seed in T1 was replaced by 1.25% untreated (T2), heat treated (T3), NaOH treated (T4) and yeast treated (T5) Jatropha seed meal

3.2.2. *Internal egg quality*

The effect of dietary inclusion of JSM on internal egg quality parameters of Lohmann brown commercial layers is presented in Table 4. Eggs from hens that fed on T5 had the highest Haugh Unit (81.4) value, which was statistically similar to the eggs from hens that fed on T1 and T4 diets. On the other hand, the lowest Haugh Unit (77.4) was recorded on the egg from hens fed diet T2, which was statistically similar to those produced from T3 ($p<0.05$). Eggs from hens that fed on T2 and T3 diets reduced the albumen height compared to eggs from hens that fed the other rations. Eggs from hens fed on T1 and T5 had a higher ($p<0.05$) yolk index (0.43) than eggs from hens fed on T2, T3, and T4 (0.41). Hens fed on T1 and T2 had higher ($p<0.05$) Value of albumen weight (32.2 g) than hens fed T3 and T4 (31.7 and 30.9), however, there was no variation between hens fed T3 and T4 and among hens fed T1, T2 and T5 at $p>0.05$.

The result indicated significant differences in yolk height, yolk weight, and yolk color among the treatment groups. Eggs from hens that fed on T1, T4 and T5 diets had higher ($p < 0.05$) yolk height (16.1, 16 and 15.9 mm) than chicken reared on T2 and T3 diets. There were no differences in yolk weight between T1 and T5, and between T3 and T4 at ($p > 0.05$). Eggs from hens that fed on T3 and T4 had a higher ($p < 0.05$) value of yolk weight (17.9g) compared to those fed on T1, T2 and T5, While eggs from hens fed on T2 had the lowest value of yolk weight (16.3 g). Hens fed on T1 produced eggs with a higher ($p < 0.05$) value of RCF (1.9) (dark yellow) on yolk color than hens that received T3, T4 and T5 diets. Eggs from hens that fed on T2 and T4 had higher ($p < 0.05$) values of RCF than those fed on the T5 diet.

The results in the current study noted that JSM treated with NaOH and baking yeast has a positive effect on HU which was related to the production of eggs with better egg weight and albumen height. The values of HU in the current study were higher than the results observed by Fasuyi *et al*. (2007) who reported values ranged from 61.30 to 67.67. The reasons for different reports on HU values compared to the current study could be due to differences in strain and age of hens (Silversides and Scott, 2001).

T2 and T3 reduced the albumen height compared to the other rations. The height of the albumen influences Haugh's unit of the egg. The higher the height of the albumen, the greater the value of Haugh's unit and the better the quality of the egg will be (Oluyemi and Roberts, 2007). Albumen height in this study is in good agreement with the study by Yilkal *et al*. (2018) who reported values ranging from 7.89 to 8.38mm. Albumen weight and height are related to the weight of the egg, which increases gradually with the weight of the egg (Sinha *et al*., 2017). The result of albumen weight in this study was higher than the work of Sinha *et al*. (2017) who reported values (of 27.361 and 33. 126 g). The reason for these variations might be due to differences in age, breed, feed and environment.

Yolk height in the present study is comparable with literature values ranging from 15.74 to 17.35mm (Sinha *et al*., 2017) but lower values were also reported (Welelaw *et al*., 2018). Treated JSM had a positive influence on yolk weight which indicates that the replacement of 5% soybean meal with treated JSM in layer rations increased the yolk weight more than the untreated JSM. The result noted that eggs collected from chickens reared under the control ration and ration containing UJSM had better yolk color.

Table 4: Internal egg quality parameters of Lohmann brown commercial layers as influenced by influenced by jatropha seed meal

Egg Quality	Treatments						
	T1	T2	T3	T4	T5	SEM	P-value
Albumen Height (mm)	8.3^{a}	7.9^{b}	7.9^{b}	8.2^{ab}	8.3^{a}	0.052	0.02
Yolk Height (mm)	16.1^{a}	15.6^{b}	15.6^{b}	16.0^{a}	15.9^{a}	0.06	0.006
Yolk Wt. (g)	17.2^{b}	16.3^{c}	17.9^{a}	17.9^{a}	17.2^{b}	0.120	0.0001
Albumen Wt.(g)	33.2^{a}	33.2^{a}	31.7^{bc}	30.9^{c}	32.5^{ab}	0.24	0.005
Haugh Unit (HU)	80.7^{ab}	77.4^{c}	78.0^{bc}	80.7^{ab}	81.4^{a}	0.49	0.022
Yolk Index	0.43^{a}	0.41^{b}	0.41^{b}	0.41^{b}	0.43^{a}	0.002	0.0002
Yolk color(RCF)	1.9^{a}	1.8^{ab}	1.2^{bc}	1.5^{b}	1.0^{c}	0.61	0.0001

Means with different superscript letters in the row differ significantly at $p < 0.05$. SEM = standard error of the mean

4. Conclusion

The inclusion of JSM in the diet of Lohmann Brown commercial layers influences the performance and egg quality parameters. Substitution of 5% of soybean with untreated 1.25% of JSM reduced DFI, HDEP and HHEP, and all the external and internal egg quality traits except egg shape index, egg weight and shell thickness. This treatment also increased FCR and mortality of hens. On the other hand, the substitution of 5% of soybean with heat, NaOH and yeast-treated 1.25% JSM diet did not influence the HDEP, HHEP, Egg shape index, Egg weight, Shell thickness, Albumin height, Yolk height, Yolk weight and Haugh Unit compared to the standard control diet. Therefore 1.25% heat, NaOH and yeast-treated JSM could be used to replace 5% of the soybean seed in the Lohmann Brown layers diet.

Conflict of Interest

The authors declare no conflict of interest exists.

Acknowledgment

The authors would like to sincerely appreciate Hawassa University, Office of the vice president for Research and Technology Transfer for the financial support

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In -vitro evaluation of mung bean (*Vigna radiata* L. Wilczek) genotypes for drought tolerance and productivity

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Received: November 16, 2022 **Accepted:** December 14, 2022

Abstract: *Drought stress is the most important factor that limits mung bean production and productivity at large in drought-prone areas of Ethiopia. It is hence necessary to identify and verify drought-tolerant and productive varieties of major crops grown in drought areas of the country like mung bean. The present study was conducted to evaluate mung bean genotypes for drought tolerance under in-vitro conditions and to assess the performance of the in-vitro developed regenerants under greenhouse conditions. The in-vitro experiment was thus arranged in a factorial experiment using a completely randomized design with three replications. Three mung bean genotypes, NLLP-MGC-06/G6 (tolerant), VC6368 (46-40-4)/G34 (moderate), and NLLP-MGC-02/G2 (sensitive) and five polyethylene glycol (PEG) levels (0, 0.5, 1.0, 1.5, and 2.0%) were used. The analysis of variance exhibited significant differences among the genotypes for all the studied parameters except the number of roots per shoot. There were significant differences observed among PEG levels for all the studied parameters. Significant genotypes x PEG interactions were observed for all the studied traits except total roots per culture and survival percentage. Increasing polyethylene glycol concentration from 0% to 2.0% in the medium caused a gradual increase in root length from 0.49 cm at 0% PEG to 1.17 cm at 2.0% PEG, respectively. This revealed an adaptive mechanism to the decreased moisture content in the root zones of plants and enhanced increased root length to reach deeper water in the soil. Regenerant from the treatment combinations of G34 (0) exhibited the highest values for the number of primary branches per plant (4.00). Grain yield for the in-vitro regenerated plants evaluated at greenhouse conditions ranged from 552.52 kg ha^{-1} at the treatment combination of G2 (1) to 996.23 kg ha^{-1} at the treatment combinations of G6 (0). Most of the regenerants obtained from NLLP-MGC-06/G6 and VC6368 (46-40-4)/G34 showed the best performance under the greenhouse for drought-tolerance under the in-vitro condition, suggesting that the accumulated performance of the tested regenerants under in-vitro conditions was realized under greenhouse conditions. It also indicated that in-vitro culture is an important tool to identify and verify drought-tolerant genotypes and improve desirable agronomical traits. Further study is indeed required to understand the mechanism of drought tolerance for in-vitro-selected somaclones.*

Keywords: Drought tolerance, Greenhouse condition, Polyethylene glycol, Somaclonal variation

1. Introduction

Drought is a major abiotic stress that adversely affects plant production in many parts of the world and had brought a significant yield reduction. Ilker *et al*. (2011) suggested that global warming is noticeable in drought-prone areas and had significantly affected plant production, thereby leading to considerable economic and social problems because of its great importance in human nutrition. Jaleel *et al*. (2009) suggested that drought is a serious problem for crop production and food security that significantly reduces the turgor potential of plants. Water stress can result in reducing crop yield worldwide (Boyer, 1982; Smirnoff, 1993; Gonzalez *et al*., 1995). Since yield is a complex trait and is strongly influenced by the environment, severe losses can be caused by drought stress which is common in most arid and semi-arid areas. One possible way to ensure the future food needs for an increasing world population involves the better use of water through the development of drought-tolerant crop varieties that need less water (El-Shafey *et al*., 2009; Mafakheri *et al*., 2010).

One of the screening techniques based on physiological traits is the use of various osmotica to induce stress in plant tissues. Therefore, to simulate the effect of water stress in vitro, several researchers have incorporated polyethylene glycol (PEG) in the culture medium (Handa *et al*., 1982; Bhaskaran *et al*., 1985; Newton *et al*., 1986; Newton *et al*., 1989; Ochatt *et al*., 1998; Guóth *et al*., 2010; Rai *et al*., 2011; Yang *et al*., 2012). Sané *et al*. (2005) found that the use of PEG under in-vitro culture allows quick and easy identification of genotypes tolerant to water stress. Plant cell and tissue cultures have been implemented as useful tools to study stress tolerance mechanisms under in vitro conditions (Bajji *et al*., 2000). Also, in-vitro-developed sugar cane regenerants were validated for agronomical and morphological traits (Gadakh *et al*. 2015; Rahman *et al*., 2016).

Information on drought stress's effect on the morphological aspects under in vitro conditions in mung bean is lacking. Therefore, there is a need to go to an alternative approach to field experiments related to moisture stress to induce stress using polyethylene glycol (PEG) under in-vitro conditions. Hence, the objectives of this study were to assess the effect of PEG-induced stress on plant cells of mung bean genotypes, to select surviving cell lines under different levels of PEG stress under in-vitro conditions, and to select suitable regenerants for drought tolerance.

2. Materials and Methods

2.1. Description of the study area

The study was conducted at the Plant Tissue Culture Research Laboratory of Areka Agricultural Research Center, Southern Ethiopia.

2.2. Plant material, treatments, and experimental design

Three mung bean genotypes with contrasting drought tolerance including NLLP-MGC-06/G6 (tolerant), VC6368 (46-40-4) /G34 (moderate), and NLLP-MGC-02/G2 (sensitive) were used for this experiment. Two genotypes (G34 and G6) were obtained from the Melkassa Agricultural Research Center, while the third genotype (G2) was a landrace collected from the southern region of Ethiopia. The base for selecting these genotypes was based on the moisture stress response in drought screening field experiments. The treatments comprised factorial combinations of three mung bean genotypes (G34, G6, and G2) and five polyethylene glycol (PEG_{8000}) levels of 0, 0.5, 1, 1.5, and 2% (w/v) adopted from Ferede *et al*. (2019). The experiment of the study was laid out in a completely randomized design in a factorial arrangement with three replications.

2.3. Culture media and growth conditions

Murashige and Skoog's (1962) medium (MS) was used as a basal medium with 3% sucrose and 0.75% agar added by melting in a microwave oven. The pH of all media was adjusted to 5.8 with 0.1 N NaOH before autoclaving. When the agar became clear, 50 ml medium was dispensed into culture tubes and autoclaved at 121°C for 20 minutes (Ferede *et al*., 2019).

2.4. Seed sterilization and germination

For sterilization, the seeds were first treated with 70% ethanol for 5 minutes and then washed in 8% sodium hypochlorite for 30 minutes, followed by six washes in sterile double distilled water in a laminar airflow cabinet. The sterilized seeds were cultured for two weeks under aseptic conditions containing a semisolid MS medium at 27 °C. After two weeks, young seedling leaves were excised and used for callus induction (Ferede *et al*., 2019).

2.5. Callus induction

Leaf explants (2 cm) were placed on an MS medium containing 0.75% agar and 3% sucrose for each treatment. Callus induction was initiated from the leaf explants placed on MS medium containing 2.4-D (2 mg/l), kinetin (0.2 mg/l), and 1 naphthalene acetic acid (1 mg/l). Different concentrations of PEG (0, 0.5, 1.0, 1.5, and 2.0%) were added to the callus induction medium. The culture tubes were sealed with parafilm and placed in a growth room at 27 ºC. In all experiments, three replicates were made, and 10 explants of leaf segments were placed with one replication represented by two culture tubes (Ferede *et al*., 2019).

2.6. Plant regeneration

After four weeks of incubation, the induced calli were transferred to culture tubes, sub-cultured under the same growth conditions, and in the same MS medium with various concentrations of

PEG_{8000} (0, 0.5, 1.0, 1.5, and 2.0%) adopted from Ferede *et al*. (2019). The resulting calli were excised, and transferred, into culture tubes containing MS medium supplemented with 1.5 mg/l kinetin + 0.2 mg/l NAA + 3% sucrose + 0.75% agar for shoot initiation. By doing this procedure, the efficiency of the embryogenic calli was determined and for further regeneration (shooting and rooting) in the presence of drought stress, the obtained calli were exposed to PEG_{8000} (0, 0.5, 1.0, 1.5, and 2.0%) in the plant regeneration medium. Rooting was initiated on half-strength fresh MS medium supplemented with 1.5 mg/l NAA. The incubation period was two cycles of two weeks each or two weeks for shooting and two weeks for rooting (Ferede *et al*., 2019).

2.7. Acclimatization of regenerated plants

Healthy and well-rooted plantlets were washed to remove the medium adhered and subjected to acclimatization, transplanted to the plastic tray under high humidity by covering the plant with plastic containing sterilized soils, coco peat, and compost, and placed under polythene shed with high humidity (>90% RH) for 3 weeks to harden. After acclimatization, plantlets were transplanted to pots under greenhouse conditions, and the survival percentages were taken four weeks later. Finally, the plants being survived were assessed for their agronomic, yield, and yield-related traits (Ferede *et al*., 2019).

2.8. Data collection

2.8.1. *Callus induction and plant regeneration*

Callus induction efficiency (CIE) was assessed as the number of explants induced callus/ total number of cultured explants used for each treatment x 100. Plant regeneration percent (PRP) was recorded as (number of plantlets/total number of calli) × 100 after PEG treatment. The total number of shoots per culture (TSPC) was counted at the stage of the shoot multiplication when treated by PEG. Similarly, shoot length (SL) and root length (RL) were measured using an autoclaved square paper and a well-sterilized measuring tape after two weeks of plantlet incubation. The total number of roots per culture (TRPC) and the number of roots per shoot (NRPS) were counted at the stage of the root regeneration medium. Data were also recorded for rooting percentage as the percent of rooted shoots (RP) per culture. Survival percentage (SP) was calculated as the percentage of surviving plants after four weeks of transfer to pots.

2.8.2. *Growth and yield parameters*

The selected regenerants were transferred to the pots that were labeled based on the genotype name of the original ex-plant and the PEG level at which the regenerants were grown.

Plants grown in the greenhouse were evaluated for different agronomic traits. In this study, a total of fifteen mung bean regenerants developed from in-vitro culture were evaluated for morpho-phenologic traits. The healthy and physiologically matured regenerants were selected for this study. The experiment was carried out using a completely randomized design with three replications at Areka Agricultural Research Center under greenhouse conditions in 2020. Data on days to flowering, days to maturity, peduncle length (cm), plant height (cm), the number of primary branches per plant, pod length (cm), the number of pods per cluster, the number of pods per plant, the number of seeds per pod, hundred seed weight (g), grain yield per plant (g), grain yield (kg ha^{-1}), biomass yield (kg ha^{-1}), and harvest index were recorded from five regenerants plants grown in pots.

2.9. Data analysis

Collected data were subjected to analysis of variance (ANOVA) and the means were separated using the LSD test at a 0.5% level of probability using the SAS software version 9.0.

3. Results and Discussion

3.1. Effect of genotypes on callus induction and plant regeneration

The analysis of variance result showed all the studied traits were significantly affected by genotypes except the number of roots per shoot (Table 1). This shows the existence of inherent genotypic variability. A similar result was reported by Tsago *et al*. (2014) on sorghum and Ferede *et al*. (2019) on tef. The highest callus induction efficiency (16.87%) was noted for the genotype (G34), while the genotypes G2 and G6 had relatively lower callus induction efficiency of 15.82 and 15.56%, respectively. In this study, the observed highest CIE for the genotype G34 might be due to the genetic makeup of the genotype to induce good callus as compared to the other two genotypes. This finding is supported by the previous reports of (Mekbib e*t al*., 1997; Ferede *et* *al*., 2019) on tef genotypes who suggested that good callus induced in some of the genotypes was due attributed to the genetic makeup of the genotypes.

The highest plant regeneration percent (28.90%) was noted for genotype G34 while the genotypes G6 and G2 had relatively similar plant regeneration percentages of 27.82 and 27.56%, respectively. The highest rooting percent (73.07%) and the number of roots per shoot (2.00) were attributed to genotype G34 (Table 1). This could be attributed to the high-quality calli obtained from the genotype (G34), which might be due to the genetic make of the genotype. This result is supported by the previous reports of Ferede *et al*. (2019) on tef genotypes, Helaly *et al*. (2013) on wheat, who reported that callus induction was a critical phase where the regeneration of plants is highly dependent on the quality of callus. In contrast, G6 and G2 showed relatively low rooting percentages and the number of roots per shoot.

3.2. Effect of PEG stress on callus induction and plant regeneration

The analysis of variance results revealed that all the studied traits were significantly affected by PEG levels except total roots per culture and survival percentage (Table 1), signifying the existence of differential responses of genotypes to different levels of PEG. But the total shoots per culture and survival percentage were not genotype-dependent. The result showed that as the PEG level increased the values for most of the studied traits declined while the number of roots per shoot and root length increased. The highest mean values of all parameters except the number of roots per shoot and root length were observed at 0% PEG which was reduced at each subsequent higher level of PEG. On the other hand, the highest number of roots per shoot and root length of mung bean regenerants were observed at 2.0% PEG (Table 1).

The highest callus induction efficiency of 22.72% was observed at 0% PEG and the lowest 10.93% was observed at 2.0% PEG. The plant regeneration percentage of 42.11% at 0% PEG was dramatically decreased to 28.69 % at 0.5%, 25.38% at 1.0%, 23.36% at 1.5%, and reached 20.93% at 2.0% PEG concentration. The highest rooting percentage of 94.53% was observed at 0% PEG and the lowest 51.69% was observed at 2.0% PEG. On the contrary, a significant increment of root length was found at 2.0% (1.17 cm) and 1.5% (1.04 cm) PEG concentrations respectively, as compared to the control and the other PEG levels (Table 1). This reveals an adaptive mechanism to the decreased moisture content in the root zones of plants that enhances increased root length to reach deeper water in the soil. These findings are supported by the previous reports of Ahmed (2014) on rice and Ferede *et al*. (2019) on tef, who found an increase in root length associated with increasing PEG concentration and observed similar trends in the study.

The highest number of roots per culture 34.09 was observed at 0% PEG and the lowest 8.33 was observed at 2.0% PEG. The mean data of shoot length revealed that with increasing PEG stress, shoot length declined in general. The highest shoot length of 1.41 cm was observed at 0% PEG and the lowest 0.82 cm was observed at 2.0% PEG. The highest survival percentage of 90.69% was observed at 0% PEG and the lowest 55.07% was observed at 2.0% PEG (Table 1). The reduced values of regenerants in most mung bean traits at an increased concentration of PEG might be due to osmotic stress which prevents water uptake and might be attributed to the toxic effects of the increased PEG concentration. Similarly, Haruna *et al*. (2019) reported that as the concentration of PEG increased there was a decrease in callus sizes across the treatments on wheat genotypes. Likewise, Tsago *et al*. (2014) on sorghum reported that there was a decrease in shoot and root-related traits with an increase in the concentration of PEG whereas the mean root number increased with an increasing level of PEG treatment in each genotype. This exhibited that as the concentration of PEG increased; the growth of callus steadily decreased and vice versa was true. This result has confirmed the previous reports of Joshi *et al*. (2011) on rice, Farshadfar *et al*. (2012) on wheat, Tsago *et al*. (2013) on sorghum, and Ferede *et al*. (2019) on tef, who reported that the mean callus induction efficiency decreased considerably under higher PEG concentration. The adverse effect of moisture stress was stronger in higher PEG levels (2.0% PEG) and about 5.0% of the cultures induced callus and the induced calli lost their regeneration ability and further growth was inhibited. Similar results were reported by (Biswas *et al*., 2002; Sakthivelu *et al*., 2008)) who stated that the addition of high PEG-6000 in culture media lowers the water potential of the medium and adversely affects cell division leading to reduced further callus growth.

3.3. Effects of Genotype x PEG interaction on callus induction and plant regeneration

The analysis of variance result depicted that all the studied traits were significantly affected by the interaction effects of genotype and PEG levels (Table 1). The highest number of total shoots per culture (4.2), total roots per culture (34.36), root length (1.23 cm), and survival percentage (93.66%), and the highest shoot length (1.45 cm) for genotypes (G6) were recorded in the control treatment. Also, at the PEG concentration of (0.5%), genotype (G6) showed better plant regeneration percent and rooting percentage of 30.26 and 94.36%, respectively. The significant interaction effects were observed due to genotype by PEG for some of the studied traits, indicating that the genotypes showed differential performances across the different PEG concentrations. This finding confirmed the report by Leila (2013) on six pearl millet genotypes exposed to three different (PEG_{8000}) levels, and Tsago *et al.* (2013) on sixteen sorghum genotypes exposed to five different (PEG_{8000}) levels namely (0, 0.5, 1.0, 1.5, and 2.0%) who found that significant differences among genotypes, PEG and genotype by PEG interactions for shoot length, root length, shoot number, and root number. A similar result was reported by Haruna *et al*. (2019) on sixteen wheat genotypes exposed to six different (PEG_{6000}) levels namely (0, 5 10, 15, 20, and 2, 5%) and observed that significant differences were observed among genotypes for the necrotic mass of the callus. The value of mean shoot length in control (0.0% PEG) for the genotypes (G34, G6, and G2) was 1.45, 1.45, and 1.34 cm, respectively which reduced significantly at each subsequent level of PEG stress till it reached 0.85, 0.75 and 0.85 cm, respectively at 2.0% PEG concentration. Generally, inconsistency in regenerants for most of the studied traits was observed.

Table 1: Callus induction and regeneration of mung bean as influenced by genotypes and PEG levels

Genotype		CIE (%)	PRP (%)	TSPC	RP (%)	TRPC	NRPS	SL (cm)	RL (cm)	SP (%)
G6		15.56b	27.82b	3.04a	72.41b	19.27a	1.94	1.05b	0.91a	71.18b
G34		16.88a	28.91a	2.31b	73.07a	18.50b	2.00	1.09a	0.82b	76.60a
G2		15.82b	27.56b	2.21c	72.34b	18.21b	1.98	1.02c	0.94a	72.26b
LSD (5%)		4.34	0.59	0.09	0.35	0.49	0.06	0.01	0.04	4.33
Sig. level		***	***	***	***	***	Ns	***	***	*
PEG levels										
0%		22.72a	42.11a	4.25a	94.53a	34.09a	0.59e	1.41a	0.49e	90.69a
0.5%		18.69b	28.69b	2.47b	82.54b	22.54b	1.19d	1.12b	0.83d	81.64b
1.0%		15.38c	25.38c	2.21c	72.07c	16.13c	2.10c	1.01c	0.92c	74.33c
1.5%		12.69d	23.36d	2.03d	62.21d	12.21d	2.79b	0.93d	1.04b	65.01d
2.0%		10.93e	20.93e	1.65e	51.69e	8.33e	3.18a	0.82e	1.17a	55.07e
LSD (5%)		1.03	0.90	0.14	0.53	0.75	0.10	0.02	0.06	6.59
Sig. level		***	*	***	***	Ns	***	***	***	Ns
Genotype	PEG levels									
G34	0%	25.36a	43.53a	2.01d	94.36a	33.51a	0.36g	1.45a	1.18a	89.85b
G34	0.5%	20.26b	30.26c	3.26b	83.26b	23.26b	1.26e	1.20c	1.02c	84.60c
G34	1.0%	16.02d	26.02e	2.02d	72.02d	17.02c	2.02d	1.02e	0.95d	78.69d
G34	1.5%	11.89h	23.89g	2.89c	62.89e	12.89d	2.89b	0.95f	0.78e	66.23e
G34	2.0%	10.81i	20.81i	2.81c	52.81f	8.81e	3.18a	0.85h	0.56f	59.84f
G6	0%	21.45b	41.45b	4.20a	94.85a	34.36a	0.85f	1.45a	1.23a	93.66a
G6	0.5%	17.70d	27.70d	4.18a	82.01c	22.01b	1.12e	1.03e	1.02c	81.12c
G6	1.0%	14.73e	24.73f	2.04d	72.04d	15.70c	2.13d	1.00e	0.78e	72.13e
G6	1.5%	12.88g	22.88i	1.77e	61.77e	11.77d	2.78c	0.89g	0.67f	66.11f
G6	2.0%	11.04i	21.04i	1.06f	51.06g	8.06e	3.11a	0.75i	0.45g	52.11g
G2	0%	21.34b	41.34b	4.37a	94.39a	34.39a	0.57g	1.34b	1.10b	88.57b
G2	0.5%	18.12d	28.12d	2.12d	82.35c	22.35b	1.19e	1.12d	1.07c	79.19c
G2	1.0%	15.40e	25.40f	2.03d	72.17d	15.68c	2.16d	1.00e	1.05c	72.16e
G2	1.5%	13.30f	23.30h	1.96e	61.96e	11.96d	2.70c	0.96f	1.04c	62.70f
G2	2.0%	10.94i	20.94i	1.08f	51.19g	8.11e	3.26a	0.85h	0.46g	53.26g
Sig. level		***	***	***	***	***	***	***	***	***
LSD (5%)		2.28	1.99	0.31	1.17	1.66	0.23	0.06	0.13	14.51
SE±		0.6	0.43	0.01	0.15	0.30	0.001	0.0004	0.002	23.03
CV		4.7	2.34	4.11	0.53	2.96	3.90	1.96	5.07	6.54

CIE = callus induction efficiency percent, PRP = plant regeneration percent, TSPC = total shoot per culture, RP = rooting percentage, TRPC = total roots per culture, NRPS = number of roots per shoot, SL = shoot length; RL = root length, SP = survival percentage; means followed similar letters in column are not statistically difference at $p \leq 0.05$

3.4. Evaluation of *In-Vitro* regenerated plants for validation under greenhouse conditions

3.4.1. *Flowering and vegetative growth*

The analysis of variance results revealed that the regenerants showed highly significant differences in all the measured flowering and vegetative growth traits (Table 2). Regenerants of the treatment combination of genotype G2 x 2% PEG flowered earlier, which took 33.16 days, while days to flowering for the regenerant from the treatment combination of genotype G6x1.0% PEG took longer time to flower with the value 36.67 days. In terms of maturity regeneratnts of the treatment combinations of G2x2.0% (60 days) matured earlier while those from the treatment combination of G6x0.5% matured late with a value of 76.00 days.

The in-vitro-developed mung beans having lower values for days to flowering and days to maturity were considered drought-tolerant since these genotypes had ability to escape terminal drought and could be recommended for drought-prone areas. Plaza-Wüthrich *et al*. (2013) reported that earliness for days to heading and maturity are important traits on tef for areas with low rainfall to escape terminal drought, and in high rainfall with long growing season areas, can be employed in double-cropping systems.

The highest terminal leaf length (6.86 cm) was recorded from the regenerant developed from the treatment combination of G34x0% PEG, while the least terminal leaf length (3.53 cm) was noted from the regenerant obtained from the treatment combination of G34x2.0% PEG. The highest terminal leaf width of 11.36 and 11.05 (cm) were recorded from the regenerants from the treatment combinations of G2x0% PEG and G34x0% PEG, respectively. The least terminal leaf width (6.36 cm) was obtained from the regenerant developed from the treatment combinations of G6x2% PEG. The highest and the least peduncle length of 9.13 cm and 5.43 cm were recorded from the treatment combinations of G6x0% PEG and G2x2% PEG, respectively (Table 2). The highest plant height of 44.16 (cm) was recorded from the regenerants from the treatment combination of G6x0.5% PEG while the least (38.13 cm) was recorded from G2x0.5% PEG. The observed variations on vegetative growth parameters at different treatment combinations of PEG levels and genotypes might be attributed to the differential responses of the tested genotypes to the induced PEG levels.

Table 2: Flowering and vegetative growth of mung bean as affected by genotypes and PEG levels

Genotypes	PEG levels	DTF (50%)	DTM (90%)	TLL (cm)	TLW (cm)	PDCL (cm)	PHT (cm)	BRN	PODL (cm)
G34	0 %	36.00a	72.66a	6.86a	11.05a	8.75a	40.00b	4.00a	9.16b
G34	0.5%	36.33a	71.66a	6.36a	10.98a	8.23a	41.33a	3.26b	10.66a
G34	1.0%	36.00a	72.66a	4.92c	10.03a	8.74a	42.00a	2.00d	6.66f
G34	1.5%	35.66a	69.66b	4.60d	9.77a	8.57a	41.00a	2.00d	7.53e
G34	2.0%	35.16a	69.66b	3.53e	8.38b	6.60c	39.00b	2.00d	10.98a
G6	0 %	34.33b	70.66a	4.64d	8.60b	9.13a	42.00a	3.00c	11.26a
G6	0.5%	36.33a	76.00a	4.93d	10.25a	7.59b	44.16a	3.00c	10.00a
G6	1.0%	36.76a	74.00a	4.83d	10.76a	7.36b	40.10b	3.00c	10.00a
G6	1.5%	35.66a	70.66a	4.94d	8.36b	8.12a	39.66b	2.00d	9.03c
G6	2.0%	34.33b	69.66b	4.53d	6.36c	5.48d	38.56b	2.00d	7.60e
G2	0 %	35.83a	72.33a	6.60a	11.36a	8.66a	40.00b	3.00c	9.86b
G2	0.5%	36.00a	72.00a	5.00b	9.11a	8.17a	38.13b	2.00d	11.00a
G2	1.0%	36.00a	68.66b	5.17 b	10.22a	8.17a	39.33b	2.00d	8.96d
G2	1.5%	34.16b	68.00b	5.41b	9.17a	6.30c	40.00b	3.00c	10.96a
G2	2.0%	33.16b	60.00c	4.93d	8.96b	5.43d	39.00b	1.00e	5.50g
Sig. level		**	**	***	***	***	***	***	***
SE±		0.89	11.82	0.69	0.28	0.85	1.79	0.01	0.41
CV (%)		2.68	4.87	10.41	9.68	10.87	3.32	2.62	6.94
LSD (5%)		2.85	10.34	1.61	2.78	2.51	4.02	0.19	1.93

DTF = days to flowering, DTM = days to maturity, TLL = terminal leaf length, TLW = terminal leaf width, PDCL = peduncle length, PHT = plant height, BRN = number of primary branches per plant, PODL = pod length; means followed similar letters in column are not statistically difference at p≤0.05

3.4.2. *Yield related traits*

The analysis of variance results depicted that the regenerants showed highly significant differences in all the measured yield-related traits (Table 3). Regenerant from the treatment combinations of G34x0% PEG exhibited the highest value for the number of pods per cluster (5) and pods per plant (19.66). The highest, seeds per pod (11.36), grain yield per plant (5.22 g), grain yield (996.23 kg ha^{-1}), and harvest index (0.27) were recorded from the regenerant from the treatment combinations of G6 (0). On the other hand, regenerants obtained from the treatment combinations of G2 (1) showed poor performance for pods per cluster (2.66) and pods per plant (12.00). The highest hundred seed weight (5.49 g) was recorded from the regenerants obtained from the treatment combinations of G6 (0), while the least hundred seed weight (3.12 g) was recorded for the regenerants obtained from the treatment combinations of G2 (1.5). The highest biomass yield of 4319.80, 4219.80, and 4219.80 (kg ha^{-1}) was recorded for the regenerants obtained from the treatment combinations of G34 (1.5), G34 (2.0), and G2 (1.5), respectively (Table 3).

The result indicated that an in-vitro culture is an important tool to screen drought-tolerant genotypes and improve desirable agronomical traits. In general, most of the regenerants obtained from G34 and G6 showed the best performance under the greenhouse and were drought-tolerant under the in-vitro condition, suggesting that the performance of the tested regenerants under in vitro conditions was realized under greenhouse conditions.

Table 3: Yield related traits of mung bean as affected by genotypes and PEG levels

Genotype	PEG levels	PPC	PPP	SPP	GYPP (g)	HSW (g)	GYLD (kg ha^{-1})	BM (kg ha^{-1})	HI
G34	0 %	5.00a	19.66a	10.63a	4.11b	4.21c	892.96b	3699.80c	0.24a
G34	0.5%	3.00c	19.00a	8.30d	4.18b	4.05c	596.12d	3819.80b	0.15c
G34	1.0%	3.00c	14.33c	10.46b	4.01b	4.12c	795.21b	3886.50b	0.20b
G34	1.5%	3.66b	14.00c	9.80c	3.97b	4.22c	822.94b	4319.80a	0.19b
G34	2.0%	3.33c	12.66d	7.40d	3.08c	4.22c	555.53e	4219.80a	0.13e
G6	0 %	4.00b	12.66d	11.36a	5.22a	5.49a	996.23a	3686.50c	0.27a
G6	0.5%	3.66b	16.66b	11.10a	3.99b	4.16c	754.74b	4119.80a	0.18c
G6	1.0%	3.00c	15.33b	10.13b	4.14b	4.18c	595.23d	3886.50b	0.15c
G6	1.5%	3.00c	15.33b	10.06b	3.96b	4.12c	729.55b	3953.10b	0.18c
G6	2.0%	3.00c	12.13e	10.16b	3.97b	4.20c	587.16d	3986.50b	0.14d
G2	0 %	3.66b	19.00a	10.20b	5.17a	5.13b	693.94c	3886.50c	0.17c
G2	0.5%	3.33b	18.66a	8.08d	4.20b	4.19c	577.27d	3786.50c	0.15c
G2	1.0%	2.66d	12.00e	10.06b	4.18b	4.08c	552.52e	4019.80b	0.13d
G2	1.5%	3.00c	17.33b	11.06a	3.95b	3.12d	589.57d	4219.80a	0.13d
G2	2.0%	3.00c	15.66b	9.60c	4.07b	4.21c	592.74d	3916.50b	0.15d
Sig. level		***	***	***	***	***	***	**	***
SE±		0.13	2.62	0.14	0.02	0.01	6136.10	29904.00	0.01
CV (%)		10.88	10.37	3.82	3.75	1.56	11.37	4.37	10.10
LSD (5%)		1.09	4.87	1.13	0.46	0.19	235.62	520.15	0.05

PPP = the number of pods per plant, SPP = number of seeds per pod, GYPP = grain yield per plant, HSW = hundred seed weight, GYLD = grain yield, BM=biomass yield and HI = harvest index; means followed similar letters in column are not statistically difference at p≤0.05

4. Conclusion

Drought is one of the most liming factors in mung bean production and productivity. Evaluating mung bean genotypes in PEG-induced drought conditions under in-vitro and greenhouse conditions is important to screen drought-tolerant genotypes. This technique is crucial because the results of the in-vitro were reproduced or realized in the greenhouse. It also indicated that an *in-vitro* culture is an important tool to develop drought-tolerant genotypes and improve desirable agronomical traits under greenhouse conditions for further field verification. Therefore, some regenerants performed better under the greenhouse conditions were became drought-tolerant under the *in-vitro* condition. In general, most of the regenerants showed the best performance under the greenhouse and were drought-tolerant under the *in-vitro* condition, suggesting that the performance of the tested regenerants under *in vitro* conditions was realized under greenhouse conditions. This suggests the accumulated performance of the tested regenerants under *in-vitro* conditions was realized under greenhouse conditions. Further study is indeed required to understand the mechanism of drought tolerance for the *in-vitro* selected somaclones and to put the recommendation on a strong basis.

Conflict of interest

The authors declare that there is no conflict ofinterest in publishing the manuscript in this journal.

Acknowledgment

The authors extend their gratitude to the Southern Agricultural Research Institute (SARI) for the financial support of this research. The authors also recognize Jinka Agricultural Research Center (JARC) for its administrative facilitation during the implementation of this research.

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Diurnal activity patterns of five distinct bird species in agricultural landscapes of Central Rajasthan during their non-breeding period in India

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Received: September 25, 2022 **Accepted:** December 12, 2022

Abstract: *The daily time activity budget explains how any species distribute their daily time for regular activities. The most typical behaviors observed in birds include foraging, feeding, roosting, flying, singing, building a nest, incubating eggs, and raising young. The temporal budgets of five bird species from three distinct feeding guilds were examined. The research area in central Rajasthan, India an ecotone of Arid and Semi-arid zones. Five bird species were examined for their behavior during the research period, with each bird being observed at least 40 (N=200) times during their non-breeding phase. The study includes the Red Collard Dove, White Eared Bulbul, Black Winged Kit, Long Tailed Shrike, and Yellow Throated Sparrow. The examination was carried out using the Scan sampling method. The data was aggregated using the un-weighted pair group method with arithmetic mean (UPGMA), and the Bray-Curtis method was used to evaluate species similarities based on time allocation in the same environment. The rates of transition between behaviors were investigated in order to understand which activity the animal does following a certain activity. Likelihood values vary from 0 to 1 were used where 0 indicated that the bird is unlikely to undertake the activity after completing any specific activity and 1 indicated that the bird has the highest probability to perform the activity after finishing any specific activity. In the behavioral research, the Yellow-throated Sparrow, Red Collard Dove, and White Eared Bulbul had the highest similarity because they devote about comparable time to similar behaviors. The results showed that the Long-Tailed Shrike and the Black-Winged Kite have very similar habits and time allocation for different tasks. When flying, the Black Winged Kite has a 0.900 chance of entering screening, and the lowest observed likelihood of flying following other behaviors such as preening is 0.100. Long-tailed Shrikes were more likely to switch from roosting to other behaviors like calling and preening, and from other activities to screening the area for food. The White-Eared Bulbul eats on insects and grains, while Red Collared Doves fly more after scanning. The Long-tailed Shrike and the Black-Winged Kite spend more time examining agricultural fields. The Red Collard Dove is among the potential pests for farmers in the study area. Long-tailed Shrike needs time to hunt, kill, and consume prey that is nearly half their body size.*

Keywords: Agro-Ecosystems, Behavior, Birds, Nagaur, Parbatsar, Time budget

1. Introduction

The diurnal time activity budget is a quantitative description of how any species allocate its daily time for routine tasks (Baldassarre & Bolen, 1994). The allocation of time to various activities differs between species and habitats. Foraging, feeding, roosting, walking, flying, singing, constructing a nest, incubating eggs, and rearing young are the most common behaviors observed in birds. Understanding the behavior of any species in their habitat and how the biotic and abiotic environment affects their daily activities is aided by time budgeting (Paulus, 1988). Observing and comprehending the daily behaviors of bird aid in establishing their life cycle, ecological adaption, and similarities with other species (Hamilton et al. 2002). The evaluation of the time spent and employed by birds in their habitat aids in understanding the niche of birds and, as a result, aids in habitat conservation (Hepworth & Hamiltion, 2001).

The feeding guild has a direct impact on bird behavior (Prajapati and Prajapati 2013). We assessed the temporal budgets of five bird species from three different feeding guilds, namely carnivorous, granivorous, and frugivorous, as well as a few that are occasionally insectivorous, that live in the agricultural fields of central Rajasthan. Some birds, such as *Lanius schach* and *Elanus caeruleus*, maintain their feeding zone for undisturbed feeding (Schemske, 1975).

The use of time to conduct any activity is determined by the individual's age and gender, the season and time of day (Martinez, 2000), the kind of habitat, and habitat usage (Eberhardt et al; 1989, Caraco, 1979). The purpose of this study is to investigate how birds from various feeding guilds divide their available time between behaviors. Especially during their non-breeding period, when the birds focus on themselves rather than being involved in different breeding tasks such as displays, collecting nest materials and creating nests, caring for eggs and nestlings, and others.

2. Materials and Methods

2.1. Description of the study area

The research was carried out in the agricultural areas of Parbatsar (26°52'36.0"N 74°44'56.7"E), Nagaur district, central Rajasthan, India (Figure 1). The study region receives around 33 mm of precipitation per year and has an average yearly temperature of 30 ºC. The area is dominated by agricultural fields and exhibits Arid and Semi-arid biogeographic zone characteristics. It is mostly composed of Dry mixed deciduous thorn woodland with some bushy plants and trees like *Anogeissus pendula*, *Capparis deciduas*, *Acacia nilotica, Acacia senegal, Salvadora persica*, and other species dominate the study area's plains. During the monsoon season, the land is cultivated. Some of the most significant seasonal crops are pearl millet, cluster bean, sesame, green gramme, moth bean, groundnut, wheat, cumin, cotton, and mustard.

2.2. Bird species studied

Throughout the year, the central Rajasthan region is home to more than 191 bird species (Choudhary et.al; 2020). The following five species were chosen (Table 1 & Figure 2) since they maintain their territory in the study area throughout the year and the study area is also their breeding ground, making it easy to study them and have a decent population here, and they all belong to four different feeding guilds, allowing us to collect a diverse dataset.

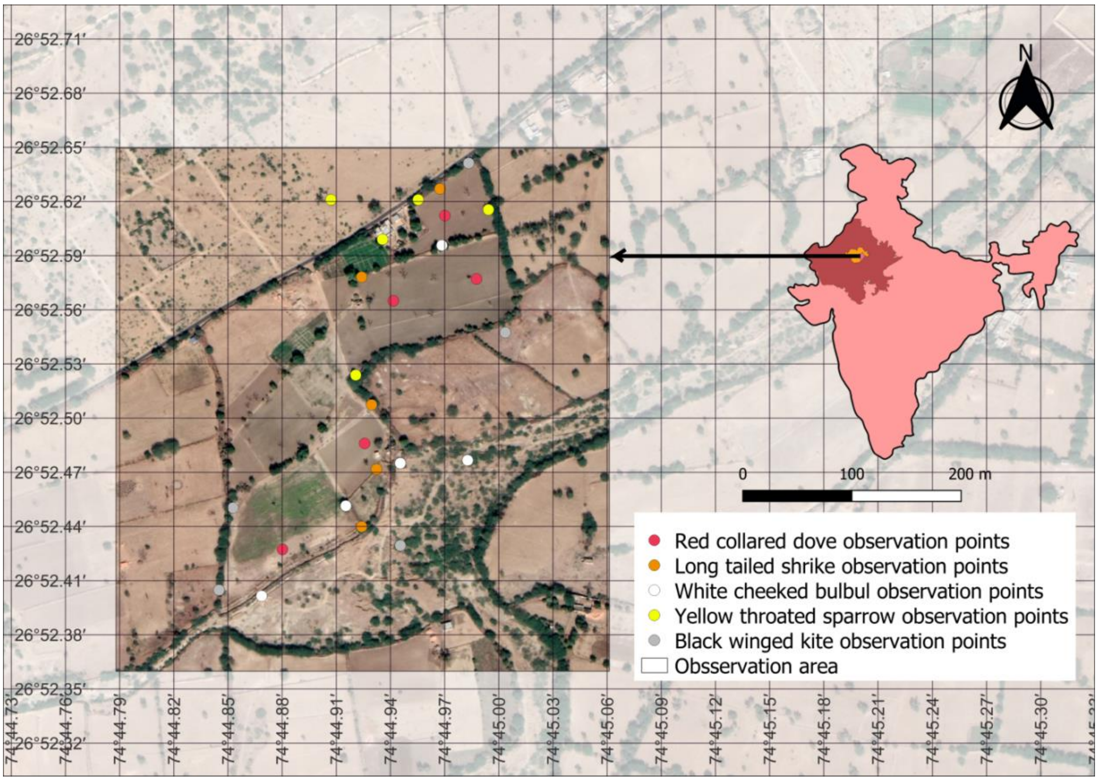

Figure 1: Map of study area

Table 1: Description of studied bird species

Common Name	Black-winged Kite	Long-tailed Shrike	Red-collared Dove	White-eared Bulbul	Yellow-throated Sparrow
Scientific name	*Elanus caeruleus*	*Lanius schach*	*Streptopelia tranquebarica*	*Pycnonotus leucotis*	*Gymnoris xanthocollis*
Breeding period	August to January	February to July	Throughout the Year	February to May	April to June
Food	Insects and Small Mammals	Insects, Lizards and Small Mammals	Grains and Seeds	Fruits and Insects	Grains and Insects
Major feeding guild	Carnivorous	Carnivorous	Grainivorous	Fruigivorous	Insectivorous

Figure 2: Photographs of studied birds from agriculture fields (left to right: Black-winged Kite (BWK); Long-tailed Shrike (LTS); Red-collared Dove (RCD); White-eared Bulbul (YEB); Yellow-throated Sparrow (YTS)

2.3. Bird Survey and Behavioral Data collection

The research was carried out from September 2020 to August 2022, particularly during the non-breeding season of the selected birds. During the study period, five bird species were observed for their behavior, with each bird being observed at least 40 (N=200) times during their non-breeding period. At every observation, the birds were observed for at least 6 hours(7:00 am – 10:am in the morning and 4:00 pm to 7:00 pm in the evening) . Black Winged Kit (*Elanus caeruleus*) was observed during February2021 to July2022, Long Tailed Shrike (*Lanius schach*) was observed from August2021 to January2022, White Eared Bulbul (*Pycnonotus leucoti*) and Yellow Throated Sparrow (Gymnoris xanthocollis) were observed from July 2021 to January 2022 and August 2020 to March 2022 respectively, and Red Collard Dove (*Streptopelia tranquebarica*) was observed throughout the year when there was no nesting involved as the bird breeds throughout year in the study area.

The scan sampling method (Altmann, 1974) was employed to conduct the research. For each observation, a single observation point was chosen and the nearest individual was taken as the observation unit. A single individual was perhaps observed throughout the day, and if the individual went out of sight, the nearby individual was observed. The birds were spotted using an Olympus Binocular 10*50 X and a Nikon P1000 camera and a stopwatch and the mean± SD of observations are presented in the result.

The analysis was done using PAST software (Hammer et al., 2001), the un-weighted pair group method with arithmetic mean (UPGMA) was used to aggregate data, and the Bray-Curtis method was employed to calculate species similarities based on time allocation in the same habitat. The rates of transition between behaviors were examined in order to determine which activity the animal does after a certain activity. A plot matrix was used to visualize the most favored behaviors of species in agricultural landscapes in form of a heatmap. The frequency of transition between behaviors was calculated by dividing the total number of switches between two particular behaviors (scanning to feeding, feeding to flying, flying to roosting, etc.)

by the total number of switches between behavior during the total observed time period that indicates how likely a bird species is to do a behavior after performing another. The values of probability range from 0 to 1, with 0 indicating no probability and the bird is unlikely to perform the activity after performing any particular activity and 1 suggesting that the bird has the highest probability to perform the activity after completing any particular activity. The visualization of data was done using R software and its circle package (Gu et. al. 2014) for making chord diagrams.

During observations, the following activities were taken into account:

Scanning: Perched on trees or at high elevations, and structures in agricultural fields actively scan their surroundings.

Feeding: Entails capturing prey, breaking it apart, and ingesting it in the case of carnivorous animals. Capturing and ingesting insects in the case of insectivorous animals, and consuming fruits and grains in the case of insectivorous and granivorous animals.

Flying: Being in the air, usually in pursuit of prey or going from one location to another.

Roosting: Sleeping perched in shrubs or trees, head retracted and eyes closed.

Other activities: Preening, wing flapping, bill cleaning, bill scratching, and body shaking, calls and songs.

3. Results and Discussion

3.1. Daily time expenditure

In this study, scanning was observed as the most important daytime activity in Black Winged Kite (56.25 ± 2.4%) and Long Tailed Shrike (48.21±3 %), and both species belonged to the same feeding guild, i.e., Carnivorous. The scanning period includes the black kite hovering over the prey. The Black-Winged Kite spent 21.87±1.7% of its time flying through agricultural areas and 14.6±3.6% roosting. Feeding accounted for only 4.7±2.5% of the Black-winged Kite's total time, with the species devoting only 2.58±2.3% of its time to other activities. Scanning and feeding are the two most time-consuming behaviors of the Long Tailed Shrike, accounting for 48.21±3%, and 20.38±2.1% of the time, respectively. Roosting takes up 12.3±1.6% of total time, whereas flying and other activities take up nearly the same amount of time (9.85±2.1% and 9.26±2.2%, respectively). In the case of the Red Collared Dove, the majority of time is spent flying and roosting (24.73±2.9% and 24.23±3.8%, respectively), followed by feeding (17.53±2.5%), scanning (16.72±3.2%), and all other activities (16.79±2.9%). The Red Collard Dove is one of the possible pests for the farmers in the research region because they feed in big groups, although they spend most of their time roosting and flying. The White Eared Bulbul spends most of its time roosting (30.43±2.7%) and flying (25.62±2.9%), scanning and feeding take up 25±2.5% of the overall time and another 18.35±3.8% of the time is spent on other pursuits. Yellow-Throated Sparrows spend more than half of their time hidden in bushes, with roosting accounting for 56.17±2.7% of total time, followed by flying (22.8±2.2%), making it a difficult species to spot in central Rajasthan's agricultural areas. Scanning and feeding take up only 3.95±1.5% and 2±1.2% of Yellow-throated Sparrows' total time, respectively. An ethnography study comparing the time allocation to different activities by different birds (Figure 3) and a heatmap of species and their most favored behavioral activity in agricultural areas (Figure 4) are presented below.

Our findings indicate that all birds spend a significant portion of their daytime engaged in four key activities, which are scanning, feeding, flying, and roosting. This is due to probably due to the abundance of types and food sources throughout the year. Because of the larger body mass of the Black Winged Kite, it is easier for them to kill and eat prey such as Hare, Mouse, Squirrels, and Lizards (Amat 1979, Tarboton 1978), whereas the Long-Tailed Shrike takes preferentially longer time for attacking, capturing, and eating the prey due to its small body mass.

Roosting is a key activity in birds, particularly in insectivorous and granivorous birds, as a technique to reduce the heat burden on a bird under high environmental temperatures (Verbeek 1972, Lee 1997, Martinez 2000). Tamisier and Dehorter (1999) suggest that scanning and feeding, usually referred to as foraging and roosting, allow birds to conserve as much energy as they need throughout both breeding and non-breeding phases, same was observed in this study as collectively all 3 behaviors account for more than 50% in time allocation of selected birds and the study area is represented as a suitable foraging and roosting habitat for these birds.

Flying symbolizes an escape, evasion, or change of location in order to avoid being predated by predators (Bensizerara 2014) and flying is one of the most energy-intensive bird activities (Casey, 1992). In this study, on average the birds allot a quarter of their total time for flying ranging from 9% to 25%, and mostly because of moving from one area to another, as the predator and disturbance pressure is very low in the study area, the major disturbances are caused by human activities.

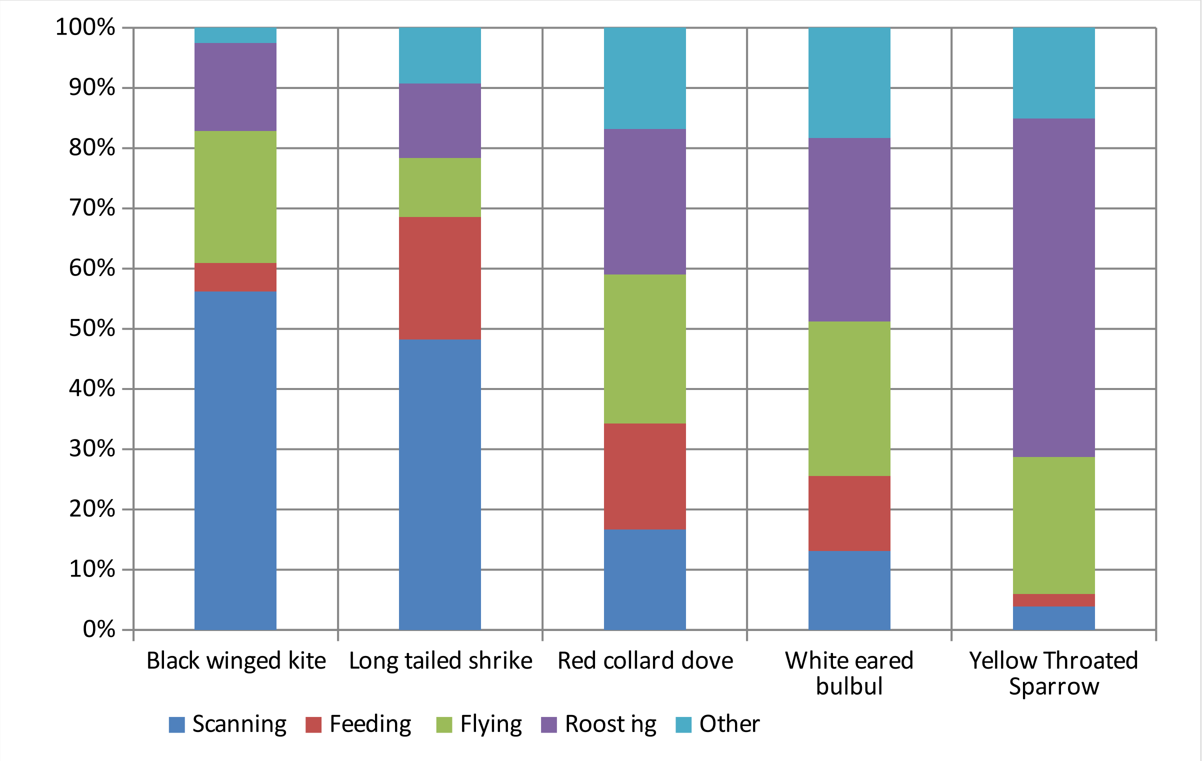

Figure 3: Ethograph of observed bird activities

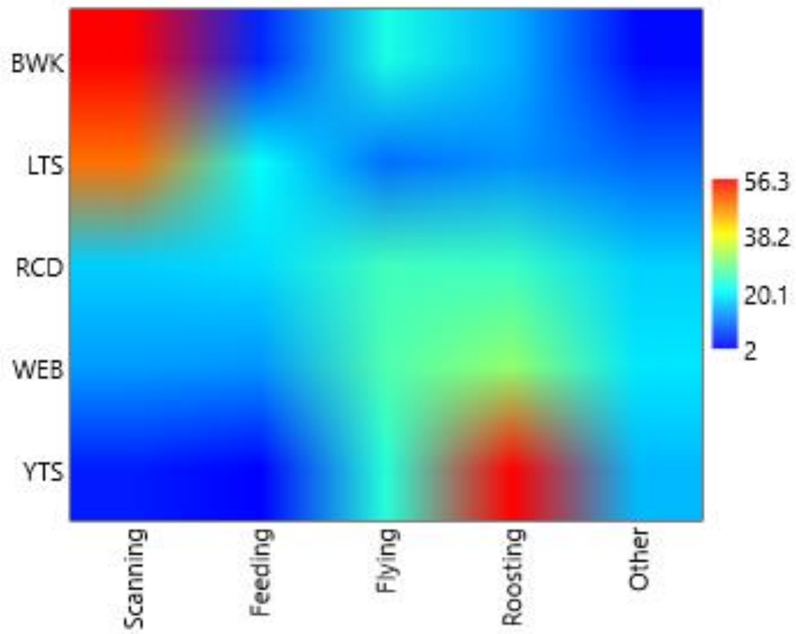

Figure 4: Plot Matrix showing species and their highly preferred activities, x-axis denoting the activities and y-axis denoting the species, the legend represents the percentage of time given to the activities ranging from 2%-56.3% of total time

Figure 5 shows that Yellow-throated sparrow, Red Collard Dove, and White Eared Bulbul are much more similar on the basis of time allotted for roosting, Moreover, Red Collard Dove and White Eared Bulbul exhibit the highest similarity in the behavioral study as they allot almost equal time to similar activities. The Long-Tailed Shrike and the Black-Winged Kite also exhibit great similarities in their behaviors and similar time allocation to different activities as they belong same feeding guild, and they roost and scan in the same areas as well.

According to the results, it is deduced that the birds of central Rajasthan do not require more time, which is associated with accessibility of food in the fields. The body size has little bearing on feeding time, but in the instance of the Long-Tailed Shrike, which feeds on food that is roughly half its body size, they need time to capture, kill, and devour the prey. Because of the hot arid conditions of the day, roosting generally occupies a larger share of the time of selected birds to limit the waste of water and energy. Flying across the fields takes around a quarter of the time for the observed species, but in the case of the Long-Tailed Shrike, the time is only about 10% since they maintain tiny territories for feeding, roosting, and other activities.

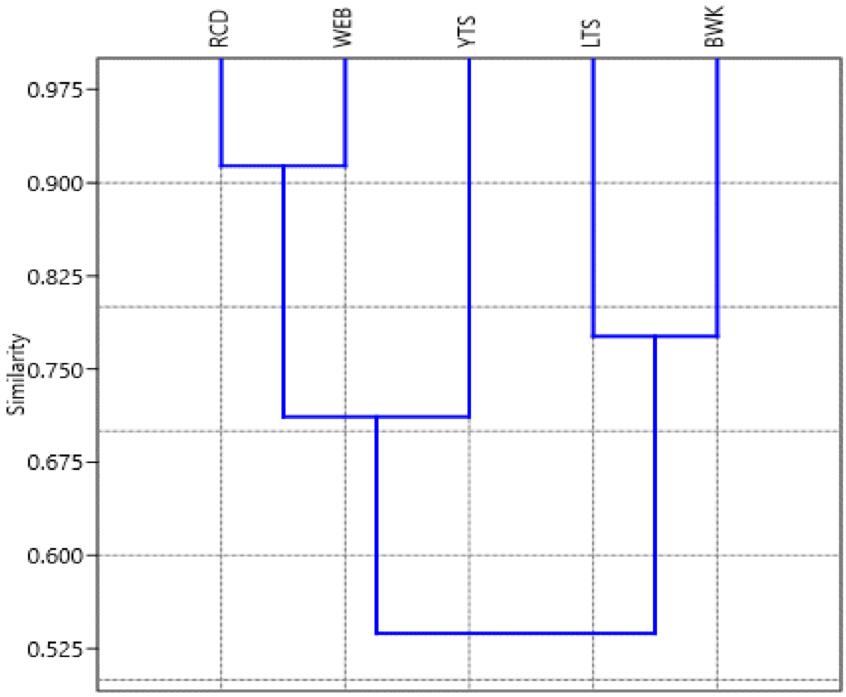

Figure 5: Similarities between species by Bray-Curtis Method

3.2. Frequencies of transition between observed behaviors

The results of frequencies of transitions between behaviors are shown as chord diagram in Figure 6 to Figure 10. The nodes at edge of circle represent particular behaviors and the bands represent transitions between the behaviors. The more the width of a band, the more is the probability of performing a particular behavior after another. The Black Winged Kite (Figure 6) has a probability of 0.900 of entering screening when flying. And the lowest measured chance of flying after other actions such as preening is 0.100. The frequency of eating after screening is only 0.450, and the bird usually returns to scanning after feeding at 0.850 since the prey is rather little in comparison to its body size, and the bird needs to finish its energy requirements. Long-tailed Shrike (Figure 7) had a higher likelihood of transitioning from roosting to other behaviours such as calling and preening, and from other activities to screening the habitat for food, with values of 0.800 for both. After scanning, the chance of feeding is 0.700. When compared to Black Winged Kite and Long Tailed Shrike, Red Collared Doves (Figure 8) have a higher likelihood of feeding after scanning, which is 0.900, because their dietary items are often static. The likelihood of flight after feeding is 0.950 in Red Collared Doves because they roost for a longer amount of time. The White-eared Bulbul (Figure 9), which feeds on fruits and barriers, has a higher likelihood of feeding after scanning, which is 0.950, as does the Yellow-Throated Sparrow (Figure 10), which feeds on insects and grains. With an observed value of 0.800, the White Eared Bulbul favors calling after roosting; the bird rarely returns to scanning after feeding. However, in the instance of the Yellow-throated Sparrow, the bird has a 0.100 chance of returning after feasting on insects.

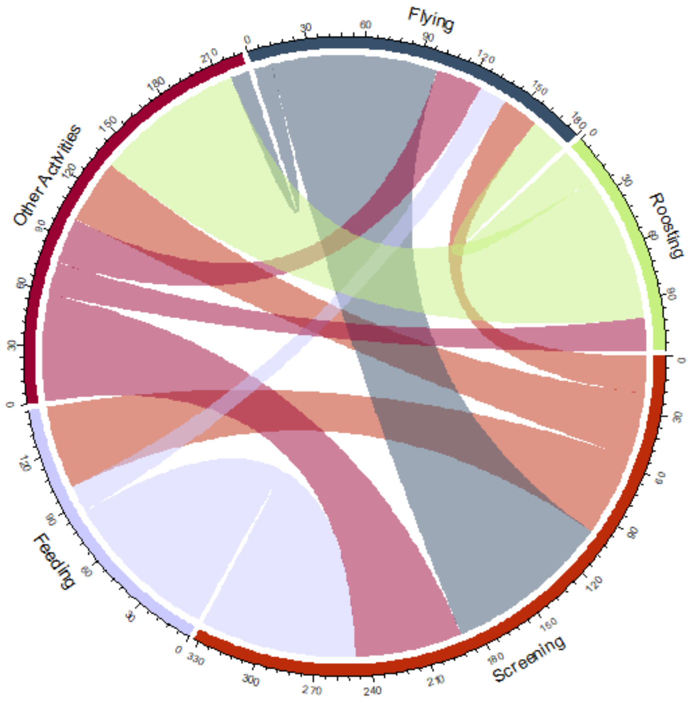

Figure 6: Transition between behaviors in Black Winged Kite

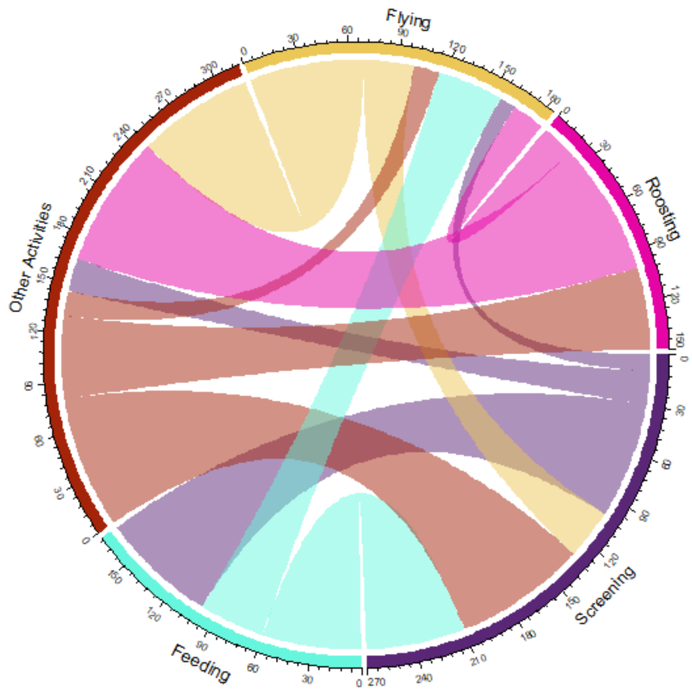

Figure 7: Transition between behaviors in Long Tailed Shrike

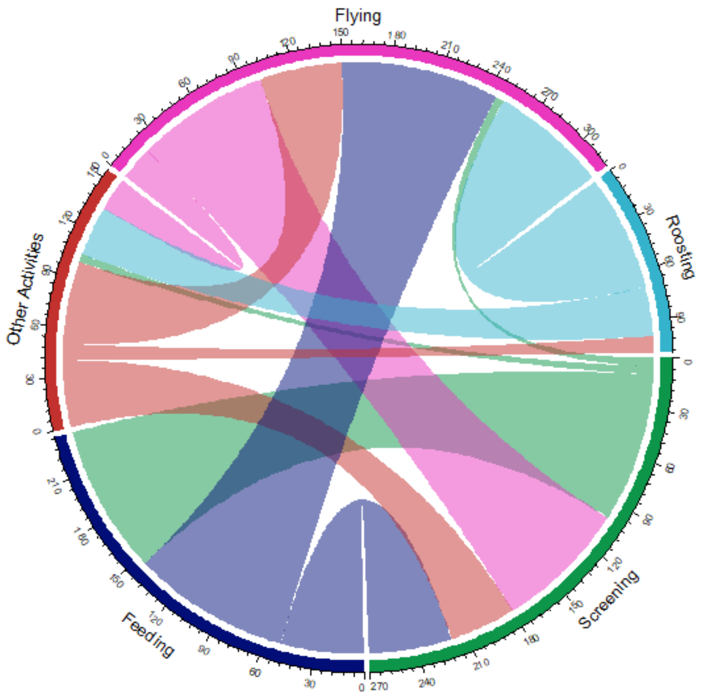

Figure 8: Transition between behaviors in Red Collard Dove

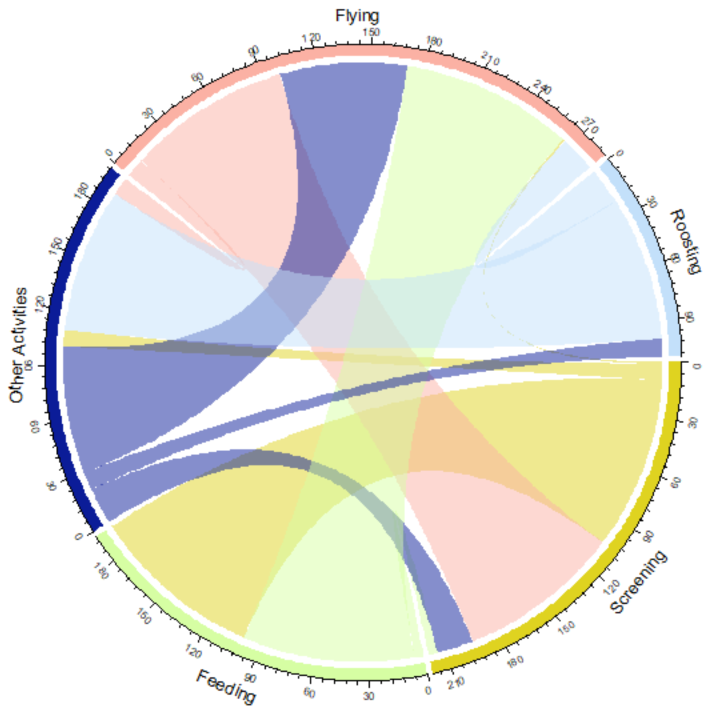

Figure 9: Transition between behaviors in White Eared Bulbul

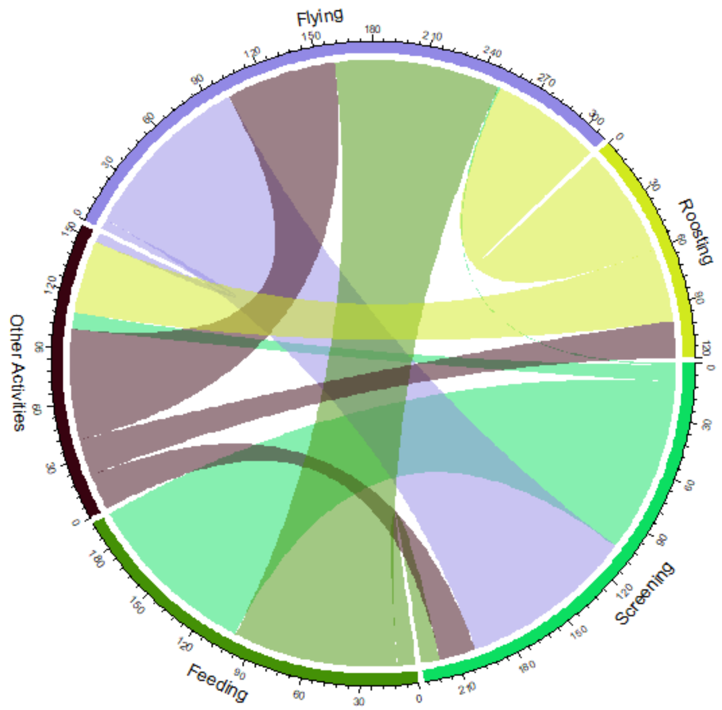

Figure 10: Transition between behaviors in Yellow Throated Sparrow

4. Conclusion

According to the findings of this study, the two carnivorous birds, the Black Winged Kite and the Long-tailed Shrike, spend more time scanning in agricultural fields because the fields provide a suitable refuge for the prey population. The Black Winged Kite, as a raptorial bird, has longer flights between landscapes, whereas the Long-Tailed Shrike has comparatively shorter flights. Based on observations, these birds are particularly prone to disturbances, causing them to displace frequently. The White Eared Bulbul spends most of its time roosting in agricultural fields; feeding often occurs between early morning and late afternoon, and it shares the least amount of time for feeding. Yellow-throated Sparrows hide in bushes or thorny trees since they have the smallest body size compared to all other observed species. Their dietary items are mostly insects and grains, and thus they spend the least amount of time feeding. Because there are fewer predators and less human disturbance in the study region, the Red collard dove spends more than half of its time being a constant threat to crops.

Conflict of Interest

The Authors declare that there is no conflict of interest in publishing the manuscript in this journal.

Acknowledgment

We would likely to acknowledge the Rajasthan State Biodiversity Board (RSBB), the Department of Science and Technology (DST) and Government of Rajasthan for funding and their collaborative efforts under the RSBB-DST Scholarship.

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Length-weight relationship, Fulton's condition factor and sex ratio of *Bagrus docmak* (Forsskål, 1775) in Lake Chamo, Ethiopia

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Received: May 24, 2022 **Accepted:** December 18, 2022

Abstract: *The objectives of the study were to determine the length-weight relationship, Fulton's condition factor, and sex ratio of Bagrus docmak in Lake Chamo. Total length (TL), total weight (TW), and sex data were collected from 469 fish samples (268 females and 201 males) for one year (January to December 2021) from the commercial fishery of Lake Chamo. The collected data were summarized by using descriptive statistics (graphs and tables) and analyzed with the application of Microsoft Excel 2010 and SPSS software. The length-weight relationship was calculated using the power function and obtained as* $TW = 0.0087*TL^{3.0272}$, $(R^2 = 0.8959)$, $TW = 0.0052*TL^{3.1412}$, $(R^2 = 0.9281)$ *and* $TW = 0.0063*TL^{3.0998}$, $(R^2 = 0.9152)$ *for females, males and combined sexes, respectively. The regression coefficient "b" was significantly different from the cubic value "3" (P < 0.05), implying that B. docmak of Lake Chamo followed a positive allometric growth pattern. There was a significant deviation in the sex ratio of male to female (1:1.33) from the hypothetical 1:1 ratio* ($\chi^2 = 4.79$; $P < 0.05$). *The average Fulton's condition factor for females, males, and combined sexes was 1.01, 0.97, and 0.99, respectively. The one-way ANOVA (P > 0.05) revealed that Fulton's condition factor between sexes was insignificant. But it was significantly different in the months of interaction (ANOVA, P < 0.05). The t-test also revealed a highly significant difference in a month's interaction (t-test, P = 0.000) indicating the seasonal variation in the mean monthly condition factor. The condition factor indicated that the health condition of B. docmak was not as good. Heavy fishing pressure and different agricultural practices were taking place around the lake which might disturb and break the chain of food availability in addition to other biotic and abiotic factors. Further investigations on water quality parameters and other biological aspects such as feeding habits and reproductive biology of B. docmak shall be undertaken for the management of the fish stocks in the lake.*

Keywords: Condition factor, Lake Chamo, fish sex, water quality

1. Introduction

Bagrus is a genus of Bagrid catfishes that are native to Africa and Asia (Nelson, 2006). *Bagrus docmak* is one of the commercially important fish species in Ethiopia. It occurs in the most southern rift valley lakes like Abaya and Chamo (Shibru, 1973), in the Segen River (Risch, 1986), and in the Nile system (Golubstov *et al*., 1995).

Fish length-weight relationships are useful for converting length observations into weight estimates to provide some measure of biomass (Froese, 1998). Length-weight relationships have been used frequently to estimate weight from length because direct weight measurements can be time-consuming in the field (Sinovcic *et al*., 2004). Knowledge of length-weight relationships and population dynamics of the fish is vital in fishery science and management (Lizama and Ambrosio, 2002; Ahmed *et al*., 2003). Also, knowledge of the sex ratio of fish is important to ensure proportional fishing of two sexes and provides information necessary for assessing the reproductive potential of a population (Vazzoler, 1996).

The condition factor is a method by which the physical condition and seasonal variation in the well-being of an individual fish could be known (King, 1995). The condition factor (K) is a quantitative parameter of the well-being, and state of the fish and reflects recent feeding conditions (LeCren, 1951). The growth of any fish is related to the prevailing environmental conditions. Many authors have explained the importance of condition factor as a useful tool for assessing fish growth rate, age, and feeding intensity (Abowei, 2006; Kumolu-Johnson and Ndimele, 2010; Oribhabor *et al.,* 2011; Onimisi and Ogbe, 2015; Abu and Agarin, 2016). The length-weight relationship is also very essential as it is possible to estimate the average weight of fish at a given length (Lawson *et al*., 2013; Ahmed *et al*., 2017; Getso *et al*., 2017; Kumar *et al.*, 2017; Melaku *et al*., 2017; Muchlisin *et al*., 2017). The well-being of the fish is considered as a good indicator of various water bodies' health in relation to water pollution due to its cheapest means of determining the stress of water pollution on the fish's body condition (Gupta and Tripathi, 2017).

Bagrus docmak is one of the four commercially important fish species with 8% catch contribution in Lake Chamo fishery (Shishitu *et al*., 2021). It is highly regarded by local people as food fish because it has few intramuscular bones. The catch contribution and production of *B. docmak* was drastically declined in Lake Chamo fishery (Shishitu *et al*. 2021). Length-weight relationship and condition factor are very important tools of fishery management as it provides information about the growth of the fish, its general wellbeing, and fitness in a water body. Therefore, this study was aimed to determine some aspects of the length-weight relationship, sex ratio, and condition factor of *B. docmak* in the lake to provide the necessary scientific information for proper utilization and management of the stock.

2. Materials and Methods

2.1. Description of the study area

Lake Chamo (5°50ˈ59ˈˈ N; 37°33ˈ54ˈˈ E) is located in Southern Nations Nationalities and People's Regional State of Ethiopia (Figure 1). The catchment and surface area of Lake Chamo is 1,109 km^2 and 329 km^2, respectively (Awulachew, 2006). The catchment of the lake is characterized by a humid to hot semi-arid tropical climate with a bimodal rainfall pattern including two wet seasons (a first from end-March to mid-June, a second from mid-September to late November) and two dry seasons (a first from December to mid-March, a second from end-June to mid-September) (Makin *et al*., 1975; Wagesho, 2014). Lake Chamo receives water from the rivers Kulfo, Sile, and Elgo (Makin *et al*., 1975; Teklemariam, 2005). The floodplains and the deltas of the lake are fertile and hence have been under extensive agricultural cultivation for the last three decades.

There are four commercially important fish species in Lake Chamo which are Nile tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*), Nile perch (*Lates niloticus*) and *Bagrus docmak*. The fishery on Lake Chamo is almost exclusively conducted with a surface gillnet, although long–lines are also used to some extent for African catfish (*Clarias gariepinus*) and *Bagrus docmak*. The nets are prepared locally by fishers themselves or by some other people involved in fishing gear-making activity. Also, a monofilament gillnet is used and it is obtained from abroad illegally and it is dangerous as it causes overfishing.

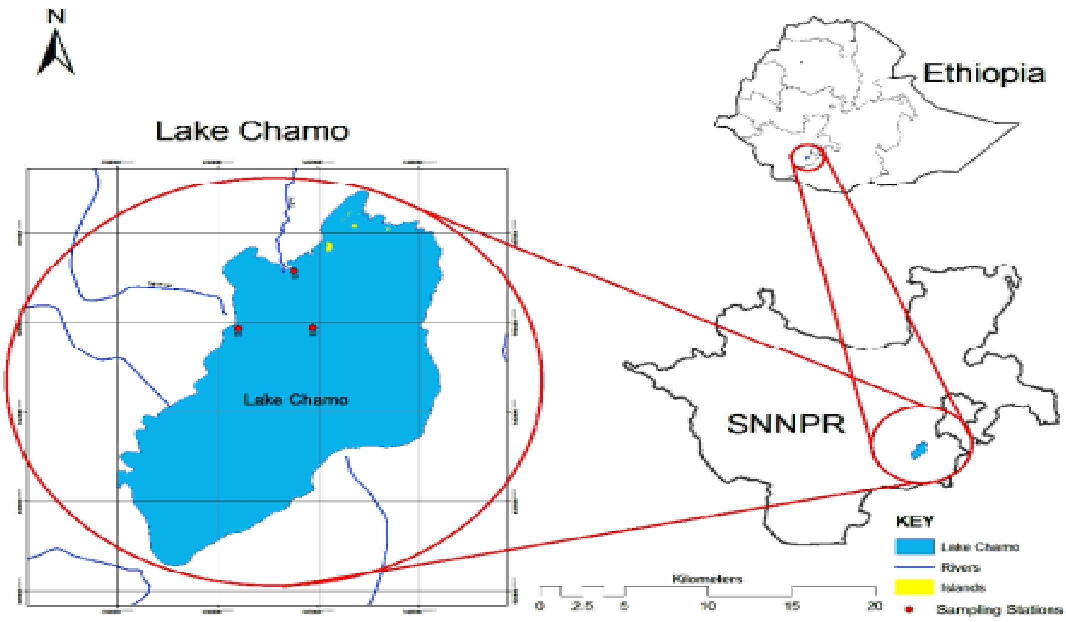

Figure 1: Location of onshore and offshore sampling stations at Lake Chamo, Southern Ethiopia (Utaile and Sulaiman, 2016)

2.2. Methods of sampling and data collection

Six legal cooperatives are organized on Lake Chamo fisheries and four cooperatives (Arba Minch, Chamo, Sego and Harura Boche) were selected for data collection. Out of the selected cooperatives, eight landing sites (Ganta fora, Bedena 1, Grawa, Wedeb, Bole, Ashewa, Chika, and Mehal) were selected and used as sampling sites. Samples of *B. docmak* were collected from the commercial fisheries of Lake Chamo randomly selected three days a week from January to December 2021. The trained fishermen were involved in data collection with regular following-up by the researcher. The total length and total weight of fresh fish samples were measured to the nearest 1 mm and 1 g using a measuring board and sensitive electronic balance, respectively. Sex determination was distinguished manually based on external sexual characters. Males have two openings which are present just before the anal fin and females have three body openings. The length-weight relationship was calculated using the power function (Le Cren, 1951).

$$TW = aTL^b \quad [1]$$

Where

- TW = total weight (g)
- TL = total length (cm)
- a = the intercept
- b = the slope of length-weight regression

The Fulton's condition factor (K) is often used to reflect the nutritional status or well-being of an individual fish. It was calculated by using the formula described by Fulton (1904) which is indicated below.

$$K = \frac{TW}{TL^3} * 100 \quad [2]$$

Where

- TW = total weight of fish in grams (g)
- TL = total length of fish in centimeters (cm)

2.3. Data analysis

The data analyses were done using Microsoft Office Excel (2010) and SPSS (Version 16.0) software. A Chi-square test (χ^2 test) was employed to determine if the sex ratio varies between males and females *B. docmak*.

3. Results and Discussion

3.1. Length-weight relationship

The values of the regression coefficient "*b*" for females, males, and combined sexes obtained from the length-weight relationship by using the best-fit regression of power function gave 3.0272, 3.1412, and 3.0998, respectively. The relationship was presented in Fig. 2, 3, and 4, respectively. Analysis of variance (one-way ANOVA) showed significant differences between the regression coefficient "*b*" and the expected cubic relationship between length and weight for an ideal fish which maintains the same shape "*b"* (3) (Table 1; P<0.05). As indicated in Table 2, the t-test revealed the presence of a significant difference between the regression coefficient "*b*" in females, males and combined sexes (P < 0.05). According to the results of this study, the growth patterns of *B. docmak* were positive allometric and curvilinear in Lake Chamo.

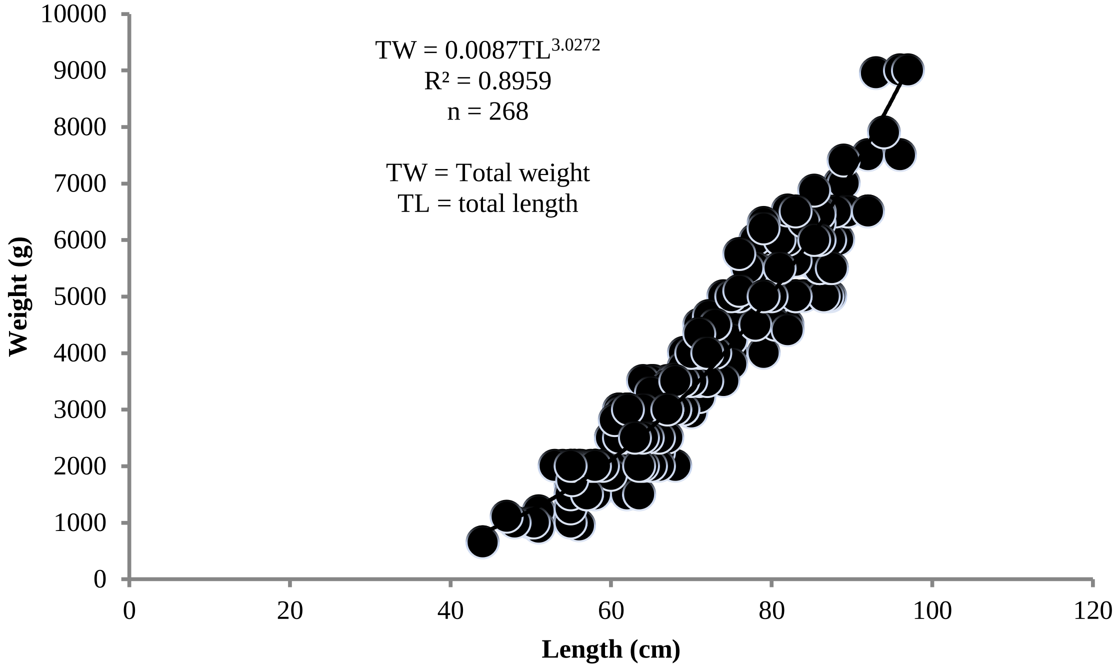

Figure 2: Length-weight relationship of female *B. docmak* from Lake Chamo

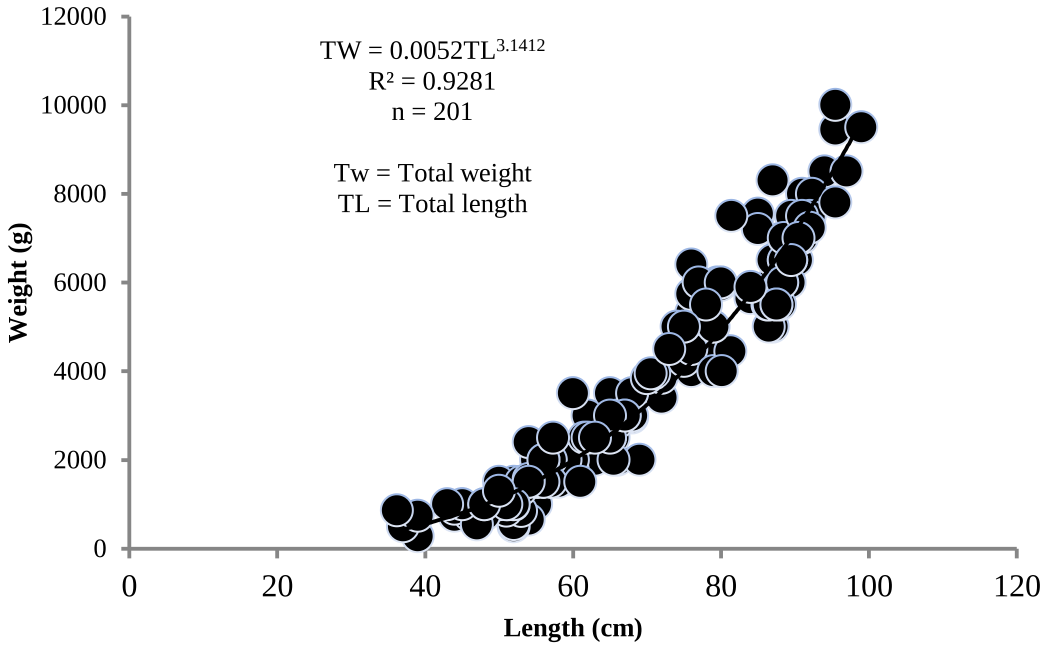

Figure 3: Length-weight relationship of male *B. docmak* from Lake Chamo

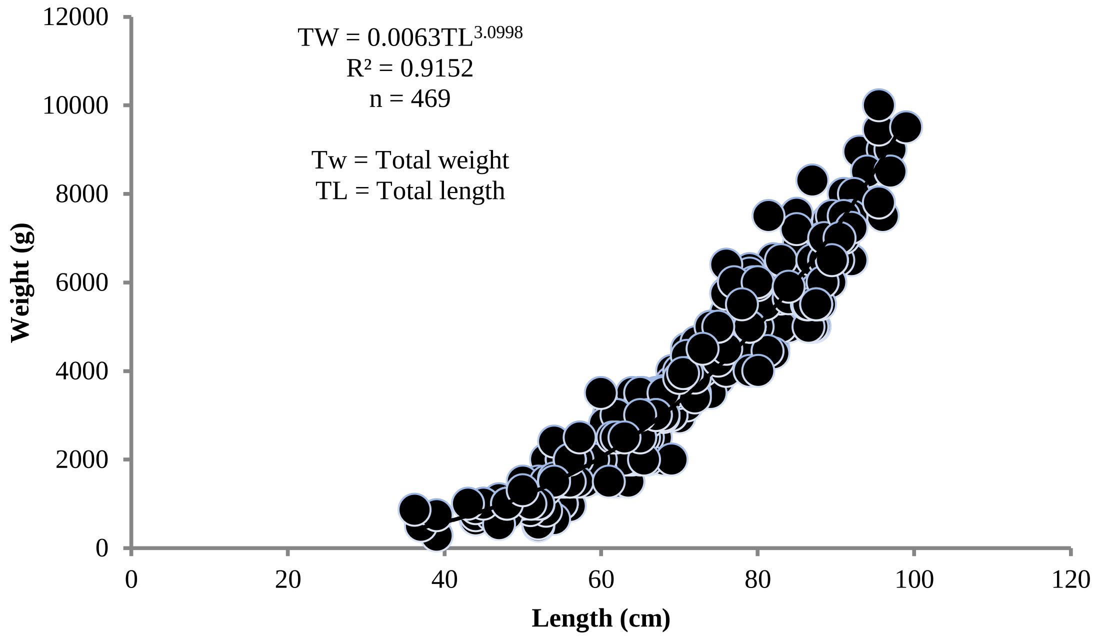

Figure 4: Length-weight relationship of combined sexes of *B. docmak* from Lake Chamo

Table 1: Analysis of variance (ANOVA) of length-weight relationship of *B. docmak* from Lake Chamo

Source of Variation	SS	df	MS	F	P-value	F-critical
Between Groups	0.0144	1	0.0144	36	0.027	18.513
Within Groups	0.0008	2	0.0004			
Total	0.0152	3				

Table 2: Regression static parameters of female, male and combined sexes

Parameters	Females	Males	Combined sexes
a value	0.0087	0.0052	0.0063
b value	3.0272	3.1412	3.0998
Std. Error (S_b)	0.063	0.062	0.043
R^2	0.8959	0.9281	0.9152
t-calculated	48.33	50.45	71.29
t-critical (5%)	1.962	1.962	1.962
No of observation	268	201	469
Significance	0.0000	0.0000	0.0000

A similar relationship has been reported by earlier studies for *B. docmak* (Anja *et al*., 2009). According to the reports of some authors, the growth patterns of *B. docmak* were negative allometric (Ikongbeh *et al*., 2012; Edwin and Simon, 2021). Fish can attain an isometric, negative or positive allometric growth pattern. The positive allometric growth implies that the fish becomes relatively broader and fatter as its length increases (Riedel *et al*., 2007). Based on the findings of this study, the growth pattern of *B. docmak* in Lake Chamo became relatively stouter and deep-bodied as they increase in length.

The variation in the value of *b* takes place due to season, habitat, gonad maturity, sex, diet, stomach fullness, health, preservation techniques, and annual differences in environmental conditions (Bagenal and Tesch, 1978; Froese, 2006; Yilmaz *et al*., 2012 and Ali *et al*., 2016). Furthermore, variations in fish growth patterns could also be related to the condition of the species itself, its phenotype, specific geographic location, and its environment (Tsoumani *et al*., 2006). However, these factors were not specifically considered in the present study, it was not possible to clarify which factors among those described above influenced these study results. It should also be noted that the growth process can differ in the same fish species on the basis of dwelling in diverse locations influenced by numerous biotic and abiotic factors.

3.2. Fulton's condition factor (K)

The analysis showed that there was no significant difference between the mean condition factor of males and females *B. docmak* (P > 0.05; Table 3). But the mean condition factor by month's interaction in Lake Chamo was significantly different (P < 0.05; Table 4). The seasonal variation in the mean monthly condition factor was highly significant in the months' interaction (t-test, P = 0.000).

The monthly mean Fulton's condition factor ranged from 0.92 to 1.2 for females, 0.8 to 1.1 for males, and 0.88 to 1.15 for combined sexes (Table 5). The average K value for females, males, and combined sexes was 1.01, 0.97, and 0.99, respectively. The lowest condition factor for females (0.92) was recorded in January, and the highest (1.2) was in November. For males, the lowest value (0.8) was recorded in March and the highest value (1.1) was in August. For combined sexes, the lowest value (0.88) was recorded in March and the highest (1.15) in November.

According to Anja *et al*. (2009), the condition factor of *B. docmak* in Lake Chamo ranged from 0.436 to 0.489 for males and from 0.449 to 0.489 for females. The condition factor (K) of the fish species in this study was not in agreement with the condition factors of the same fish species as reported by Ikongbeh *et al*. (2012); 1.61, 1.62, and 1.62 for male, female and combined sexes, respectively, in Lake Akata. Variations in condition factors are influenced by many biotic and abiotic factors such as phytoplankton abundance, predation, water temperature, and dissolved oxygen concentrations (Ahmed *et al*., 2011). The condition factor of fish can vary on the basis of the species type, prevailing environmental conditions, and food availability in their occupied habitats (Okach and Dadzie 1988; Wanyanga *et al*., 2016). The condition factor of fish can also be affected by season, reproductive cycles, and water quality parameters (Khallaf *et al*., 2003). When the condition factor K value is equal to or greater than one, it means the fish have attained a better condition (LeCren, 1951). Ayoade (2011) also suggests that a condition factor higher than one is a good fish health condition.

Fisheries of Lake Chamo are under heavy fishing pressure related to recruitment and growth overfishing with increased effort and reduced mesh size. There are also different agricultural practices taking place around the lake which might disturb and break the chain of food availability for the fish (Shishitu, 2020). In the present study, the average condition factor of *B. docmak* in Lake Chamo did not lie in the range of a good health condition. Even if, factors affecting the wellbeing of *B. docmak* in Lake Chamo were not specifically considered, it might be due to heavy fishing pressure, changes in the environmental conditions of the lake, and thereby changes in the nutritional status of the fish.

Table 3: One-way ANOVA of Fulton's condition factor by sex

Source of variation	SS	df	MS	F	P-value	F-critical
Between groups	0.012	1	0.012	1.667	0.210	4.301
Within groups	0.160	22	0.007			
Total	0.172	23				

Table 4: One-way ANOVA of Fulton's condition factor by months

Source of variation	SS	df	MS	F	F-critical	Sig.
Between groups	0.136	11	0.012	4.077	2.717	0.011
Within groups	0036	12	0.003			
Total	0.172	23				

Table 5: The mean monthly condition factor of females, males and combined sexes of *B. docmak* in Lake Chamo

Moths	Females	Males	Combined sexes
January	0.92	0.89	0.91
February	0.96	0.94	0.95
March	0.94	0.8	0.88
April	0.99	0.95	0.95
May	0.97	0.88	0.94
June	0.93	0.92	0.91
July	0.99	0.99	0.97
August	1.01	1.1	1.04
September	1.03	0.95	1
October	1.11	1.07	1.1
November	1.2	1.04	1.15
December	1.07	1.05	1.06
Average	1.01	0.97	0.99

3.3. Sex ratio

About 469 samples of *B. docmak* were collected. Among these samples 268 (57.14%) were females and 201 (42.86%) were males (Table 6). The monthly sex ratio (M:F) was statistically insignificant between males and females except for April and May. But the total sex ratio (M:F) was 1:1.33 and statistically highly significant (χ^2 = 4.79; P<0.05). The finding indicates that there was a deviation from the expected sex ratio of one male to one female and reveals that females were more numerous than males in Lake Chamo. The sex disparity could be a result of the differential survival to certain environmental conditions and is described as a mechanism for regulation in fishes.

Contrarily to the present study, the sex ratio of males to females of *B. docmak* was not significantly different Anja *et al*., (2009) sex ratio (1.0:1.07), Ikongbeh *et al*., (2012) sex ratio (1.0:1.08) and Edwin and Simon, (2021) sex ratio (1.0:1.26) in Lake Chamo, Lake Akata (Nigeria) and Lake Victoria (Kenya), respectively. In the present study, females were more numerous than males in Lake Chamo. The general bias towards females might be due to a potential mechanism to produce more offspring in situations wherein the populations are under some stress and as a result, allocations of resources to increase biomass.

Table 6: Sex ratio of *B. docmak* from Lake Chamo

Months	Female	Male	Total	Expected frequency	Sex ratio (M:F)	Chi-square (χ^2)	P-value
January	21	11	32	16	1:1.91	1.56	0.08
February	12	17	29	14.5	1:0.70	0.43	0.35
March	25	16	41	20.5	1:1.56	0.99	0.16
April	28	14	42	21	1:2	2.33	0.03*
May	20	9	29	14.5	1:2.22	2.09	0.04*
June	21	24	45	22.5	1:0.88	0.10	0.65
July	25	22	47	23.5	1:1.14	0.10	0.66
August	21	25	46	23	1:0.84	0.17	0.56
September	27	18	45	22.5	1:1.5	0.90	0.18
October	26	17	43	21.5	1:1.53	0.94	0.17
November	18	8	26	13	1:2.25	1.92	0.05
December	24	20	44	22	1:1.2	0.18	0.55
Total	268	201	469	234.5	1:1.33	4.79	0.00*

***Significant value**

4. Conclusion and Recommendations

The length-weight relationship of *B. docmak* in Lake Chamo followed a positive allometric growth pattern. The body condition of *B. docmak* showed seasonal variability in the monthly condition factor and its health condition was not as such good. The sex ratio of *B. docmak* deviated from the expected sex ratio of one male to one female where females were more numerous than males in Lake Chamo. Further study on water quality parameters and biological aspects of *B. docmak* and other fish species are recommended for better management of the fish species in the lake.

Conflict of interest

The author declares that there is no conflict of interest in publishing the manuscript in this journal.

Acknowledgment

The author would like to acknowledge the Ethiopian Institute of Agricultural Research (EIAR) for the financial support and Arba Minch Agricultural Research Center for allowing access to the necessary facilities.

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ISSN: 2616-3721 (Online); 2616-3713 (Print)