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Journal of Science and Sustainable Development (JSSD)

The International Journal of Ambo University

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Journal of Science and Sustainable Development (JSSD)

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Following the abstract, about 3 to 5 **key words** that will provide indexing references should be listed.

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Abayomi (2000), Agindotan et al. (2003), (Kelebeni, 1983), (Usman and Smith, 1992), (Chege, 1998; Chukwura, 1987a,b; Tijani, 1993,1995), (Kumasi et al., 2001)

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Moran GJ, Amii RN, Abrahamian FM, Talan DA (2005). Methicillinresistant *Staphylococcus aureus* in community-acquired skin infections. Emerg. Infect. Dis. 11: 928-930.

Chikere CB, Omoni VT and Chikere BO (2008). Distribution of potential nosocomial pathogens in a hospital environment. Afr. J. Biotechnol. 7: 3535-3539.

Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing *Escherichia coli* in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

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RESEARCH PAPER

A Critical Discourse Analysis of Hachalu Hunsessa's Lyrics: Applied Linguistic Perspectives

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Abstract

The article attempt was to explore the contents of Hachalu's musical lyrics critically from applied linguistics perspectives. Song is a short musical work set in a poetic text with equal importance given to music and to the words. The objectives of the study are to assess critically the socio-cultural issue addressed and evidenced in the lyrics of Hachalu's song, to interpret, and analyses the cultural content of the lyrics in Hachalu's song, and to archive the lyrics of Hachalu's song with its authenticity. In examining the songs, the study gave an emphasis on the three inter-related levels of analysis tied to the three inter-related dimensions of discourse proposed by Faiclough. Figurative Language such as personification, imaginative, and comparative and contradictive were used as a theoretical Framework in this study. It could be attributed to the different major categories of metaphor, simile, metonymy, and synecdoche as important constituents. The result of the study shows that the life experience, background, and ups and down of Hachalu himself explicitly narrated in the songs he performed. More precisely, the songs written by him closely related to the idea proposes within the song lyrics. The concept <jir-> /ʤir-/ 'live' was exist since long ago. But the concept was artistically introduced for the first time by Hachalu. Besides, Hachalu came with a discourse of forgiveness, integrity, reconciliation, truth, equality, unity, and tolerance. Moreover, Oromo philosophy, language, psychology, culture, value, norm, assets, and wisdom are unambiguously promoted in his music. Thus, the researcher found that Hachalu's song significantly influences the entire Oromo people in particular and Ethiopian people in general. Therefore, Oromo should give especial attention in producing numerous Hachalu.

Keywords: song lyrics, critical discourse analysis, Hachalu Hunsessa's Lyrics

Introduction

The word "music" was etymologically derived from Greek word "mousike" taken from the name of God which led the world of art and science. The primary subject matter of music is feelings and sounds. These imply that the content of music is a revelation of feelings and sounds and that music gives us a more sensitive understanding of them Peter (2010). The other point in touch with Peter (2010) is that "music is the science of art ordering tones or sounds in succession, in combination and in temporal relationship to produce a composition having unity and continuity as well as rhythm, melody, and harmony as its elements". In general, the role of philosopher was paramount in concept creation and etymological definition of music. Greek philosophers and ancient Indian philosophers defined music as tones ordered horizontally as melodies and vertically as harmonies.

Lyric derives from the Greek word lyrikos, meaning "singing to the lyre". The word lyric came to be used for the "words of a song"; this meaning was recorded in 1876. The common plural (perhaps because of the association between the plurals lyrics and words), predominates contemporary usage. Use of the

singular form lyric remains grammatically acceptable yet remains considered erroneous in referring to a singular song word as a lyric. Lyrics can be studied from an academic perspective. For example, some lyrics can be considered a form of social commentary. Lyrics often contain political, social and economic themes as well as aesthetic elements. The messages in music can be explicit or implied through metaphor or symbolism (International Music Federation 2018, Abdi, 1990).

The lyric in a song is actually non-musical aspect. However, it gives a new and unique dimension in harmony of the music. In addition, its presence in music is not only as an embedded element but also as a part of the music. More precisely, lyric in a song should compose of huge information and core idea of the singer. Many songs are created from text or beautiful poems. The difference is that a lyric of a song is written and combined with music. We usually meet a poem as word on page and a song generally hear as sounds in the air. However, we can say that a song lyric is same. In that sense, the lyrics of Hachalu's songs are full of Oromoo philosophy, psychology, culture, language, and wisdom. Music among Oromo is one and major aspect of spiritual culture. There are also material cultures that subordinate the content of music in Oromo culture. Oromo use music for happiness and condolence during weeding and dirge respectively. Language is not literal; it is called figurative, as in a figure of speech. Literal and figurative language is a distinction within some fields of language analysis (Soley and Hannon 2010, Dibaba 2015).

More specifically, in this study, the question how an icon Oromo singer Hachalu Hunsessa addresses the problems encountered the Oromo, to what end and in what situations he expresses and publicize the heartbeat of lyrics in Hachalu's song.

Song generally conveys message and its own meaning. The composer needs time to think, to choose the words and word order, to read what she or he writes, to rethink, revise and arrange the messages and meanings in a song. Then he or she considers its effect on the listener. Songs have special characteristics in their lyric. Each lyric is created to have its own nuance (Soley and Hannon, 2010, Cerulli, 1922). In this case Hachalu's song lyrics are composed of strong message and tone. The lyric in Hachalu's song were framed with the figurative language. In art with figurative language, stories and songs become more vivacious and interesting. Therefore, the objectives of this study were to assess critically the socio-cultural issues addressed and evidenced in the lyrics of Hachalu's song, interpret, and analyze the cultural content of the lyrics of Hachalu's song and archive the lyrics of Hachalu's song with its authenticity.

Conceptual framework

Fairclough (1995) stated that, the term discourse refers to the entire social interaction process, the text is only a part of it. More precisely, Fairclough's critical discourse analysis of these is a rather comprehensive model that allows micro-, meso- and macro-level research in accordance with the multi-layered nature of social research as compared to the other discourse analysis. Critical discourse analysis (Fairclough, 1995) is a three-step analysis that consists of textual analysis, the production, consumption and distribution of the text called interaction, and the interpretation of text in its social context which is called contextual analysis. During analysis, discourse under inspection is examined in a very general way. Micro, meso and macro level analyzes are utilized to reveal different levels of connectivity from the same set of questions.

Figurative Language

The researcher sticks to the figurative language framework for this particular study. Figurative language is a language which uses figures of speech (a way of saying one thing and meaning another). Keraf (1994) identifies that figurative language is divided into two major categories. These are direct and indirect meaning.

Numerous scholars from different perspectives define figurative language. According to Pungsley (1990) figurative language is the language that cannot be taken literally (or

should not be taken literally) and say something other than ordinary ways or say one thing and mean another. Figurative language is used in imaginative rather than literal sense, it is used widely in daily speech and writing.

Glucksberg (2001) on his part identifies that figurative language as language where the meaning does not coincide with literal language´s meaning and points at metaphors and idioms as examples of it. According to Kennedy (1993), figurative language consists of comparative, contradictive, relation and repetition figurative language. Comparative figurative language consists of personification, metaphor, and simile. contradictive figurative language consists of hyperbole, litotes, paradox, and irony. Correlative figurative languages consist of metonymy, synecdoche, symbol, allusion, and ellipsis. Meanwhile repetition figurative language consists of pleonasm, climax, anti-climax, rhetoric and repetition. More precisely, comparative figurative language consists of personification, metaphor, and smile.

a) Personification

Personification is figure of speech in imagination, which does not have soul, as though they have human characteristic (Potter, 2007, Assefa, 2003). It means that inanimate things in this world are guessed as animate by giving some attributes in inanimate things.

School alarm calls students to enter their classroom. Calls are verb form in dictionary. Letters is addition in present tense form because the subject is singular (alarm), alarm is inanimate thing; meanwhile it is given attribute like activity that is done by animates.

b) Metaphor

Metaphor is a variety of analogy, which compares two things directly, but in short pattern (Keraf, 1994). It means that between subject and object have same attributes, and writer uses it to compares it to another. It is a common poetic device where an object in, or the subject of, a poem is described as being the same as another otherwise unrelated object Blechner (2018).

c) Simile

Simile is comparison, which has explicit characteristic. It means that they state something similar with each other directly that use words likes as and like (Potter, 2007). Song is a short musical work set a poetic text with equal importance given to music and to the words more [precisely, Song is a short metrical composition intended for singing. Thus, according to Soley and Hannon, (2010), Lyrics:

1) Lyrics are compositions in verse which is sung to a melody to constitute a song. Lyric is expressing deep personal emotion or observations.

2) According to Merriam Webster, a song is a melody for a lyric poem or ballad.

3) Lyrics are a set of words that make up a song. Lyrics can be studied from an academic perspective. For example, some lyrics can be considered as a form of social commentary. Lyrics can also be analyzed with respect to the sense of unity (or lack of unity) with music.

4) According to (Astari, 2016), song is a short musical work set a poetic text with equal importance given to music and to the words. It may be written for one or several voices are generally performed with instrumental accompaniment. It is special about them is the fact that songs have a personal quality that makes the listeners react as if the song was sung for their personality.

5) According to the Oxford Dictionary (1995), lyrics are composed for singing. Lyrics are a set of words that make up a song. Lyrics can be studied from an academic perspective. Lyrics can also be analyzed with respect to the sense of unity it has with its supporting music. Lyric is a simple word of song. The lyrics or song texts do not only act as a complement to the song, but also as an important part of the music elements which determine the theme, character and mission of the song. It can also make sense

to be stable. To know the sense of the song, we can feel the rhythm and melody, harmony and voice of the singer by the singing of the song. A music composition is not always a sequence of melody with a lyric. The composition without a lyric on its melody is called instrumental music. On the contrary, the one with lyric is called a song. The music composition performed by a song contains an attractive aspect. The attractive aspect is language. The language, which consists of a sequence of words, gives a new dimension of the music, which cannot be found in other compositions, instrumental music.

Having said this much concerning the scientific content of lyrics and its interpretation in general, now let proceed to nature of Oromo music.

The birth of modern Oromo music was serving as a vivacious for Oromo nationalism. In other word imaging <Oromumma> 'being an Oromo' in Oromo modern music is a paramount. Oromo as a nation used its traditional music for social inclusion and social unity. Hachalu as a symbol of ethno and ethio-nationalist and his song inflamed the large community enthusiasm. Oromo music is a powerful manifestation of the process and display the critical role of affects in the building of the giant nation called Oromo.

Afran Qallo is the first modern band in history of modern Oromo Music industry. During the Emperor Hailesilassie (1932- 1974) and Derg Regime (1974-1991) Oromo in general and Oromo artists in particular are politically oppressed. By then, the Oromo musicians are enforced to censorship. In Oromo culture music is not only something performed during happiness events. But also, it is a means to resistance against brutal regime. Day by day, the protest songs against the Emperor have been produced up to now. In modern Oromo music, most of Hacalu's song on the one hand pave the way for resistance and on the other hand promote the request for equality at national level.

Research Method

The researcher follows a qualitative approach which means that the data were analyzed qualitatively. Critical Discourse Analysis (CDA) as Fairclough (2003) defines, is "a framework for studying connection between language, power, and ideology". CDA might also observe issues like ethnicity, gender, ideology, identity and culture differences and the ways these reflected in particular texts (Pennycook, 1997 cited in Paltridge 2003). With this line it is helpful that by using figurative language in analyzing an icon singer Hachalu Hundessa song lyric thoroughly. It can give better point of view in perceiving and understanding how the song lyrics construct the social identity and build unity among Oromo. This study applied the Critical Discourse Analysis design with a qualitative approach. Fairclough (1995) defines Critical Discourse Analysis as "discourse analysis which aims to systematically explore often opaque relationships of causality and determination between (a) discursive practices, events and texts, and (b) wider social and cultural structures, relations and processes." This study focused on analyzing the linguistics structure used in the Hachalu song's lyrics.

In this study, it is vital to collect song lyrics performed by Hachalu from the first album until the second album. Segni moti 'a clan of Royal', and waye kegna 'our affairs' are the first and second Albums released in 2009 and 2013, respectively. All the selected songs of the lyrics are directly quoted from each album performed by Hachalu. In addition, some lyrics are chosen for this particular study. These lyrics are those related to the concept <jir-> /ʤir-/ 'live'. The lyrics were classified by two main concerns which are representations of social issues. All the lyrics are collected from his songs written in Afan Oromo. The study examined the aspects of social issues addressed in the lyrics of Hachalu's song. Then the concept of <jir-> /ʤir-/ 'live' were analyzed carefully, continued with an interpretation of the texts, and ended with explanation. As mentioned above the songs of the lyrics were collected and critically transcribed and analyzed from different perspectives. The reason for the selection of the songs <tokkummaa>, <maalan jira>, and <jirraa> are

all the lyrics are written and modified by Hachalu. The first one is originally written by Nuho Gobana and modified by Hachalu. Hachalu writes the last two songs.

Result and Discussions

In the songs selected in this study, Hachalu implicitly and explicitly presented ups, and downs of his people in general and his life in particular. In addition, life experience, background, real life situation and problems of his own were addressed thoroughly. In this part the signs <for orthographic writing>, /phonemic transcription/, 'free translation' and [phonetic transcription] were used. Modern linguistics has introduced the concept of text that includes every type of utterance. For example, text may be a magazine article, a television interview, a conversation, or a cooking recipe. Besides that, according to De Beaugrande and Dressler (1981), text is defined as communicative events which have seven criteria; there are: cohesion, coherence, intentionality, acceptability, informative, situational, and textual.

<Tokkuummaa> /tok:um:a:/ 'Unity' is the first song written and performed by Hachalu from his first album. This concept by itself is a positive idea. More precisely, in this song the socio-cultural issues were addressed thoroughly. In this song lyric, he explicitly preaches and narrates about unity among Oromo nation. The Oromo as a nation is very keen to keep its unity (Legesse, 1973, Hussein, 2005, Bessa, 2013)

Title: Tokkummaa… Tokkummaa

/tok:um:a:/

Theme: unity

<Tokkummaa>

/tok:um:a:/ 'Unity'

<Tokkummaa>

/tok:um:a:/ 'Unity'

<yaa ilmaan Oromoo>

/ja: ilma:n ʔoromo:/

'Oromoo as a nation'

<Tokkummaa>

/tok:um:a:/ 'Unity'

<tokkummaan humna tokkummaa>

/tok:um:a:n humna /tok:um:a:/

'Unity is power!'

In the above lyric, the political and socio-cultural type of discourse has been indicated thoroughly. The elements of "Tokkummaa" song, <Tokkuummaa> in line 1, <Tokkummaa> in line 2, <yaa ilmaan Oromoo> in line 3, <Tokkummaa> in line 4, and <tokkummaan humna tokkummaa> in line 5. At the first glance this song is the first song Hachalu wrote while he was in jail. On the other hand, all lines of the lyrics preach, promote, and describe unity and forgiveness. He emphasizes that the unity is expected from Oromo and the community ought to have unity. He boldly also explains that unity is very important and power to everything. <Tokkummaa> 'unity' is a positive concept. With this song, he narrated way in which <tokkummaa> 'unity' plays a vital role in socialization of the target community. Besides, through unity it is possible to preserve and maintain cultural aspects of the community for the next generation. This is vital to all human beings. Such concept of positive thought is never created in individual's mind haphazardly. It requires positive thinkers, optimist, and genuine people. Hachalu is among them. Positive notion, emotion, and idea are intermingling with his thought and soul. That is why he started his song with the concept of unity. Nuho Gobena was also song <tokkuummaa> thirty years before. Finally, he presented the other big positive concept <Jirraa> to the world.

Hachalu as an icon artist addressed unity as a key to everything. Not only in his songs, but

also in his discourse he repeatedly preaches about unity. Moreover, his first album was composed of peace, unity, love, integrity, reconciliation, truth, equality and so on. All the concepts aforementioned are composed of positive notions. Thus, a positive idea was found in both Hachalu's mind and blood. In the 21st centuries in the entertainment world, most artists' works were designed in market monopolization. Most of them produce artwork in a way that paves a way to get money. Astonishingly, Hachalu's works were designed in which it can be a voice for the people, restore peace, and keep unity. Unity is key to any nation. Astonishingly, it is a unity, what our community lacks in general. The protest towards Oromo victims can be seen from these lines of song lyrics:

Title: <"Maalan jira…..?">

/ma:län ʤira/

'Am I alive?'

Theme: Together

<Galgalookoo gullalleen kan tufaa>

/gälgälo:ko: gul:äl:e:n kän tufa/

Darling my N –det PN

'My darling Gulele belong to Tufa'

<Gaara Abichuu ture galaan finfinnee meesee>

/ga:ra ʔabiʧu: ture gala:n finfin:e: me:se:/

Over there PN DET. N N V

'Abichu was over there while Gelan gets ready the land for Teff cultivation'

<Silaa akka jaalalaa walirraa hin fagaannuu>

/sila ʔak:a ʤa:lala: walir:a: hin fäga:n:u:/

'Our love remain us not to depart'

<Jaran nufageessee>

/ʤärän nufäge:s:e:/

'They prompted us to depart'

<Diigani gaara sana gaaradigamuun mallee>

/di:gäni ga:ra säna ga:rädigämu:n mäl:e:/

'They raze the hill that couldn't be'

<Addaan nubaasanii nu addaan bahuun mallee>

/ʔad:a:n nubasa:ni: nu ʔad:a:n bahu:n mäl:e:/

'They forced us to depart. But we couldn't'

<Sooreetti hadha sooree irbaannii irra buusa qaba>

/so:re:t:i hadʿa ro:re: ʔirba:n:i: ʔir:a bu:sa k'aba/

'Dear Sooreettii dinner should be presented with dessert'

<Seeqani seseeqani kan gargar nubaasee jara>

/se:k'ani sese:k'ani kän gärgär nuba:se: ʤära/

'They forced us to depart by showing their teeth'

In the above lyric, the political type of discourse has been indicated. The elements of "Maalan jiraa…..?" 'Am I alive'? song, < gullalleen > in line 1, and < galaan finfinnee meesee > line 2, it is all about history of Tulama linage. In history, Macca and Tulama are the children of Rayyaa from different mothers Siiree and Akkituu respectively. Galaan is among the Tulama's children. In this music Hachalu explicitly remarked on the place where this linage is lived for a long period of time using very few words.

The other element of "Maalan jiraa…..?" song <walirraa hin fagaannuu> in line 3, <Jaran nufageessee> in line 4, <gaaradigamuun mallee> in line 5, and < nu addaan bahuun mallee> in line 6 all narrate about unity among Oromo people. He preached about unity is the key to success. Most importantly, he addressed

culture in the same song. For instance, <Sooreetti haadha sooree irbaani irraa buusaa qaba> in line 7 is about Oromo culture. <Sooreettii> is a personal noun given to Oromo daughter. Because of "modernization" and "globalization" such names are endangered. Thus, Hachalu reminds us to give such a beautiful name to our kid. In addition, the concept of <irbaani irraa buusaa qaba> is to describe the type of food presented usually after dinner. In a single line this icon artist clearly recites the two types of culture namely spiritual and material culture. The content of this lyric is more of cultural genres and composed of historical aspect.

Most Hachalu's songs are more humanitarian songs. It is written to support Ethiopian people in general and Oromo in particular. This song is performed to be the voice for voiceless. More precisely, this song is written to support the Oromo victims from the Tigray People's Liberation Front (TPLF) regime. The song was very well known all over the world because it is spread as a free MPE4 which means it can be downloaded without any charge from YouTube. It has been downloaded and viewed by over 8 million people from the official YouTube. Astonishingly, as of the first release, hundreds of websites have uploaded the clip and posted the lyric. The appreciation of the song is very high since the statistic shows that over 1,000 comments and messages are sent to respond this song. Thus, this song can gain many respects, listeners, responds, or claims from many people around the world. The lyric in this song tells as the misery or the suffering of Oromo people by TPLF regime.

Titile: "Jirraa"

/ʤɨr:a/

'We are alive'

Theme: Together

<Jirra bullee barii arguuf>

/ʤɨr:abul:e: bäri: ʔargu:f/

'Here we are to see tomorrow'

<Garaa nubal'isee yaanuyii>

/gäranulʔise: ja:nuji:/

'We are delighted to respect others'

<Yaawaairranfachuu yaanuuyii>

/ja: wa: ʔir:anfäʧu: ja: nu:ji:/

'We are good in forgiveness'

<Tafkiidhaaf utaalchoo gergoodhaaf miliqqii>

/täfki:ɗa:fʔuta:lʧo: ge:rgo:ɗa:fmilik':i:/

'The wisdom given to insects'

<Xaddee kuttee baaneef waayyuudhaaf rasaasaa>

/t'ad:e: kut:e: ba:ne:fwa:j:u:ɗa:fräsa:sa:/

'Change is gradually. Being a wise take to wisdom'

<Hallaattiidhaaf koochoo>

/hal:a:t:i:ɗa:fko:ʧo:/

'The wisdom given to birds'

<Qocaadhaaf dhagaachaa>

K'oča:ɗa:f ɗaga:ʧa:/

'the wisdom given to tortoise'

<Kennaa maaltu dida jirra hunda baachaa>

/ken:a: ma:ltudidaʤir:ahundäba:ʧa:/

'This is the wisdom given to Oromo. We are blessed'

In the above lyric, the political and socio-cultural type of discourse has been indicating. Lexical aspect used in this discourse to support cohesion and coherence from the semantic

perspective. There are some lexical aspects in the song lyrics "Maalan jiraa…...?" In fact, Anaphoric repetition is the repetition of lingual constituent in the form of word or the initial phrase on every verse or subsequent sentence. The pronoun they, is reputedly exist in most sentences of the lyric. <jara> /ʤära/ line 4, <diganii> /digäni:/ line 5, and <addaan nubasani> /ʔad:a:n nubasäni/ line 6. The objective of the repetition of the pronoun they, is to influence the listeners hearers whether they are supporters or opponents of the positive idea brought by the singer/the author. All concepts presented positive thought in different sentences of the lyrics. As mentioned above the content of the lyrics in general composed of from the concept of unity, togetherness, unification, collectiveness and so on.

Situational context consists of physical, epistemic, social context with personal, locational and temporal analogical interpretation principle. Accordingly, Hachalu as a wise singer and lyric writer used the situation based on the existing contexts. For instance, the <Geerarsaa> /ge:rarsa:/ presented frequently at millennium hall.

Hachalu performed <geerarsaa> /ge:rarsa:/ in millennium hall pre TPLF kicked out by <Qeerroo> /k'e:r:o:/ 'Youth'. Besides his popularity achieved from the song, he also received some critiques for his presentation on live streaming on television. The first, of course, comes from the TPLF politician Zeray Asgedom and other politicians too because they would get the disadvantages from it.

In principle, literature is a means to teach language. Songs and languages might have some similar features. By using songs, people can express themselves. Astonishingly, an icon singer like Hachalu expresses the entire community through song. Like songs, language is also a means used by people to express their thoughts, feelings or concern about particular things. In this case, songs are a media to introduce new thought and language. In the same manner Hachalu's song plays an important role in promoting new concepts and producing grammar and vocabulary in Afan Oromo.

Conclusion

In conclusion, there are configurations within song lyrics, which conclude that song represents a part of discourse. In this study, Hachalu's song lyrics lines or sentences were analyzed from three different levels of discourse aspects: discourse relation, topic structure and text cohesion. Hachalu's song lyrics have been analyzed based on the aspects of discourse analysis. Music news from different sources makes a great contribution to the understanding of the contextual meaning and analysis. In most Hachalu's songs, it is difficult to find lexical aspects of the song's discourse. There is only one form of anaphoric repetition. It is the repetition of the pronoun they with positive thought in different sentences of the lyrics. In the song "Jirraa" <Garaa nuba'isee yaa nuyii> /gära: nulʔise: ja:nuji:/ 'We are delighted to respect others' Hachalu came with a discourse of forgiveness that comes with love. How love blinds us if we will. Hachalu himself was making excuses for the former regime and individuals took part in. From illocutionary act, it is the way of the receivers to respond the speaker's utterance in this song. Hachalu aggressively used the word <tokkummaa> in his speech and song to indicate unity lacks Oromo in particular and Ethiopians in general. Objectives of these song lyrics were to give an overview of Oromo Philosophy, psychology, culture, wisdom, and language. In addition, the ups and downs of Oromo in particular and Ethiopia people in general were narrated in Hacalu's song. Moreover, there was a cultural process of the target community in the song lyrics. Therefore, the researcher found that Hachalu's song significantly influences the entire Oromo as a nation. An Oromo icon artist Hachalu Hunsessa frequently and reputedly preached about unity, oneness, togetherness, and so on. Therefore, unity to Oromo people, unity to Ethiopian people, and unity to African people is very important..

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RESEARCH PAPER

Individualized Educational Therapy for Child with Dyslexia at Tsehay Chora Primary School, Addis Ababa, Ethiopia

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Abstract

Dyslexia is one of the most common manifestations of specific learning disorders. Early diagnosis, appropriate educational therapy, and support can mitigate dyslexia before it advances to severe level. The maxim "catch the child before he/she fails" is an inspiring and sensible axiology. The purpose of this study was to investigate the effectiveness of individualized educational therapy for students with dyslexia. Wakuma (pseudonym) was identified as a student with dyslexia based on diagnostic baseline assessment tests. A-B single-subject experimental research design with repeated measures and visual inspection techniques were used to investigate effectiveness of individualized educational therapy for student with dyslexia. Three different alphabet tests were used to collect data. Educational therapy package that has four individualized educational therapies and positive reinforcement was manipulated through alphabet song, alphabet naming, matching alphabet, and wooden letters arranging game. Diagnostic baseline assessments result showed that Wakuma's level of alphabet recognition was 39.6%. Mean stable alphabet recognition of pretest was 10.3. Post-therapy results showed that the change in level between pretest and post-test was 14.2 and the immediacy of educational therapy effect was 15.3. Literacy scores at post-test were significantly higher than pre-test scores. The study has implication that intervention through individualized educational therapy was effective in bringing change in alphabets recognition of student with dyslexia.

Keywords: Alphabet recognition, Dyslexia, Intervention, Reinforcement, Therapy

Introduction

Dyslexia is a hidden specific learning disability. According to the American Psychiatric Association Diagnostic Statistical Manual-Five (2013), dyslexia is a specific learning disability diagnosed when there are specific deficits in an individual's ability to perceive or process information efficiently and accurately. Dyslexia is a developmental disorder that mainly affects brain activity that associated with learning and memory system (Démonet et al., 2004), a language-based disorder characterized by difficulties in single-word decoding (Ward et al., 2019; Wajuihian and Naidoo, 2011), phonological processing (Tijms, 2004), that prevent learning of alphabet and phoneme associations (Castles and Coltheart, 2004). Dyslexia is characterized by difficulties in alphabet sensing (Butler, 2022), mental confusion in letter identification, and struggle to recognize written words (American Psychiatric Association, 2013), poor spelling, encoding, and decoding disabilities (Vellutino et al., 2004).

In the early stage when children are at the level of catching the alphabet, some of the children could be identified with reading difficulty, commonly known as foundation-level dyslexia (Seymour and Evans, 1999). Specific learning disability, typically dyslexia is caused by a deficit in the way in which a child was taught to read (Butler, 2022) and the phonological component of language (Hurford et al., 2016) that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction (Lyon et al., 2003). The

evidence suggests that inadequate facility in word identification due to basic deficits in alphabetic coding is the basic cause of difficulties in learning to read (Vellutino et al., 2004). The common symptoms of dyslexia are difficulties with reading and writing (Rose, 2009; Snowling and Hulme, 2012). Literal dyslexia is a condition in which a child has difficulty identifying letters, matching letters, name letters, or letter-sounds matching (Vellutino et al., 2004).

According to Elliott and Grigorenko (2014), the estimation of dyslexia for any population often ranges from 5%-20%. Statistical survey in America showed that approximately 20% of children in America have dyslexia (Butler, 2022). Similarly, International Dyslexia Association (2016) stated that the global prevalence rate of dyslexia is approximately 15%-20%. Findings are not consistent regarding the gender prevalence of dyslexia. According to Hall (2008), males are 3-4 times more likely to be affected by dyslexia than females. Some argue that it affects both boys and girls nearly at about the same rates (Zauderer, 2023). However, boys are more often sent for diagnosis of dyslexia than girls in which 60% for males and 40% for females (Jiménez et al., 2011; Zauderer, 2023), and about 85% of students with an individualized education program have a dyslexion (Zauderer, 2023). It occurs in at least 1 among 10 people and putting more than 700 million children and adults worldwide at risk of life-long illiteracy and social exclusion (International Dyslexia Association, 2016).

Enhanced teaching method through individualized educational therapy (IET) is an effective instructional intervention to teach alphabets recognition for child with dyslexia (Rose, 2009). Children who have literal dyslexia also have difficulty recognizing characters, learning the sounds of letters, and even identifying words that rhyme. Alphabet recognition is the ability to name letters, identify characteristics specific to said letter, and letter formation of all 26 uppercase and lowercase letter symbols used in the English language. According to Share (2004), children need to know letter names as well as letter-sounds to experience ease in learning how to read.

Children who do not successfully recognize the alphabet at an early age have a heightened chance of struggling with general reading skills throughout their lives. Hence, effective teaching methods through individualized educational therapy (IET) in their early educational paths are critical (Hurry and Sylva, 2007). According to Fawcett et al. (2014), early intervention through individualized education has lasting benefits for young children. The theories of Orton (Miles and Miles, 1999) investigated dyslexia alongside learning style proponents. The importance of reinforcement in education of students with dyslexia has theoretical background.

A student with dyslexia has difficulty reading (Doyle, 2002). A student with dyslexia needs his/her own way of learning. Teaching methods for children with dyslexia are independent of conventional teaching (Blocksidge and Dudley, 2003). Early diagnosis, appropriate educational therapy, and support can mitigate dyslexia before it advances to severe or profound levels that are difficult to remedy.

The reason for conducting this study was that an eight-year-old boy, Wakuma (pseudonym) has recognized few uppercase English alphabets despite his three years of schooling experience. He was born being fraternity twin. He born with birth underweight and stayed in incubation for three weeks at Menelik Hospital. There is no family history of reading difficulties (dyslexia). Wakuma was placed in three different schools due to his difficulty of alphabet recognition. After two schools refused him to attend his education, he placed to Tsehay Chora Primary School at special class for children with different disabilities including autism spectrum disorder. He has no other impairments except struggling with alphabet recognition. In addition to this background information gathered from child's mother and coordinator of special needs education teachers of the school, Wakuma was screened as a child with dyslexia on the basis of baseline diagnostic assessment. This diagnostic baseline assessment was based on Diagnostic and

Statistical Manual of Mental Disorders (DSM-5) that reveals symptoms of children with dyslexia as listed in diagnostic criteria A3, B, C, and D.

The maxim in early intervention "catch the child before he/she fails" is a sensible and inspiring axiology in inclusive education system. Providing proper early instructional support through individualized education therapy that is designed to teach students with dyslexia on alphabet recognition is an essential strategy. Regarding this, British Dyslexia Association (2007) noted that the impact of dyslexia can be mitigated by proper teaching, strategy development, and the use of information technology in education. Similarly, most children and adults with dyslexia can learn to read and can be successful in college and careers (The Dyslexia Guide, 2019).

This study was intended to improve a student's specific learning disability in alphabet recognition by targeting uppercase letter recognition at early grade one. The measurable learning target in this therapy was the level of alphabet recognition. The main objective of the current study was to investigate effective individualized educational therapy that would enhance the learning of alphabet for a student with dyslexia at an early grade. To deal with this study, the following research questions were addressed. These were:

1. What is the effect of individualized educational therapy on uppercase alphabet recognition of a student with dyslexia?

2. What is the functionality level of the designed individualized educational therapy package of alphabet recognition?

3. How positive reinforcement is important in individualized educational therapy for students with dyslexia?

Methods and Materials

Research Design

This study was conducted in A-B single-subject experimental research design with repeated measures. According to Mills and Gay (2019), single-subject experimental research design is design that can be applied when the sample size is one or when a number of individuals are considered as one group. A-B single-subject experimental research design in this study was used to investigate the effectiveness of individualized educational therapy on letter recognition of a student with dyslexia. Accordingly, the student's performance on the dependent variable (letter recognition) was recorded in the baseline phase (phase A) until his performance level became stable. Following the establishment of a baseline, the proposed individualized educational therapy was provided. In the therapy phase (phase B) student's performance on letter recognition was repeatedly measured. At the end of IET, student's performance on letter recognition at baseline phase and therapy phase (pre-tests and post-tests) were compared. Results were presented by computing means and percentages and displayed by visual inspection in tables and figures.

Instruments

In this study, three types of alphabet tests that have different letter arrangements were used. The first test was an alphabet test in which letters were arranged in alphabetical order i.e., A B C D E F G H I J K L M N O P Q R S T U V W X Y Z. The second alphabet test was adapted from the work of Clay (2016) titled as Observation Survey of Early Literacy Achievement. The Observation Survey of Early Literacy Achievement is an assessment tool used to gather information about children's alphabet recognition skill and development. This tool is designed to be administered individually to children aged 3-8 years old. This alphabet test consists of essential information about how to assess young children's progress in alphabet learning such as letter identification. The arrangement of this alphabet test was A F K P W Z B H O J U C Y L Q M D N X S I E G R V T. The third alphabet test was adapted from a reliable alpha assessment website by Lakeshore (n.d). The arrangement of this alphabet test was A C D G F H L R P O Q E W J N V K U ST Z Y X B M I.

Procedures

To accomplish this individualized educational therapy, 31 sessions were used on a daily basis. Letter song practice by means of simple melody local tune was the first educational activity in this therapy. This activity was used as eye-breaking and motivating the child to learn the alphabet. Letter song activity was provided for three (3) sessions in the whole alphabets learning approach and formative assessment was made on the whole uppercase alphabets learning activity. The data recording format was prepared in tabular form for formative assessments. Following the letter song activity, letter naming rehearsal was provided by chunking alphabets into a part learning approach. This learning activity was used for more than half sessions of the total sessions of the intervention phase. Chunking, rehearsing, and using a learning computer for a multi-sensory learning approach to the teach alphabet were used in letter-naming rehearsal instructional sessions which took fifteen (15) sessions. Formative assessments were made on chunked part learning activities.

Matching letters' shape-symbols instructional activity was the third activity used in this therapy. This activity took five (5) sessions. Wooden letters arranging game was the fourth instructional activity used in this educational therapy. This activity also took five (5) sessions. Formative assessments were conducted at the end of every session for letter-matching and letter-arranging game learning activities.

The effectiveness of this therapy was evaluated by means of visual inspection, tabular and graphic presentation of results. Baseline assessments were conducted and mean scores were calculated. Formative assessments were conducted and results were organized in tables. Summative assessments were conducted and the mean scores were calculated. The mean scores at the baseline condition and at therapy conditions were compared to determine the effectiveness of the educational therapy. The mean difference, range, and percentage change were computed to determine the consistency of scores and immediacy effect of educational therapy. The trend of student's progress in alphabet recognition was detected by means of the slope on a line graph of formative assessments.

Variables of the Study

The dependent variable in this therapy was the student's alphabet recognition of uppercase letters. This variable was measured three times at the baseline conditions (Phase A) and nine times at the therapy conditions (Phase B). The alphabet knowledge assessment results were recorded without manipulation of independent variables at the baseline phase. The independent variable (treatment variable) in this therapy was individualized educational therapy (IET) package. This package consists of letter learning activities that consisted of letter song, letter naming rehearsal, letters' shape matching, and wooden letters arranging game. These instructional activities were used as a single independent variable to measure their effect on a student's alphabet recognition ability. Student's alphabet recognition was measured by means of summative assessments to determine whether the therapy has an effect on the dependent variable.

Table1. Proposed individualized educational therapy package

Intervention package	Providers
Alphabet song	Investigator and special education teachers
Alphabet naming rehearsal	Investigator and special education teachers
Matching alphabet shapes to its bolded graphemes	Investigator and special education teachers
Wooden letters arranging game	Investigator and special education teachers

Reinforcement Strategies

Reinforcing students in general and students with disabilities in particular in educational settings by means of variable ratio schedule has very high response rate and very steady as well as the most resistant of all schedules to extinction. Hence, this reinforcement schedule was selected and used during the provision of IET. Accordingly, the investigator used substance-positive reinforcements, chocolate and candy as well as positive social reinforcements. The investigator provided the mentioned substance-positive reinforcements for Wakuma initially on a continuous reinforcement basis (for every correct response of letter name, he received one chocolate/candy) and gradually the provision of reinforcements was shifted from continuous to variable ration reinforcement and the number of correct responses in a ratio was elapsed. The elapsing number of correct responses in a ratio was followed by smooth shifting in such a way that 1: 2, 1: 3, 1: 4, and 1:5. In addition to the substance-positive reinforcements, social-positive reinforcements were also used in this therapy. Social positive reinforcements included verbal reinforcements (your work is great! viva! keeping it up! and you did it correctly!) and nonverbal reinforcements (shack hand and clap hand) for correct responses to alphabet recognition activities.

Data Analysis

The effectiveness of the individualized educational therapy package in alphabet recognition was examined by computing mean differences between phases, immediacy, and percentage of change in alphabet recognition. Based on A-B single-subject experimental research design, visual inspection (level, trend, variability, immediacy of effect, and consistency of data) were analyzed. Table and figure presentations were used to determine functionality level of the proposed educational therapy package and how much student's alphabet recognition was improved in post-therapy tests. In order to measure the effectiveness of this educational therapy, the current investigator opted to analyze the data using mean scores (levels), range, and percentage change (variability) in dependent variable (alphabet recognition).

Ethical Statement

The researcher received permission from the director of the school and from the parent of the child to conduct this study. After the purpose of the study was disclosed, informed consent was obtained. Discussion made with the school's individualized education program teams including the parent of the child. The investigator gave informed consent to respect personal rights of the child which require protection of autonomy (privacy, confidentiality, and anonymity) and the right to know the purposes of the study. The investigator was ethically obliged not to commit any harmful deed in this study and any condition that could have a harmful effect on the child was not attempted.

Results

Comparison of Pre- and Post-therapy Alphabet Recognition

Baseline data were collected in three steps for 26 uppercase English letters. The scores for baseline assessments were 10, 11, and 10 respectively for first round, second round, and third round on alphabetical order letter recognition test. A stable baseline with a mean of 10.3 and a range of 1 was observed by test-retest reliability. The results of formative assessments are indicated in the following figure.

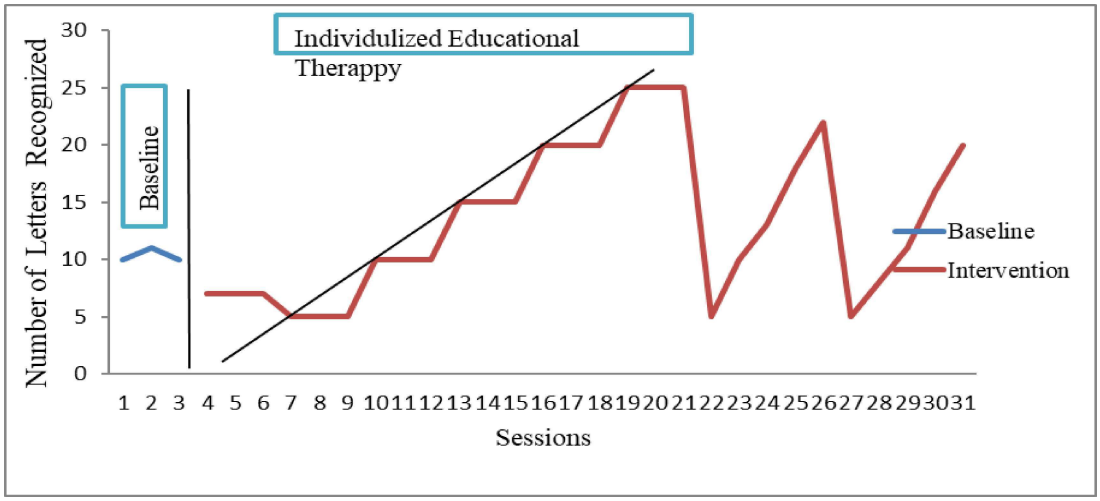

Figure.1. Formative assessment results for alphabet recognition progress during IET sessions.

As indicated in Figure1, the slope (trend) of alphabet recognition increased as IET continued. Sessions were divided based on different therapy activities to teach the student with literal dyslexia. Accordingly, sessions 1-3 were baseline, sessions 4-6 were letters teaching by letter song activity, sessions 7-21 were letter naming rehearsal on the basis of read it again (RIA) strategy, sessions 22-26 were letter matching activities, and sessions 27-31 were wooden letter arranging game. The mean score for therapy phase (phase B) was 24.5 with a range of 4 at nine steps (repeated measures). This mean score was calculated from Wakuma's alphabet attainment in three tests of alphabet recognition which each of the tests administered three times. Wakuma had achieved 25, 26, and 26 on the first test (sequenced alphabet test). He had achieved 23, 25, and 25 on the second test (non-sequenced type 1 alphabet test). He had achieved 22, 24, and 25 on the third test (non-sequenced type 2 alphabet test). The sum of correctly recognized letters from repeated measures was 221. The mean score of these tests was 221÷9 = 24.5. The mean scores for each test respectively were 25.6, 24.3, and 23.6. With a range of 2, these mean scores have consistency. The comparison of alphabet recognition at the baseline phase and therapy phase is indicated in the following tables.

Table 2. Pre- therapy alphabet recognition test result at the first round

Correctly named alphabets		**Incorrectly named alphabets**		
B	S	A	M	W
C	X	E	P	Y
D	Z	F	Q	
G		H	R	
K		I	T	
N		J	U	
O		L	V	

Table 2 shows that a child with dyslexia recognized 10 alphabets before receiving educational therapy. This was a very low achievement when compared with three years of schooling experience for a child.

Table 3. Post-therapy alphabet recognition

Correctly named alphabets				**Incorrectly named alphabets**
A	H	O	V	W
B	I	P	X	Y
C	J	Q	Z	
D	K	R		
E	L	S		
F	M	T		
G	N	U		

Table 3 shows that a child recognized 24 alphabets after therapy. Both substance-positive reinforcements and social reinforcements played roles in the success of this therapy. Positive substance reinforcements (candies and chocolates) were provided on a continuous reinforcement basis for the first three sessions of the letter song activity. Variable ratios in the number of responses that gradually increased were used in the rest of the sessions. Social reinforcements were provided every time the child finished the learning activity along with positive substance reinforcements.

The immediacy of effect was calculated from three data points in the baseline phase and from the first three data points in the therapy phase. The change in level between these two phases was obtained by subtracting the mean score of alphabet recognition on pre-therapy phase (pretest), i.e.10.3 from the mean score of alphabet recognition on the therapy phase of the first three data points, i.e. 25.6. Hence there was a 15.3 mean difference between these two phases which indicated that IET had a significant effect on alphabet recognition of a child. Data in the ovals of Figure 2 below illustrated the immediacy of the effect.

Immediacy of Effect

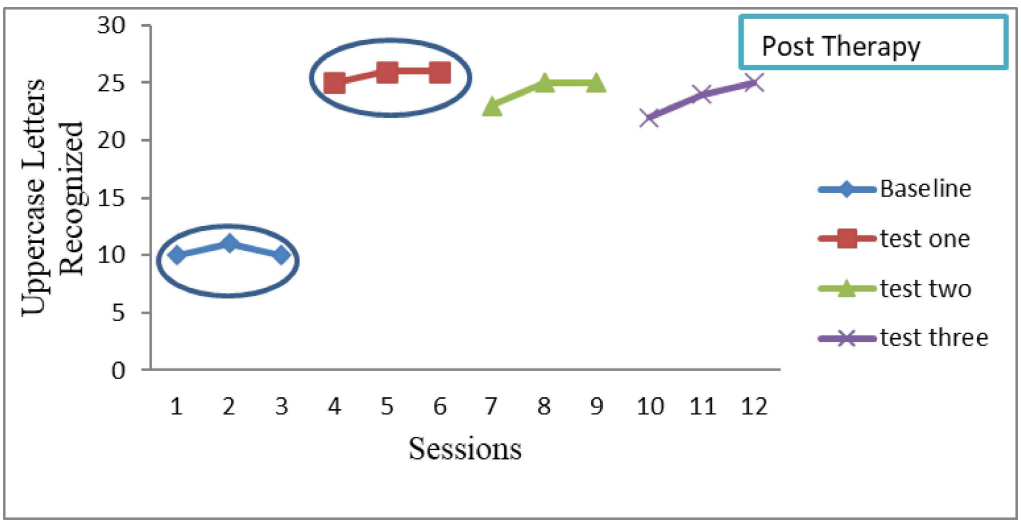

Figure.2. Immediacy effect of individualized educational therapy

As Figure 2 revealed, there was a rapid change in alphabet recognition (strong effect of therapy i.e., 15.3 mean deference). When the mean differences were calculated for the baseline phase and for the three post-therapy assessments, i.e. 24.5-10.3, there was a 14.2-point increase in the mean and a 54.6% increase in alphabet recognition from the baseline phase to the therapy phase. This was 94.2% (24 out of the total 26 uppercase English letters).

Discussion

Results are discussed in terms of the individualized educational therapy objective initially planned. The purpose of this therapy was to improve alphabet recognition of a student with dyslexia by means of IET. There are strong research findings that suggest rehearsing and chunking letters of the alphabet influence letter recognition of student with dyslexia (Annmarie and Nancy, 2013). The alphabet recognition assessment results of the current study indicated that child's alphabet recognition ability was progressively increased. This finding is in lined with previous studies that stated letters song, letters naming rehearsal, letters matching, and wooden letters arranging game learning activities were effective academic therapy package used to teach a student with dyslexia on alphabet

Figure1 depicted that assessment results of sessions 4 to 6 were approached, but lesser than the baseline data. Letter song learning activity was practiced by whole learning rather than chunked. The child simply sings a song without paying attention to grapheme of the alphabets. This made assessment results fall under the baseline data as displayed in Figure 1. Even though few letters were recognized by this learning activity, the student was motivated to learn letters after practicing letter song. Regarding this, Aguirre et al. (2016) stated that songs stimulate students to participate more actively. The graph in Figure 1 also depicted the consistent increase in letter recognition from session 7 to session 21, from session 22 to session 26, and from session 27 to session 31 due to the introduction of IET. This is in line with consistency criteria that state there should be sufficient data with sufficient consistency to demonstrate a predictable pattern of responding (Kratochwill et al., 2010).

The reason why the graph in Figure 1 moved downward at sessions 22 and 27 and then raised up was that session 22 was where letter naming rehearsal learning activities were accomplished and letters matching activities started on chunked groups of letters and session 27 was where letters matching learning activities end and wooden letters arranging game started. Summative assessment results indicated that the letter recognition ability of the student with literal dyslexia was significantly increased due to the manipulation of IET. In congruence with the findings of an earlier study (Schultz, 2015), the findings of the current study reveal that the IET through proposed therapy package and reinforcement strategy is an effective educational therapy in learning alphabet recognition by student with dyslexia. Similarly, Berninger (2004) stated that redundancy is important to hold letters in multiple formats in memory. Repeated measures were conducted to reduce the probability of threats to internal validity that might be confounded with the effect of educational therapy. This is in line with the recommendation of Kratochwill et al. (2010) that stated statistical regression would be a major concern when only pretest and posttest scores were used to evaluate outcomes. Hence, repeated measures with alternate forms of assessment are acceptable.

With a range of 2, the mean scores of the three tests used in post-therapy assessments have consistency. These consistencies of data points show that the functionality level of the educational therapy package for dyslexia remedy to alphabet recognition is effective. Regarding this, Kratochwill et al. (2010) stated that the greater the consistency, the more likely the data represent a functional relation. The 54.6% increase in alphabet recognition indicated that there was a positive effect of IET for students with dyslexia. As a result of this

educational therapy, student recognized uppercase English alphabets more than double percent of what he had recognized at baseline. This is in line with Brooks (2013) that stated when at least a double rate of progress is achieved in intervention for a child with dyslexia, that intervention has a good impact. Within a 15.3 point increase in mean from baseline to the first three data points of the therapy phase (immediacy), there is a rapid change in alphabet recognition due to individualized educational therapy. This is evidence that this therapy has a strong effect on alphabet recognition. Regarding this, Kratochwill et al. (2010) stated that the more immediate the effect, the more convincing the inference that change in the outcome measure was due to manipulation of the independent variable.

Chunking the alphabet into smaller groups facilitated conditions for a student to learn the alphabet in small steps. It enhanced student's learning of letters name and symbol. Singleton (2009) reviewed that small step as one of the common features of teaching students with dyslexia. On the basis of this construct, uppercase letters were chunked into five small groups of letters. The chunked letters were explicitly taught by means of IET instructional activities. Educational therapy brought significant change in student's alphabet recognition and the intended objective was achieved as the student recognized 24 uppercase alphabets at the end of the therapy.

Conclusion and recommendation

Based on the results of the current educational therapy, the following major findings were concluded. Wakuma's alphabet recognition significantly increased from 10 letters to 24. This alphabet attainment was more than double when compared with baseline alphabet recognition. Individualized educational therapy for a student with dyslexia was effective in alphabet recognition. Both substance and social reinforcements were important in educational therapy for students with dyslexia. Individualized educational therapy brought significant changes in Wakuma's uppercase English alphabet recognition. After therapy was provided, student's alphabet recognition was significantly improved and educational therapy for student with dyslexia has a 94% functionality level and has a strong effect on student's alphabet recognition.

Recommendations

This educational therapy matches the student's needs. So, teachers can take useful experience (lesson) from this educational therapy and plan for high expectations to achieve rapid improvement when used it. Teachers can also find ways to embed this educational therapy into their daily lessons when teaching the alphabets to students with dyslexia at kindergartens or at early grade one or even at primary schools. Specifically, instructing alphabet recognition (letters' names and symbols) will be effective if delivered in similar way this therapy is delivered. Schools can use this therapy to teach alphabet recognition to students with dyslexia. If similar individualized educational therapy is implemented for students with dyslexia by following similar steps, students can learn lowercase English alphabets more easily because uppercase alphabets recognition can facilitate condition to learn lowercase alphabets. The concepts and practices of educational therapy should be introduced in every preprimary and primary school in Ethiopia. It is also suggestible for higher education institutions, particularly department of Special Needs and Inclusive Education to include educational therapy in their practicum course to equip undergraduate students with educational therapy/intervention skills.

Limitation of the Study

Different educational experimentalists used different independent variables as intervention packages to improve the learning of students with dyslexia. To the extent of current investigator's knowledge, no exactly the same package and procedure used to provide individualized educational therapy. Thus, this individualized educational therapy through A-B single-subject experimental research design would have limitation in controlling extraneous factors that can affect the generalizability of results.

Implications

A-B single-subject experimental research design with repeated measures was used to evaluate the effectiveness of individualized educational therapy. The independent variables used in this educational therapy have a positive effect on a child with dyslexia to master alphabet recognition. Individualized educational therapy is a good instructional intervention to help child with specific learning disability-dyslexia. The study reveals that student's alphabet recognition ability is increased due to educational therapy. Alphabet recognition learning activities through the mixture of different methods (letters song, letters naming rehearsal, chunking, letters matching, and wooden letters arranging game) are good compositions of educational therapy to teach student with dyslexia. Repeating learning activities such as "name it again", "match it again", and "arrange it again" are crucial therapeutic strategies to teach students with dyslexia. Manipulation of positive substance reinforcements and social reinforcements during treatment help to increase the rate of alphabet recognition for students with dyslexia.

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RESEARCH PAPER

Antibiofilm Activity of Green Synthesized Silver Nanoparticles

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Abstract

Numerous diseases that affect both humans and animals are due to the growth of biofilms on a variety of inanimate surfaces. This study investigated bacterial biofilms in water and poultry drinkers and their control using silver nanoparticles (AgNPs). Water and swabs of poultry drinkers were collected from five poultry houses. Isolation and characterization of bacterial isolates were carried out using standard microbiological techniques and identified bacterial isolates were screened for biofilm potential using Congo Red Agar method (CRA) and tube method (TM). Antibiotic susceptibility of the isolates was carried out using the agar well diffusion method. Fungal isolate was used to synthesize AgNPs and the synthesized AgNPs was confirmed through visual, UV-Vis and FT-IR analysis. Fifty-nine bacterial isolates were identified and the predominant bacterial isolates were: Staphylococcus spp and Citrobacter spp. CRA revealed that fifteen isolates (25.4%) were biofilm formers while TM showed only 9 isolates (15.3 %) to be strong biofilm formers. All the biofilm formers were multi drug resistant isolates except Proteus vulgaris and high resistance was observed in gentamycin. The synthesized AgNPs was brown in colour, UV-Vis spectra was observed at 410nm and FT-IR revealed the presence of functional groups that are responsible for the synthesis of silver nanoparticles. AgNPs inhibited the growth of the biofilm formers with highest and lowest inhibition zone of 2.6 cm to 0.4 cm by Proteus vulgaris and Enterobacter aerogene. AgNPs are thus a crucial bio resource due to their capacity to suppress the establishment of bacterial biofilms.

Keywords: Biofilms, Congo red agar, Tube method, silver nanoparticles

Introduction

education and just ensure that there is water availability for their animals to drink but are generally unaware of the negative effects that poor hygiene has on both their animals and the general public. The quality of water is frequently disregarded, despite the fact that it is the most important nutrient for birds and serious disease outbreaks are seen by many farmers as more spiritual developments than those that emerge from farm hygienic issues (Folorunso *et al*., 2014). The most prevalent and successful forms of life on Earth are biofilms and are responsible for driving the biogeochemical cycling of the majority of elements in water, soil, sediment and subterranean habitats (Meckenstock et al., 2015). Biofilms are pervasive, long-lasting microbial communities that may form on almost any surface in contact with water. They can shed cells continuously, which aids in the spread of germs (Liu et al., 2016).

The biofilms' ability to build an exopolysaccharides matrix, which can hold and store substances including nutrients to offer food reserves for microbial members during a starving time contributes to the bacteria improved resistance (Liu et al., 2016). It is imperative to develop a strong treatment and prevention strategy to tackle biofilms because,

according to earlier study of Abdullah et al., (2016), about 61% of human biofilm infections are zoonotic in nature. The growing resilience of biofilm to standard treatments increases the need for innovative control measures. The hunt for naturally occurring substances/chemicals capable of preventing the formation of biofilms is a viable approach to controlling biofilms (Lizana *et al*., 2013).

Nanoparticles are biologically active substances that have served as an important source of natural products for the treatment and prevention of diseases, promoting human health (Salleh et al., 2020). Green synthesis of nanoparticles (NPs) display an excellent approach whereby NPs are produced through the oxidation/reduction of metallic ions by secreted biomolecules such as enzymes, proteins, sugars and carbohydrates in order to combat pathogens (Zhang *et al*., 2016). Saif *et al.,* (2016) reported that stable and well-functionalized nanoparticles from bacteria, actinomycetes, fungus and yeasts serve as environmentally friendly and sustainable precursors. Studies have indicated that silver nanoparticles are broad spectrum antiseptic that are effective against both Gram negative and Gram positive bacteria, fungi and viruses (Sharmin et al., 2021).

The oligo-dynamic impact of silver in ionic or nanoparticle form has a broad spectrumbroad-spectrum antibacterial activity and is particularly effective against microbial colorizations linked to biomedical illnesses and the anti-microbial properties of silver are known to fight a variety of harmful microbes (Ramasamy and Lee, 2016). Typically, silver nanoparticles (AgNPs) have a diameter of 1–100 nm and contain 20–15,000 silver atoms (Han et al., 2017). Silver nanoparticles have a greater surface area to volume ratio for interactions, which makes it easier for them to penetrate and damage bacterial cells (Duran et al.,. 2016). They have also been demonstrated to destroy biofilm matrices (Sinha *et al*., 2011) and their antibacterial properties include cell barrier contact, microbial cell penetration, diffusion and adsorption (Wang et al., 2017).

Due to paucity of information on the potential of AgNPs on biofilm formers from poultry drinkers and its bacterial identification; this study aimed to characterize bacteria in water and crevices of drinkers from poultry houses, screen isolates for biofilms, determine the antibiotic susceptibility of biofilm formers and control their growth using synthesized AgNPs.

Materials and methods

Sample collection

Fifteen samples each of water and poultry drinker swabs were collected from five poultry houses at Alabata and Odo–eran area in Abeokuta, Ogun State.

Isolation and identification of bacteria

Swabs and water samples were collected from poultry drinkers and serial dilutions were carried out using sterile saline. Aliquot of the samples were plated on Nutrient agar, MacConkey agar, Eosin methylene blue and *Salmonella shigella* agar sterile plates. The plates were incubated for 37°C for 24h and 48h, respectively and isolates were subcultured to obtain pure colonies. Pure colonies were identified using microscopic, physiological and biochemical characterization (Karim *et al*., 2018).

Production of AgNPs

Production of fungal biomass

Biomass of A. *flavus* obtained from water sample was prepared by introducing the spores into Erlenmeyer flasks containing 100 ml of sterile Potato dextrose broth, placed in an orbital shaker, incubated at 25°C and agitated at 100 rpm for 72 h. The biomass was harvested and then centrifuged at 3000 rpm for 40 mins. The filtrates obtained were discarded and the biomass (residue) was washed twice with sterile distilled water (Gaikwad and Gade, 2013).

Synthesis of AgNPs

Silver nitrate was prepared by dissolving 0.17g of silver nitrate into 1000 ml of distilled water. Biomass (10g) was inoculated into conical flasks containing 100 ml of distilled water and placed in the orbital shaker again at 100 rpm for 72 h. The mixture of the biomass and the distilled water was then centrifuged after which the resulting cell filtrate (50 ml) was mixed with 50ml of 1 mM silver nitrate solution. The flask was finally agitated in the orbital shaker for 72 h. A conical flask containing only the fungal biomass was also placed in an orbital shaker to serve as a control sample (Gaikwad and Gade, 2013).

Characterization of AgNPs

Visual observation

This was done using the development of color change as compared to the control.

UV-Vis spectroscopic analysis

The reduction of pure silver ions synthesized by fungal culture was monitored by measuring the UV- Vis spectrum of the reaction mixture in the range of 250–800 nm.

Fourier-Transform Infrared spectroscopy

The filtrate was freeze-dried and diluted with potassium bromide in the ratio of 1:100. The FTIR spectrum of sample was recorded on a FTIR instrument (model, maker and country) with diffuse reflectance mode. All measurements were carried out in the range of 4000–400 cm−1 at a resolution of 4 cm−1 (Saifuddin *et al*., 2009).

Screening of isolates for biofilm activity

Isolates from the water and poultry-drinkers were screened for the potential to produce biofilms using the congo red agar and tube assay.

Congo Red Agar (CRA) was prepared according to Thilakavathy et al. (2015) and composed of 37g/L of Brain heart infusion (BHI) broth, 10g/L agar base, 50 g/L sucrose, 1 L water and 0.8 g/L Congo red indicator. The pure isolate was inoculated on the sterile congo red agar plates and were incubated at 37 °C for 24 h. Positive results were indicated by black colored colonies which indicate biofilm producers while negative results were indicated by pink colored colonies.

Tube method

A loopful of bacterium was inoculated into tryptic broth and incubated at 37 °C for 72 h. After incubation, the broth was discarded and the test tubes were washed with phosphate buffer saline pH 7.2 and stained with safranin. The tubes were air-dried and observed for the occurrence of a visible film along the walls of the test tube which indicates the presence of biofilm. The empty tubes were graded visually as absent, moderate and strong biofilm formation respectively (Ugwoke *et al.,* 2019).

Antibiotic susceptibility tests of biofilm formers

Antibiotic susceptibility tests were carried out following the Kirby–Bauer disc diffusion method on Mueller–Hinton agar, as described by (Daniel *et al.,* 2020). The test organisms (positive biofilm formers) were swabbed each on the surface of the Mueller-Hinton agar plates. Then, a sterile forceps was used to place the Gram- negative antibiotic discs (Amoxicillin, Augmentin, Chloramphenicol, Gentamycin, Ciprofloxacin, Tarvid, Pefloxacin, Streptomycin, Sparfloxacin, Septrim) and Gram-positive antibiotics discs (Amoxicillin, Augmentin, Gentamycin, Ciprofloxacin, Erythromycin, Pefloxacin, Rocephin, Streptomycin, Septrim, Zinnacef) on the surface of the plates and were incubated at 37°C for 24 hrs. The results were interpreted according to the Clinical Laboratory Standards Institute Guidelines (CLSI, 2018).

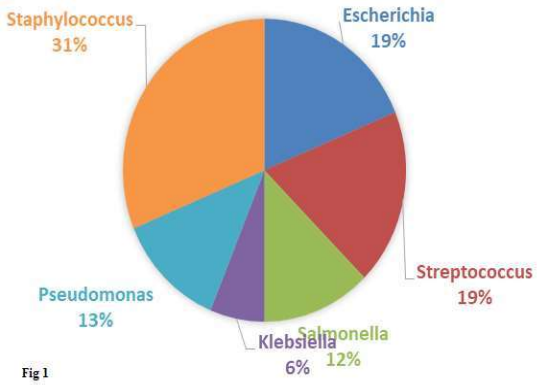
Application of silver nanoparticles (AgNPs) on biofilm formers Activity of the synthesized AgNPs on biofilms

Biosynthesized silver nanoparticles produced by A. *flavus* were assayed for antibacterial activity as suggested by Gudikandula et al. (2017) using the agar well-diffusion method. Bacterial biofilms formers (100 µl) in nutrient broth was used to prepare bacterial lawns (1 × 105 CFU/ml). Agar wells of 8 mm diameter were prepared with the help of a sterilized stainless steel cork borer. The wells were loaded with 100 µl of AgNPs and 100 µl of culture broth from A. *flavus* as control. The plates were incubated at 37 °C for 24 h and then were examined for the presence of zones of inhibition. The diameter of zones of inhibition was measured and the mean value for each organism was recorded.

A total of fifty-nine bacteria were isolated from both the water and drinkers sample. Sixteen bacterial isolates were recovered from the water samples while forty-three bacterial isolates were obtained from poultry drinkers. *Staphylococcus* spp and *Citrobacter* spp from water and poultry drinkers, respectively were the predominant isolates. *Klebsiella* spp had the least occurrence from poultry water samples (6%) while *Proteus* and *Escherichia* spp had the least occurrence from drinker samples (4%). All the bacterial isolates identified in water samples were also present in the poultry drinkers (*Pseudomonas, Streptococcus Salmonella, Staphylococcus, Klebsiella and Escherichia coli*).

Results

Identification of bacterial isolates



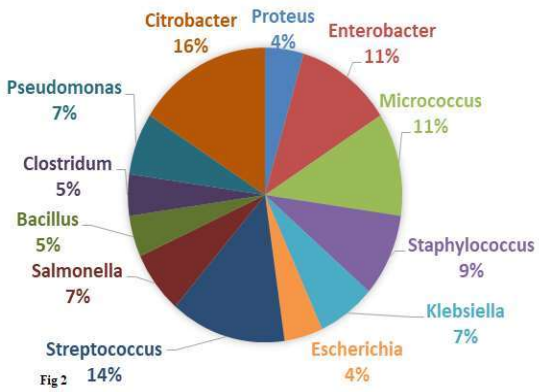


Fig 1: Percentages of different genera in water samples Fig 2: Percentages of different genera in poultry drinkers

Characterization of silver nanoparticles

The ultraviolet visible spectrophotometry showed the peak of absorbance surface plasma resonance spectrum of the solution. Visual observation of the filtrate to brown is an indication of silver nanoparticles produced after incubation as shown in Fig 3. Fig 4 shows the UV spectral of the synthesized nanoparticles. The absorption around the region of 400 nm is an indication of silver nanoparticles synthesis. The functional groups in the FTIR analysis suggested the synthesis of nanoparticles through the reduction of the silver nitrates (Fig 5).

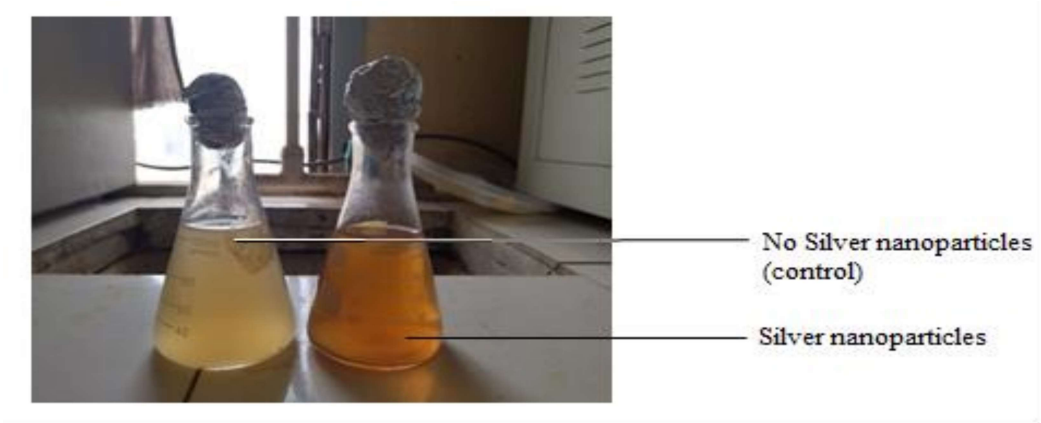


Fig 3: Colour change of the filtrate containing *Aspergillus flavus* (and AgNO3) to brown

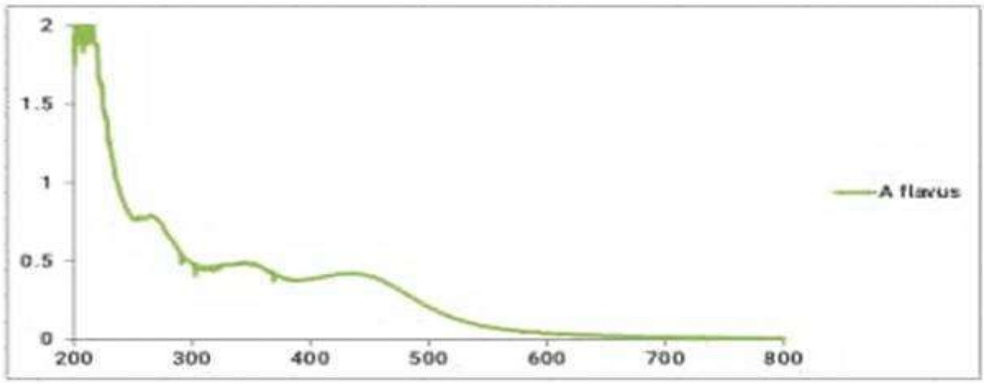


Fig 4: UV-spectra of the synthesized AgNPs of A. flavus

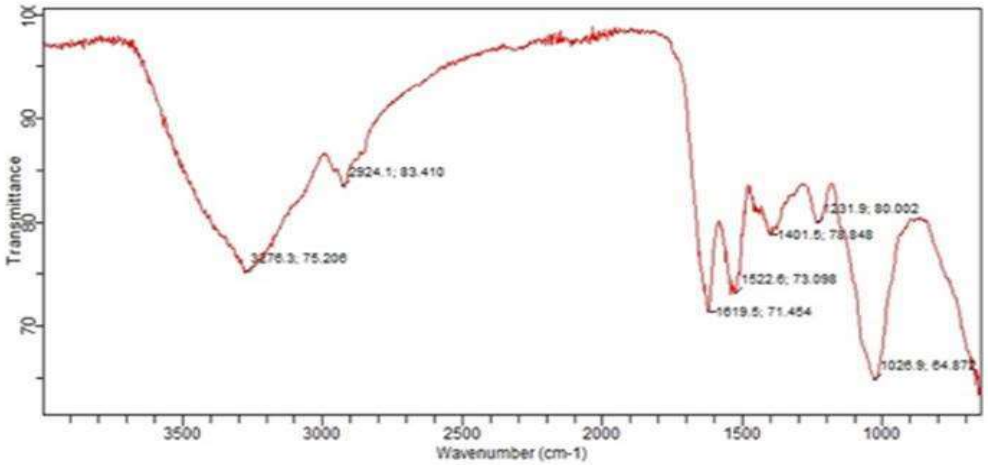


Fig 5: FTIR spectrum of silver nanoparticles synthesized from *Aspergillus flavus*

Congo red screening method for biofilm formation

Among the fifty-nine bacterial isolates, 15 bacterial isolates (25.4%) were positive while 44 (74.6%) tested negative as non-biofilm formers. The highest diameter of zone was observed from Streptococcus *pyogens* and the lowest diameter was observed from *Citrobacter freundii* (Table 1).

Table 1: Congo red agar assay

S/N	Bacterial isolates	Diameter of zone in cm
1	*Proteus vulgaris*	2.0±0.2
2	*Klebsiella oxytoca*	5.6±1.2
3	*Staphylococcus aureus*	4.6±1.5
4	*Pseudomonas aeruginosa*	1.7±0.4
5	*Salmonella typhi*	3.8±0.6
6	*Citrobacter freundii*	1.0±0.0
7	*Klebsiella pneumonia*	5.8±0.4
8	*Staphylococcus aureus*	6.2±0.3
9	*Enterobacter cloacae*	5.7±0.4
10	*Enterobacter aerogene*	2.5±0.2
11	*Escherichia coli*	2.1±0.6
12	*Klebsiella pneumonia*	3.9±1.2
13	*Streptococcus pyogens*	7.1±0.9
14	*Micrococcus luteus*	2.4±0.8
15	*Streptococcus pyogens*	3.0±1.0

Tube method

Strong biofilm producers could be easily detected using this method but it was difficult to differentiate between moderate and weak biofilm producers due to the variations in the results obtained visually. Nine isolates (15.3 %) tested positive as strong biofilm formers, twenty-four isolates (40.7%) were moderately positive and twenty-six bacterial isolates (44%) were non-biofilm formers. Most of the strong biofilm formers were Gram negative bacteria (Table 2).

Table 2: Tube assay for detection of strong biofilm formers

S/N	Bacterial isolates	Results
1	*Proteus vulgaris*	Positive
2	*Klebsiella oxytoca*	Positive
3	*Staphylococcus aureus*	Positive
4	*Escherichia coli*	Positive
5	*Pseudomonas aeruginosa*	Positive
6	*Klebsiella pneumonia*	Positive
7	*Salmonella typhi*	Positive
8	*Enterobacter aerogene*	Positive
9	*Streptococcus pyogens*	Positive

Antibiotic susceptibility test

Results of the antibiotic susceptibility pattern of the bacterial isolates (Table 3) demonstrated that all the biofilm formers were multidrug resistant and were resistant to the six classes of antibiotics except for *Proteus vulgaris. Staphylococcus aureus, Escherichia coli* and *Klebsiella pneumonia* depicted highest resistance potential to the antibiotics.

Table 3: Antibiotic susceptibility pattern of bacterial isolates

Biofilm formers	**Gram positive antibiotics**									
	Am	**Aug**	**Gen**	**Cp**	**Ery**	**Pef**	**Roc**	**Str**	**Sep**	**Zin**
Streptococcus pyogens	R	R	R	S	R	S	S	S	S	R
Staphylococcus aureus	S	R	R	R	R	R	R	R	R	R
	Gram negative antibiotics									
	Am	**Aug**	**Chl**	**Gen**	**Cpr**	**Tar**	**Pef**	**Str**	**Spa**	**Sep**
Proteus vulgaris	S	S	S	S	S	S	S	S	S	S
Salmonella typhi	R	S	R	S	S	R	S	S	S	R
Klebsiella oxytoca	R	R	R	R	S	R	R	S	S	S
Escherichia coli	R	R	S	R	S	R	R	S	R	R
Klebsiella pneumonia	R	R	R	R	S	R	R	S	S	R
Enterobacter aerogene	S	S	S	R	R	R	R	R	S	R
Pseudomonas aeruginosa	S	R	S	R	S	S	R	R	R	R

Antibacterial activity of the synthesized AgNPs on biofilm formers

Table 4 shows the ability of AgNPs on biofilm isolates and results revealed that the silver nanoparticles synthesized from Aspergillus *flavus* has an inhibitory effect on *Klebsiella oxytoca, Pseudomonas aeruginosa, Escherichia coli, Salmonella typhi, Enterobacter aerogene* and *Streptococcus pyogens* at varying levels. Maximum inhibitory zone of 1.9 cm was observed on Proteus vulgaris and minimum inhibitory zone of 0.4 cm was observed on *Enterobacter aerogene*. However, the AgNPs did not inhibit the growth of Staphylococcus *aureus and Klebsiella* pneumonia.

Table 4: Antibacterial activity of synthesized AgNPs by *Aspergillus flavus* on biofilm formers

Isolates	Zone of Inhibition (cm)
Proteus vulgaris	2.6±0.3
Klebsiella oxytoca	0.8±0.0
Staphylococcus aureus	Resistant (no zone)
Pseudomonas aeruginosa	1.2±0.2
Escherichia coli	0.6±0.0
Klebsiella pneumonia	Resistant (no zone)
Streptococcus pyogens	0.5±0.0
Enterobacter aerogene	0.4±0.0
Salmonella	1.9±0.4

Discussion

Poor farming management, overcrowding, unsanitary conditions, insufficient ventilation and poor feed quality may cause diseases in poultry houses (Karkhanis *et al.,* 2021). Favorable growth and proliferation of organisms may be fostered when water is refilled without cleaning the water drinkers properly (Folorunso *et al.,* 2014). This study revealed that unhygienic poultry drinkers and water are vehicles for the introduction of multi-drug resistant isolates. The presence of bacteria in the water and drinker sample provided to the birds revealed poor sanitation and renders the chicken a carrier of the bacterium, which might be consumed by humans who take chicken or poultry meat. Different methods for handling and distributing water, feed ingredients, levels of hygiene, biosafety precautions and management techniques for raising chickens may all play a role in the variations in the dispersion of microbes from water and poultry drinkers (Islam *et al.,* 2017).

E. coli, Proteus, Salmonella, Pseudomonas, Staphylococcus and *Streptococcus* etc. identified in this study had been reported in the previous studies of Islam *et al., (*2017). These organisms can harm both humans and animals and their presence indicated a potential health risk.

It was evident that silver nanoparticles had formed in the medium when the color of fungal cell filtrates with silver ions changed to an intense brown. This was primarily because the nanoparticles' surface plasmon vibrations had

been excited. The color of the cell filtrate did not alter in controls (those without silver ions) under the same incubation conditions. The reduction of silver nitrate solution to silver nanoparticles is confirmed by the unique and solitary surface plasmon resonance (SPR) band at 410 nm. Studies by Othman *et al., (*2019) have recorded similar observations and Kalimuthu *et al., (*2008) submitted that fungi secrete several proteins into the medium that may be crucial to the stabilization and reduction of silver ions in the form of nanoparticles.

The functional groups that might have been involved in the production and stability of the produced silver nanoparticles were found in the FTIR spectroscopy spectrum. Also discernible were O-H stretching vibrations in flavonoids, alcohols and phenolic compounds; C-H stretching vibrations of methylene, methyl and methoxyl groups at 2924; absorption peaks at 1026 cm1 that may have been caused by C-N aromatic and aliphatic amine stretching vibrations and presence of sulphonamide at 1231cm-1. Sharp peak at 3276cm-1 strongly shows that silver ions are bound to the hydroxyl (-OH) group and is believed to be overlapping -NH stretching vibration, a common occurrence in proteins (Mishra et al., 2015). These findings imply that the hydroxyl/carbonyl groups might be in charge of the synthesis and stabilization of silver nanoparticles (Mohanta et al., 2019). AgNPs are produced via the reduction of silver nitrates, which is carried out by the hydroxyl and amine groups of OH/NH2, C-H Alkene, N-H Bend, C-O Alcohol, and S=O Sulfones.

The biosynthesis of AgNPs occurred through the mediation by A. flavus and it exerted an antimicrobial action against harmful microorganisms depending on the microbe type and its biological constituents (Shrivastava et al., 2007). The increased effectiveness of nanoparticles in entering bacterial cells was due to their smaller size. Numerous studies have demonstrated the effectiveness of silver nanoparticles as antibacterial agents against microorganisms (Muddassir et al., 2022).

Proteus, Klebsiella, Staphylococcus, E. coli, Enterobacter, Pseudomonas, Salmonella and Streptococcus species were found to exhibit considerable tendency to form biofilms by CRA and TM. Seven isolates from the biofilm formers were Gram negative while two species were Gram positive.

Reddy et al., (2017) noted that in order to increase the sensitivity for biofilm detection, multiple screening assays should be employed to screen isolates for biofilm formation. The Congo red agar method was discovered to be quicker and easier to perform than other phenotypic approaches. Our findings agree with those of Manandhar et al., (2018) who found significant differences between the results of CRA and TM, where CRA recorded two isolates as positive and TM showed eleven isolates out of 78 as strong biofilm formers. However, our results do not agree with Fatima et al., (2011) who submitted that 87.6% of isolates to be strong biofilm producers.

Results on antibiotic susceptibility showed that 100% of the Gram-positive bacteria were resistant to Erythromycin, Gentamycin, Augmentin, and Zinnacef, while only 55.6% were resistant to Amoxicillin and Gentamycin, 22.2% to Ciprofloxacin, 66.7% to Augmentin and Pefloxacin, and 71.4% to Tarvid. The potential for multidrug resistance of the bacteria to eight of the nine antibiotics aggravated the issue of antibiotic resistance worldwide and had major health implications for the use of antibiotics in poultry (Eja et al., 2012). This outcome is consistent with research by Mohammed and Dubie (2022), who both observed high levels of bacterial drug resistance. Proteus vulgaris was the only biofilm-forming bacterium that did not exhibit multiple resistance to the tested antibiotics. Ciprofloxacin had high sensitivity when compared to the other tested drugs, which is consistent with the conclusions of Abebaw et al., (2018).

The antibacterial activity of AgNPs toward microbes can be understood using a variety of modes of action. One of these methods is that AgNPs may adhere to the negative charge on the surface of microorganisms, changing the

characteristics of the cell wall, cell membrane and affecting respiration, permeability, electron transport and osmoregulation (Marambio-Jones and Hoek, 2010). According to AshaRani et al., (2009), after piercing the microbial cell wall, AgNPs can interact with cell components such as DNA and proteins.

AgNPs capacity to dislodge biofilms and bacteria may be a result of their ability to penetrate bacterial cell walls, alter their structural makeup as a result of their nanoscale size and disrupt cellular membranes, which will ultimately cause organelles rupture and cellular lysis (Yassin et al., 2022). In the report by Muddassir et al., (2022), measurements of inhibition zones were demonstrated to be a valid method for determining the inhibition effects of silver nanoparticles on harmful bacteria. Lower dose of AgNPs could be responsible for its inability to inhibit the growth of Staphylococcus aureus and Klebsiella pneumonia and we suggest an increase in the dosage of AgNPs application for future research. The effectiveness of silver nanoparticles against biofilms produced by P. aeruginosa and E. coli was demonstrated by Gurunathan et al., (2014). Goswami et al., (2015) also discussed the removal of biofilms using silver nanoparticles and discovered that 89% of S. aureus and 75% of E. coli biofilm formation was inhibited by silver nanoparticles. This was supported by Franci et al., (2015) who discovered that silver nanoparticles significantly inhibited the growth of bacteria and biofilms.

Conclusion

The study revealed the presence of multidrug-resistant (MDR) isolates in poultry drinkers and water. Green synthesis of AgNPs by Aspergillus flavus was also accomplished and the biosynthesized AgNPs had antibacterial efficacy on biofilm-forming organisms. Increment dose of AgNPs and conventional antibiotic combinations may be investigated as potential substitutes for antimicrobial drugs for removal of biofilms caused by Klebsiella pneumonia and Staphylococcus aureus etc. Moreover, the implications of multidrug resistant bacteria in chicken products should be made clear to livestock and poultry owners as well as enforcement of strict cleanliness and sanitation standards.

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RESEARCH PAPER

Soil Fertility Evaluation and Mapping in Sdeyni Watershed, Habru District, Northeastern Ethiopia

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Abstract

Soil nutrient mining, poor use of external inputs, soil erosion, are the major soil constraints affecting sustainable crop production in Ethiopia. In the study area, the soils were not characterized to provide location specific information for crop producers. Thus, this study was initiated with the objective of evaluation and mapping of soil fertility in Sdeyni Watershed. Cultivated lands in the watershed were selected and divided into eight land units (LUs). Three replicated composite soil samples were collected from the depths of 0-20 cm from each land unit comprising a total of 24 composite soil samples. Data analysis was done following one way ANOVA using R software, and mapping was performed using GIS software. The result showed that most soil properties were significantly different in the land units. Clay texture, slightly acidic soils (6.02-6.74), medium organic matter (OM) content (2.96-4.59%), low to medium total nitrogen (0.10-0.24%), medium to high available phosphorus (6.40-12.44 mg kg-1), and medium to high cation exchange capacity (11.90-27.00 cmol (+) kg-1), and moderate to high percent base saturation (41.40- 67.23%) were the observed soil fertility parameters. Soil fertility management through addition of organic and inorganic fertilizer sources should get immediate attention to maintain optimum crop production sustainably.

Keywords: GIS, Habru District, Land units, Soil fertility

Introduction

Ethiopia's economy is dependent on agriculture, which accounts for 40% of the GDP, 80% of exports, and an estimated 75% percent of the country's workforce (USAID, 2021). However, high level of nutrient mining, poor use of external inputs, soil erosion, old farm management practices, and limited capacity to respond to environmental shocks (Amante et al., 2014; Agegnehu et al., 2016) are major characteristics of this economic activity. Replenishment of soil nutrient stock from organic and inorganic sources is very low as compared with the need of the soil and the crop. Average productivity of cereals is revolving around 2.1t ha-1 as compared to that of the estimated average potential (3.2 t ha-1) in the country for the studied crops (Daniel and Rozina, 2022).

In order to foster agricultural development in Ethiopia, the soil resource information available is not sufficient to decide the nutrient requirement of each crop across regions with complex land form and diverse climate. Most areas in the country continue to use blanket fertilizer recommendation though some attempts were done to cluster based on nutrient limitations as explained by soil fertility maps prepared through EthioSIS (2014).

Based on the result of the national soil fertility survey, it was reported that Ethiopian soils are characterized by either acidity or alkalinity and are poor in macro-and micronutrients (e.g. S,

Zn, B, Cu, and Fe) in addition to N and P (Tamene et al., 2017). Soil properties are subjected to changes due to erosion, leaching, fixation, and volatilization. These necessitate periodic assessment of soils nutrient stock to maintain the fertility and productivity of soils. Soil fertility management as part of the improved farming practices need local assessment to quantify the status of essential nutrients, rating, and mapping (Kedir et al., 2016). Such evaluation and mapping are helpful to planning and applying fertilizer resources in a sustainable agroecosystem.

The chemical and physical properties of soils are effects of soil forming factors which have spatial variations at a specific mapping scale. These soil properties were used for interpretation of soil fertility without reference to area class map until the introduction of Global Positioning Systems (GPS) and Geographic Information Systems (GIS) technologies (Khadka et al., 2019). The application of these tools has simplified geographic data collection, map synthesis, and generation of soil attribute data for users. Researchers worldwide have used GIS for soil fertility mapping, soil type mapping, and suitability of soils for various crop productions (Prabhavati et al., 2015; Fekadu et al., 2018; Fekadu and Negese, 2020). The most powerful geostatistical tool which is used to interpolate spatial variation of soil fertility is ordinary kriging because it provides a higher level of prediction accuracy (Song et al., 2013).The soil fertility mapping can be used for delineating soil fertility status, studying soil fertility changing due to land use dynamics and determining nutrient requirement for the deficient areas.

Soil testing is one of the techniques to evaluate the nutrient content of a soil, the reaction of a soil (acid or alkaline), nutrient dynamics, and helps to recommend how much nutrient is to be added to meet crop requirement. However, the soils in the study area were not systematically analyzed and documented to provide information for crop producers. Farmers in the study area still continue application of blanket recommendation of fertilizers without sufficient research based information on the types and levels of soil nutrients. Therefore, this study was initiated with the objective of evaluating soil fertility status and mapping in Sdeyni watershed, Habru District, Northeastern, Ethiopia.

Materials and methods

Description of Study Area

The study was conducted at Sdeyni Watershed, which is located in Habru District of Northeastern, Ethiopia (Figure 1). The center of the district is Mersa, which is located at 491 km North of Addis Ababa on the main road to Woldia. Geographically, the study area lies between 11˚45’13” to 11˚27’35’’ North latitude and 39˚38’17” to 39˚49’22’’East longitude, and at an altitude ranging from 500 to 2400 meters above sea level (m.a.s.l.). The area coverage of the watershed is about 10461ha.

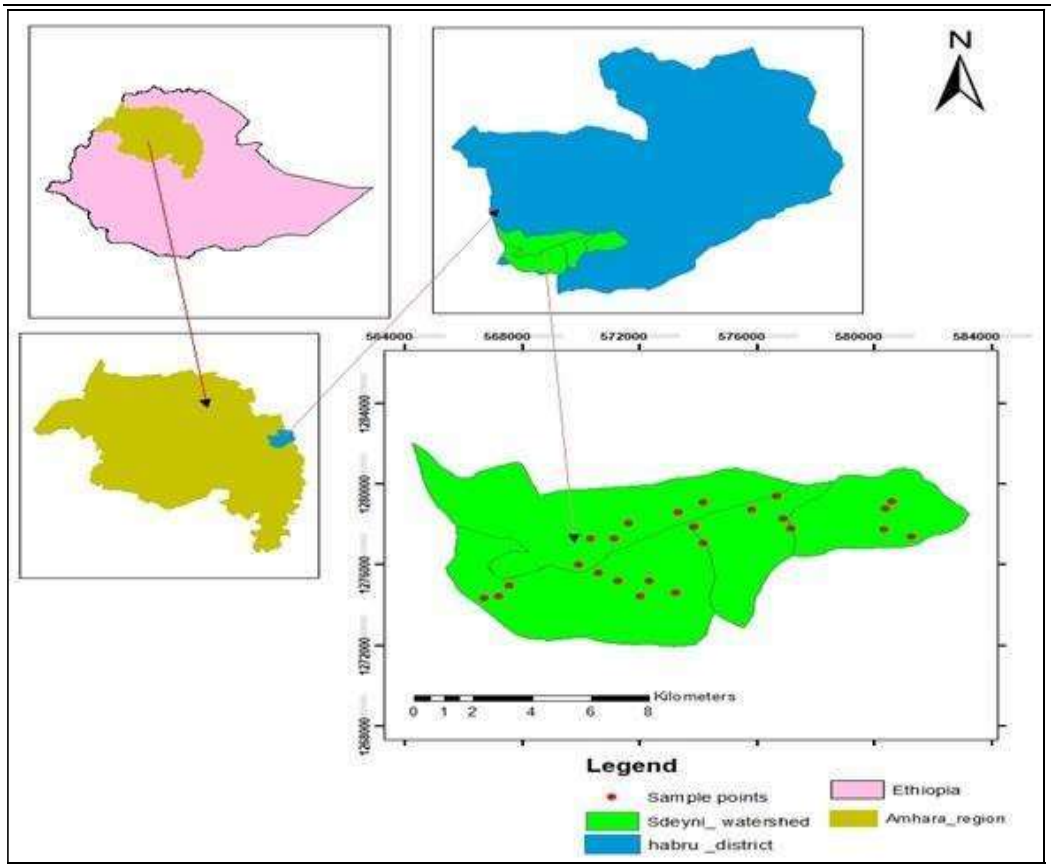

Figure1 Map of Sdeyni Watershed

The topography of the study area is mostly characterized by 35% mountains, 40% flat, 22% valleys and 3% others (Habru District Office of Agriculture, 2021). The major land use patterns of the study area comprise of cultivated land (44%), grazing land (20%), forest/shrub land (23%), infrastructure and settlement (10%), and unproductive land (3%). The agro-ecological situation of the district is divided into three elevation and temperature zones, namely: lowland (kolla) (64.7%), midland (woina-dega) (32.3%), highland and (dega) (3%). The annual mean temperature ranges from 15oC to 28oC. The coldest month is October while the warmest month is May. The area receives a mean annual rainfall of 700 to 1000 mm with erratic distribution.

Most of the people in the study area mixed crop-livestock agriculture system. Crop production is dependent on both rain-fed and irrigation system. The most common annual crops in the study area are Teff, Sorghum, and Maize which are grown in rainfed system while different vegetables such as Cabbage, Pepper, Tomato, Onion, and fruits like, Orange, Mango, and Lemon are grown through irrigation.

Field Survey, Sampling Site Selection, and Soil Sample Collection

A preliminary survey and field observation was carried out in December 2021 in the watershed to have general information about the land use and land cover types, topography, and farming system, and to decide the representative land units for soil sampling.

Field data collection and soil sampling was carried out with the help of atopographic map of the study area, and satellite image of April 2020. Prior to the actual field work, tentative sampling sites were fixed on the satellite image

on the basis of topography and land unit of the area.

From the study area soil fertility assessment on cultivated land was done by dividing the land in to different land units (LUs) according to their differences in terms of surface soil color, altitude, slope gradient and aspect, surface land features, and to a lesser extent soil management practices such as type of fertilizers used, and current crop. Accordingly, a total of eight land units were identified and demarcated (Table 1). Delineation was done using GPS to collect geographic data in each boundary, and the map was produced using GIS software. Once the representative LUs were identified, description of sampling site and soil sampling was carried out for each land unit. Three replicated composite soil samples were collected from the depths of 0-20 cm for each land unit. The samples were collected following a zigzag pattern based on the complexity of topography and heterogeneity of the soil type. A total of 24 composite soil samples were collected from 8 LUs. Depending on the size of the replications and their variability, 10 to 15 auger points were taken to make one composite sample.

The soil samples collected from representative fields' were air-dried, mixing and passing through a 2 mm sieve for the analysis of selected soil physical and chemical properties parameters except for total nitrogen and organic carbon which were passed through 0.5 mm sieve. After mixing, approximately 0.5 kg of the composite soil samples was transported to laboratory for analysis with proper labeling on each sampling bag. Undisturbed soil samples were collected from the same soil depth, and eight land units to determine soil bulk density values. Cylindrical metal core with a volume of 100 cm3 was pressed into the soil until it is filled. The soil was trimmed at both ends with a knife and covered with a cap, labeled, and packed in a box. whereas the disturbed soil samples were taken by using an auger to measure the rest selected soil physical and chemical properties. Following sample preparation, the selected soil physical and chemical properties were analyzed at Srinka Agricultural Research Center soil laboratory, following the standard procedures.

Table 1. Summary of characteristics of land units in Sdeyni watershed (Authors' survey)

Land unit	Area (ha)	Altitude (m a.s.l)	Slope (%)	Aspect	Soil type	Land use type	Current crop	Residue Mgt.	Fertilizers used
1	1267.6	1865	5	Southeast	EutricLeptosols	Crop land	Teff	cleared	NPS
2	1255.5	1678	2	Northeast	Lithic Leptosols	Crop land	Sorghum	cleared	NPS
3	2281.6	1624	5	Northeast	Lithic Leptosols	Crop land	Teff	Well-managed	NPS
4	1418.0	1710	5	Southeast	Lithic Leptosols	Crop land	Sorghum	cleared	NPS
5	86.8	1558	4	Southeast	Lithic Leptosols	Crop land	Teff	cleared	Urea
6	1595.0	1443	4	Northeast	EutricVertisols	Crop land	Sorghum	cleared	Urea
7	23.0	1415	5	Southeast	EutricVertisols	Cropland	Sorghum	cleared	Urea
8	1134.2	1396	2	Southeast	EutricVertisols	Crop land	Sorghum	cleared	Urea

Sample Preparation and Laboratory Analysis

For determination of particle size distribution, hydrometer method was used (Day, 1965). Then after, soil textural class names was assigned based on the relative contents of the percent sand, silt, and clay using the soil textural triangle of the USDA. Bulk density (BD) of soils was determined from undisturbed soil samples collected from each land use type using a core sampler and weighed at field moisture content and then dried in an oven at 105°C for 24 hours.

The soil pH was measured using soil to water suspension (1:2.5) by pH meter, whereas electrical conductivity was measured by conductivity meter(Van Reeuwijk, 1992) using the suspension prepared for pH analysis. The determination of organic carbon, the Walkley and Black (1934) method was used in which the carbon will oxidized under standard conditions with potassium dichromate (K2Cr2O7) in sulfuric acid solution. Finally, the organic matter content of the soil was calculated by multiplying the organic carbon percentage by 1.724 following the assumptions that OM is composed of 58% carbon. The total nitrogen content in soils was determined using the Kjeldahl digestion, distillation and titration method by oxidizing the OM in concentrated sulfuric acid solution (0.1N H2SO4) as described by Black (1965).

Exchangeable bases (Na+, K+, Mg2+ and Ca2+) were determined after extracting the soil samples by ammonium acetate (1N NH4OAc) at pH 7.0. Exchangeable Na+ and K+ were analyzed by flame photometer while Ca and Mg in the extracts were analyzed using atomic absorption spectrophotometer (AAS) as described by Rowell (1994). Cation exchange capacity were determined titrimetrically by distillation of ammonium that could be displaced by sodium from NaCl solution (Chapman, 1965). Percent base saturation was calculated by dividing the sum of the charge equivalents of the base forming cations (Na+, K+, Mg2+ and Ca2+) by the CEC of the soil and multiplying by 100.

Statistical Analysis

One-way analysis of variance (ANOVA) was applied using R software to analyze the selected soil physicochemical properties it indicates soil fertility assessment. Moreover, the least significant difference (LSD) test ($P < 0.05$) was used to compare the mean values of the selected soil physicochemical properties of the land units.

Soil Fertility Mapping

Using topographic (1:50,000) map and satellite image as a reference, location map of the study area was developed using Arc GIS 10.3. This watershed was then divided into 8 land units. After that, the respective coordinate points marked using GPS were fed into the GIS environment; then, polygons for the watershed and for each land unit were created by digitizing the recorded boundary points. Ordinary kriging was used to predict unknown values of soil nutrients concentration for non–sampled areas based on the nearby surveyed data. Point data of selective soil attributes were interpolated across the study area using the geo–statistical model and their spatial prediction were evaluated. For every soil property the experimental variogram was calculated. Mapping of predicted soil nutrients were carried out by using Arc GIS software version 10.3.

Based on the results of the laboratory analysis, soil fertility indices were generated and ratings made. Accordingly, the soils were classified into different fertility categories, i.e., very low, low, medium, high and very high on the basis of the content of each selected soil parameters. For each fertility class, different symbol, colors, and patterns were selected from symbol selector of Arc Map 10.3. Finally, the fertility status of the land units was mapped by using the respective legend symbols. Selected soil fertility parameters mapped were soil pH, organic matter (OM), total N, available P, CEC, exchangeable Na+, K+, Ca2+, and Mg2+.

Results and discussions

Physical Properties of Soils under Different Land Units

Significant differences ($P \leq 0.05$) were perceived among the three soil separates (Table 2) in different land units (LUs). The highest mean values of clay (65.41%), silt (27.91%), and sand (22.08%) fractions were recorded for LUs 3, 2 and 5, respectively, whereas the lowest clay (52.91%), silt (19.58%), and sand (15.00%) fractions were observed in LUs 2, 3 and 3, respectively. The textural classes in all land units fall in clay, as confirmed from the result, the clay content in all land units were above 50%. The most probable reasons for the minor variations in each soil separate may be due to differences in topography, slope gradient, erosion and deposition. Consistent with this suggestion, Fekadu et al. (2018) reported that variation in soil texture may be caused by variation in parent material, topography, in situ weathering and translocation of clay. From this study, it was found that soils of lower elevation sites have higher clay content than higher elevation sites. In agreement with this finding, Teshome et al. (2016) reported that textural variations are mainly associated with variation in parent material and topography.

Table 2. Selected soil physical properties under different land units

Land unit	Bulk density	Clay (%)	Silt (%)	Sand (%)	Textural class
LU1	0.85^{b}(0.13)	57.91^{a}(2.88)	23.75^{a}(5.44)	18.33^{a}(8.32)	Clay
LU2	0.84^{b}(0.10)	52.91^{a}(1.44)	27.91^{a}(5.05)	19.16^{a}(3.60)	Clay
LU3	0.87^{b}(0.09)	65.41a(11.81)	19.58^{a}(9.54)	15.00^{a}(5.72)	Clay
LU4	0.95^{b}(0.02)	56.25^{a}(2.50)	25.00^{a}(2.50)	18.75^{a}(2.50)	Clay
LU5	0.92^{b}(0.06)	54.25^{a}(3.81)	23.33^{a}(3.81)	22.08^{a}(1.44)	Clay
LU6	1.02^{b}(0.01)	56.25^{a}(5.00)	23.33^{a}(1.44)	20.41^{a}(5.20)	Clay
LU7	1.37^{a}(0.07)	55.41^{a}(3.81)	25.00^{a}(2.50)	19.58^{a}(3.81)	Clay
LU8	1.41^{a}(0.08)	57.08^{a}(3.81)	26.25^{a}(2.16)	16.66^{a}(2.60)	Clay

Note: Values followed by the same letter within a column are not significantly different at $p \leq 0.05$

Bulk density

Statistically significant differences ($P \leq 0.05$) were observed among average soil bulk density values of the land units (Table 2). The highest (1.41 g cm-3) and the lowest (0.84 g cm-3) mean bulk density values were recorded for LUs 8 and 2, respectively. The variation in bulk density could be attributed to variation in soil OM content, and intensity of cultivation (Sharma. and Anil, 2003). Accordingly, the highest bulk density for LU 8 could be due to lower soil OM content and higher degree of soil compaction due to intensive cultivation since this LU has been cultivated for a long period of time. In contrast, the lower bulk density in LU 2 could be attributed to relatively higher soil OM content owing to trees litter fall and dieback of fine roots, higher total porosity and less frequent disturbance of the land, and the contribution of trees in loosening the soil structure through their roots. According to Hazelton and Murphy (2016), the limiting value of bulk density at which crop roots are likely to be restricted is 1.4 g cm-3 for clay soils. Most of the soil bulk density values of the different land units of the area were suitable for crop production.

Chemical Properties of Soils under Different Land Units

Soil reaction (pH)

Statistically significant differences ($P \leq 0.05$) were observed among soil pH values of the land units (Table 3). The lowest (6.02) and highest (6.74) pH values were recorded for LU 1, and 8, respectively. As per the ratings established by Jones (2012), soils having a pH value of 6 to 7 are classified as slightly acidic in their reaction (Figure 2). Thus, the pH values of soils of the study area are ideal for plant growth and the availability of most of plant nutrients might not be limited within the observed pH range.

Organic matter, total N, and available P

Significant differences ($p \leq 0.05$) were observed among soil OM values of the land units (Table 3). The mean organic matter content of the soils in the area ranges from 2.96% (LU 8) to 4.59% (LU 3). According to the rating suggested by Tekalign (1991), the soil OM content of all LUs in the study area can be categorized in the range of medium soil OM content (Figure 2). Although the OM content of the soils in all land units falls in the same rating, there is statistical difference in the land units. The most probable source of variation in soil OM contents among the land units might be variation in altitude, intensity of cultivation, cropping system and soil management practices. The highest OM content of LU 3 could be due to the relatively better residue deposition of the previous crop, and the addition of litter from scattered trees around the crop land. On the other hand, the lower OM content in other land units might be due to higher rate of OM decomposition aggravated by intensive cultivation, and also perhaps because of low rate of return of organic materials as crop residues due to a number of competing ends such as animal feed, fuel, construction, etc. Similarly, Alemayehu and Sheleme (2013) reported that lower OM was recorded in cultivated field than other land uses; and this was because of the effect of continuous cultivation and OM oxidation. The medium content of OM in land units indicates good structural condition, high structural stability, pH buffering capacity, soil nutrient levels (especially N), water-holding capacity Hazelton and Murphy (2016).

Table 3. Soil pH, EC, OM, Total N, and available P under different land units

Land unit	PH (H_2O)	EC (dS/m)	OM (%)	Total N (%)	Available P (mg kg^{-1})
LU1	6.02^{d}(0.01)	0.17^{b}(0.03)	3.99^{b}(0.19)	0.21a(0.01)	12.44^{a}(1.00)
LU2	6.04^{d}(0.01)	0.19^{b}(0.07)	3.78^{b}(0.15)	0.21a(0.01)	11.76^{ab}(0.37)
LU3	6.20^{c}(0.10)	0.17^{b}(0.07)	4.59^{a}(0.45)	0.24^{a}(0.03)	11.98^{a}(0.75)
LU4	6.02^{d}(0.01)	0.27^{b}(0.14)	3.13^{c}(0.16)	0.15^{b}(0.01)	11.38^{ab}(0.92)
LU5	6.41^{b}(0.01)	0.19^{b}(0.09)	3.04^{c}(0.11)	0.12^{bc}(0.01)	$9.91b^{c}$(0.67)
LU6	6.64^{a}(0.04)	0.34^{b}(0.16)	3.06^{c}(0.18)	0.12^{bc}(0.01)	8.63^{cd}(0.38)
LU7	6.73^{a}(0.03)	0.49^{ab}(0.36)	3.02^{c}(0.09)	0.10^{c}(0.00)	7.33^{de}(0.87)
LU8	6.74^{a}(0.01)	0.79^{a}(0.04)	2.96^{c}(0.05)	0.11^{c}(0.00)	6.40^{e}(0.33)

Note: Values followed by the same letter within a column are not significantly different at $p \leq 0$; EC=Electrical conductivity; OM=Organic matter

The total N was significantly ($p \leq 0.05$) affected by differences in land units (Table 3). The average percent total N content of the soils in the study area ranged from 0.10% (LU7) to 0.24% (LU3). According to the rating suggested by Tekalign (1991), soils of LUs 1, 2, 3 and 4 were medium while the soils of LUs 5, 6, 7 and 8 were found to be low in total N content. The contents of total N of soils in the area showed a similar trend with the contents of OM. These facts indicate that the major source of total N and its ultimate source of variation is OM content. Consequently, the lower total N content in LU 7 could be due to its lower OM content as a result of faster rate of degradation and consequent removal of the OM, coupled with limited application of mineral N and organic fertilizers. Land units 1, 2, 3, and 4 had moderate contents of total N as compared to the remaining cultivated land units. These land units are found with dispersed trees on farm lands, near settlements and they have better chances for receiving organic N sources due to anthropogenic activities. These lands in general need optimum N application for increased productivity and sustainable yield of agricultural crops.

The average contents of available P in the soils of the area ranged from 6.40 mg kg^{-1} (LU 8) to 12.44 mg kg^{-1} (LU 1) of soils (Table 3). Based on the rating suggested by Olsen (1954), the available P contents of LUs 1, 2, 3, and 4 were found in high ranges, whereas, the LUs of 5, 6, 7 and 8 are rated in medium ranges (Figure 2). The variability in available P contents of soils might be due to different soil management practices, specifically, type and rate of organic fertilizers and inorganic fertilizer applied to the cultivated land units.

The higher P content in all cultivated land units could be due to the application of NPS fertilizer (residual P), suitable soil pH for P availability, and the consequence of long-term manure and house refuse applications and the associated increase in microbial activity as they are found near to settlement areas.

Table 4. Cation exchange capacity, exchangeable bases, and percent base saturation of soils under different land units of the crop land

Land unit	CEC (cmol(+)/kg)	Ca^{2+} (cmol(+)/kg)	Mg^{2+} (cmol(+)/kg)	K^{+} (cmol(+)/kg)	Na^{+} (cmol(+)/kg)	PBS (%)
LU1	27.00^{a}(1.58)	7.08^{a}(0.40)	3.93^{a}(0.65)	0.67^{a}(0.07)	0.63^{a}(0.09)	45.59^{c}
LU2	22.40^{bc}(0.91)	6.22^{ab}(0.08)	3.03^{abcd}(0.03)	0.65^{ab}(0.04)	0.61^{a}(0.09)	46.92^{c}
LU3	20.23^{ab}(1.60)	6.35^{ab}(0.11)	3.36^{ab}(0.34)	0.58^{abc}(0.01)	0.57^{ab}(0.03)	41.40^{d}
LU4	$2.4b^{c}$(0.91)	6.67^{a}(1.21)	3.25^{abc}(0.40)	0.58^{abc}(0.03)	0.62^{a}(0.01)	49.64^{bc}
LU5	19.46^{cd}(1.20)	5.58^{ab}(0.57)	2.34^{cd}(0.29)	0.55^{bcd}(0.02)	0.51^{ab}(0.01)	46.15^{c}
LU6	$15.86d^{e}$(1.70)	5.91^{ab}(0.36)	2.57^{bcd}(0.44)	0.52^{cde}(0.03)	0.45^{b}(0.03)	59.58^{b}
LU7	2.66^{e}(1.61)	5.02^{b}(0.68)	2.30^{cd}(0.08)	0.45^{de}(0.02)	0.45^{b}(0.02)	64.93^{ab}
LU8	1.90^{e}(0.78)	4.93^{b}(0.35)	2.21d(0.07)	0.43^{e}(0.01)	0.43^{b}(0.02)	67.23^{a}

Note: Values followed by the same letter within a column are not significantly different at $P \leq 0.05$; CEC=Cation exchange capacity; PBS=Percent base saturation

Cation exchange capacity, exchangeable cations, and PBS

Analysis of variance showed that the CEC of the soils in the study area varied significantly ($p \leq 0.05$) among the land units (Table 4). The highest (27.00 $cmol_{(+)}$ kg^{-1}) and the lowest (11.90 $cmol_{(+)}$ kg^{-1}) mean values of CEC were recorded in LUs 1 and 8, respectively. Based on the rating suggested by Hazelton and Murphy (2016), soils of LUs 1 and 3 were categorized to high range, whereas the CEC value of the remaining land unit were medium (Figure 3).

The variation in CEC values of the studied soils may be because of variation in OM content,

type and amount of clay, and intensity of cultivation. The relatively higher CEC value of soils of LUs 1 and 3 could be mainly due to relatively higher clay content and probably the predominance of 2:1 clay mineral like semectites. The highest CEC value of land unit 1 may be due to its relatively higher OM content. Consistent with this suggestion, Solly *et al.* (2020) reported that OM is responsible for about 35-50% of the total CEC of surface mineral soils. Therefore, soil CEC is expected to increase through improvement in soil OM content. Although there is variability in CEC values of the studied soils, the medium to high CEC values indicate that the soils can retain high amounts of cations such as K^{+}, Ca^{2+} and Mg^{2+} to support plant growth. Fekadu *et al.* (2018) reported that high CEC offers high buffering capacity to the soil. Furthermore, high CEC values have been implicated in high yields obtained from most agricultural soils.

Exchangeable basic cations varied significantly ($P \leq 0.05$), for exchangeable Ca2+, Mg2+, K+ and Na+ ($P < 0.05$) for the land units (Table 4). The highest (7.08 cmol(+) kg-1) and the lowest (4.93 cmol(+) kg-1) mean values of exchangeable Ca2+ were recorded for LUs 1 and 8, respectively. Soils of LUs 1 and 8 had the highest (3.93 cmol(+) kg-1) and lowest (2.21 cmol(+) kg-1) exchangeable Mg2+. The highest exchangeable K+ (0.67 cmol(+) kg-1) the lowest exchangeable K+ (0.43 cmol(+) kg-1) were recorded in LUs, 1 and 8. The lowest (0.43 cmol(+) kg-1) exchangeable Na+ was recorded in LU 8 while the highest exchangeable Na+ (0.63 cmol(+) kg-1) was recorded in LU 1 (Table 4). The order of exchangeable basic cations in the studied land units is Ca2+ > Mg2+ > K+ > Na+. Based on the rating of exchangeable basic cations set by FAO (2006), the mean values of exchangeable Ca2+ in all LUs except LUs 8 are medium ranges and the only LUs 8 are low range. The mean value of exchangeable Mg in LUs 1, 2, 3, 4, were high whereas it was medium in LUs 5, 6, 7, 8. The mean value of exchangeable K+ in LUs, 1 and 2 were high but medium in LUs, 3, 4, 5, 6,7,8 (Figure 3). On the other hand, the soils of all LUs exchangeable Na were medium.

The variation in exchangeable basic cation content among land units could be due to variation in OM content, amount of clay, cultivation intensity, elevation, and soil management practices. Exchangeable Ca2+ and Mg2+ appeared to decrease in the lower elevation sites of the study area. This might be attributed to removal of these exchangeable basic cations by leaching from higher topography and their subsequent accumulation in the lower elevations. From soil fertility point of view, exchangeable Ca2+, Mg2+, and K+ in most of the land units were in the range of medium. This implies that soils of the study area are not deficient in exchangeable basic cations. However, supplementing the soils with regular addition of organic and inorganic fertilizers materials are required to meet its maintenance requirement and sustaining productivity. Corroborating this result, Tuma (2007) also reported the same order of abundance of basic cations on the exchangeable complex of fluvial soils in Gamo Gofa zone, Ethiopia, and pointed out that such an order is favorable for crop production.

The highest (67.23%) and the lowest (41.40%) mean values of PBS were recorded for LUs 8 and 3, respectively (Table 13). Based on the rating suggested by Hazelton and Murphy (2016), soils of LUs 1-6 are in a moderate range in status while LU 7 and 8 fall in a high rating. The trends in a high PBS followed the trend of the LUs with lower CEC values. Thus, variability in PBS could also be due to variation in pH, OM content, soil texture, and soil management practices.

Mapping of Soil Fertility status

The topographic map of the study area (1: 50000) was used as a reference to undertake field survey and thereby to demarcate the initial sampling sites using GPS. The easting and northing coordinates (grids) of each sampling sites were thoroughly recorded. The size of each sampling site was large enough to represent each of the respective 8 land units for mapping the spatial variability of the soil fertility in the study area. Accordingly, the total area of the land units was 10461 ha with the

minimum and maximum areas of 686.8 and 2281.6 ha for land units 5 and 3, respectively.

The selected soil fertility parameters mapped are pH, OM, Total N, available P, K+, Ca2+, Mg2+, and CEC (Figure 2 and 3). Area of each selected soil fertility parameters with respective soil fertility status is presented in Appendix Table 14. Medium total N content covers 9327.5 ha (89.2%) of the total area of the land units whereas high total N content takes greater portion (10.8%) of the land units. The available P contents of the soils covers 6222.7 ha (59.5%) for high, 4239 ha (40.5%) for medium status of the land units.

The area coverage of available K+ is 1267.6 ha (12.1%) and 9194.1ha (87.9%) for the low and medium status of land units respectively. High CEC shared 1267.6 ha (12.2%) and low CEC shared 9194.1 ha (87.9%) of the total area of the land units. The total area of the watershed contained moderate soil OM (Figure 2).

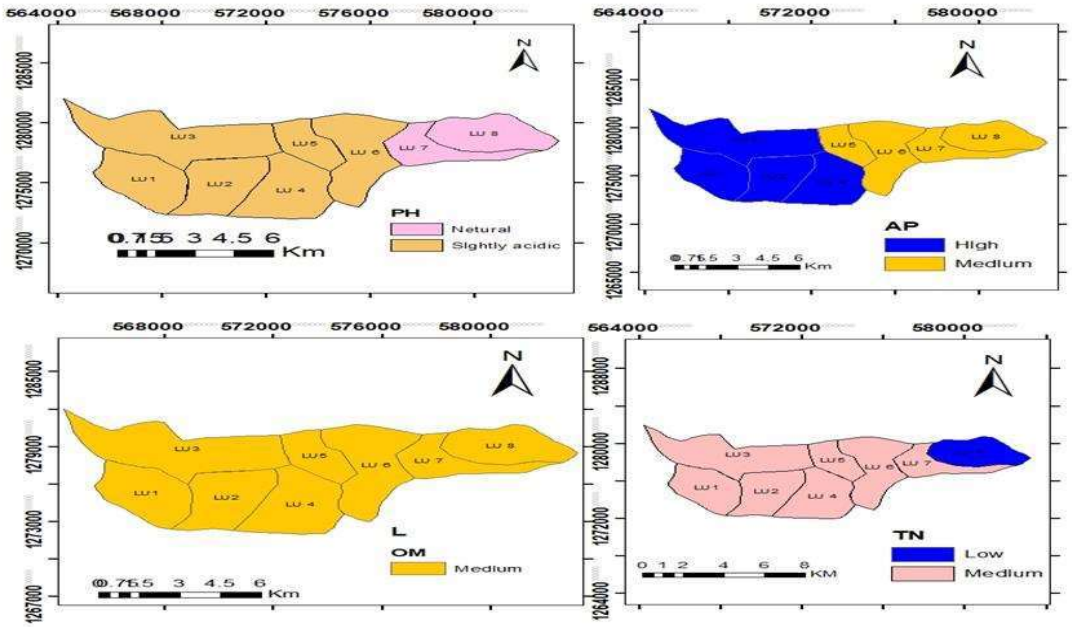

Figure 2. Spatial distribution of pH, OM, total N, Available P

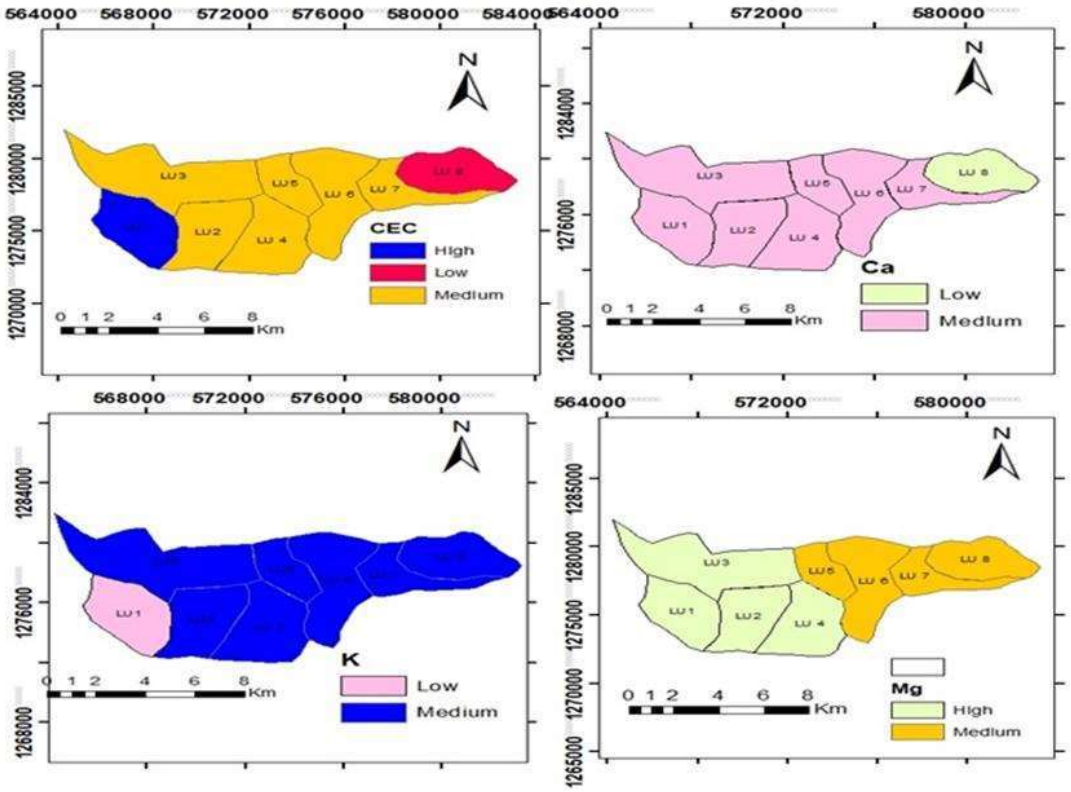

Figure 3. Spatial distribution of exchangeable Ca2+, K+ Mg2+ and CEC

Conclusions

Twenty four soil samples from eight land units were collected, analyzed and the maps were generated using GIS software. Generally, the soil textural class was clay in all land units. The bulk density value varied significantly among the sampled land units. However, these bulk density values were under unsuitable range for crop production. Soil pH was slightly acidic in all land units and preferred by most agricultural crops. Soils of half of the sampled land units had medium total N content, while the remaining had low. The available P contents of the sampled land units were rated between high to medium range. Similarly, the soils from two of the land units were categorized to high CEC range, whereas the CEC value of the remaining land unit was medium. The overall result showed immediate soil fertility management intervention should be applied. Organic and inorganic fertilizers sources should be applied depending on the limitation of the identified nutrient in each land unit to maintain the fertility of the land for sustainable production of agricultural crops.

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RESEARCH PAPER

The Relationship between Students' Attitude towards Learning English, their Age and their English Proficiency: The Case of First Year Undergraduate Students of Ambo University

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Abstract

This study examined the relationship between first year undergraduate students' attitude towards English language learning, their age and their English language proficiency. It employed descriptive research design and guided by two specific objectives. First, it investigated the relationship between students' attitude towards English and their English language proficiency. Second, it assessed the relationship between students' age and their English proficiency. To do so, a questionnaire of attitude and test of proficiency were used to collect pertinent data. First, the test of proficiency was administered to a randomly selected 172 first year students. Next, the participants completed a questionnaire of attitude towards learning English. The data collected were analyzed by using both descriptive and inferential statistics. The Spearman Rank-Order Correlation was run to determine the relationship between students' attitudes towards English language learning and their English proficiency. The findings disclosed that there was a low positive correlation (r= 0.097), and no significant relationship between students' attitudes towards English language learning and their English language proficiency (p= 0.206>0.05). On the other hand, Pearson Correlation Coefficient was used to determine how age correlate with language proficiency. To this end, it was found that there is a positive correlation between age and English language proficiency (r= 0.05) although there was no significant relationship between the two variables (p=0.514>0.05). Since learners' language proficiency can be influenced by the belief they hold about the language, English experts and instructors should devise a strategy of shaping learners' beliefs about the role of a language. Similarly, they should consider students' ages while planning lessons, delivering and evaluating their progress.

Keywords: Age, Attitude, English language proficiency, undergraduate students

Introduction

English is considered as an important language in the academic world, and it is a required course in Ethiopia like many other countries. In Ethiopia, recognizing learners' needs and finding the best strategies to develop positive attitudes towards language learning is not taken into consideration too much. Nunan (2000) claims that attitudes, skills, and strategies influence learners' underachievement or achievement. As University students' English language proficiency is a significant standard in their academic achievements and employment; English language learning deserves special attention by language instructors as well as learners.

There might be some learner variables that influence language learning and language proficiency. Among these variables, learners' attitude towards learning second language is of

particular importance which motivates the learners to learn second language. According to Baker (1993), students with positive attitudes will try harder to learn the language by using strategies like questioning, volunteering information and answering questions. Hence, attitude influences the rate of development and the final proficiency achieved in the target language. Fortunately, attitudes are not static. They can be changed through the learning process such as by using appropriate teaching materials, teaching techniques and strategies. Attitude also improves due to language learning as students who learn well will acquire positive attitudes.

This study was mainly necessitated for two reasons. First, English as a foreign or second language is one of the ways of improving the knowledge of University undergraduate students. University undergraduate students have to learn English and improve their level of proficiency which is necessary to meet their goals. Although the students expose to English, its daily use is limited and the students' proficiency does not meet the teachers' expectations. Bachman (1990) describes the language proficiency as the ability of language use, and Oller (1983, as cited in David, 2014) asserts that language proficiency is not a single unitary ability that comprises several distinct but related constructs in addition to a general construct of language proficiency. Second, the language acquisition can happen if the students have favorable attitudes towards the English language. Baker (1992) conceived attitude as some abstract embrace both positive and negative beliefs such as beliefs towards a language situation. Students with more favorable attitudes towards English language and English speakers probably perform better in the language learning than otherwise.

Some international studies were conducted on students' attitude towards English and English proficiency. For instance, Begheri (2015) found that there was a low positive correlation between medical students' attitude towards English language learning and English language achievement. In addition, Ubonrat (2005) found that there exists relationship between students' attitude toward a study of English and their English proficiency.

Moreover, Shams (2008) carried out a study on learners' attitudes towards English language learning and found that most language learners had positive attitudes towards English language learning. According to Al-Tamimi and Shuib (2009), it is also conceived that students' motivation in language learning is influenced by their language learning attitudes. Chalak and Kassaian (2010) found that EFL learners' attitude and motivation towards English language learning and the target language community were explored. The research gave more emphasis on the motivation orientations of the students and their attitudes towards the target language and its community. The results indicated that non-native speakers of English learned the language for both instrumental and integrative reasons and their attitudes towards the target language community and its members were generally found to be highly positive. Latif *et al*. (2011) found the relationships between attitudes, motivation, anxiety and instrumental orientation and English language learning demonstrated that all these variables were correlative with learners' performance, with attitude having a positive effect. Also Dehbozorgi (2012) studied the effects of attitude towards language learning on Iranian EFL students' proficiency. To this end, correlation results were not substantial between attitude towards English language learning and proficiency.

Among the few local studies include studies conducted by Jibril (2021) and Dagnaw (2017) on the relationship between the attitude of students towards learning English language, and the relationship between students' attitudes towards school, values of education, achievement motivation and academic achievement respectively. Both studies focus on secondary schools. On the contrary, the present study emphasized on studying the relationship between student related variables such as attitude and age, and language proficiency at higher learning institutions. Form the researcher's observation as English language teacher in higher learning institutions so far, many students demonstrate less than

average level of language proficiency. Students' competency in almost all language skills is not satisfactory, and they did not have a strong desire to learn and improve their present status. It seems that they accepted their gaps and fail to put as much effort as possible to enhance their language competence. In addition, it is uncommon to see most students make communications in English in their everyday activities both inside and outside the classroom. Ironically, there are still very limited numbers of students who are able to communicate simple in English although they have better mastery of the grammar aspect. According to Shams (2008), in foreign language learning context, there are various factors that influence the English language proficiency which include motivation, attitude, anxiety, learning achievements, aptitude, intelligence, age, personalities, etc. Attitude is one of the most significant factors that impacts on English proficiency. Dehbozorgi (2012) states that attitude is directly unobserved hypothetical construct and must be inferred from measureable responses which reflect and evaluate positive or negative attitudes.

The students' attitudes have to influence all of the students' responses to the target language, especially the students' attitude towards English. Oller (1979) claims that attitude is merely one of the types of factors that give rise to motivation which eventually results in the attainment of proficiency in second language. According to Gowhary (2015), attitude is crucial in language growth or decay, restoration or destruction. It is internal states that influence what the learners are likely to do. The internal state is some degree of positive/negative/unfavorable reaction towards an object.

Likewise, undergraduate students are supposed to have good mastery of English as it is a medium of instruction for their courses and thesis works. Besides, most undergraduate courses involve essay tasks such as seminar, proposal and thesis writing. It also involves advanced reading ability such as reviewing literature when taking notes and making summary. Moreover, undergraduate students' writing tasks should be to the standard in terms of grammatical structure. Grammatically incorrect structures affect the overall message of the essay. Obviously, these writing tasks should be presented where English speaking skill plays significant role. From experience, some students submit a well-organized piece of essay, but are not expressive enough due to limitations in speaking using English. The other most indispensable skill is the use of appropriate vocabulary in composing essay. Limitation in the use of relevant vocabularies leads to inability to meet the purpose of a given essay. It is also uncommon to see undergraduate students properly read in English. They mispronounce words when reading out for the class during presentations. In this case, attitude towards the language itselfplays a significant role since someone who holds a positive attitude has a greater tendency to put much effort to improve one's language proficiency than someone who ignores its role as a tool for studying second degree. According to Dalvit and Klerk (2004), if someone has positive attitude to a language, he or she is more likely to learn it well. For Montano and Kasprzyk (2008), attitude is influenced by someone's beliefs about results or attributes of performing the behavior (behavioral beliefs), gained importance by evaluations of those results or attributes. Hence, a person who has strong beliefs that positively evaluated results will result from performing the behavior will have a positive attitude towards the behavior. On the contrary, a person who has strong beliefs that negatively evaluated results will result from the behavior will have a negative attitude. Chapman and McKnight (2002) state that attitude is your general tendency or your mental starting point for seeing life and the people and events in it.

Gardner (1985, as cited in Soleimani & Hanafi, 2013) states that attitude is the amount of a person's instinction and feelings, prejudice, preconceived ideas, fears, threats, and convictions about any intended topic. As to Gardner, attitude is, thus, connected to a learner's values and beliefs and encourages or discourages the choices made in all areas of activity, whether academic or informal. It is a part of motivation in language learning. He asserts motivation is the combination of effort

and desire to accomplish the goal of learning the language and favorable attitudes towards learning the language.

In Ethiopia, English as a second or foreign language is taught starting from primary school through tertiary education levels. Although the students are exposed to English, its daily use is limited and the students' proficiency does not meet the teachers' expectations. Regardless of its necessity for advanced education, most students speak English with poor fluency. English language proficiency is applied in different contexts. However, English language learning is comprehended to be a hard process. Stern (1983) defines proficiency as the actual performance of a learner in a given language, and it includes the mastery of (a) the forms, (b) the linguistic, cognitive, affective and socio-cultural meanings of those forms, (c) the capacity to use the language with focus chiefly on communication and minimum attention to form, and (d) the creativity in language.

Bachman (1990) describes language proficiency as the language ability or ability in language use, and Oller (1983, as cited in David, 2014) asserts that language proficiency is not a single unitary ability, but it comprises several distinct, related constructs in addition to a general construct of language proficiency. Bachman and Palmer (1996, as cited in Hamidi & Montazeri, 2014) believe that learner's language proficiency level is defined as his or her knowledge of L2 grammar and vocabulary, which is a subcomponent of general language ability. According to Cloud *et al*. (2000), language proficiency is defined as the ability to use a language accurately and appropriately in its oral and written forms in a variety of situations. This definition comprises four aspects of language namely listening, speaking, reading and writing. The first two aspects represent oral proficiency which in most cases is developed outside the University environment without any exposure to written language.

On the other hand, age is one of the most determining variables in foreign or second language learning. There is no doubt that the learners can acquire the language effectively in the critical period. According to the Critical Period Hypothesis by Penfield and Roberts (1959), there is a time in human development when the brain is predisposed for success in language learning (Lightbown and Spada, 2001). The development of acquiring the language is very fast at the age from 0-12 years old. It is the time when the human brain affects the success in language learning. According to Singleton and Ryan (2004), people who begin learning a second language in childhood in the long run may generally achieve a higher level of proficiency than those who begin later. Obviously, this statement contributes to the hypothesis for starting foreign language instruction earlier. It seems as a good start for young learners holding the chances to acquire foreign language with early immersion to the foreign language instruction.

As Pinker (1994), brain research shows that children are at a suitable age for language learning. Although language study is advantageous and effective at any nearly age, some researchers suggest that human brain is more open to language learning from birth to pre-adolescence. During this critical period, or put in another term, window of readiness, there seem to be greater synapses and plasticity that is highest before the age of six, and then step by step declines.

Hu (2016) found that when young learners are exposed to foreign or second language earlier, they will achieve better performance and proficiency in the target language acquisition. This again correlates with the assumption held by Critical Period Hypotheses which assumes that early acquisition of foreign language will facilitate their learning later in the life. They will learn second language better and win the ultimate achievement in the long run. Childhood is considered to be the golden age for second language learning. Therefore, it is good idea to conduct the foreign language instruction at an early age to improve children's learning and enhance language proficiency as there is a logical association between the two variables.

Thus, both age and attitude are among the key variables influencing foreign or second

language learning. In short, success in a target language is based not only on intellectual capacity, but also the students' related variables such as attitude and age which may affect in learning English to enhance language performance. With this in mind, the researcher intended to study the interface between undergraduate students' attitude towards English language learning, their age and their proficiency in English language, particularly at Ambo University.

More specifically, the study aimed to answer the following two basic research questions.

1. What is the relationship between students' attitude towards English language learning and their language proficiency?
2. What is the relationship between students' age and their English language proficiency?

In connection to this, the study attempted to test the following research hypotheses:

Ha1=There is a significant relationship between undergraduate students' attitudes towards English language learning and their English language proficiency.

H_O1= There is no significant relationship between undergraduate students' attitudes towards English language learning and their English language proficiency.

Ha2= There is a significant relationship between the age of undergraduate students and their English language proficiency.

Ho2= There is no significant relationship between the age of undergraduate students and their English language proficiency.

Operational definition of terms

Attitude refers to a predisposition or a tendency to respond positively or negatively towards a certain idea, object, person or situation. So, in this study, it refers to University undergraduate students' predisposition towards learning English. Learner variables refer in this study to student characteristics such as attitude, age and gender their relationship with students' language proficiency.

English Language Proficiency is the ability of students to use English language to make and communicate meaning in spoken and written contexts at a certain level of study.

Materials and methods

Research design

In this study, descriptive study was used. Descriptive research design describes data on variables of interest. It is useful for gathering factual information, data on attitudes and preferences, beliefs and predictions, behavior and experiences both past and present (Weisberg *et al.* 1996, as cited in Cohen *et al*., 2007).

So, in this design, attempts were made to determine the relationship between variables followed by explanation and interpretation of the results that may appear. Towards answering the basic research questions of this study, pertinent data were collected from undergraduate first year students of Ambo University by using simple random sampling techniques. Finally, correlation was used to show the degree of association between two learner variables and their language proficiency.

Study participants, sample and sampling technique

For the purpose of this study, the researcher intended to undertake a study on first year undergraduate students of Ambo University in the academic year 2020/2021. The total population of first year undergraduate social science stream students who were admitted to Ambo University is 1,308. To this end, simple random sampling technique was employed to obtain the sample for the study. From the total

population of 1,308, the researcher took 15% as a representative sample for the study. The sample size of the study was 196, but 24 of them did not return the questionnaire and did not sit for the proficiency test as well. So, complete data was obtained from 172 students.

Data collection tools

Questionnaire

A questionnaire of attitude which is adapted from the attitude questionnaire used in a study by Soleimani and Hanafi (2013) was employed to collect pertinent data for the study. Surveys typically rely on large-scale data, e.g. from questionnaires, test scores, attendance rates, results of public examinations etc., all of which enable comparisons to be made over time or between groups (Cohen, 2007).

Proficiency Test (TOP)

Test of Proficiency (TOP) was used to determine undergraduate students' English language proficiency. The test of proficiency consisted of all the four language skills, vocabulary and grammar. Tests for reading skills, grammar and writing skills were given together at once whereas the remaining two tests (i.e., speaking skills and listening skills) were given separately. For the speaking skills test, a standardized speaking assessment rubric was prepared and administered. In doing so, the examinees were given codes and assessed in a small group of five to six students. For the listening skills test, the researcher used an audio text in which the examinees listened to it twice and answered cloze-type test and comprehension questions. Since the researcher tried to maintain its standardization, the tests were administered to all the sample participants regardless of their educational background and exposure to the target language.

Methods of data analysis

Quantitative data collected from students were analyzed quantitatively. Accordingly, descriptive statistics (such as frequency distribution, percentage, mean, variance and standard deviation) were used to analyze quantitative data which was obtained through questionnaire by the help of SPSS version 20. Similarly, for the quantitative data collected through attitude questionnaire and test, both Pearson and Spearman Rank-Order correlation coefficients were used to show the degree of association between learner variables and their language proficiency. In Kothari (2004), it is stated that Pearson Correlation Coefficient is the best test of correlation when two data sets for two variables are normally distributed (i.e., parametric data). On the other hand, the Spearman Rank Order Correlation is the best test of correlation when two data sets for two variables are not normally distributed non-parametric data).

Results

The main aim of the present study was to assess the relationship between undergraduate students' attitude towards learning English language, their age and their English proficiency. Data was collected from Ambo University first year undergraduate social science stream students through questionnaire and test of proficiency. Questionnaire was used to collect information pertaining to students' attitude towards learning English language. Test of language proficiency was administered to these undergraduate students to determine their level of proficiency to enable the researcher gain an insight about the association between their attitude and their proficiency.

Demographic characteristics of the respondents

This section of the research report presents the demographic information of the study participants, analysis of the questionnaire data and test score to answer the basic research questions posed under the first chapter of this study.

Table 1. Age of the Participants

Age of the respondents	Frequency	Percent
Valid >18	172	100.0

Table 1 depicts the age of participants of the study. Hence, all the 172 (100%) of them were above 18 years old

The relationship between students' attitude towards English and their English language proficiency

The first basic question was whether there is association between students' attitude towards English and language proficiency. So, in order to answer this question, it is important to see the descriptive statistics as in table 2.

Table 2. Descriptive Statistics of the Participants

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Attitude	172	1.87	4.11	3.0499	0.42019	0.177
Proficiency test	172	12.00	83.00	47.5087	15.02994	225.899
Valid N(listwise)	172					

Table 3. Test of Normality for the Proficiency Test of Participants and their Attitude.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Attitude	0.159	172	0.000	0.912	172	0.000
Proficiency test	0.057	172	0.200*	0.992	172	0.449

*.This is a lower bound of the true significance. a. Lilliefors Significance Correction

As it can be seen in table 3, the significance value of the Shapiro-Wilk Test is higher than 0.05 (p=0.200) for the proficiency test score, but lower than 0.05 (p=0.000) for the attitude score. This indicates that since one of the two sets of scores is not normally distributed, the best test of correlation for relationship would be the Spearman Rank-Order Correlation.

Table 4. Result of Spearman Rank-Order Correlation

			Proficiency	Attitude
Spearman's rho	Proficiency test	Correlation Coefficient	1.000	0.097
		Sig. (2-tailed)	.	0.206
		N	172	172
	Attitude	Correlation Coefficient	0 .097	1.000
		Sig. (2-tailed)	0.206	.
		N	172	172

The Spearman Rank-Order Correlation was run to determine the relationship between undergraduate students' attitudes towards English language learning and their English language proficiency. There was a low positive correlation between their attitudes towards English language learning and their English language proficiency, which was statistically described as ($r = 0.097$, $p = 0.206>0.05$). Thus, it could be concluded that the null-hypothesis "there is no significant relationship between undergraduate students' attitudes towards English language learning and their English language proficiency" was accepted, meaning that there is no significant relationship between Ambo University first year undergraduate students' attitudes towards English language learning and their English language proficiency.

The relationship between students' age and their English language proficiency

Table 5. Tests of Normality

	Age	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	Df	Sig.
Proficiency	23.00	0.307	3	.	0.903	3	0.394
	24.00	0.270	6	194	0.828	6	0.103
	25.00	0.326	10	0.003	0.761	10	0.005
	26.00	0.107	24	0.200*	0.984	24	0.959
	27.00	0.121	13	0.200*	0.951	13	0.621
	28.00	0.147	14	0.200*	0.965	14	0.797
	29.00	0.109	36	0.200*	0.983	36	0.838
	30.00	0.128	19	0.200*	0 .977	19	0.897
	31.00	0.115	26	0.200*	0.917	26	0.039
	32.00	0.205	8	0.200*	0.898	8	0.278
	33.00	0.300	5	0.162	0.771	5	0.046
	34.00	0.260	2	.			
	35.00	0.260	2	.			
	36.00	0.260	2	.			
	38.00	0.260	2	.			

* This is a lower bound of the true significance.
a. Lilliefors Significance Correction

As can be seen in 5, the *p* value of the Shapiro-Wilk test is higher than 0.05 for age and test of proficiency, the two sets of scores are normally distributed. Therefore, the best test for relationship would be the Pearson Correlation Coefficient

.Table 6. The Correlation Between Age of Participants and their English Proficiency Test

		Age of the respondents	Proficiency
Age	Pearson Correlation	1	0.05
	Sig. (2-tailed)		0.514
Proficiency test	Pearson Correlation	0.05	1
	Sig. (2-tailed)	0.514	

In 6, Pearson Correlation Coefficient was run to determine the relationship between students' age and their English language proficiency. The result indicated that there is a moderate positive correlation between age and English language proficiency, which was statistically described as ($r = 0.05$, $p=0.514>0.05$). So, it could be concluded that the null-hypothesis "there is no significant relationship between the age of undergraduate students and their English language proficiency" was accepted; meaning that there is no significant relationship between age of the participants and their English proficiency.

Conclusion and recommendation

This experiment has clearly demonstrated that nitrogen had significant effects on seed yield, oil content and fatty acid composition of linseed varieties. The optimum oil yield and percent of fatty acid compositions were obtained in response to application of 46 kg ha^{-1} nitrogen in the study area. The maximum seed (1508 kg ha^{-1}) and oil (604.4 Lt ha^{-1}) yields were recorded from 46 kg N ha^{-1} with Jeldu variety. The fatty acid composition of linseed oil had high level of unsaturated fatty acid such as linolenic (56.24%), oleic (19.43%) and linoleic (14.37%) fatty acids from 46 kg N ha^{-1}, while the saturated fatty acids like palmitiec (5.82 %) and stearic (4.89%) were also to the optimal range. Therefore, based on this study Jeldu variety with 46 kg N ha^{-1} gave high seed and oil yields, and oil quality, thus it can be recommended to the study area and other similar agro-ecology.

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RESEARCH PAPER

Factors Affecting the Choice of Rural Households' Livelihood Diversification: The Case of Sayo District, Kelem Wollega Zone, Oromia National Regional State, Ethiopia

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Abstract

The carrying capacity of agriculture to attain livelihood security is extremely declining from time to time. Diversifying livelihood strategies in the current time of rural households to sustain and secure their livelihoods as well as to supplement their agriculture have become a common phenomenon in the study area. Hence the study is to analyze factors affecting the choice of rural households' livelihood diversification in the district. The data were obtained from 202 sample household heads that were selected proportionally from three kebeles. The study used descriptive statistics and an econometrics model. Accordingly Multinomial logit model was employed in analyzing the factors affecting the choice of rural household's livelihood diversification strategies. The result indicates that among 16 hypothesized explanatory variables, 11 variables were found to affect the choice of rural household's livelihood diversification strategies. Accordingly, sex of household head, land holding size, input utilization and participation in social activity have positive and significantly effect on the rural household's livelihood diversification. Furthermore, family size, frequency of contact with agricultural extension agent, remittance received and agro ecology location have negative and significant effect on the rural household's livelihood diversification. However, livestock holding, irrigation facility and access to credit have positive effect across on the rural household's livelihood diversification. Therefore, the results of this study suggest that development interventions, policies makers and supportive services should be designed and strengthened to promote livelihood activities in addition to agriculture through awareness creation to improve the overall wellbeing of the rural societies in improving livestock holding, irrigation utilization and credit facilitation.

Keywords: Livelihood diversification, farm, non-farm, off-farm, Multinomial logit, Ethiopia

Introduction

Agriculture and non/off-farm livelihood diversifications are essential for reducing poverty in sub-Sahara African countries (Emanuel, 2011). However, livelihood diversification strategies are dynamic and sensitive to geographic, socioeconomic and institutional settings, and households with similar capital asset endowments may demand different technologies (Ellis and Allison, 2004, Arega *et* al. 2013). Agriculture alone may not be a long-term option due to factors such as small landholdings, drought, floods, crop loss, poor road status and gaps in market access (Yishak *et al.,* 2014).

For Ethiopia, undiversified livelihood options and complete dependency on agricultural production is the main problems that aggravate food insecurity in rural area (*FDRE,* 2002). According to Wondimagegnhua *et al.* (2016), Yona and Mathewos (2017), the limited opportunity for livelihood diversification, due to the absence of supplementary income from

other non-farm activities has made the Ethiopian rural poor more vulnerable. Similarly, Debele and Desta (2016) argue that the decline in the size of cultivable land (land scarcity) is imagined to further exacerbate the currently observed worse food insecurity situation unless non-farm activities are made to compensate for the livelihood stress prevalent in the rural areas.

The Ethiopian policy focus is on increasing agricultural productivity and farm income to achieve food self-sufficiency (Devereux *et al*., 2005, Beyene, 2008). However, livelihood diversification is playing an important role in rural households' income and food security. Research and extension activities have not been done adequately on the issues related to livelihood diversification, off and non-farm employment. Rural people have their own strategies to secure their livelihoods, which vary depending on socio-economic status, education and local knowledge, ethnicity, and stage in the household life cycle (*Gebru et al.,* 2012).

Like the national economy of Ethiopia, households in the study area are mainly dependent on small scale subsistence agriculture which is highly dependent on rain feed to derive their livelihoods. Nevertheless, the decline in carrying capacity of agriculture forces rural farm households to engage activities takes place outside the agricultural sector and aggregates a range of activities that span from regular salaried work to self-employed; agricultural activities which take place outside the person's own farm or sale of labor for agricultural activities; farm +off-farm + non-farm activities. In diverse off/non-farm livelihood activities and crop diversification to maintain and improve their wellbeing. Thus, understanding the driving factors of each livelihood strategy is crucial to improve the response mechanisms related to poverty, food security and livelihoods improvement in the study area. This study, therefore, aims to identify the existing livelihood strategies adopted by rural households; and to analyze factors that affect the choice of rural household's livelihood diversification in the study area.

Materials and methods

Description of Study Area

The study was conducted in Sayo district, which is located in Kelem Wollega Zone, Oromia National Regional State, Western Ethiopia. Sayo district is one of the Kelem Wollega Zone districts, which is located around the capital town Dembi Dollo.

Based on the 2019 Sayo district data, the total population of the district is 152,654 of whom 76,286 were males and 76,368 were females, and 5.45 % of its population was urban dwellers. The district has three agro-ecology zones; highland 16.2%, midland 78.8% and lowland 5% which has potential for crop, horticulture, coffee and livestock production, which is mainly undertaken by small holder farmers.

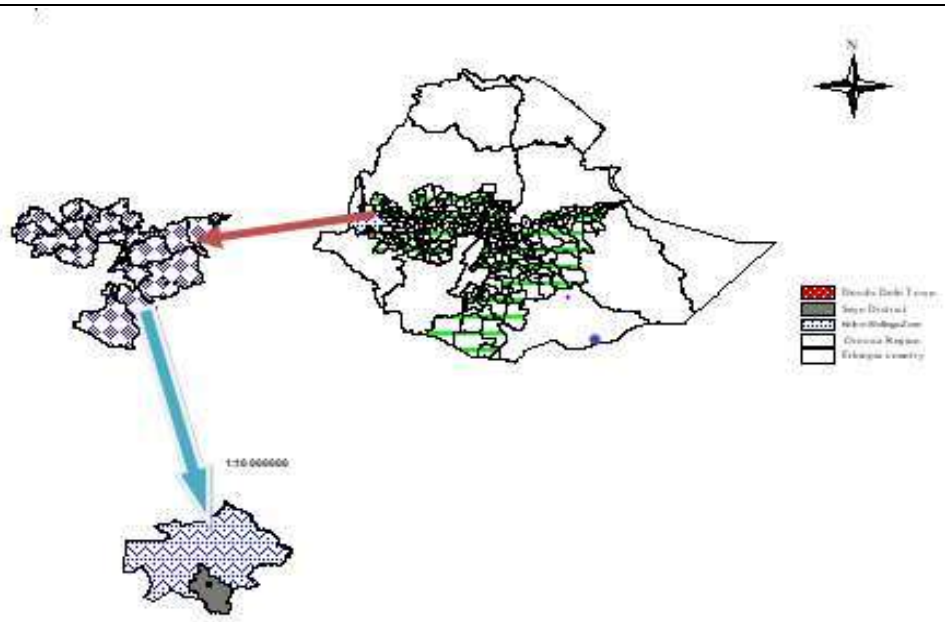

Figure 1. Map of the study area/ Sayo District (2019/2020)

Data Types and Sources

During the study, both quantitative and qualitative data were used to attain the stated objectives of the study. Sampled households, key informants and focus group discussion participants were the main sources of primary data. Secondary data like published and unpublished documents such as books, journals and also office records and reports of the district have been used in this study.

Sample Size and Sampling Methods

The study employed multi-stage random sampling techniques to select sample households. A proportionate to size technique was applied to determine households from each kebele. Accordingly, a total of 202 respondents were randomly selected from three *kebels* (Table 1).

The total sample size for this study was determined by using the formula of Yamane (1967). The formula is given by:

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

Where,

n= is sample size, N = population of the selected kebele's

e= designates maximum variability or margin of error. Therefore, using the above formula the total sample size is calculated as follows:

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

$$n = \frac{502}{1 + 502(0.05^2)} = 202$$

In general, using the above formula total sample size of the respondents' household heads from three *kebeles* 202 were selected at 95% confidence interval and level of precision equal to 5% are used to obtain a sample size required (Table 1).

Table 1. Sample households from each kebeles

Sample kebeles	Total Households	Sample households	Percent
Humbi Kero	191	76	38
Aleku Soti	179	73	36
Yangi	132	53	26
Total	502	202	100

Source: SWANRO, 2019/20 own processed

Data collection and analysis method

Primary data was collected by using qualitative and quantitative approaches. Survey data were collected through face-to-face interview using structured and scheduled that were filled up by recruited and trained enumerators under the close supervision of the researcher. The study employed descriptive and inferential statistics along with a Multinomial logit model to analyze the data. Descriptive statistics such as mean, percentage and frequency were used.

Econometric model specification

Following Green (2003), the multinomial logit model for a multiple choice problem is specified for dependent variables as follows; suppose for the i^{th} respondent faced with j choices, the study specifies the utility choice j as:

$$Uij = Zij\beta + \varepsilon ij \text{……………………. (2)}$$

If the respondent makes choice j in particular, then we assume that Uij is the maximum among the j utilities. So the statistical model is derived by the probability that choice j is made, which is:

$$Prob(Uij > Uik) for\ all\ other\ K \neq j \text{ … ……………………………(3)}$$

Where, Uij is the utility to the i^{th} respondent from livelihood strategy j and Uik is the utility to the i^{th} respondent from livelihood strategy k. Thus, the i^{th} household's decision can be modeled as maximizing the expected utility by choosing the j^{th} livelihood strategy among J discrete livelihood strategies, that is:

$$Maxj = E(Uij) = fj(xi) + \varepsilon ij, j = 0..J$$

In general, for an outcome variable with J categories, let the j^{th} livelihood strategy that the i^{th} household chooses to maximize its utility take the value 1 if the i^{th} household choose j^{th} livelihood strategy and 0 otherwise. The probability that a household with characteristics x chooses livelihood strategy j, Pij is modeled as:

$$Pij = \frac{\exp(X'i\beta j)}{\sum Jj{=}0 \exp(x'i\beta j), J{=}0} \text{…………..(4)}$$

With the requirement that $\sum_{j=0}^{J} \text{Pij} = 1 \text{ for any } i$

Where: *P*ij = probability representing the i^{th} respondent's chance of falling into category J; *X* = Predictors of response probabilities β*j*= Covariate effects specific to j^{th} response category with the first category as the reference. A convenient normalization that removes indeterminacy in the model is to assume that $\beta_1 = 0$ (this arise because probabilities sum to 1, so only j parameter vectors are needed to determine the j + 1 probabilities), (Greene, 2003) so that exp ($Xi'\beta_1$) = 1, implying that the generalized equation (4) above is equivalent to;

$$\Pr(yi = \frac{j}{Xi} = pij = \frac{\exp(X'i\beta j)}{1 + \sum Jj = 1 \exp(X'i\beta j)}\ for\ any\ j = 0,1 \ldots\ldots J\ and$$

$$\Pr(yi = \frac{1}{Xi} = pi1 = \frac{1}{1+\sum Jj{=}1\ exp(X'i\beta j)} \text{…(5)}$$

Where: y = A polynomous outcome variable with categories coded from 1… j. *Note*: The probability of *Pi1* is derived from the constraint that the j probabilities sum to 1. P_{i1}=1-Σ P_{ij}. Similar to binary logit model it implies that we can compute j log-odds ratios which are specified as;

$$\ln[\frac{pij}{pij} = x'(\beta j - \beta J) = x'\ \beta j, if, j = 0 \text{ ……………………………………. (6)}$$

Results and discussions

This chapter discusses and presents the analysis that has been conducted by descriptive statistics with the inferential statistics of testing the statistical significance of the variable and econometrics analysis to address the research objectives.

Descriptive Results

Livelihood strategies are ranges and combinations of activities and choices that people undertake in order to maintain their livelihoods or address existing challenges or vulnerability and to deal with positive and negative effects of policies, institutions and processes (Ellis and Allison, 2004). Accordingly, the most common livelihood strategies pursued by households in the study area were farming, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off-farm activities.

Out of the total sampled households, households engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off farm was 126 (62.4%), 42(20.8%), 20 (9.9%) and 14 (6.9%) respectively. Even if, agricultural sector is characterized by decreasing farm sizes due to population pressure, low levels of output per farm and a high degree of subsistence farming, a significant part of the sample respondents still engaged in farming activities. As observed from the survey result, about 62.4% of the total sample households depend solely on agriculture for their livelihood strategies and the remaining respondents combine agriculture with other activities like non-farm and off-farm (Table 2). Among the main reasons for their engagement in off and non-farm activities of the diversifiers were limited agricultural incomes, seasonal nature of agricultural produce and large family size.

Agricultural /on-farm activities

Agriculture is the sector given attention in policy documents and in practice on the ground as it is expected to be the source of primary surplus to fuel the economic growth. The livelihoods of the surveyed households were mainly dependent on agricultural activities (62.4%). Most of the households in study, kebeles practice mixed farming activities, involving both crop production and animal husbandry.

Different types of crops, commercial and horticultural crops are grown in the study areas. Key informants and focus groups stated that crop production was the major source of income (food and cash) for most households. In this regard, different types of crops (coffee, maize, sorghum, vegetables, faba beans, etc.) are grown in the areas.

Livestock are assets that households quickly change into cash when they need cash. Different kinds of livestock; Cow, Ox, sheep, goats, donkey, mule, and poultry are reared for both income and consumption purposes in the study area. According to the key informants of the study sites, livestock production was the second most important income source, next to crop production and serves as a draught power, transportation service, and provides meat, milk and milk products and manure.

Table 2. Choice of households' livelihood strategies

Choice of HH livelihood Strategies	Frequency	Percent (%)
Agriculture alone (Y1)	126	62.4
Agriculture + non-farm (Y2)	42	20.8
Agriculture + off-farm (Y3)	20	9.9
Agriculture + non-farm + off-farm (Y4)	14	6.9
Total	202	100.

Source: Survey result, 2019/20

The survey results revealed that the overall mean age of the sample households to be found was 47.91 years. The mean age of the households engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off-farm activities was 47.83, 49.23, 44.90 and 49.21, respectively. This indicates that households engaged in farm and non-farm activities were relatively older than the other categories. The probable justification for this is that as age increases farmers have more chances to have more children, which in turn helps to have available labor to engage in diverse activities. The statistical analysis revealed that there is a significant difference at less than 5%level significance in the mean age of sample household heads across livelihood diversification strategies (Table 3).

The survey results showed that households with an average year of high education level lead a better life by diversifying their livelihood. The mean years of schooling completed by household heads were 6.56. Similarly, the mean years of those engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, nonfarm and off-farm activities was 6.53, 6.04, 7.10 and 7.57 respectively Table 3. This is likely due to the possibility of acquiring salaried jobs and self-employment activities, and better educated households can calculate costs and benefits of income generating activities.

The survey results revealed that the overall mean family size was 5.84 persons per household, which is more than that of the national average, i.e., 5 persons per household (CSA, 2010). Similarly, the mean family size for the households engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off-farm activities was 5.75, 6.45, 5.25 and 5.85 respectively (Table 3).

Table 3 shows that the overall mean dependency ratio of economically inactive members of the household to active was 1.39. Similarly, the mean dependency ratio for the households engaged in farm only, farm and non-farm, farm and off farm and a combination of farm, non-farm and off-farm activities was 1.38, 1.48, 1.53 and 1.08 respectively. This briefly indicates that, one productive labor force of household members covers all the expenses of 1.39 unproductive members of the household. The survey results also show that the proportion of female headed households engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off-farm activities was 24 (19.1%), 16 (38.1%), 3 (15.0%) and 0(0.0%) respectively, whereas the proportion of male headed households engaged in farm only, farm and non-farm, farm and off-farm and a combination of-farm, non-farm and off-farm activities was 102 (80.9%), 26 (61.9%), 17 (85.0%) and 14 (100%), respectively. This indicates that in all livelihood diversification strategies the proportion of male headed households exceed that of female headed households. The possible reason is that households headed by female have more responsibilities in home management and are subject to discrimination in labor, credit and a variety of other markets and they own less property compared to men. The statistical analysis revealed that there is a

significant difference at less than 5% level of significance in the variable list of sample household heads across livelihood diversification strategies (Table 3).

The survey results showed that the overall mean land size owned by household heads was 2.36 hectares. Similarly, the mean land size of those engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off-farm activities was 2.48, 2.26, 2.11 and 1.98 hectares respectively. This result implies that farmers with large farm size are less likely to diversify their livelihood strategies into non-farm and/or off-farm than those farmers who have small land size (Table 3).

The main livestock types owned by households in the study area are oxen, cows, mule, donkeys, sheep, goats and poultry. The survey results showed that the mean number of total livestock owned by household heads was 5.37 TLU per household. The mean number of total livestock holding for household engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off-farm activities was 5.26, 6.62, 3.71 and 4.58 TLU per household respectively. This result suggests that a household having a larger size of livestock is more likely to diversify their livelihood into farm + non-farm activities than compared to those who own small number of TLUs. (Table 3).

Table 3. Descriptive statistic for continuous explanatory variables

Variable	**Households' diversification of livelihood strategies (Mean)**					**F value**
	Y1	Y2	Y3	Y4	Total	
Age of the household	47.83	49.23	44.90	49.21	47.91	4.28**
Education level	6.53	6.04	7.10	7.57	6.56	7.04***
Family size	5.75	6.45	5.25	5.85	5.84	9.01***
Dependence Ratio	1.38	1.48	1.53	1.08	1.39	10.332***
Land size	2.48	2.26	2.11	1.98	2.36	7.58***
Livestock ownership	5.26	6,62	3.71	4.58	5.37	12.31***
Extension contacts	2.42	2.52	2.15	2.64	2.43	3.90**
Market distance	4.34	4.64	4.50	4.35	4.42	2.93*

Source: Survey result, 2019/2020. ***, ** and *stands for statistical significance at less than 1%, 5% and 10% probability level, respectively

Socio-economic characteristics of the sample households

The survey result shows that the proportion of households that participated in social activities were 80(39.6%) while 122(60.4%), did not participate in social activities. Results further showed that households engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off-farm activities were 49(38.9%), 16 (38.1%), 4(20.0%) and 11 (78.6%) participated in social activities while 77 (61.1%), 26 (61.9%), 16(80.0%) and 3 (21.4%), did not participate in social activities respectively (Table 4). The survey results also showed that the proportion of households that received remittances from foreign/urban relatives was 60 (29.7%) while 142 (70.3%), did not receive remittances. Results further showed that households engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off-farm activities was 24 (19.1%), 26 (61.9%), 5(25%) and 5(35.7%) received remittances while 102 (80.9%), 16 (38.1%), 15

(75.0%) and 9 (64.3%), did not receive remittances respectively (Table 4).

The analysis result showed that the overall mean of total contacts the farmers made with extension agents was 2.43 within a year. Similarly, the mean contact of households engaged in farm only, farm + non-farm, farm + off-farm and a combination of farm + non-farm + off farm activities was 2.42, 2.52, 2.15 and 2.64 within a year respectively. The objective of agricultural extension is to change farmers' outlook towards their difficulties which assists them to adapt better solutions to their livelihoods (Samuel, 2003). The statistical analysis revealed that there is a significant difference at less than 5% level of significance across livelihood diversification strategies of sample household (Table 4).

As Table 4 indicates the mean distance of the household residence to the nearest market center was found to be 4.42 km. Similarly, the mean distance of the household residence from the nearest market center for households engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, nonfarm and off farm activities was 4.34, 4.64, 4.50, and 4.35 kilometers respectively. The survey results showed that the proportion of households' participation to cooperatives membership was 140(69.3%) while 62(30.7%) did not participate in cooperative membership.

The survey results showed that the proportion of households used different improved agricultural inputs (improved seed and commercial fertilizers), pest sides and herbicides was 143 (70.8%) while 59 (29.2%), did not use them. Results further showed that households engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off-farm activities was 97(76.9%), 29(69.1%), 8(40%) and 10(71.4%) used different agricultural technologies while 29 (23.1%), 13 (30.9%), 12(60.0%) and 4 (28.6%), did not used agricultural technologies respectively. This implies that those farmers who have used different agricultural technologies are more likely to diversify their livelihood into a non-farm and a combination of farm, non-farm and off-farm activities than their counterparts (Table 4).

Table 4 results showed that 57 (28.2%) of the sample households reported that they were irrigation users while 145 (71.8%) of them were non- users. Results further showed that households engaged in the farm only, farm + non-farm, farm + off-farm and a combination of farm + non-farm + off-farm activities was 27 (21.4%), 27(64..3%) 4 (20.0%), and 0 (0.0%) were irrigation users while 99 (78.6%), 15 (35.7%), 16 (80.0% and 14 (100.%) were non-users of irrigation respectively. The chi-square analysis result shows that there is a statistically significant difference at less than 5% level of significance in irrigation users and non-users' household heads across livelihood diversification strategies (Table 4). The result is in line with the findings of Dilruba and Roy (2012).

The study result showed that 53(26.2%) of the sample households received credit while 149(73.8%) of them did not receive any credit. Results further showed that households engaged in the farm only, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off-farm activities 30(23.9%), 10 (23.8%), 3 (15.0%) and 10 (28.6%) were received credit while 149(76.1%), 32(76.2%), 17 (85.0%) and 4 (71.4%), did not receive any credit respectively. The survey results suggested that those farmers who have received credit are more likely to diversify their livelihood into the combination of farm + non-farm + off-farm activities than those farmers who did not receive any credit (Table 4).

The study result showed that 76(37.6%) of the sample households live in midland area while 126 (62.4%) of them live in highland area. Results further showed that households engaged in farm only, farm and non-farm, farm and off-farm and a combination of farm, non-farm and off-farm activities 52(41.3%), 11(26.2%), 8(40.0 %) and 10(71.4%) live in midland area while 74(58.7%), 31(73.8%), 12(60.0%) and 4(28.6%) live in highland area respectively.

The result shows that Highland farmers are more likely to diversify their livelihood into farm and non-farm activities due to land quality, rainfall distribution, and soil quality. This leads to increased access to food and income, promoting demand push for farm and non-farm livelihood strategies. However, no significant difference in agro-ecological location was found across livelihood diversification strategies (Table 4).

Table 4. Descriptive statistic for discrete explanatory variables

Variable	Response	Households' diversification of livelihood strategies					χ^2-value	Sig.
		Y1	Y2	Y3	Y4	Total		
Sex of the house holds	Male	80.9	61.9	85.0	100.0	79.20	5.780**	0.016
	Female	19.1	38.1	15.0	0.0	20.80		
Participation in social activities	Yes	38.9.	38.1	20.0	78.6	39.6	1.063	0.302
	No	61.1	61.9	80.0	21.4	60.4		
Cooperative membership	Yes	65.9	80.9	75.0	64.3	69.8	1.883	0.170
	No	34.1	19.1	25.0	35.7	30.2		
Receiving remittance	Yes	19.1	61.9	25.0	35.7	29.7	5.592**	0.018
	No	80.9	38.1	75.0	64.3	70.3		
Improved inputs use	Yes	76.9	69.1	40.0	71.4	70.8		
	No	23.1	30.9	60.0	28.6	29.2	2.204	0.138
Irrigation utilization	Yes	21.4	64.3	20.0	0.0	28.2		
	No	78.6	35.7	80.0	100	71.8	6.030**	0.015
Credit utilization	Yes	23.9	23.8	15.0	28.6	26.2		
	No	76.1	76.2	85.0	71.4	73.8	1.218	0.270
Agro ecology	Midland	41.3	26.2	40.0	71.4	37.6	0.642	0.423
	Highland	58.7	73.8	60.0	28.6	62.4		

Source: Survey result, 2019/20. ***, ** and * stands for statistical significance at less than 1%, 5% and 10% probability level, respectively.

Econometric Model Results

Multinomial logit model regression shows the effect of hypothesized explanatory variables on farmer's choice of livelihood diversification strategies. The dependent variable is the category of farmers' selection of diversified livelihood strategies, taking a value of 1 if a farm household is pursuing agriculture only (Y1=126), a value of 2 if selecting farming plus non farming (Y2=42), a value of 3 if adopting farm with off-farm activities (Y3=20) and a value of 4 if choice is farm plus non-farm and off-farm (Y4= 14). Accordingly, the base category is the household who choose farm only as a livelihood strategy. This strategy is used as a reference category.

The multinomial logit model analysis shows that out of the total sixteen explanatory variables entered into the model eleven variables including sex of households, family size of the household, land holding size (ha), livestock ownership (TLU), frequency of agricultural extension contact, access to irrigation facility, improved agricultural input utilization, access to credit facility, receiving remittances, participation in social activities and Agro ecology were found to be the significant variables of livelihood diversification strategies up to less than 10% level of significance (Table 5). However, the magnitude effect of some significant variables is not similar for the three livelihood strategies. Some may be highly significant to affect the choice of a strategy and may be insignificant for the other. Therefore, multinomial logit analysis results indicate selection of each type of livelihood strategy is affected by different factors and at different levels of significance by the same factor. The possible implication and marginal effects for the significant explanatory variables on the choice of household's livelihood diversification strategies are presented as follows:

In this study, the sex of the households had positively and significantly affected the probability of diversifying the livelihood into the combination of farm + non-farm + off-farm activities at less than 10% probability level. The positive result implies that the households headed by females are more likely to participate in combination of farm + non-farm + off-farm livelihood activities than male headed households. By keeping other factors constant, the likelihood of female headed households to diversifying into the combination of farm + non-farm + off-farm livelihood strategy is more by a factor of 47.1% relative to the base case (Table 5). This implies that, if the households are members or beneficiaries of some developmental programs or projects then they are more likely to be diversified in their livelihoods by more accessing to information, awareness, financial support and scope to intensify their income sources. In the study area, there are developmental programs or projects such as the Agricultural growth program (AGP), Sustainable land use management (SLM), and Catholic micro finance project having an intervention specifically targeting women farmers with tailor made innovations, activities, technical assistance, support business plan preparation and implementation, provision of equipment and inputs to qualifying groups. The result of this finding is in line with the finding of Adugna and Wegayehu (2012).

Family Size of a household is an important variable that impacts livelihood diversification. The result revealed that family size was found to have a negative and significant relation to the diversification of livelihood strategies with farm + non-farm at less than 10% probability level. The marginal effect depicted that, if other factors held constant, the probability of the households to diversify into farm + non-farm activities is decreased by 3.8% as household size increases by one relative to the base agriculture only (Table 5). The underlined point here is that a large household size does not mean all the household members are productive labor force. In fact, those family children may be in school and under productive age. So, the maximum labor force of the family can operate on the existing farm and unable to diversify into other activities and for the newborn child to need care due to this even if the family member was there in diversified livelihood activity may stop it and back to childcare. By gradually expecting that, they diversify their livelihood activities as their labor force increases. The result of this finding is in line with the findings of Gebru *et al.* (2012) and Beyene (2008).

On the other hand, it also negatively and significantly affected the livelihood diversification into farm + non-farm activities at less than 1% probability level. The marginal effect revealed that, if other factors remain constant, the livelihood of rural households to choose farm + non-farm livelihood diversification strategies decrease by a factor of %3.2 as the livestock holding increases by one TLU. This means rural households having large size livestock are less likely to diversify into farm + non-farm livelihood activities compared to other counterparts. The possible reason for this could be attributed to the fact that

households with more TLU have a better chance to earn more income from livestock which enables them to fulfill their livelihood requirements. Consequently, farm households can get the required income from livestock but may not engage in other income generating activities. Conversely, households with a smaller number of livestock endeavor to diversify their income sources by participating in a range of livelihood activities. This is because a small number of livestock holds does not enable them to generate enough income to support family needs which causes them to participate in other alternative livelihood options. (Abera *et al*. 2021).

Table 6 identified that access to extension services plays a central role in improving and attaining the goal of increasing the production and productivity of agriculture. Contrary to prior expectations, the study showed that the frequency of extension contact has a negative and significantly influenced diversified livelihood strategy into a combination of farm + non-farm + off-farm activities at less than 1% probability level. Extension workers' contact with farmers is focused on increasing production and productivity but does not focus on entrepreneurial skills and entry points for non-farm and/or off-farm business activities (Gebru, *et al.,* 2012).

As Table 6 shows, irrigation utilization had positively and significantly influenced the household choices combination of farm + non-farm + off-farm activities at less than 5% probability level. From the model result, other things being constant, the marginal effect reveals that the probability of a household diversifying into a combination of farm + non-farm + off-farm activities increase by 50.8 % for those households who are participating in irrigation utilization activities. The results suggest that those farmers who have used irrigation are more likely to diversify their livelihood activities than their counterparts. A possible justification is that irrigation, whether it is modern or traditional, has a great contribution to increasing production and productivity and enhances the income of the household. Moreover, irrigation opportunities make multiple cropping possible which would create agricultural surplus and improve the income of the households. The result is in line with the findings of Dilruba and Roy (2012) and Mideksa (2019).

On the other hand, this study showed irrigation utilization negatively and significantly influences the household choice of farm + non–farm activities at less than 1% probability level. The model result showed that keeping other factors constant; as irrigation utilization increases by one the farmers dislike diversifying their livelihood into farm +non-farm activities by factor of 25.9%. The possible reason for this could be irrigation is the most interesting income generating and producing throughout the year. Then farmers who are utilizing irrigation as well could earn more income from irrigation which enables them to fulfill their livelihood requirements.

The result showed, input use has been found to influence households' participation positively and significantly in farm + non-farm and farm + off-farm livelihood diversification strategies at less than 1% and 5% probability levels respectively. The model indicates keeping another factor constant, as utilization of agriculture inputs increases with the recommended way the livelihood into farm + non-farm and farm + off-farm livelihood diversification strategy also increases by factor of 13.2 and 12.2, respectively (Table 6). The possible justification is access to agricultural inputs and its recommended application practices are an indispensable part of improving agricultural production and productivity which enhance household income and enable them to participate in diversified livelihood activities. It is obvious that there is no good agricultural production without applying recommended agronomic practices with improved agricultural inputs and no food security without improving agricultural production and productivity in the study district. The result of this study is in line with the findings of Gebru *et al*. (2012).

Capital is the major ingredient in starting up or running any business activity and credit will enhance income generating activities. In this study, credit use is found to have a positive

impact and significant influence for farm + non-farm and farm + off-farm activities at less than %10 probability level and also it has a negative impact and significantly influences the combination of farm+ non-farm + off-farm activities at less than %1 probability level. Credit has a positive impact and significantly influences the diversification of farm + non-farm and farm + off-farm activities at less than 10% probability level. Hence, providing credit for poor farmers will enhance livelihood diversification (Debele and Desta, 2016). Keeping other factors constant, the marginal effect showed, smallholder farmers choosing farm + non-farm and farm + off-farm livelihood diversification strategies increased by a factor of 8.8% and 7.6% respectively as access to credit increased (Table 6). In fact, formal savings and credit institutions are available in the study area and farmer households use credit for the purpose of reducing the problem of working capital, purchase of farm inputs and farm oxen; and to cover social obligatory expenditures. However, most of the smallholder farmers were not users of credit due to high interest rates (18%), fear of the ability to repay, lack of collateral and lack of enough entrepreneurial skills training. The result agrees with the findings of Wondim (2019).

On the other hand, it has a negative impact on livelihood diversification into the combination of farm+ on-farm + off-farm activities. Since credit use allows farmers to follow agricultural intensification (only farming activities) by accessing farm inputs which in turn improves their production and productivity rather than diversifying their livelihoods. The formal and informal credit facilities that avail for rural farmers are a very important asset in rural livelihoods not only to finance agricultural inputs activities, but also to protect against loss of crucial livelihood assets such as cattle due to seasonal food shortage, illness or death. From the model result, the marginal effect reveals that the likelihood of participating in a combination of farm + non-farm + off-farm activities in the household drops by 15.8% for a household using credit (Table 6).

Even though receiving remittance constitutes a small part of total households' income, it is expected to have a positive contribution to the diversification of livelihood strategies (Brown *et* al., 2006). Contrary to the expectation, the model result showed, remittance had a negative and significant impact on farm + non- farm livelihood activities at less than 1% probability level. This may imply that those farmers who received remittances from foreign/urban areas may consume directly what they had gotten, which they do not use for other additional income generating activities. The remittance gained may be too small and insignificant to start non-farming activities in the study area and due to this the negativities relationship happened (Table 6). The result is inconsistent with the findings of Adugna and Wagayehu (2012).

As hypothesized, participation in social activities had positively and significantly influenced the household choices of farm + off-farm activities at less than 5% probability level. The results of this study suggest that those farmers who have participated in social activities are more likely to diversify their livelihood than their counterparts. The possible reason may be farmers' participation in social activities can help to have more access to information, share more experiences with others in a social environment, and creating more social networks with different institutions. From the model result, other things being constant, the marginal effect reveals that the probability of household who are participating in social activity diversifying their livelihoods was increased by 10% in farm + off-farm activities, (Table 6). This result is in agreement with previous studies conducted by Dilruba and Roy (2012).

In line with prior expectations, agro-ecology had negatively and significantly influenced the household choices of farm and off-farm activities at less than 10% probability level. This result demonstrates that the incidence/magnitude of diversifying the livelihood into farming with farm + off-farming increases as we go from highland to midland. A possible reason might be due to differences in the quality and size of land, the amount and

distribution of rainfall that influence highlands and midlands. Diversity in land quality, distribution of rainfall, and ability to grow diverse food crops are different within the agro ecological zones. In the highlands the distribution and amount of rainfall are better as compared to the midlands. From the model result, the marginal effect reveals that the probability of a household diversifying into agriculture + off-farm drops by 8.1% for highland households (Table 6). The result is in line with that of Adugna and Wegayehu, (2012).

Table 2. Multinomial logit model results of households' choice of livelihood diversification

	Household livelihood diversification strategies								
	Y2			Y3			Y4		
Variables	Coef.	Marginal effect	P-value	Coef.	Marginal effect	P-value	Coef.	Marginal effect	P-value
SEX	-0.871	-0.073	0.164	-0.370	-0.025	0.978	20.130	0.471	0.077*
AGE	-0.057	-0.004	0.123	0.038	0.002	0.648	-0.039	-0.000	0.676
EDULHH	0.069	0.005	0.987	-0.129	-0.009	0.474	-0.084	-0.001	0.364
FAMSHH	-0.448	-0.038	0.055*	0.097	0.006	0.719	-0.928	-0.021	0.173
DEPR	0.106	0. 009	0.781	-0.266	-0.018	0.726	1.097	0.025	0.107
LANDSIZ	1.017	0.086	0.005***	0.408	0.028	0.397	0.224	0.005	0.241
TLU	-0.385	-0.032	0.002***	0.408	0.028	0.077*	0.967	0.022	0.008***
AETCON	0.760	0.064	0.375	0.081	0.005	0.476	-4.225	-0.099	0.002***
MKTDIS	-0.320	-0.027	0.277	-0.182	-0.012	0.586	-0.726	-0.017	0.436
IRGU	-3.059	-0.259	0.000***	1.079	0.075	0.276	21.710	0.508	0.018**
IMPRINPU	1.055	0.132	0.044**	1.753	0.122	0.006***	-1.568	-0.036	0.765
CREDITU	1.046	0.088	0.054*	1.090	0.076	0.080*	-6.751	-0.158	0.000***
REMMIT	-1.821	-0.155	0.000***	0.050	0.003	0.782	-1.177	-0.027	0.127
COOPER	-0.929	-0.078	0.120	-0.793	-0.055	0.363	-0.313	-0.007	0.471
PISA	-0.878	-0.074	0.176	1.446	0.100	0.021**	-3.009	-0.070	0.005
AGROECO	-0.644	-0.054	0.610	-1.166	-0.081	0.094*	1.254	0.029	0.699
_CONS	7.964		0.076	-1.540		0.114	22.754		0.163

Source: computed from own survey data, 2022. ***, ** and * stands for statistical significance at less than 1%, 5% and 10% probability level, respectively. Standard errors and z-ratio are not reported here because of space constraints. Number of observations = 202

Log likelihood = -56.479472 LR chi2 (16) = 93.56

Prob>chi2= 0.0000 Pseudo R2 = 0.4530

Summary and Conclusion

The study examined rural households' livelihood strategies in Sayo district, Ethiopia, focusing on socioeconomic status, education, ethnicity, and life cycle stages. Results showed agriculture as the dominant economic activity, with 62.4% of households relying solely on agriculture. 37.6% engage in diverse non-farm and off-farm activities for survival and livelihood improvement.

The research reveals that the agricultural sector alone cannot be the sole source of livelihood for rural households generally in Ethiopia particularly in the study area. Lifestyle diversification is crucial for income and food security. Rural households practice diversified livelihood strategies in addition to agriculture, making it essential to design sustainable interventions that enhance non-farm and off-farm activities. Rural development strategies should focus on increasing agricultural production and productivity while promoting these activities in rural areas.

The study found that sex and family size significantly impact rural households' livelihood diversification choices. To encourage gender equality and reduce fertility, the government should encourage developmental interventions targeting rural women. Family size also affects livelihood diversification, with larger farmland providing better opportunities for non-farm activities. Government support should be provided to help rural households achieve food self-sufficiency and eradicate poverty.

The most important details are that livestock production and productivity is important for rural households' livelihood diversification strategies, and that government should strengthen the agricultural extension system and improve the knowledge gap of the development agent. Irrigation utilization is also important for enhancing rural livelihood diversification strategies and improving rural households' livelihood. Government should supply agricultural inputs to increase production and productivity, while credit use should be increased to protect livelihood assets. Remittance should be advised to start other income generating activities for well-being and capital accumulation. Participation in social activities had positively and significantly influenced the choice of rural households' livelihood diversification. Thus, the service providers of the area should share the experiences of those model farmers, who participate in social activities to other farmers as to get the information which help them in their livelihood diversification. Agro-ecological location was found to be negative and significantly influence the choice of rural households' livelihood diversification strategies. Thus, context specific based on their agro ecology intervention and technologies which can improve the livelihood has to be designed.

In the future, studies on factors affecting the choice of rural households' livelihood diversification strategy should be important to improve alternative sources of livelihoods and employment for the rural poor and provide clues to promote the rural economy. The choice of rural households' livelihood diversification strategies is dynamic and sensitive to geographic, socioeconomic and institutional settings which need area specific investigation to improve the rural household's livelihood problem.

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RESEARCH PAPER

Ecological Impacts of Imperialism in Kimani's *Dance of the Jakaranda*: A Critical Analysis

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Abstract

The study examined the ecological impacts of colonization in Peter Kimani's Dance of the Jakaranda. The scope of the study included the analysis of colonial strategies used by British colonizers in East Africa, the plunder of resources, and the resulting environmental consequences as depicted in the novel. Textual analysis was employed as a method of study. The novel was selected using a purposive sampling method for its strong environmental and ecological concerns. The data were collected through close reading of the novel. Excerpts were gathered and categorized according to postcolonial thematic categories with direct connections to the environment and ecology, and the analysis was conducted using tenets of ecological imperialism. The result of the analysis shows that the novel depicts colonial plunder of resources as an archetypal issue, illustrating that the colonizers' subjugation of the indigenous peoples of East Africa was exclusively to satisfy materialistic desires. The plunder involves both human and nonhuman entities. This is followed by the catastrophic environmental repercussions of colonial rulers' violent colonial strategies, or ecological imperialism, which include the use of disease, deforestation, conservation, and ecological degradation caused by military aggression and fire. The text depicts a complete environmental transformation as a result of the sequential exertion of colonial instruments, colonial exploitation, and resource transfer. Colonialism causes the nation's birth in East Africa, evolves into neocolonialism eventually, and continues to impact this new nation and its ecosystem, either directly or indirectly.

Keywords: Ecological imperialism, colonialism, environmental impacts, Peter Kimani, Dance of the Jakaranda

Introduction

Ecological imperialism as a theoretical concept is coined from two words: ecology (adj., ecological) and imperialism. The term ecology is derived from Ancient Greek (oîkos) to mean "house", and (-logia) to mean "study". It is defined as the scientific study of the relationships between the living organisms, including humans, in the house (the environment) and the house itself (Real & Brown, 1991, p. 1-2). The word "imperialism", on the other hand, is derived from the Latin word "imperium", which means ultimate power, "sovereignty", or "rule" (Etymonline, 2020). It is the strategy of expanding a state's control and influence through colonization, the use of military force, or other means. Thus, the term "ecological imperialism" refers to a system of political, economic, and cultural oppression as well as coercion and violence of the environment and its inhabitants.

The theory of ecological imperialism, first put forth by Alfred Crosby, holds that the reason why European settlers were successful in

colonizing other areas was due to their unintentional or intentional introduction of animals, plants, and diseases that caused significant changes in the ecology of the colonized regions and population collapses among the endemic peoples (Mayor, 1995). Ecological imperialism as a process can be seen as a byproduct of capitalism's globalization. It contends that colonization was not only a kind of cultural and political oppression, but also a sort of environmental violence.

Ecological imperialism can be viewed as a legacy of the globalization of capitalism, where the exploitation of natural resources in colonized territories was used to fuel the growth of capitalist economies. The impact of ecological imperialism can still be seen in postcolonial societies, where environmental degradation and resource depletion continue to affect the trajectory of development.

Ecological imperialism is often seen as a form of environmental terrorism, as it can have devastating effects on local ecosystems and the people who depend on them. The concept of ecological imperialism has been explored in various academic fields, including history, ecology, and literature. In literature, authors use their works to shed light on the environmental and social consequences of ecological imperialism and to critique the power dynamics that perpetuate it. For example, in Yvonne Owuor's Dust and Ngũgĩ wa Thiong'o's Petals of Blood, the authors use their characters and settings to illustrate how ecological imperialism is intertwined with political power dynamics and social inequality. The post/neo-colonial nation-state perpetuates this legacy by continuing to prioritize economic development over environmental conservation, leading to devastating consequences for local ecosystems and communities (Anthonia, 2023, p. 2-3).

Ecological imperialism is better understood if it is articulated in terms of the contact between native and non-native nations in the colonial zone. The non-natives who are commonly known as settlers come to the territory of indigenous peoples not as fugitives, or exiles, or guests, but as masters or rulers to occupy large and fertile land. They bring their socio-political and cultural ideologies, technologies, and animals and plants, and they also come with microorganisms that are not visible to the naked eye (Crosby, 1986). They used military force to evict the natives from the land. They intentionally or unintentionally destroyed the natural ecology and culture of the native land during the contact process. They settled among the natives, pushing them to the periphery and enslaving them on the ancestral homestead. They also established a center that serves as a dominant culture among the natives. This center eroded the nation's culture and natural resources.

Besides, they controlled all trade routes and took part in using all possible means to take wealth to their mother country. They imposed self-serving laws to control natives and show the politics of ownership. In this way, they had colonial empires which had the goal to increase their wealth through trade and resource extraction. This was accomplished through the growth of cash crops and the exploitation of natural resources. These were frequently done with grudging concern, worse, with little regard for the local ecology (Fairhead & Leach, 2000).

The dichotomy of mind and matter gave the Europeans the power to advance science, which unintentionally facilitated the process of colonization itself. Carolyn Merchant refers to this approach to "mechanistic science" as "egocentric ethics," and she claims that this opens the door to the operation of utmost dominion over nature by a superior human agency (1992, p. 66). She claims that mechanical philosophers and scientists proposed a world of spirit separate from the world of matter. A separate human mind functioning in accordance with reasonable laws might describe, fix, and control nature, the human body, and animals, like individual components of a machine.

European anti-ecological thinking is attributed to theories by Francis Bacon, René Descartes, and Isaac Newton, who led the Scientific Revolution. Descartes, the main proponent of this theory, saw nature as a machine and believed humans would become masters and possessors of it. He reduced animals to robots,

analyzing their physical and chemical components for mankind's benefit. Descartes argued that animals had no mental faculties, making them bodies or machines, and therefore, incapable of feeling pain (Sessions, 1995).

In this view, nature is treated as a subordinate, inanimate resource that can be exploited by rational beings for their own material benefit. The assumption is that natural organisms are machines that obey "universal mathematical laws," in contrast. Descartes' mechanistic perspective receives the scientific legitimacy it deserves from the Newtonian mechanical model of the cosmos, which is based on reason and experiment and is articulated by the ostensibly distinct and unambiguous mathematical laws. The basic concepts of classical science are thus represented by the Cartesian-Newtonian paradigm.

Francis Bacon, nevertheless, was the first to make the connection between scientific knowledge and imperialism, highlighting the necessity of the coexistence of scientific knowledge and imperial power in order for the colonial ideologies that underlie ecological imperialism to be successfully established. Bacon's work thus served as a framework for applying scientific theories that eventually led to Newtonian mechanics. It had a noticeable impact on the advancement of western anthropocentric ideologies, which viewed humans as imperialist agents and nature as a pure commodity. Thus, Bacon's program to establish man's superiority over nature was very useful in enabling the imperialist policies of environmental conquest in the colonized lands.

Ecological imperialism and mechanistic science emptied nature of its intrinsic value and turned it into a wholesale commodity. The impact of enforced land conversion to production value, or for capital resource, regardless of its suitability to the local ecosystems, in the indigenous environments, for instance, resulted in such damage that it included not only the non-human resources but also the indigenous peoples themselves.

The study is thus aimed at critically reading, analyzing, and interpreting Peter Kimani's novel for its representation of the ecological impacts of colonization, with the specific intention of investigating the disastrous ecological repercussions of imperialism.

. Materials and methods

Methods

This study uses textual analysis to examine how characters make sense of the physical world in narratives. It focuses on setting and scenery events, observations, and experiences of characters, as they are the writer's articulations of what is happening in the ecological setting. The study explores the behaviors, interactions, interconnections, and feelings of characters, as well as environmental tropes and ecological landscape crises used in natural ecology. The textual analysis follows the post-structuralist perspective, asserting the multiplicity of readings, and considers a range of textual features in the analysis.

Criteria for Text Selection

The study employed a purposive sampling technique to select the novel for analysis based on its relevance to the study's research objectives. It was used to investigate how Peter Kimani depicts the ecological impacts of colonization in his narrative as an African literary writer. This novel was selected for its strong environmental and ecological concerns. The selection criteria for the novel took into account what Buell refers to as "environmentally oriented" literary texts as well as "those" that do not appear to be so (1995, p. 195). The selection method was based on searching for thematic concerns that are relevant to the study rather than simply taking samples from geographical variants.

Data Analysis Procedures

This research employed close reading, interpretation, and in-depth analysis of the primary source to identify areas for further investigation and evaluation. Data analysis was

used to organize and cross-examine excerpts collected from the novel, allowing for pattern identification, theme discovery, relationships, explanations, interpretations, and pattern findings. Textual analysis was used to analyze the novel, with ecological and colonial thematic categories connected to the environment and ecology. Then the analysis was conducted using the tenets of ecological imperialism, which examined the representation of ecology, human-nonhuman connections, and the ramifications of (neo)colonization.

Results and Discussion

Peter Kimani's historical novel, Dance of the Jakaranda, can be critiqued as a tale of environmental horrors caused by colonization. His novel shows how imperialist control is promoted by taking advantage of natives' ecological vulnerabilities. Kimani condemns the use of military violence, disease, deforestation, and torture by imperialists to establish their colonial enterprise. He also condemns colonial conservationist activity and its effects on animals and gaming in East Africa.

Ecological Destruction through Military Violence and Fire

Military aggression and fire are often used as strategies of ecological imperialism, leading to environmental degradation and deforestation (Hussain, 2019). The British colonial power, as depicted in Dance of the Jakaranda, used military violence to expand into East Africa, affecting both human and nonhuman individuals. Kimani's novel reveals that the colonization of Kenya was not based on treaties between the British government and native village councils, as documented in colonial documents. The British colonial administrators destroyed the environment and natural ecosystems through military power, resulting in the complete annihilation of both humans and nonhumans in one village. The novel highlights the devastating effects of military violence on both humans and nonhumans.

The very purpose of the British colonialism in Kenya is expressed in the words of the British East Africa Protectorate commissioner on the day of the inauguration of the railway construction as being commerce, civilization, and Christianity. Commerce is understood in the sense of taking part in the competition with European powers for the exploitation of East African natural resources and wage labor. This precious and sacred purpose, as the colonizers think, becomes successful by battling the grassroot resistance from the natives using military technologies that the natives are not capable of using.

McDonald, the colonial administrator, faces stiff challenges as a result of the natives' opposition to colonialism in general and the construction of a railway in their territory in particular. Consequently, he instructs his policemen to encircle the kaya, the place which is considered sacred and "the hallowed seat of god" (p. 95). Kimani describes kaya as that the natives "have mortal fear of the place and the elders." The people feed the trees with honey and meat, which grows the trees to "gigantic scales that several men cannot hold the girth of one such tree" (p. 95).

The colonial authorities prioritize capturing the kaya, the central and unifying place for the natives, as it is the epicenter of resistance. Without the kaya, fathers are powerless to influence their offspring's affairs, and elders' influence dwindles. Captain John Adams emphasizes this in his letter to McDonald. McDonald orders the clan head to provide 500 men for the construction of a railway as a pretext for theft of materials and detention of two engineers. When the clan head challenges him, McDonald instructs the chief to work on the rails as punishment for attacks on his caravans and kidnappings. The inhabitants of the nine villages of Griama drumbeat, mourn, and show hesitation as the code to summon the community to a meeting in the kaya the following day.

At the meeting, the nine elders' leader describes the perilous situation that threatens their collective future, eloquently stating that McDonald had imposed a fine on the natives to be paid—"not in terms of money, not in terms of grains, not in terms of animals, but in terms

of humans" (p. 112). To incite more rage among the people, the chief elder recalls the prophecy, saying, "This thing that the white man is building on our land is the snake that Me Katilili warned about. And for an appetizer, he is asking for five hundred men to push into the belly of the beast..." (p. 112). The head of the elders is describing the nature of the colonizers as materialists. This is part of the mission of the colonizers as they diminish the value of humans and nonhumans into commodities. The colonizers come to the villages with the intention of integrating both human and nonhuman resources in order to satisfy their materialistic desires through the exploitation of ecosystems, which is expressed in capitalism.

Following the speech, more ferocious eruptions break out. The women dance around cursing the white man, their genitalia on display and their loincloths ripped off. The boys draw their swords from their sheaths and show how they kill the white man. Elderly men openly cry as a result of an unjust intrusion into their way of life. They end the meeting by taking the oath to defend their hallowed land to the "last man, to the last woman, to the last child," and to their "last breath."

McDonald sends 40 policemen to swoop into three villages and arrest all the men after hearing about the meeting's reports. However, women and children are found during the search because all of the elderly and young men from the three villages have already left for the forest. Then, among the policemen, as one of them tries to pull at the breast of a young woman, and the woman screams her protest and shakes off his hand, the pan tosses oil on the open flame, and a new blaze leaps into the air and burns down huts. Since there are no men to contain the fire, it spreads quickly, razing an entire village.

The colonizers are unethical in their approach towards both the humans and the nonhumans because they have got inverted image of the natives and their environment in their discourse, and this brings a total environmental damage. As Joseph Conrad's narration depicts, Africa is a dark continent where uncivilized and pagan people live. McDonald and his policemen have similar attitude towards the Africans and their natural environment. Consequently, they do not sympathize with the natives and their overall environment.

It is clearly understandable that the destruction caused by the fire is extremely horrific; not only the huts and possessions within the huts are burned down, but as Kimani puts it, "the entire village is razed by the fire." In rural villages in Africa, huts are not normally interconnected in their structural construction. Since each household in the village has its own plot of land and hut, they are simply scattered in different locations in the form of dots. Therefore, in order for the fire to jump from hut to hut, it must first burn the ground in between them, along with any nearby forest and living things. The number of microbial and tree species that are wiped out in the village is unimaginable. The entire habitat, including their homes, is destroyed by the fire caused by the policeman's uncaring gratification.

The kaya remains the epicenter of the local uprising. McDonald struggles with his next move. He has tried and failed to appoint local elders as chiefs in order for his colonial strategies to succeed. He has also taken rams, as he was ordered to do by the elders to appease the rage of their gods for stepping into kaya without permission. He eventually becomes irritated and erupts in violence, ordering the kaya to be destroyed with dynamite (p.119). McDonald, as an experienced colonial soldier, decides to follow cautious and quick steps to avoid an expected backfire during the operation.

McDonald secures the perimeter of the Edenic kaya, an Edenic place with mangrove forests and palm trees, with the help of British policemen. The darkness within the forest is intense, especially at night. McDonald rings the kaya with dynamite, turning it into ashes within a blink of an eye. The incident is described as a flash of lightning lit the dark forest, followed by a clap of thunder. McDonald aims to demonstrate his country's superior military and technology to the locals, a strategy used by the colonial power, as Alfred Crosby states. British

imperialism's success was largely due to their superior organization and technological prowess.

Kimani describes the destruction caused by colonial authorities, giving it a transcendental demeanor, and attributing it to the annellation of nature altogether, including the religious cite (kaya), as "it was an episode recorded in local lore as the day the figs walked and birds froze in midair." (p. 136). He also refers to it as "the day of the earthquake, for the powerful blast upturns trees, casting light upon the dark enclave that has preserved the power and mystery of ancient gods for generations."

When the colonial authorities are unable to persuade the native elders through argument, they do not hesitate to demonstrate the power of militarism and technology. The colonial master, McDonald, shows the natives that his power in the technological military can do anything. He threatens that he can wipe out the natives from the face of the earth at once. One of the characters in the text, called Nyundo, first compares the cannon blast to none of the gun in his admiration of the white man's power. "Mark my word: a cannon blast has no equivalent; it is the mother of all blasts." (p. 88). Nyundo describes the horrific blasts and its environmental consequences as:

Sparrows suspended their fluttering to listen to the blast, for they had never heard such a sound. The roaring sea waves, he said, flattened out to duck the cannon fire so that the sea lay flat like a mirror reflecting the sun above. The palm trees dropped all their fruit—mature, immature, raw, and ripe." Nyundo dropped his voice and said sotto voce, "Like a woman losing a pregnancy." Then, resuming his narration in a well-modulated tone: "The swinging branches were suspended in midair, the leaves arched awkwardly like a dreadlocked head . . . Maajabu! (p.88).

In this excerpt, Kimani uses Nyundo's account to illustrate the ecological destruction caused by military violence and fire. Nyundo is a survivor of the second explosion, which was dynamite and targeted the kaya, the cultural and religious center of the nine villages. The blast causes a complete obliteration of the environment.

In general, during a rebellion against the colonial government, as depicted in the novel, colonial authorities use various methods that are unsafe for the natural ecosystems, including killing natives' animals and razing their villages, which are done through military tactics, machines, and fire to show the power of the white man.

The Use of Disease

Campbell et al. (2010) elaborate on colonialism's violent engagement by asserting, "[T]he impacts of colonialism were similar, regardless of the specific colonizer: disease; destruction of indigenous social, political, and economic structures; repression; exploitation; land displacement; and land degradation" (p. 37). The colonial powers were harsh toward the natives and their environment. According to Crosby (1986), the success of European imperialism has a "biological and ecological component" in particular. Unintentionally—and less frequently, purposefully—spreading European diseases to other parts of the world led to the annihilation of local populations, which paved the way for European military and technological invasion (Ashcroft et al., 2013, p. 92). In order to propagate themselves in the strategic land of Kenya, the imperialists do not flinch from using whatever means necessary to subdue natives along with their homestead.

As depicted in the novel, they embark on the use of viruses and kill the cattle of the natives to make them weak and dependent on the colonial enterprise. What makes the situation horrific is that the virus does not kill the herds instantly; instead, it is a gradual act that affects the mouth and feet, prohibiting the herds from going far for grazing. After it lends them suffering from starvation, it kills them at the end.

Colonizers manipulate the Maasai tribe to support railroad construction in their territory. Captain John Adams introduces a disease from Europe that kills their herds, using it as a divide-and-rule strategy. He discovers Chief

Lonana and his brother Sadaka are at odds and plans to exploit the conflict. The British School of Tropical Medicine is about to open a field station in the colony, and the discovery of foot-and-mouth disease in Europe provides an opportunity for colonizers. Pellets containing the virus are dropped in specific paddocks, leading to thousands of herds starving to death. The community blames Chief Lonana for not informing their medicine men about the disease, leading to the colonizers sending agricultural extension agents to spray a foot-and-mouth antidote in Sadaka's paddocks. Sadaka overthrew his brother's leadership by staging a palace coup. The colonizers exploit the situation by introducing a foot-and-mouth antidote in Sadaka's paddocks.

In general, the use of disease is depicted as a deliberate strategy employed by the colonizers to weaken and control the indigenous population. The British School of Tropical Medicine provides the virus, known as nagana, to the Maasai, which causes their herds to start dying off, leading to starvation and economic devastation. This illustrates how the use of disease was a tool of colonial violence and exploitation, causing ecological destruction and social disruption.

Deforestation

Deforestation is the act of destroying forests, which have a dreadful effect on the ecosystem. Ecological imperialism is the phrase used to characterize the subjection of a nation's political, economic, and social institutions to the biophysical, metabolic needs of another nation, usually in order to make resources available and conducive to the accumulation of foreign capital (Burkett, 2006). Deforestation and ecological imperialism are related because deforestation is a type of ecological imperialism. Environmental injustices result from the powerful nations' ability to dominate other nations' natural resources.

There are noticeable effects of railroad construction, which natives are made to endure, on humans and nonhumans, as depicted in Dance of the Jakarand. Forests are cleared to get wood for the construction of the railway and houses for the workers, who come from different regions. As has been discussed, the rail work brings huge movements of population and labor that are interconnected with the exploitation and transfer of resources. These huge population movements are dispatched on the colonial environment and yield environmental degradation and cultural erosion. In addition, the colonizers cut down trees to supply the firewood needed to run the steam-powered trains. Additionally, they cut down trees to provide wood for building rail tracks. Large areas of forest are destroyed by all these activities in the colonies, and the results are catastrophic. Since most of the forested land is destroyed as a result of cutting trees, increased soil erosion results, which worsens the drought in the area.

On the day the railway construction is inaugurated, the first thing the colonial authorities do is show their covert project in the treatment of the natives and their environment through the cutting of the mvinje tree, which is revered as sacred among the natives. Charles Erickson, the colonial governor, comes to Mombasa in order to commence the East Africa Railway Construction. After making a brief speech, he is given a pitchfork and shovel, and he scoops up the soil from the ground to show their ultimate power to do whatever they want with land of aliens. McDonald then arranges the cutting down of the mvinje tree to represent "the clearing of virgin lands" to make way for the railroad and to landscape for the forthcoming colonial settlement. He orders the native workers to cut down the tree and remove it forever, but they all shrug and leave the place. (p.215).

The mvinje tree holds a great position of importance to the natives, and Kimani describes its importance in his novel. He explains that the tree shields the village from the elements, just as a mother hen shields her chicks, and that is why it is named after the word nifiche, which means shelter (p. 213). The mvinje provides more than just safety for the community; when the old men gather beneath the tree to drink, they also build trust among one another.

The tree also gives them the confidence to speak more clearly and improves their memory. The locals also hold the belief that mvinje restores health to the sick. Kimani claims that leprosy sufferers only need to touch the bark in order to recover. Children with hookworm simply need to chew its leaf in order to have the last worm washed out of their stomachs. The locals also hold the view that fire will breed itself if the old men clap their hands together and utter a certain phrase being beneath the tree. In general, the mvinje tree is associated with the natives' daily lives; it is part of their cultural lore for people to meet under this tree.

The destruction of the mvinje tree involves not only clearing the forest, which is understood from the perspective of environmental annihilation, but also obliterating the culture and the existence of the locals. The tree is a metaphor for the natives' metaphysical consciousness of their environment. Unlike that of the colonizers, their culture is interwoven with their environment, and the two define and support one another's existence. The destruction of the environment is reciprocally linked to the destruction of culture. The people know that cutting down mvinje tree is cutting down their culture. It is beyond destroying the tree. We later witness the workers that McDonald orders to cut the tree failing to follow his orders. They are aware of the distinction between adhering to a colonial-energized anthropocentric culture's rules and following the norms of their own pro-environment culture.

The colonizers use ecological imperialism as an insidious method to establish their colonial rule in their East African protectorate. Any environmental calamity is permissible as long as it aids colonialism's nourishment in the land. The railroad is deemed necessary for this purpose, and the railroad affects the natives and their natural environment. Starting from its construction commencement, it greatly impacts the ecosystem. Cutting down the mvinje tree is thought to be necessary in order to debilitate the conscious cultural resistance that could empower natives to organize themselves to oppose the colonial enterprise. It is thus the deliberate act taken by the colonizers to ravage the natural ecologies that the natives consider sacred, with a purpose to enfeeble them and include them in the colonial dominion.

Conservation: Its ecological impacts

National parks and conservation areas are the colonial government's attempts to restore pre-colonial ecosystems. These efforts have frequently encountered opposition and have been seen as a version of neocolonialism (Ashcroft et al, 2013, p.133). To make room for game parks for affluent tourists, indigenous people are driven off their land. The key conflicting area raised in both postcolonial ecocriticism and postcolonial zoocriticism is whether poor human communities are given less focus than wildlife on land. Human communities are uprooted from their homes to make way for game parks that will serve wealthy tourists, where the indigenous people are subjected to a double burden imposed on them by the colonizers: natives were evicted from their land and lost their ties to the environment during the colonial era's exploitation; their ecological environment was transformed and severely damaged. Conversely, natives are subjected to displacement for the colonial conservation projects run in the name of restoring the tranquil precolonial environment and conserving natural inhabitants.

As depicted in Dance of the Jakaranda, McDonald's conservation project is actually torturing wildlife, destroying the environment, and displacing and exploiting local people. At the end of his unsuccessful series of projects, he makes a tactical change in the use of his deteriorated vast land and turns it into a conservation area (sanctuary). He acquired the land by displacing a large number of natives during the colonization as explained here: "McDonald's farm, whose acreage was expanded during the 1923 land adjudication to include the lake and the hot water spring, was certified as his with a shiny red seal; the embossed letters announced that Her Majesty had granted him a hundred-year lease for the thousand-acre piece of land." (p. 200-201).

McDonald is unconcerned about the number of families who had to relocate in order for him to construct his project. In 1923, he uses his clout to craft a policy known as the Devonshire White Paper, which prohibits other foreigners, particularly Indians, from owning land in the colony under the guise that African land ownership takes precedence (p. 201). Meanwhile, white farmers have taken over all arable land, claiming to be holding it in trust for Africans. The land is given to them when they are ready for it.

McDonald devotes himself to farming, cultivating wheat to feed the nation until the war broke out in Europe which prevents him importing pesticides. Kimani writes, “He’d had enough with trying to domesticate the land and its people. He simply walked away, leaving farm equipment and the diseased crops still standing” (p. 201).

This demonstrates how colonizers appropriate native land and apply pesticides and fertilizers to produce a single crop repetitively, which in turn completely degrade the land eventually, even until the land is transformed into something to be done for. When large tracts of land are used to grow a single crop, the deterioration of the soil is accelerated. Regarding the environmental impact of the use of pesticides, environmentalists suggest that pesticides and herbicides have played a significant role in the extinction of numerous species. It is important to note that "for every extinct species, approximately 30 other dependent species move into the "at-risk" category."

McDonald now seeks to restore the peaceful and tranquil environment that existed prior to the British colonial establishment, which he himself witnessed and was an integral part of the cause of the destruction. He concentrates on conservation to construct a sanctuary and make a study the wild animals. He observes their behaviors and makes note of their habitats. All wealthy tourists in the colony and from Europe eventually turn to him for tour guides to enjoy nature at its finest. He keeps the native poacher, who kills animals for food, away from wild animals. He has no trouble passing legislation that outlaws poaching because he is the chairman of the Farmers' Association, which is entirely composed of white people. He denies local communities by making normal subsistence pursuits like hunting and wood collection illegal. In contrast to the natives’ concordance with the environment, he considers them the adversaries of wildlife conservation—that they are the illegal traders, poachers, hunters, and habitat destroyers.

Kimani criticizes the Western style of conservation through the characterization of McDonald. The Western idea of conservation is not used to create a sustainable environment by adhering to environmental protection principles. It is instead used to marginalize and exploit nonhuman animals and indigenous people. In the text, it is permissible for the white, wealthy tourists to poach and feed on animals, and to fish in the lake, hunt, and kill animals for trophies, while it is legally prohibited for the natives:

Wealthier tourists arrived on hunting expeditions. They lived in tented camps where they could shoot kudu for dinner, trail impala for lunch, and fell rhinos for trophies to take home. It was the only resort of its kind in the entire colony, where man and wildlife lived in such close contact (p. 202).

McDonald creates a kind of animal sanctuary that serves white settlers so they can easily access and feast on fresh animal meats, fish, and plants. In this conservation area, he kills animals and exploits native servants alongside other colonial settlers. McDonald alone has thousands of male servants under his command (p. 202). Natural ecologies, animals, and indigenous peoples are organized in such a way that they are meaningfully useful for colonizers' materialistic needs rather than receiving safe protection from conservationists. The goal of colonial conservation was to benefit the colonizing power, despite the fact that nature preservation was promoted as a universal goal. The colonizing states, whose own lands had already been developed for other economic purposes, initially reaped benefits from the protection and preservation of pristine natural environments (through tourism, trophy hunting,

and scientific research) (Laltaika et al., 2018). In addition, these policies were used as a cover for imposing control over the locals and the colonized territory.

Ecological Transformation

Alfred Crosby, a pioneering scholar, emphasized the importance of ecological change in the conquest and colonization of non-Western environments. He referred to this as ecological imperialism, highlighting the irreparable damage Indigenous people experienced due to colonization. These relationships were crucial to their understanding of their existence as part of the land, unlike those of their conquerors.

These are visible in the conflicts over land claims that are portrayed in Dance of the Jakaranda between natives and settlers. The natives' relationships to the land go beyond personal possession of material goods. African indigenous cultures view land as a vital part of communal holism, in contrast to how Europeans view it as a personal possession. Kimani depicts that, as a result of colonial incursion, the natives are alienated from their land and subjected to suffering.

Natives and their land suffer from the loss of their cultural heritage due to the colonizers' exploitation. The land and natives are subjected to harsh exploitation, with the people becoming servants of the colonizers. The land and its nonhuman habitats become an economic target for the colonizers' materialistic desires. The bodies of humans and land are pillaged for the economic development of England. Despite this, natives have lived on the land for ages without causing harm to their natural environment. They adopt submerged cultural practices that function with the will of the ecosystem, understanding that when nature is mistreated, it responds in kind. In the African worldview, all life, including spirits, humans, animals, plants, trees, oceans, and rocks, comes from God, infused by the active and dynamic life force of the creator.

Like indigenous communities in Africa, the people in the novel live off hunting, farming, and raising animals. People in all the established farming areas observe the particularities of their own environment and look for ways to rationally deal with it. Some regions employ cutting-edge techniques like terracing, mixed cropping, green manuring, mixed farming, and controlled swamp agriculture. The use of iron tools, particularly the axe and hoe, to replace wooden and stone tools is the single most important technological development underlying agricultural production. Even in cultivation activities, the majority of them consider the farming of their own unique staple to be a form of art.

Agriculture is conducted based on an accurate assessment of the soil potency, which is not as great as it first appeared from the dense vegetation, and the outcome was devastating when the colonists began disturbing the thin soil surface (Rodney, 1972, p. 63–64). This demonstrates that a new ecological system is not as effectively functional for the non-natives who are not adopted to the culture, even if they are more skilled, as it is for those who have become accustomed to the environment over centuries. There is a fine art embedded within the culture of cultivation that protects the environment both virtually and contextually. These people's defining characteristics are harmonious, intricate relationships between nature and humanity, so they are not harmful to the environment.

When the powerful pillage native land, it becomes a commodity for colonial settlers. The colonizers brutally exploit it in order to produce more crops to ship back to the mother country and other European nations. The voracious capitalism of colonial enterprise causes ecological transformation. Capitalism consumes people, land, and nature in general. Me Katilili, Kenya's traditional prophet, foretold environmental change in the text. The giant snake, which symbolizes capitalism, requires "communal feeding for an eternity" (p. 176). Me Katilili foreshadows the years of colonialism that will come to indigenous people's land.

The colonizers pillage the natives of their land and launch the British East African Protectorate

railway as the first colonial project in order to exploit what the Kenyan land produces. The natives and the land undergo irreversible changes during the construction of this railway. In the process of building the railroad, natural ecosystems, people, and nonhuman animals are all exploited and suffer irreparable harm. After the railroad is finally completed, colonizers create non-native settlement areas strategically along its path. The colonial government designs resource use policies that benefit the Europeans by giving them complete access to Kenya's arable lands. Then, these settlers transform Kenya into a farmhouse, using all possible means at hand to produce any type of crop on the land.

Kimani depicts the life of McDonald as that of a representative who engages in the appropriation, modification, and alteration of the landscapes. He first acts as a commissioner of the colonial government and supervises the railroad's construction. In his role, he exploits both humans and nonhumans. He instructs policemen to destroy the villages, including sacred nature and religious sites, using military technologies in order to show the power of his country. He plunders the natives' land based on the willingness of his government in England. He uses the land for whatever he wants, even if it goes against human interests.

He shows his country’s power over the land as well. He constructs a replica of Taaj Mahal, which symbolically represents the British empire in Africa, for his wife in England who divorces him later for his unchanging bad behavior. He converts the place into a farmhouse, where he exploits and tortures domestic animals. When he fails with the farmhouse, he converts the place into a club and a sporting venue for settlers to enjoy the maximum of life in a foreign land. He becomes unsatisfied with it and changes his mind, converting the land into farming, where he repetitively grows wheat using fertilizers, pesticides, and herbicides. Eventually, McDonald is unable to harvest wheat because he cannot import pesticides because of the war in Europe. The land has already lost its fertility and is incapable of producing any crop. As a result, near the end of his life, McDonald launches a conservation program. As he puts it, his goal is to restore the pristine environment of the pre-colonial era. However, he continues the colonial goal of exploitation of natives and their natural resources. He allows colonization to continue in the country, exploiting it under the guise of "neo-colonization," knowing that Kenya's independence is inevitable. He advocates a conservationist policy that excludes natives and Indians as chairman of the Kenyan Farmers Association, and he claims that Europeans own all lands. Kimani describes how the country's colonial exploitation is upgraded to neocolonial exploitation in the independence era.

Following in the footsteps of the colonizers, particularly Ian Edward McDonald, the newly independent Kenya continues to aid conservation efforts. Tourists from Europe are greeted at the train station by tour guides eager to retell an old story. They will point to the imposing Jakaranda Hotel, a replica of which is restored shortly after independence at a huge cost to the independent government. Experts from London are flown in to ensure that the house is an exact replica of the one built by Ian Edward McDonald in 1901. Tour guides will point out various features of the establishment and proudly proclaim, "That's the place that heralded the birth of this town" (p. 259). This demonstrates that even in the post-independence era, all development projects and policies are designed in such a way that they benefit the colonial nations and their innovators at the expense of the colonized countries.

In addition to McDonald, who experiments with the indigenous land, Reverend Turnbull also contributes a lot to the transformation of the ecological environment. He represents colonizers in ecological transformation by contributing to the transformation of the ecological environment. He modifies the indigenous cows into the cows that Europeans use, inseminating the cows of indigenous people with those of Europeans to help the cows give more milk. Turnbull is preparing the way for the settlers’ coming to Kenya and plays

a key role in fueling the establishment of British imperialism in East Africa. Although he picks evangelism as his main role to save the heathen from their sins, this role becomes only an overt masquerade as he is used by the colonial rulers in order to pave the way for imperialism. Turnbull's actions reflect the anthropocentric practices of European colonizers, which allowed nature to be exploited to the maximum, resulting in ecological destruction and transformation.

Conclusion

The environmental consequences of ecological imperialism were examined in Peter Kimani's historical novel, Dance of the Jakaranda. The novel focuses on colonial strategies used by colonizers as well as historical colonial exploitation and suffering of both humans and nonhumans during British colonial rule in Kenya. Colonial plunder of resources is identified as an archetypal issue, demonstrating that the colonizers' occupation of the indigenous peoples of east Africa is solely to satisfy materialistic desires. The plunder includes the pillage of both human and nonhuman entities. This follows by the horrifying environmental effects of colonization, which were a direct result of the harsh colonial strategies used by the colonial rulers. There are several of them, including the use of disease, building railroads, conservation, and ecological destruction caused by military violence and fire. A complete environmental transformation as a result of serial exertion of colonial tools, colonial exploitation, and resource transfer is observable in the text. The colonization becomes the cause of the nation's birth and evolves into neo-colonization, directly or indirectly affecting this new nation and its environment.

Recommendations

The study recommends that ecological imperialism can provide a useful framework for understanding the complex relationships between colonialism, ecology, and literature, and can contribute to ongoing efforts to address environmental issues in Africa and beyond. The study also recommends further research in this area to expand the scope of the study and to provide a more comprehensive understanding of the ecological impacts of colonialism in Africa. Additionally, the study suggests that environmental activists and policymakers can benefit from the insights provided by ecological imperialism to develop more effective strategies for addressing environmental issues in Africa and beyond.

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RESEARCH PAPER

Effectiveness of Fructón Fertilizer on Growth, Yield, and Quality of Tomato (*Solanum lycopersicum* L.) at West Shewa, Ethiopia

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Abstract

This study aims to investigate the impact of using a combination of Fructón, a bio-stimulant fertilizer, with inorganic nitrogen and phosphorus fertilizers on tomato crop performance. The experiment was conducted from October 2019 to March 2020 under irrigation in the field at two locations in the west Shewa zone: Toke Kutaye and Ilu Gelan districts. There were four treatments in the study: organic Fructón, inorganic nitrogen, and phosphorus fertilizers; a combination of Fructón and nitrogen and phosphorus fertilizers; and control plots that received no fertilization. Each treatment was replicated three times in a randomized, complete block design. Results revealed that integrated application of organic Fructón (50 g L^{-1} ha^{-1}) with inorganic nitrogen (80 kg N ha^{-1}) and P (90 kg P_2O_5 ha^{-1}) fertilizers significantly improved the growth, yield, and quality of tomato fruits. The combination treatment resulted in the highest plant height, number of primary and secondary branches, number of fruits per plant, marketability, and total yield at both Toke-Kutaye and Ilu-Gelan locations. Conversely, the untreated plot exhibits the lowest results. Additionally, supplemental application of organic Fructón with conventional nitrogen and phosphorus fertilizers enhanced the total soluble solids, pH, and titratable acidity of the tomatoes. These findings suggest the combination of organic fructón with inorganic nitrogen and phosphorus fertilizers holds promise for improving tomato growth and yield performances.

Keywords: *Fructón*, Tomato, Bio-stimulant, Fertilizer

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important, nutritious, and extensively grown vegetables in the world (Dragan *et al*., 2010; Gharezi *et al*., 2012). It is an integral part of the human diet and is popularly used in a variety of dishes, such as salad, and in cooked or processed products more than any other vegetable (Awas *et al.,* 2010; Mujtaba and Masud, 2014). Matured tomato fruits are used to prepare puree, paste, tomato powder, ketchup, sauce, and soup, whereas the unripe ones are used for preserves (Pinheiro *et al*., 2013). Tomato fruits are rich in bioactive phytochemicals such as vitamins, minerals, lycopene, carotenoids, sugar, essential amino acids, and other dietary fibers (Gupta *et al*., 2011; Gharezi *et al.,* 2012). The phytochemicals found in tomato fruit are thought to reduce the risk of human ailments (Canene-Adams *et al.,* 2005). As a result, consuming tomatoes is considered a functional food that is used to reduce the risk of malignant diseases like cancer, cataracts, heart diseases, diabetes, hyperglycemia, inflammation, arthritis, immune system decline, and brain dysfunction (Tan *et al.,* 2013; Mujtaba and Masud, 2014). Subsequently, the use of tomato in every diet is so extensive that it is almost impossible to separate it from the menus of fast-food and pizza parlors (Silva *et al.,* 2008; Tan *et al.,* 2013).

In Ethiopia, tomato is considered as a cash-generating crop for small-holder and medium-scale commercial farmers (Teka, 2013). Many farmers are interested in tomato production for its multiple harvests, high profitability, and

potential to improve the revenue and nutrition of households (Awas *et al.,* 2010). Despite the tremendous benefits of the crop, the overall yield and quality of tomatoes in Ethiopia are very low compared to the regional and global average yield (Gemachu and Beyene, 2019). According to FAO (2018), the productivity of tomatoes in Ethiopia was 6.18 tons ha-1, which is by far very low when compared to the average productivity of the world (38.27 tons ha^{-1}), Africa (16.08 tons ha-1), and East Africa (14.45 tons ha-1), respectively.

The main reasons for low production and productivity of tomatoes in Ethiopia are inappropriate agronomic practices such as poor fertilization, inappropriate spacing, pests, diseases, and a lack of improved varieties (Aseffa, 2013). Inappropriate fertilization and the indiscriminate use of chemical fertilizers are the major factors that cause low crop productivity in Ethiopia (Balemi, 2015). Omidire *et al.* (2015) reported that the exclusive use of inorganic fertilizer can affect soil properties and negatively affect soil productivity. Balemi (2015) also stated that indiscriminate use of chemical fertilizers alone can result in the depletion of essential micronutrients, thereby resulting in an overall reduction in total productivity. Due to the soil fertility depletion from the exclusive use of inorganic fertilizers, along with the reality of their negative impact on the environment, the combined application of organic and inorganic fertilizer sources is becoming a suitable nutrient management practice (Omidire *et al.,* 2015).

Several investigators reported that a long-term and sustainable crop production system could be achieved through the integration of inorganic and organic sources of nutrients (Graham *et al.,* 2017; Saha *et al.,* 2017; Biramo, 2018). To maintain the sustainability of crop production, it is advisable to choose a production system that has a less harmful effect on the environment while helping to achieve optimum yields and quality produce (Gomes *et al.,* 2017). *Fructón* fertilizer is a newly produced organic fertilizer used to improve vegetable yield and quality. It is water-soluble and the product of the kimetic group, which contains micro-elements such as boron and molybdenum in addition to nitrogen and potassium. It is an excellent bio-stimulant fertilizer that is used to increase the fruit size and to avoid flower drops and fruit cracking in fruit vegetables. However, the efficacy of integrated application of *Fructón* with inorganic nitrogen and phosphorus fertilizer sources has not been evaluated on the production and quality of tomatoes yet. Keeping this in view, the present research was aimed to evaluate the effectiveness of integrated organic *Fructón* fertilizer and inorganic nitrogen and phosphorus fertilizers on the growth, yield, and quality of tomato fruits at the West Shewa zone, Oromia region, Ethiopia.

Materials and methods

Description of Study Areas

The field trials were conducted at two locations in the west Shewa zone: Toke Kutaye and Ilu Gelan districts, from October 2019 to March 2020, under irrigation. Toke Kutaye district is located at 8º58' to 8.97º N latitude and 37º 46' to 38º E longitude, and Ilu Gelan district is located at 8º49' to 9º5.3' N latitude and 37º 31.3' E longitude. The experiment in the Toke Kutaye district was conducted at Ambo University, a horticulture experimental field located in Guder. For the Ilu Gelan district, a farmer's field was used for the trial. The altitudes of the experimental sites in Toke Kutaye and Ilu Gelan districts were 1800 and 1812 meters above sea level, respectively. Both study areas have a unimodal rainfall pattern (Balemi, 2015; Tadesse et al., 2018). The soil texture of Toke Kutaye's experimental site was clay with 21% sand, 26% silt, and 53% clay with a pH (1:2.5 - H2O) of 5.96, and that of the Ilu-Gelan soil was also clay with 27% sand, 24% silt, and 49% clay with a pH (1:2.5 - H2O) of 5.63.

Experimental design and treatments

The experiment consisted of four treatments: organic nitrogen (N) and phosphorus (P) fertilizers, *Fructón* fertilizer, a combination of organic nitrogen and phosphorus and organic *Fructón* fertilizers, and a control (no fertilizer applied). The treatments were replicated three times and laid out on experimental units using a randomized complete block design (RCBD). For the inorganic nitrogen and phosphorus fertilization, the recommended rates (80 kg of N ha-1 and 90 kg of P2O5 ha-1) were used. For the *Fructón* receiving plots, organic *Fructón* at the rate of 50 g L-1 ha-1 was applied four times at different stages of growth. The sources of inorganic fertilizers used for nitrogen and phosphorus were UREA (46.0.0) and DAP (18.46.0), respectively. For the inorganic fertilizer-receiving plots, DAP was applied at transplanting and urea was applied at the flower initiation stage. Details about the treatments set up for this study and the nutrient contents of *Fructón* were shown in Table 1 and 2, respectively.

Table 1. Details of fertilizer treatments used in the study.

Treatment code	Treatments details
TF0	Control (no fertilization)
TF1	Inorganic nitrogen and phosphorus fertilizers at the rate of 80 Kg N ha^{-1} and 90 Kg of P_2O_5 ha^{-1}
TF2	*Fructón* at the rate 50 g L^{-1} ha^{-1} applied four times at every 15 days after 1^{st} flower appearance
TF3	Combination of inorganic nitrogen and phosphorus fertilizers at a rate of 80 Kg N ha^{-1} and 90 Kg of P_2O_5 ha^{-1} in combination with *Fructón* at a rate of 50 g L^{-1} ha^{-1} applied four times every 15 days after 1^{st} flower appearance

Table 2. Nutrient contents of *Fructón* used for the Study.

Composition	%W/W
Nitrogen (N)	1.5
Potassium (K_2O)	5.0
Boron (B)	13.5
Molybdenum (Mo)	5.0

Source: (Ficha, 2017)

Experimental Procedures and Crop Management

The seed of the Roma VF tomato variety was drilled on a 1.5 m x 4 m-sized seedbed at the Ambo University Guder campus experimental site on October 24, 2019. The experimental fields were cleared, ploughed, harrowed, and prepared to a fine tilt. Then the experimental areas were divided into small homogenous blocks, to which a complete set of treatments were assigned randomly. Transplanting of seedlings on the experimental fields was done at the 3–5 true leave stage. The seedlings were planted at a spacing of 90 x 40 cm between rows and between plants, respectively. Watering was done using furrow irrigation. Inorganic fertilizer, phosphorus, and nitrogen were applied to the experimental field following the recommended rate of 90 kg P_2O_5 ha^{-1} and 80 kg N ha^{-1} in the form of diammonium phosphate (DAP) and urea, respectively. *Fructón* was applied every 15 days using the foliar application method after the first flower appearance. All agronomic

practice has done as per recommendation uniformly to all plots except for fertilization.

Data collection

Growth, yield, and quality data of tomatoes were recorded from five randomly selected tomato plants in the central rows of each plot, and the mean value was used for analysis. Growth parameters: plant height (cm) measured from the ground to the tip apex of the tomato plant at maturity stage. Primary branches and the number of secondary branches were counted and recorded at the maturity stage.

Yield and yield-related parameters: number of clusters per plant, average number of fruits per cluster, and marketable and unmarketable yields (tons ha-1) were collected. The number of clusters was counted at 50% flowering. Marketable and unmarketable yields (tons ha^{-1}) were measured according to the method prescribed by Zeleke and Derso (2015) by considering diseased, infected fruit insect pests, physiologically, and mechanically damaged fruits as unmarketable, while fruits free from any visible damages as marketable. Marketable and unmarketable fruits obtained from each net plot area were weighed with an analytical balance in kilograms and converted into hectares. Total fruit yield (tons ha^{-1}) was obtained by adding marketable and unmarketable fruit yields. Fruit diameters were measured from three randomly selected sample fruits from the selected plant using digital calipers, and the mean value was calculated for the analysis.

Quality parameters: total soluble solids, pH, and titrable acidity of tomato juice were determined and analyzed. For the quality analysis, two tomato fruits from each selected plant were taken and sliced. An aliquot of clear juice was prepared using a juice extractor (Model: 31JE35, USA) and used for all chemical analysis. The pH value of tomato juice was measured using a pH meter (model: ME962, Max Electronics, India). Total soluble solids (TSS in °Brix) were determined based on the methods described by Tsegay *et al. (*2013). A digital Palm Abbe Refractometer (Model: #PA201, MISCO®, Virginia) with a lower range (0 to 32 °Brix) and resolutions of 0.2 °Brix was used to determine it by placing a few drops of clear juice on the prism of the refractometer. The titratable acidity (TA) of tomato pulp was determined according to the method prescribed by Moneruzzaman *et al.* (2009). Ten milliliters of tomato pulp were taken from the prepared juice and diluted with 30 ml of distilled water. The diluted juice was filtered through cheesecloth, and 10 ml of filtrated tomato juice was poured into the conical flask. Then, two drops of 1% phenolphthalein indicator were added, and the flask was shaken vigorously. A 50-ml burette was filled with 0.1N NaOH solutions, and the solution was titrated into a conical flask while keeping the flask shaking till a permanent pink color appeared. The volume of NaOH solution used for titration was recorded, and the percentage titratable acidity was calculated using the following formula: $\text{TA}\ (\%) = \frac{\text{T X N X V1 X E}}{\text{V2 X Wt X 1000}}\ X\ 100$, where: T: Titre, N: normality of NaOH, V1: volume made up, E: mill equivalent wt. of acid, *i.e.*, citric acid in tomato = 0.06404, V2: volume of extract, and Wt: the weight of the sample. A total soluble solid-to-acid ratio was calculated by dividing the value of TSS (°Brix) by the value of the percentage of titratable acidity.

Statistical data analysis

The collected data were subjected to statistical analysis using Genstat 16th edition software. The statistical significance of the hypotheses was assumed when the P-value was less than 0.05.

Results and discussions

Plant height (cm), number of primary and secondary branches per plant

Analysis of variance revealed that the growth parameters of tomatoes, including plant height, number of primary branches, and number of secondary branches per plant, were significantly affected by the type of fertilizer used (Table 3).

Table 3. Effect of integrated application of Fructón and NP (nitrogen and phosphorus) fertilizers on growth parameters of tomato plant

Location	Treatments	Plant Height (cm)	Number of Primary Branches	Number of Secondary Branches
Toke Kutaye	Control	49.89^{c}	2.78^{c}	5.11^{c}
	Inorganic nitrogen and phosphorus fertilizers	56.89^{b}	3.11^{b}	6.45^{b}
	Organic *Fructón* fertilizer	61.22^{b}	3.22^{b}	6.56^{b}
	Organic *Fructón* plus inorganic nitrogen and phosphorus fertilizers	70.44^{a}	4.33^{a}	9.00^{a}
	LSD	5.692	0.246	1.009
	CV (%)	4.8	3.7	7.5
Ilu Gelan	Control	49.33^{c}	2.22^{c}	4.11^{c}
	Inorganic nitrogen and phosphorus fertilizers	55.00^{bc}	2.56^{bc}	5.44^{b}
	Organic *Fructón* fertilizer	56.00^{b}	2.89^{b}	5.56^{b}
	Organic *Fructón* plus inorganic nitrogen and phosphorus fertilizers	65.11^{a}	3.67^{a}	7.89^{a}
	LSD	6.35	0.43	0.91
	CV (%)	5.6	7.6	7.9

Means with the same letters in a column are not significantly different at 5% level of significance according to Duncan's Multiple Range test (DMRT); LSD: Least Significant Difference, CV: coefficient of variance

The combined application of organic *Fructón* with conventional nitrogen and phosphorus fertilizers significantly improved the plant height of tomatoes ($P < 0.05$). The tallest plant heights (70.44 cm) in Toke Kutaye and (65.11 cm) in Ilu Gelan were recorded from plots applied with a combined application of *Fructón* (50 g L^{-1} ha^{-1}) and inorganic nitrogen and phosphorus fertilizers (80 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1}), whereas the shortest plant height was obtained from the control plot at both locations. This finding is consistent with previous studies that have reported the application of mixed organic and inorganic fertilizers resulting in taller tomato plants (Islam *et al.,* 2017). The increase in plant height can be attributed to balanced nutrition, improved nutrient uptake, and increased carbohydrate synthesis (Omidire *et al.,* 2015).

Similarly, the number of primary branches per plant of tomato was significantly ($P < 0.05$) influenced by the types of fertilizers used. The highest number of primary branches was observed in the plots treated with the combination of *Fructón* and inorganic fertilizers, while the lowest number was in the control plot. Furthermore, the highest number of secondary branches per plant was observed in the treatment with the combination of *Fructón* and inorganic fertilizers, while the lowest number was in the control treatment. The result aligns with previous studies that have shown integrated application of organic and inorganic fertilizers leading to a higher number of primary branches per plant (Meaza *et al*., 2007; Ogundare *et al.,* 2015; Jat *et al.,* 2018). According to Meaza *et al. (*2007), the integrated application of organic ComCat® and inorganic nitrogen and phosphorus fertilizer resulted in a significantly higher number of

primary lateral branches per plant compared to tomato plants applied with ComCat® and control treatments. The increase in primary and secondary branches can be attributed to the influx of nitrogen and phosphorus from both organic and inorganic sources.

Fruit cluster per plant, number of fruits per cluster, and number of fruits per plant

The number of fruit clusters per plant, the number of fruits per cluster, and the number of fruits per plant were all significantly ($P < 0.05$) affected by fertilizer types at both locations in Toke Kutaye and Ilu Gelan districts, as depicted in Table 4. The maximum number of fruit clusters per plant (21.00 in Toke Kutaye and 20.11 in Ilu Gelan) was obtained from plots treated with a combination of *Fructón* and inorganic nitrogen and phosphorus fertilizers. On the other hand, the minimum number of fruit clusters per plant (14.56 in Toke Kutaye and 14.22 in Ilu Gelan) was counted in the control plots. The result of this study coincides with the findings of Islam et al. (2017) who obtained a higher number of fruit clusters per plant from the combined application of organic and inorganic fertilizer compared to the sole application of organic or inorganic and control treatments.

The number of fruits per cluster was significantly affected by the combined use of organic *Fructón* and inorganic nitrogen and phosphorus fertilizers ($p < 0.05$). Plants treated with *Fructón* alone also produced a higher number of fruits per cluster, although not significantly better than those treated with recommended rates of inorganic fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1). This complementary application of organic and inorganic fertilizers resulted in a higher number of fruits per cluster, which might be due to a reduction in the number of aborted fruits.

Furthermore, the combined application of *Fructón* and inorganic nitrogen and phosphorus fertilizers significantly increased the number of tomato fruits per plant at both the Toke Kutaye and Ilu Gelan experimental sites. In Toke Kutaye, the combination treatment increased the number of fruits per plant by 30.1% and 47.8% compared to the use of inorganic fertilizers alone and the control group, respectively. Similarly, at Ilu Gelan, the combination treatment increased the number of fruits per plant by 25.6% and 44.3% compared to the use of inorganic fertilizers alone and the control group, respectively. The control group had the lowest number of fruits per plant at both locations. The result of this study is in line with the findings of Yeptho et al. (2012), who reported that integrated application of 50 percent NPK, 50 percent poultry manure, and biofertilizer resulted in a higher number of fruits per plant over the other treatments in tomatoes. Ogundare et al. (2015) also revealed that the combined use of 125 kg ha-1 NPK and 3 tons ha-1 poultry waste produced the highest number of tomato fruits per plant compared to the use of inorganic NPK fertilizer alone or control treatments. The improved yield parameters of tomatoes from combined application could be attributed to the bio-stimulant activity of *Fructón* in accelerating flower bud formation.

Table 2. Effect of integrated application of *Fructón* and NP fertilizers on the number of fruit clusters per plant, fruits per cluster, and fruits per plant of the tomato plant

Location	Treatments	Number of fruit cluster per plant	Number of fruits per cluster	Number of fruits per plant
Toke Kutaye	Control	14.56[c]	2.04[c]	29.67[c]
	Inorganic nitrogen and phosphorus fertilizers	16.67[b]	2.40[b]	39.78[b]
	Fructón Fertilizer	17.22[b]	2.41[b]	41.33[b]
	Fructón + inorganic N and P fertilizers	21.00[a]	2.72[a]	56.89[a]
	LSD	1.443	0.250	6.354
	CV (%)	5.6	5.2	7.6
Ilu Gelan	Control	14.22[c]	2.02[b]	28.78[c]
	Inorganic Fertilizers	16.00[b]	2.41[a]	38.44[b]
	Fructón Fertilizer alone	16.22[b]	2.55[a]	41.22[b]
	Fructón + inorganic N and P fertilizers	20.11[a]	2.58[a]	51.67[a]
	LSD	0.596	0.308	5.277
	CV (%)	1.8	6.4	6.6

Means with the same letters in a column are not significantly different at 5% level of significance according to DMRT; LSD: least significant difference, CV: coefficient of variance.

Marketable, unmarketable and total yield

The total yield, marketable yield, and unmarketable yield of tomatoes were significantly affected by the combined use of *Fructón* and inorganic fertilizer ($p < 0.05$). The highest total yield of tomato (46.20 tons ha-1) in Toke Kutaye and (39.40 tons ha-1) in Ilu Gelan, respectively, was obtained from plots applied with Fructón + inorganic nitrogen and phosphorus fertilizers, followed by plots applied with Fructón alone (Table 5). The

combined application of *Fructón* with inorganic nitrogen and phosphorus fertilizers significantly increased the total yield of tomato fruits compared to other treatments. The minimum yield was obtained from the control plots. Combined application of *Fructón* with inorganic nitrogen and phosphorus fertilizers at Toke Kutaye significantly increased the total yield of tomato fruits by 22.2%, 30.3%, and 43.3% compared to plots applied with *Fructón*, inorganic nitrogen and phosphorus fertilizers, and the control plot, respectively. A similar trend was also observed at Ilu Gelan, where the mixed application of *Fructón* with inorganic nitrogen and phosphorus fertilizers significantly increased the number of tomato fruits per plant by 25.4%, 39.6%, and 53.8% compared to plots applied with sole *Fructón*, inorganic nitrogen and phosphorus fertilizers, and the control treatment, respectively.

Table 5. Effect of integrated application of *Fructón* and NP fertilizers on the marketable, unmarketable, and total yield of tomato plants

Location	Treatments	Marketable Yield (tons ha^{-1})	Unmarketable yield (tons ha^{-1})	Total Yield (tons ha^{-1})
Toke Kutaye	Control	18.20^{c}	8.40^{b}	26.20^{c}
	Inorganic N and P fertilizers	26.13^{b}	6.07^{ab}	32.20^{b}
	Fructón Fertilizer alone	30.33^{b}	6.60^{ab}	35.93^{b}
	Fructón + Inorganic N and P fertilizers	42.47^{a}	3.73^{a}	46.20^{a}
	LSD	4.822	2.985	5.594
	CV (%)	8.2	25.1	7.9
Ilu Gelan	Control	9..33^{d}	8.87^{c}	18.20^{d}
	Inorganic N and P fertilizers	17.27^{c}	6.53^{b}	23.80^{c}
	Fructón Fertilizer alone	23.80^{b}	5.60^{b}	29.40^{b}
	Fructón + Inorganic N and P fertilizers	35.93^{a}	3.27^{a}	39.40^{a}
	LSD	2.510	1.922	1.805
	CV (%)	5.8	15.9	3.3

Means with the same letters in a column are not significantly different at a 5% level of significance according to DMRT; LSD: Least Significant Difference, CV: coefficient of variance

The result of this study coincides with the findings of Ogundare et al. (2015), who obtained the highest total yield of tomato plants applied with 124 kg ha-1 NPK fertilizer and 3 tons ha-1 poultry manure. Besides, this result agrees with the finding of Islam et al. (2017), who reported that mixed fertilizer (2/3 organic vermicompost + 1/3 inorganic NPK fertilizers) resulted in the highest number of fruits per plant compared to sole application organic vermicompost and inorganic NPK fertilizers. Furthermore, the result coincides with the findings of Jat et al. (2018), who reported that the integration of organic manures with inorganic fertilizers improves the overall plant growth, yield, and soil macronutrient status more than the sole application of either of these nutrients.

The marketable yield of tomato fruits also varied significantly due to the integrated application of nutrients. The highest marketable yield (42.47 tons ha-1 and 35.93 tons ha-1) in Toke Kutaye and Ilu Gelan, respectively, was obtained from plots applied with a combination of *Fructón* and inorganic nitrogen and phosphorus fertilizers. The minimum marketable yield at both experimental sites was obtained from a plot that received no fertilizer (control). This result is in line with previous studies (Pandey and Chandra 2018) that have shown the positive effects of integrated nutrient application on marketable yield. The increase in total and marketable yield can be attributed to the additive effect of each fertilizer as well as the enhanced translocation of carbohydrates towards fruit formation. The frequent foliar application of *Fructón* may have also contributed to the overall increase in yield. On the other hand, the combined application of *Fructón* and inorganic nitrogen and phosphorus fertilizers significantly reduced the unmarketable yield of tomatoes. This result is consistent with previous studies that have observed a reduction in unmarketable yield with the use of integrated organic fertilizers. The reduction in unmarketable yield can be attributed to the foliar application of *Fructón*, which enhances the concentration of trace elements and accelerates fruit formation. On the other hand, the combined application of *Fructón* (50 g L-1 ha-1) and inorganic nitrogen

and phosphorus (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers significantly reduced the unmarketable yield of tomato at both experimental sites. The result of this study agrees with the findings of Yanar et al. (2011), who observed a reduction in unmarketable yield in tomato plants applied with integrated organic fertilizers.

Quality parameters

The variability of tomato fruit quality parameters in response to applied fertilizer types is presented in Table 6. The fruit diameter, pH, total soluble solids (TSS), and titrable acidity (TA) were significantly ($P < 0.05$) affected by the sole and integrated use of inorganic nitrogen and phosphorus fertilizers and organic sources. The largest fruit size of tomato (52.07 mm) in Toke Kutaye and (51.73 mm) in Ilu Gelan were obtained from tomato fruits harvested from plots applied with *Fructón* (50 g L-1 ha-1) + chemical nitrogen and phosphorus (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers. At both experimental sites, the smallest fruit sizes (40.77 mm) and (40.37 mm) of tomato fruits in Toke Kutaye and Ilu Gelan, respectively, were obtained from plots that received no fertilizer (control). Several investigators have also reported similar findings in terms of fruit length, fruit diameter, and fruit volume due to integrated nutrient management (Kochakinezhad et al., 2012; Ilupeju et al., 2015; Saha et al., 2017). The increment in fruit diameter of tomato fruits harvested from plots applied with a combination of *Fructón* and mineral nitrogen and phosphorus fertilizers could be attributed to the additive effect of each fertilizer, which enhanced the translocation of carbohydrates and water absorption toward fruit and resulted in increased turgor pressure and larger tomato fruit.

Table 6. Effect of sole and integrated use of inorganic nitrogen and phosphorus fertilizers and organic *Fructón* fertilizer on quality parameters of tomato fruits

Location	Treatments	FD (mm)	pH	TSS (°Brix)	TA (%)	TSS/TA ratio
Toke Kutaye	Control	40.77^{d}	4.50^{c}	4.23^{c}	0.16^{c}	26.67^{c}
	Inorganic N and P fertilizers	44.83^{c}	4.30^{b*}	4.40^{b}	0.28^{b}	15.70^{b}
	Fructón fertilizer alone	48.03^{b}	4.37^{b}	4.43^{b}	0.31^{b}	14.20^{ab}
	Fructón + Inorganic N and P fertilizers	52.07^{a}	4.03^{a}	4.73^{a}	0.42^{a}	11.67^{a}
	LSD	2.62	0.09	0.115	0.055	4.294
	CV (%)	2.8	1.1	1.3	9.4	12.7
Ilu Gelan	Control	40.37^{d}	4.67^{c}	3.90^{c}	0.18^{c}	22.29^{b}
	Inorganic N and P fertilizers	42.70^{c}	4.47^{b}	4.37^{b}	0.29^{b}	15.32^{a}
	Fructón fertilizer alone	45.67^{b}	4.40^{b}	4.40^{b}	0.31^{b}	14.36^{a}
	Fructón + Inorganic N and P fertilizers	51.73^{a}	4.10^{a}	4.70^{a}	0.41^{a}	11.50^{a}
	LSD	2.294	0.088	0.23	0.057	5.729
	CV (%)	2.5	1.0	2.7	9.5	18.1

Means with the same letters in a column are not significantly different at 5% level of significance according to DMRT; LSD: least significant difference, CV: coefficient of variance; FD: fruit diameter; TSS: total soluble solids; TA: titrable acidity

The effect of sole and integrated use of inorganic nitrogen and phosphorus fertilizers, and organic *Fructón* fertilizer on the pH of tomato juice is shown in Table 6. The least pH values of tomato juice (4.03) in Toke Kutaye and (4.50) in Ilu Gelan were obtained from tomato fruits harvested from plots applied with *Fructón* (50 g L-1ha-1) and inorganic nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1). Plants with *Fructón* (50gL-1ha-1) also resulted in a higher pH value of tomato fruits compared to plots with inorganic nitrogen and phosphorus (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers and control treatments, although there was no statistically significant difference between them. At both experimental sites, the highest pH values of tomato juice (4.50) and (4.67) in Toke Kutaye and Ilu Gelan, respectively, were obtained from plots that received no fertilizer (control). These results are consistent with the results of Ilupeju et al. (2015), who reported that the combined application of 75% NPK and 25% Tithonia compost (organic) reduced the pH value of Roma VF tomato fruits compared to the control and the respective separate applications of the fertilizers alone.

According to Anthon *et al*. (2011), the pH value, which ranges from 4.25 to 4.4, is optimum for fresh tomato fruits to ensure desirable food safety. Teka (2013) further reported that tomato fruits that have a pH value greater than 4.4 are not suitable for processing as the pulp can be susceptible to thermophilic pathogens. Low pH values of tomato juice are associated with high fruit quality, which accounts for the flavor and sourness of the fruits (Aklile *et al*., 2016). Thus, pH values as low as possible (up to the point that they do not adversely affect the taste) are desirable for industrial use. In the present study, the pH value of tomato juices varied from 4.03 to 4.5 in Toke Kutaye and from 4.1 to 4.67 in Ilu Gelan, respectively. Except for the control treatment, other treatments resulted in considerably higher-quality tomato fruits suitable for both processing and fresh consumption. The reduction of the pH value in tomato fruits applied with the combined application of *Fructón* and inorganic nitrogen and phosphorus fertilizers might be due to the high supply of potassium, nitrogen, boron, and molybdenum from the integrated application, which might increase the acid content of the fruits and thereby reduce the pH value of the fruit.

The result revealed that the total soluble solids (TSS) of tomato fruits were significantly ($P < 0.05$) influenced by the sole and integrated use of nitrogen and phosphorus fertilizers and organic sources (Table 6). The highest TSS values of tomato (4.73 ºBrix) and (4.7 ºBrix), which were harvested from the experimental sites of Toke Kutaye and Ilu Gelan, respectively, were recorded from the juice of tomato fruits harvested from plots applied with *Fructón* (50 g L-1ha-1) and inorganic nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1), followed by tomato fruits harvested from plots applied with *Fructón* (50 g L-1ha-1) and nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1), which were statistically similar when compared to each other. Conversely, the least TSS value (4.23 ºBrix) in Toke Kutaye and (3.90 ºBrix) in Ilu Gelan were recorded from the juices of tomato fruits prepared from tomato fruits harvested from control treatments. This result agrees with the findings of Shobo *et al.* (2017), who reported that combined application of poultry manure (PM) and NPK fertilizers resulted in a maximum TSS value in tomatoes compared to plants applied with poultry manure (PM), cow dung (CD), NPK, CD + NPK, and control treatments.

According to Tigist *et al*. (2013), the optimum TSS value for processing tomatoes ranges from 4.43 to 5.67 °Brix. A small increase in its value can significantly increase the product yield and decrease the costs of dehydration of pure sauce and paste (Bilalis *et al*., 2018). The TSS value in this study ranges from 4.20 to 4.73 ºBrix in Toke Kutaye and 3.90 to 4.70 ºBrix in Ilu Gelan. Except for the control treatment, other treatments resulted in high-quality tomato fruits and increased the TSS value, which is suitable for both processing and fresh consumption. The increase in TSS value in tomato fruits applied with the combined application of *Fructón* and inorganic N and P fertilizers might be attributed to a high supply of nitrogen from the fertilizer

sources, which contributed to the high production of TSS through a high rate of photosynthesis.

Total titratable acidity (TA) estimates the content of the organic acid in fleshy fruits, and it is one of the most important organoleptic quality factors for most fruits (Petriccione et al., 2015). The total TA content of tomato pulp varied significantly ($P < 0.05$) in fruits harvested from plots applied with different types of fertilizers (Table 6). The maximum TA values (0.42) in Toke Kutaye and (0.41) in Ilu Gelan, respectively, were obtained from the juice of tomato fruits harvested from the plots applied with *Fructón* (50 g L-1ha-1) and inorganic nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1), followed by tomato fruits harvested from plots applied with *Fructón* (50 g L-1ha-1) and chemical nitrogen and phosphorus (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers. Tomato plants applied with *Fructón* (50 g L-1ha-1) resulted in higher TA values compared to plants applied with inorganic nitrogen and phosphorus fertilizers and control treatments; however, there is no significant difference between organic *Fructón* and inorganic nitrogen and phosphorus fertilizers. At both locations, the lowest TA values (0.16) in Toke Kutaye and (0.18) in Ilu Gelan were recorded from the juices of tomato fruits harvested from control treatments. This result is in line with the findings of Al-Kharusi et al. (2009), who reported that the use of NPK, organic peat, and micronutrients resulted in a higher TA value in Khasab date fruit varieties as compared to plants applied with organic peat, NPK, and micronutrients and control treatments. Genanew (2013) suggested that an extreme reduction in the TA content of tomato fruits reduces the desirable quality of the fruit, and measures that minimize the reduction should be emphasized. The increment of the TA value in tomato fruits applied with the combined application of *Fructón* and inorganic fertilizers might be attributed to the reduction of pH values in this treatment due to the high potassium, nitrogen, boron, and molybdenum content, which increased the acid content of the fruits.

The total soluble solids (TSS) to total titratable acid (TA) ratio of tomato pulp varied significantly ($P < 0.05$) in fruits harvested from plots applied with different types of fertilizers (Table 6). The minimum TSS to TA ratio (11.67) in Toke Kutaye and (11.5) in Ilu Gelan, respectively, were obtained from the juice of tomato fruits harvested from the plots applied with *Fructón* (50 g L-1ha-1) and inorganic nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers, followed by tomato fruits harvested from plots applied with *Fructón* (50 g L-1ha-1) alone and chemical nitrogen and phosphorus (80 kg N ha-1 and 90 kg P2O5 ha-1) fertilizers alone. However, the maximum TSS to TA ratio (26.67) in Toke Kutaye and (22.29) in Ilu Gelan were obtained from the juices of tomato fruits harvested from control treatments. The total soluble solids (TSS) to titratable acidity (TA) ratio often refers to the better-related palatability of the fruit than either sugar or acid levels alone (Genanew, 2013). According to Owusu et al. (2012), tomato fruits that have a TSS to TA ratio not greater than or equal to 10 are generally considered good-flavored quality fruits. For processing cherry-type tomatoes, the optimum TSS to TA ratio ranges from 9 to 15 (Samukelo and Linus, 2015). Hamdu et al. (2016) suggested that the reduction of organic acid ought to be retained to balance sweetness and acidity at an acceptable level for the human palate. The TSS to TA ratio in this study ranges from 11.67 to 26.67 in Toke Kutaye and 11.5 to 22.29 in Ilu Gelan. Except for the control treatment, other treatments resulted in considerably high-quality tomato fruits with an optimum TSS to TA ratio, which is suitable for both processing and fresh consumption.

Conclusion

The integrated use of inorganic nitrogen and phosphorus with organic *Fructón* fertilizer significantly improved the growth, yield, and quality of tomato fruits. Marketable yield and yield-related parameters of tomatoes, such as the number of fruit clusters, the number of fruits per cluster, and the number of fruits per plant, were significantly influenced by the combined application of *Fructón* and nitrogen and phosphorus fertilizers. A significantly

higher marketable yield of tomato was obtained from the integration of 50 g L-1ha-1 *Fructón* with inorganic nitrogen and phosphorus fertilizers (80 kg N ha-1 and 90 kg P2O5 ha-1) based on N equivalence with the recommended nitrogen and phosphorus fertilizer application. Therefore, it can be concluded and recommended that the integrated use of Fructón with inorganic nitrogen and phosphorus fertilizers be used to increase the yield and improve the quality of tomato fruits. However, further research is needed to determine the optimum rate of *Fructón* required to enhance the growth and yield of tomatoes.

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Conflicts of interest

The authors declare no conflict of interest.

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