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Research Article

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Sustainable Development in Green Energies and the Environment

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ABSTRACT

The move towards a de-carbonized world, driven partly by climate science and partly by the business opportunities it offers, will need the promotion of environmentally friendly alternatives if an acceptable stabilization level of atmospheric carbon dioxide is to be achieved. This requires the harnessing and use of natural resources that produce no air pollution or greenhouse gases and provides comfortable coexistence of humans, livestock, and plants. This article presents a comprehensive review of energy sources, and the development of sustainable technologies to explore these energy sources. It also includes potential renewable energy technologies, efficient energy systems, energy savings techniques, and other mitigation measures necessary to reduce climate change. The article concludes with the technical status of the ground source heat pump (GSHP) technologies.

INTRODUCTION

Over millions of years ago, plants have covered the earth converting the energy of sunlight into living plants and animals, some of which were buried in the depths of the earth to produce deposits of coal, oil, and natural gas (Cantrell and Wepfer; 1984; Ashrae; 1995; Kavanaugh and Rafferty, 1997). The past few decades, however, have experienced many valuable uses for these complex chemical substances and manufacturing from them plastics, textiles, fertilizer, and the various end products of the petrochemical industry. Indeed, each decade sees increasing uses for these products. Coal, oil, and gas, which will certainly be of great value to future generations, as they are to ours, are however non-renewable natural resources. The rapid depletion of these non-renewable fossil resources need not continue. This is particularly true now as it is, or soon will be, technically and economically feasible to supply all of man's needs from the most abundant energy source of all, the sun. Sunlight is not only inexhaustible but, moreover, it is the only energy source, which is completely non-polluting United Nations (2003).

Industry's use of fossil fuels has been largely blamed for warming the climate. When coal, gas, and oil are burnt, they release harmful gases, which trap heat in the atmosphere and cause global warming. However, there had been an ongoing debate on this subject, as scientists have struggled to distinguish between changes, which are human-induced, and those, which could be put down to natural climate variability. Notably, human activities that emit carbon dioxide (CO_2), the most significant contributor to potential climate change, occur primarily from fossil fuel production. Consequently, efforts to control CO_2 emissions could have serious, negative consequences for economic growth, employment, investment, trade, and the standard of living of individuals everywhere.

Energy Sources and Uses

Energy Sources

Scientifically, it is difficult to predict the relationship between global temperature and greenhouse gas (GHG) concentrations. The climate system contains many processes that will change if warming occurs. Critical processes include heat transfer by winds and tides, the hydrological cycle involving evaporation, precipitation, runoff, and groundwater, and the formation of clouds,

snow, and ice, all of which display enormous natural variability. The equipment and infrastructure for energy supply and use are designed with long lifetimes, and the premature turnover of a capital stock involves significant costs. Economic benefits occur if capital stock is replaced with more efficient equipment in step with its normal replacement cycle. Likewise, if opportunities to reduce future emissions are taken in a timely manner, they should be less costly. Such a flexible approach would allow society to take into account evolving scientific and technological knowledge while gaining experience in designing policies to address climate change United Nations (2003).

The World Summit on Sustainable Development in Johannesburg in 2002 United Nations (2003) committed itself to ''encourage and promote the development of renewable energy sources to accelerate the shift towards sustainable consumption and production''. Accordingly, it aimed at breaking the link between resource use and productivity. This can be achieved by the following:

- Trying to ensure economic growth does not cause environmental pollution
- Improving resource efficiency
- Examining the whole life cycle of a product
- Enabling consumers to receive more information on products and services
- Examining how taxes, voluntary agreements, subsidies, regulations, and information campaigns, can best stimulate innovation and investment to provide cleaner technology

The energy conservation scenarios include the rational use of energy policies in all economic sectors and the use of combined heat and power systems, which are able to add to energy savings from autonomous power plants. Electricity from renewable energy sources is by definition an environmentally green product. Hence, a renewable energy certificate system, as recommended by the World Summit, is an essential basis for all policy systems, independent of the renewable energy support scheme. It is, therefore, important that all parties involved supporting the renewable energy certificate system in place if it is to work as planned. Moreover, existing renewable energy technologies (RETs) could play a significant mitigating role, but the economic and political climate will have to change first. It is now universally accepted that climate change is real. It is happening now, and GHGs produced by human activities are significantly contributing to it. The predicted global temperature increase of between 1.5 and 4.5^{o}C could lead to potentially catastrophic environmental impacts UNFCCC (2009). These include sea level rise, increased frequency of extreme weather events, floods, droughts, disease migration from various places, and possible stalling of the Gulf Stream. This has led scientists to argue that climate change issues are not ones that politicians can afford to ignore, and policymakers tend to agree on UNFCCC (2009). However, reaching international agreements on climate change policies is no trivial task as the difficulty in ratifying the Kyoto Protocol and reaching an agreement at Copenhagen has proved.

Therefore, the use of renewable energy sources and the rational use of energy, in general, are the fundamental inputs for any responsible energy policy. However, the energy sector is encountering difficulties because increased production and consumption levels entail higher levels of pollution and eventually climate change, with possibly disastrous consequences. At the same time, it is important to secure energy at an acceptable cost in order to avoid negative impacts on economic growth. To date, renewable energy contributes only as much as 20% of the global energy supplies worldwide UNFCCC (2009). Over two-thirds of this comes from biomass use, mostly in developing countries, and some of this is unsustainable. However, the potential for energy from sustainable technologies is huge. On the technological side, renewables have an obvious role to play. In general, there is no problem in terms of the technical potential of renewables to deliver energy. Moreover, there are very good opportunities for RETs to play an important role in reducing emissions of GHGs into the atmosphere, certainly far more than have been exploited so far. However, there are still some technical issues to address in order to cope with the intermittency of some renewables, particularly wind and solar. Nevertheless, the biggest problem with relying on renewables to deliver the necessary cuts in GHG emissions is more to do with political and policy issues than with technical ones Rees (1999). For example, the single most important step governments could take to promote and increase the use of renewables is to improve access to renewables in the energy market. This access to the market needs to be under favorable conditions and, possibly, under favorable economic rates as well. One move that could help, or at least justify, better market access would be to acknowledge that there are environmental costs associated with other energy supply options and that these costs are not currently internalized within the market price of electricity or fuels. This could make a significant difference, particularly if appropriate subsidies were applied to renewable energy in recognition of the environmental benefits it offers. Similarly, cutting energy consumption through end-use efficiency is absolutely essential. This suggests that issues of end-use

consumption of energy will have to come into the discussion in the foreseeable future (Bos et al. 1994).

However, RETs have the benefit of being environmentally benign when developed in a sensitive and appropriate way with the full involvement of local communities. In addition, they are diverse, secure, locally based, and abundant. In spite of the enormous potential and the multiple benefits, the contribution from renewable energy still lags behind the ambitious claims for it due to the initially high development costs, concerns about local impacts, lack of research funding, and poor institutional and economic arrangements Duchin (1995). Hence, an approach is needed to integrate renewable energies in a way that meets the rising demand in a cost-effective way.

Role of Energy Efficiency Systems

The prospects for development in power engineering are, at present, closely related to ecological problems. Power engineering has harmful effects on the environment, as it discharges toxic gases into the atmosphere and also oil-contaminated and saline waters into rivers, as well as polluting the soil with ash and slag and having adverse effects on living things on account of electromagnetic fields and so on. Thus there is an urgent need for new approaches to providing an ecologically safe strategy. Substantial economic and ecological effects for thermal power projects (TPPs) can be achieved by improvement, upgrading the efficiency of the existing equipment, reduction of electricity loss, saving fuel, and optimization of its operating conditions and service life leading to improved access to rural and urban low-income areas in developing countries through energy efficiency and renewable energies.

Sustainable energy is a prerequisite for development. Energy-based living standards in developing countries, however, are clearly below standards in developed countries. Low levels of access to affordable and environmentally sound energy in both rural and urban low-income areas are therefore a predominant issue in developing countries. In recent years many programs for development aid or technical assistance have been focusing on improving access to sustainable energy, many of them with impressive results. Apart from success stories, however, experience also shows that positive appraisals of many projects evaporate after completion and vanishing of the implementation expert team. Altogether, the diffusion of sustainable technologies such as energy efficiency and renewable energy for cooking, heating, lighting, electrical appliances, and building insulation in developing countries has been slow. Energy efficiency and renewable energy programs could be more sustainable and pilot studies more effective and pulse-releasing if the entire policy and implementation process was considered and redesigned from the outset Givoni (1998). New financing and implementation processes, which allow reallocating of financial resources and thus enable countries themselves to achieve a sustainable energy infrastructure, are also needed. The links between the energy policy framework, financing and implementation of renewable energy and energy efficiency projects have to be strengthened and as well as efforts made to increase people's knowledge through training.

Renewable Energy Technologies

Buildings consume energy mainly for cooling, heating, and lighting. The energy consumption was based on the assumption that the building operates within the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) - thermal comfort zone during the cooling and heating periods ASHRAE (1993). Most of the buildings incorporate energy-efficient passive cooling, solar control, photovoltaic, lighting and daylighting, and integrated energy systems. It is well known that thermal mass with night ventilation can reduce the maximum indoor temperature in buildings in summer Kammerud, Ceballos, Curtis, Place, and Anderson (1984). Hence, comfort temperatures may be achieved by the proper application of passive cooling systems. However, energy can also be saved if an air conditioning unit is used Shaviv (1989). The reason for this is that in summer, heavy external walls delay the heat transfer from the outside into the inside spaces. Moreover, if the building has a lot of internal mass the increase in the air temperature is slow. This is because the penetrating heat raises the air temperature as well as the temperature of the heavy thermal mass. The result is a slow heating of the building in summer as the maximal inside temperature is reached only during the late hours when the outside air temperature is already low. The heat flowing from the inside heavy walls could be reduced with good ventilation in the evening and night. The capacity to store energy also helps in winter, since energy can be stored in walls from one sunny winter day to the next cloudy one. However, the admission of daylight into buildings alone does not guarantee that the design will be energy efficient in terms of lighting. In fact, the design for increased daylight can often raise concerns relating to visual comfort (glare) and thermal comfort (increased solar gain in the summer and heat losses in the winter from larger apertures). Such issues will clearly need to be addressed in the design of the window openings, blinds, shading devices, heating system, etc. In order for a building to benefit from daylight energy terms, it is a prerequisite that lights are switched off when sufficient daylight is available. The nature of the switching regime; manual or automated, centralized or local, switched,

stepped or dimmed, will determine the energy performance. Simple techniques can be implemented to increase the probability that lights are switched off Shaviv (1989). These include:

- Making switches conspicuous and switching banks of lights independently
- Loading switches appropriately in relation to the lights
- Switching banks of lights parallel to the main window wall

There are also a number of methods, which help reduce lighting energy use, which, in turn, relates to the type of occupancy pattern of the building Shaviv (1989). The light-switching options include:

- Centralized timed off (or stepped)/manual on
- Photoelectric off (or stepped)/manual on
- Photoelectric and on (or stepped), and photoelectric dimming
- Occupant sensor (stepped) on/off (movement or noise sensor)

Likewise, energy savings from the avoidance of air conditioning can be very substantial. Whilst day-lighting strategies need to be integrated with artificial lighting systems in order to become beneficial in terms of energy use, reductions in overall energy consumption levels by the employment of a sustained program of energy consumption strategies and measures would have considerable benefits within the buildings sector. The perception is often given however that rigorous energy conservation as an end in itself imposes a style on building design resulting in a restricted aesthetic solution. It would perhaps be better to support a climate-sensitive design approach that encompasses some elements of the pure conservation strategy together with strategies, which work with the local ambient conditions making use of energy technology systems, such as solar energy, where feasible. In practice, low-energy environments are achieved through a combination of measures that include:

- The application of environmental regulations and policy
- The application of environmental science and best practice
- Mathematical modeling and simulation
- Environmental design and engineering
- Construction and commissioning
- Management and modifications of environments in use

While the overriding intention of passive solar energy design of buildings is to achieve a reduction in purchased energy consumption, the attainment of significant savings is in doubt. The non-realization of potential energy benefits is mainly due to the neglect of the consideration of post-occupancy user and management behavior by energy scientists and designers alike. Calculating energy inputs in agricultural production is more difficult in comparison to the industry sector due to the high number of factors affecting agricultural production. However, considerable studies have been conducted in different countries on energy use in agriculture **(**Singh, 2000; CAEEDAC, 2000; Yaldiz et al. 1993); Dutt, 1982; Baruah, 1995; Thakur and Mistra, 1993) in order to quantify the influence of these factors.

Sustainable Development

Sustainable energy is the energy that, in its production or consumption, has minimal negative impacts on human health and the healthy functioning of vital ecological systems, including the global environment. It is an accepted fact that renewable energy is a sustainable form of energy, which has attracted more attention in recent years. Increasing environmental interest, as well as economic consideration of fossil fuel consumption and a high emphasis on sustainable development for the future, helped to bring the great potential of renewable energy into focus Wu, and Boggess (1999)**.** Nearly a fifth of all global power is generated by renewable energy sources, according to a new book published by the Organisation for Economic Co-operation and Development (OECD) / International Energy Association (IEA) OECD/IEA (2004). ‘‘Renewables for power generation: status and prospects’’ claims that, at approximately 20%, renewables are the second largest power source after coal (39%) and ahead of nuclear (17%), natural gas (17%), and oil (8%) respectively. From 1973-2000 renewables grew at 9.3% a year and it is predicted that this will increase by 10.4% a year by 2010. Wind power grew fastest at 52% and will multiply seven times by 2010, overtaking biopower and hence helping reduce greenhouse gases, GHGs, and emissions to the environment.

RESULTS AND DISCUSSIONS

The availability of data on solar radiation is a critical problem. Even in developed countries, very few weather stations have been recording detailed solar radiation data for a period of time long enough to have statistical significance. Solar radiation arriving on earth is the most fundamental renewable energy source in nature. It powers the bio-system, ocean, and the atmospheric current system and affects the global climate. Reliable radiation information is needed to provide input data in modeling solar energy devices and a good database is required in the work of energy planners, engineers, and agricultural scientists. In general, it is not easy to design solar energy conversion systems when they have to be

installed in remote locations. First, in most cases, solar radiation measurements are not available for these sites. Second, the radiation nature of solar radiation makes the computation of the size of such systems difficult. While solar energy data are recognized as very important, their acquisition is by no means straightforward. The measurement of solar radiation requires the use of costly equipment such as pyrheliometers and pyranometers. Consequently, adequate facilities are often not available in developing countries to mount viable monitoring programs. This is partly due to the equipment cost as well as the cost of technical manpower. Several attempts have, however, been made to estimate solar radiation through the use of meteorological and another physical parameter in order to avoid the use of an expensive network of measuring instruments.

A sustainable energy system includes energy efficiency, energy reliability, energy flexibility, fuel poverty, and environmental impacts. A sustainable biofuel has two favourable properties, which are the availability of renewable raw material, and its lower negative environmental impact than that of fossil fuels. Global warming, caused by CO2 and other substances, has become an international concern in recent years. Protect forestry resources, which act as major absorbers of CO2, by controlling the ever-increasing deforestation and the increase in the consumption of wood fuels, such as firewood and charcoal, is, therefore, an urgent issue. Given this, the development of a substitute fuel for charcoal is necessary. Briquette production technology, a type of clean coal technology, can help prevent flooding and serve as a global warming countermeasure by conserving forestry resources through the provision of a stable supply of briquettes as a substitute for charcoal and firewood.

District Heating (DH), also known as community heating can be a key factor to achieve energy savings, reducing CO2 emissions and at the same time providing consumers with a high-quality heat supply at a competitive price. Generally, DH should only be considered for areas where the heat density is sufficiently high to make DH economical. In countries like Denmark for example, DH may today be economical even to new developments with lower density areas, due to the high level of taxation on oil and gas fuels combined with the efficient production of DH.

Platinum is a catalyst for fuel cells and hydrogen-fuelled cars presently use about two ounces of the metal. There is currently no practicable alternative. Reserves are in South Africa (70%), and Russia (22%). Although there are sufficient accessible reserves in South Africa to increase supply by up to 5% per year for the next 50 years, there are significant environmental impacts associated with its mining and refining, such as groundwater pollution and atmospheric emissions of sulfur dioxide ammonia, chlorine, and hydrogen chloride.

Hydrogen is now beginning to be accepted as a useful form for storing energy for reuse on, or for export off, the grid. Clean electrical power harvested from wind and wave power projects can be used to produce hydrogen by electrolysis of water. Electrolyzers split water molecules into their constituent parts: hydrogen and oxygen. These are collected as gases; hydrogen at the cathode and oxygen at the anode. The process is quite simple. Direct current is applied to the electrodes to initiate the electrolysis process. The production of hydrogen is an elegant environmental solution. Hydrogen is the most abundant element on the planet, it cannot be destroyed (unlike hydrocarbons) it simply changes state (water to hydrogen and back to water) during consumption. There is no CO or CO2 generation in its production and consumption and, depending upon methods of consumption, even the production of oxides of nitrogen can be avoided too. However, the transition will be very messy and will take many technological paths to convert fossil fuels and methanol to hydrogen, build hybrid engines, and so on. Nevertheless, the future of hydrogen fuel cells is promising. Hydrogen can be used in internal combustion engines, fuel cells, turbines, cookers gas boilers, roadside emergency lighting, traffic lights, or signaling where noise and pollution can be a considerable nuisance, but where traffic and pedestrian safety cannot be compromised.

Water is the most natural commodity for the existence of life in remote desert areas. However, as a condition for settling and growing, the supply of energy is the close second priority. The high cost and the difficulties of mains power line extensions, especially to a low-populated region can focus attention on the utilization of different and more reliable and independent sources of energy like renewable wind energy. Accordingly, the utilization of wind energy, as a form of energy, is becoming increasingly attractive and is being widely used for the substitution of oil-produced energy, and eventually to minimize atmospheric degradation, particularly in remote areas. Indeed, the utilisation of renewables, such as wind energy, has gained considerable momentum since the oil crises of the 1970s. Wind energy, though site-dependent, is non-depleting, non-polluting, and a potential option of an alternative energy source. Wind power could supply 12% of global electricity demand by 2020, according to a report by the European Wind Energy Association and Greenpeace.

The challenge is to match leadership in GHG reduction and production of renewable energy with developing a major research and manufacturing capacity in

environmental technologies (wind, solar, fuel cells, etc.). More than 50% of the world's area is classified as arid, representing the rural and desert parts, which lack electricity and water networks. The inhabitants of such areas obtain water from borehole wells by means of water pumps, which are mostly driven by diesel engines. Diesel motors are associated with maintenance problems, high running costs, and environmental pollution. Alternative methods are pumping by photovoltaic (PV) or wind systems. At present, renewable sources of energy are regional and site-specific. It has to be integrated in the regional development plans.

CONCLUSION AND RECOMMENDATIONS

Conclusion

There is strong scientific evidence that the average temperature of the earth's surface is rising. This is a result of the increased concentration of carbon dioxide and other GHGs in the atmosphere as released by burning fossil fuels. This global warming will eventually lead to substantial changes in the world's climate, which will, in turn, have a major impact on human life and the built environment. Therefore, the effort has to be made to reduce fossil energy use and to promote green energy, particularly in the building sector. Energy use reductions can be achieved by minimizing the energy demand, rational energy use, recovering heat, and the use of more green energy. This study was a step towards achieving this goal. The adoption of green or sustainable approaches to the way in which society is run is seen as an important strategy in finding a solution to the energy problem. The key factors to reducing and controlling CO2, which is the major contributor to global warming, are the use of alternative approaches to energy generation and the exploration of how these alternatives are used today and may be used in the future as green energy sources. Even with modest assumptions about the availability of land, comprehensive fuel-wood farming programs offer significant energy, economic and environmental benefits. These benefits would be dispersed in rural areas where they are greatly needed and can serve as linkages for further rural economic development. The nations as a whole would benefit from savings in foreign exchange, improved energy security, and socio-economic improvements. With a nine-fold increase in the forest – plantation cover, a nation's resource base would be greatly improved. The international community would benefit from pollution reduction, climate mitigation, and the increased trading opportunities that arise from new income sources. The non-technical issues, which have recently gained attention, include (1) Environmental and ecological factors, e.g., carbon sequestration, reforestation, and revegetation. (2) Renewables as a CO2-neutral replacement for fossil fuels. (3) Greater recognition of the importance of renewable energy, particularly modern biomass energy carriers, at the policy and planning levels. (4) Greater recognition of the difficulties of gathering good and reliable renewable energy data, and efforts to improve it. (5) Studies on the detrimental health efforts of biomass energy particularly from traditional energy users.

Recommendations

The following are recommended:

• Launching of public awareness campaigns among local investors', particularly small-scale entrepreneurs and end users of RETs to highlight the importance and benefits of renewable, particularly solar, wind, and biomass energies.

● Amendment of the encouragement of investment act, to include further concessions, facilities, tax holidays, and preferential treatment to attract national and foreign capital investment.

● Allocation of a specific percentage of soft loans and grants obtained by governments to augment budgets of (R & D) related to the manufacturing and commercialization of RETs.

● Governments should give incentives to encourage the household sector to use renewable energy instead of conventional energy.

● Execute joint investments between the private sector and the financing entities to disseminate the renewable with technical support from the research and development entities.

● Availing of training opportunities to personnel at different levels in donor countries and other developing countries to make use of their wide experience in the application and commercialization of RETs, particularly renewable energy.

● The governments should play a leading role in adopting renewable energy devices in public institutions, e.g., schools, hospitals, government departments, police stations, etc., for lighting, water pumping, water heating, communication, and refrigeration.

● Encouraging the private sector to assemble, install, repair, and manufacture renewable energy devices via investment encouragement and more flexible licensing procedures.

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REFERENCES

ASHRAE. Energy efficient design of new building except new low-rise residential buildings, BSRIASHRAE proposed standards, 90-2P-1993, alternative GA. American Society of Heating, Refrigerating, and Air Conditioning Engineers Inc., USA. 1993.

ASHRAE. Commercial/Institutional Ground Source Heat Pump Engineering Manual. American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc. Atlanta, GA: USA, 1995.

Baruah, D. Utilization pattern of human and fuel energy in the plantation. Journal of Agriculture and Soil Science. 1995; 8(2), 189-92.

Bos, E.; My, T.; Vu, E.; Bulatao, R. World population projection: 1994-95, Baltimore and London: World Bank by the John Hopkins University Press, 1994.

CAEEDAC. A descriptive analysis of energy consumption in agriculture and food sector in Canada. Final Report, February, 2000.

Cantrell, J.; Wepfer, W. Shallow ponds for dissipation of building heat: A case study. ASHRAE Transactions, 1984, 90 (1), 239-246.

Duchin, F. Global scenarios about lifestyle and technology, the sustainable future of the global system. Tokyo: United Nations University, 1995.

Dutt, B. Comparative efficiency of energy use in rice production. Energy, 1982, 6:25.

Givoni, B. Climate consideration in building and urban design, New York: Van Nostrand Reinhold, 1998.

Kammerud, R.; Ceballos, E.; Curtis, B.; Place, W.; Anderson, B. Ventilation cooling of residential buildings. ASHRAE Trans: 90 Part 1B, 1984.

Kavanaugh, S.; Rafferty, K. Ground source heat pumps. design of geothermal systems for commercial and institutional buildings. American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc. Atlanta, GA, USA, 1997.

OECD/IEA. Renewables for power generation: status and prospect, UK, 2004.

Rees, W.E. The built environment and the ecosphere: a global perspective. Building Research and Information. 1997, 27(4), 206-20.

Shaviv, E. The influence of the thermal mass on the thermal performance of buildings in summer and winter. In: Steemers, T.C.; Palz, W.; Editors. Science and Technology at the service of architecture. Dordrecht: Kluwer Academic Publishers, 1989, 470-472.

Singh, J. On-farm energy use pattern in different cropping systems in Haryana, India, Germany: International Institute of Management-University of Flensburg, Sustainable Energy Systems and Management, Master of Science, 2000.

Thakur, C.; Mistra, B. Energy requirements and energy gaps for produc.ion of major crops in India. Agricultural Situation of India. 1993; 48, 665-89.

The United Nations Framework Convention on Climate Change (UNFCCC). The draft of the Copenhagen Climate Change Treaty, 2009, 3-181.

United Nations. World urbanization project: the 2002 revision, New York: The United Nations Population Division, 2003.

Wu, J.; Boggess, W. The optimal allocation of conservation funds. Journal Environmental Economic Management. 1999; 38.

Yaldiz, O.; Ozturk, H.; Zeren, Y. Energy usage in production of field crops in Turkey. In: 5th International Congress on Mechanisation and Energy Use in Agriculture. Turkey: Kusadasi, 1993, 11-14.

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Research Article

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Knowledge, Awareness, and Practice on Natural Disasters among Residents of San Juan Baño Arayat, Pampanga

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ABSTRACT

The study aimed to find out the knowledge, awareness, and practice of natural disasters among the selected residents of Barangay San Juan Baño, Arayat, Pampanga. National Integrated Climate Change Database Information and Exchange System, Climate change is the long-term change in climate (i.e., temperature, rainfall, extreme weather, etc.). Scientific studies indicate that most global warming in recent decades is due to the great concentration of greenhouse gases (GHG) in the atmosphere, which is released mainly as a result of human activities. Causing numerous natural disasters affecting many communities. This study was conducted to determine the awareness of San Juan Baño, Arayat, Pampanga to natural disasters, specifically typhoons and landslides. The study was conducted on randomly selected residents of San Juan Baño, Arayat, Pampanga. A questionnaire survey was prepared to determine residents' awareness of natural disasters. A descriptive analysis of residents' responses was used to analyze the data. Based on the analyzed data, it can be mentioned that the majority of the respondents were aware of the following natural disasters such as drought, earthquakes, landslides, floods, extreme heat, wildfires, typhoons, hurricanes, viral epidemics, pest attacks and volcanic eruptions. In terms of respondents' awareness of typhoons, the majority believe that San Juan Baño, Arayat, Pampanga are prone to typhoons. In terms of Landslides, most of the responses fall under the "Agree" section that San Juan Baño, Arayat, Pampanga is prone to landslides causing road destruction, crop damages, destroying houses, power interruption, and death of family members.

INTRODUCTION

Climate change, which is a long-term change in temperature and typical weather patterns in an area, may make weather patterns less predictable. The entire world or a single area may be impacted by climate change. Fossil fuel consumption, including the use of coal, natural gas, and oil, is a significant factor in the current climate change. Burning these substances releases greenhouse gases into the atmosphere (National Geographic Society, 2019).

It is generally known that the Philippines, which ranks third out of 173 countries in terms of disaster risk, is incredibly susceptible to natural disasters (United Nations University- Institute for Environment and Human Security, 2011). The potential for loss of life, a reduction in health and standard of living, and potential harm to resources and services as a result of an already existing natural hazard are all factors that are taken into account

when calculating disaster risk (Tyson Brown, National Geographic Society).

Among the most commonly observed media headlines globally are tragic accounts of natural calamities like drought, heat waves, storm/cyclones, floods, and landslides. Since the 1970s, the Emergency Occurrences Database (EM-DAT) of the Center for Research on the Epidemiology of Disasters (CRED) has been keeping tabs on the losses and damages caused by disaster occurrences in various nations, as well as the expenses of economic harm. According to EM-DAT data (Warner and van der Geest, 2013) severe drought and storm disasters occurred between 1900 and 2014 in the least developed and less developing countries, where the population is less equipped to cope.

Within San Juan Baño Arayat Pampanga, there are various eco-tourism spots such as Tree House, Mt. Arayat National Park, 100 steps, and the famous view of Mt. Arayat. Therefore; this study aimed to assess the knowledge, awareness, and practice of the selected residents of San Juan Baño, Arayat, Pampanga specifically on typhoons and landslides which are prone and dramatically visible within the said Barangay.

MATERIALS AND METHODS

The locale of the study was conducted in Barangay San Juan Baño, Arayat Pampanga San Juan Baño.

The research was conducted using a quota random sample method of every household in San Juan Baño, Arayat Pampanga. Quota random selection will be conducted among all households in the Barangay who are 18 years old or older. The said Barangay will be presented with a list of the households' respondents.

There are 7 purok and 1,839 total households in the Barangay, the respondents of this study are thirty percent (%) of the 553 household heads in barangay San Juan Baño, Arayat Pampanga and the barangay officials. This study used the Quota Random Sampling Method in determining the sample.

The primary data will be obtained from 553 households of Barangay San Juan Baño Arayat, Pampanga, while the secondary data will come from barangay officials. Interview questions and face-to-face surveys will be used to gather data. Every question in the survey will be analyzed and interpreted. Each response on the questionnaire will be assigned a numerical value, and the computed mean will reveal the respondents' level of knowledge, awareness, and practice.

RESULTS AND DISCUSSION

General Knowledge and Awareness of Natural Disasters

In average (Table 1), the results of the study showed that 66.23 % of the total respondents are aware and knowledgeable on different disasters such as: Drought; earthquakes, landslides, floods, typhoons, pest attacks and etc. This means that the majority of respondents are knowledgeable of the above-mentioned natural disasters within the environment. The majority of people relate to disasters through personal experience, knowledge, the balance of benefits and costs, and trust in other societal elements, according to Aekerlof et al. (2006).

This holds true for Ahmad et al. (2017) study, which demonstrates disaster awareness among the pupils in the Ganderbal region based on an analysis of the data gathered, and shows that every student included in the sample has some understanding of catastrophes.

People are seriously at risk from disasters like floods, earthquakes, and fires, among others. One strategy for minimizing the effects of disasters is disaster education, which includes instruction on preparedness, mitigation, and risk management measures (Smith, 1993); (Mulyasari et al, 2011) a greater comprehension of disaster knowledge and awareness would promote advancements in disaster management planning.

For individuals to be able to handle the negative effects of natural and man-made disasters, it is essential to raise their awareness of and attitude toward such events. We must acquire knowledge, skills, and values at all levels if we are to be properly informed about disasters and prepared for them. The goal of disaster education, according to the 2005-2015 Hyogo Framework for Action (Basabe, 2013), is "to establish a culture of safety and resilience at all levels," in order to lessen the negative social and economic effects of hazards.

Table 1: General Knowledge and Awareness of Natural Disasters

Awareness	Yes (%)	No (%)	I Don't Know (%)
Drought	85.53	9.04	5.42
Earthquake	78.3	13.92	7.78
Landslide	70.52	20.07	9.4
Flood	75.95	15.01	9.04
Extreme Heat	65.1	24.41	10.49
Wildfire	50.27	22.42	27.31
Typhoon	75.59	16.46	7.96
Hurricane	53.16	20.43	26.4
Viral epidemic	50.81	27.31	21.88
Pest attacks	53.89	28.21	17.9
Volcanic eruption	69.44	19.17	11.39
Average	66.23%	19.68%	14.09%

Knowledge and Awareness of Typhoon

Respondents from Brgy. San Juan. Bano Arayat agrees that their Barangay, the Pampanga, and the Philippines are prone to Typhoon (Table 2). They are also aware that typhoons can cause landslides, damage crops, destroy houses, spread illness, diseases, power interruption, and possibly death. With an average of 95.49% awareness of typhoon causes.

Effective risk communication methods must take into account the public's awareness of dangers from natural disasters like typhoons. Recent studies have emphasized more and more how important it is for people to understand natural disasters and how risky they are. According to Chinese studies, people who live in typhoon-prone areas are more conscious of the risk of a disaster than the general population. Residents' risk awareness and preparedness knowledge were also favorably correlated with their coping strategies. People with prior experience in southern Thailand have high risk perceptions, which are manifested as a heightened fear of typhoons and a propensity to take impending disasters seriously, according to a study.

Typhoons are considered to be extremely devastating natural hazards worldwide. There are seven to eight typhoons on average landing in the Philippines each year, which makes the Philippines one of the countries that were hit most frequently by typhoons.

Studies have reported that the impact of a typhoon disaster depends on the intensity and strength of the typhoon, which is also linked with the precautionary concerns and knowledge of local residents. Lack of attention to disaster warnings might lead to significant damage and bring risks of typhoon-related injuries even facing a low-risk typhoon, which suggests a need to pay attention to typhoon disaster prevention, regardless of the intensity of storms.

Additionally, data on disaster awareness reveals that 93.3% of respondents give typhoon disaster avoidance a lot of thought. And among the respondents, 89.7% believed that training on preventing typhoon disasters was important, with 18.1% indicating a considerable need for it; 83.2% said they would participate in a formal program (Torani et al. 2019).

Knowledge and Awareness of Landslides

The Philippines,Pampanga, and Brgy San Juan Bano were also prone to Landslides as evidenced by the respondent's awareness of Landslides garnering 90.47%. It was also shown in Table 3 that landslides can cause road destruction, and community and houses damages, which may also cause the death of a family member.

Table 2: Knowledge and Awareness of Typhoon

Typhoon knowledge and awareness	AGREE (%)	DISAGREE (%)
Philippines is prone to typhoons.	96.75	3.25
Pampanga is prone to typhoons.	94.39	5.61
Our Barangay is prone to typhoons	94.75	5.25
I am aware of the weather forecast symbols/terms used by PAGASA for appropriate response.	95.11	4.89
Typhoons can cause landslides.	96.38	3.62
Typhoons can damage crops.	95.3	4.7
A typhoon can destroy houses and buildings.	96.02	3.98
A typhoon can spread disease and illness.	95.12	4.88
A typhoon can result in the death of a family member.	94.04	5.96
Typhoons can cause power interruption/ outrages.	95.47	4.52
Climate change causes an increasing number of typhoons.	96.39	3.61
PAGASA and NDRRMC disseminate Typhoon Public Information via radio, social media, television and SMS blasts	96.2	3.8
Average	95.49%	4.51%

Source of Information on Natural Disasters

Shown in Table 4 is how respondents get information about an approaching typhoon and the danger of a landslide in their barangay. Out of the five hundred fifty-three (553) respondents, 5% answered Newspaper, 37.97% answered Television, 15.55% answered Barangay announcements, 7.05% answered Radio, 5.42% answered Cellphone, 17.54% answered social media, 7.05% answered Friends and 4.52% answered others. The majority of the respondents were under Television with a total of 210 counts. Based on Leelawat et al., 2013, study found that the most preferred method for officials to announce disaster warnings was TV for any period of time.

Table 3: Knowledge and Awareness of Landslides

Landslides knowledge and awareness	AGREE (%)	DISAGREE (%)
The Philippines is prone to landslides.	95.66	4.34
Pampanga is prone to landslides.	87.53	12.47
Our Barangay is prone to landslides.	86.26	13.74
Landslides are one of the causes of Typhoons.	91.14	8.86
Landslides are caused by earthquakes.	88.24	11.76
Landslides can cause damage to communities.	91.32	8.68
Landslides can cause damage to roads.	91.32	8.68
Landslides can destroy houses and buildings.	92.05	7.95
A landslide can result in the death of a family member.	88.42	11.57
Landslide can cause power interruption/ outrages.	89.69	10.31
PAGASA, PHIVOLCS and NDRRMC disseminate Landslide Public Information via radio, social media, television and SMS blasts.	93.49	6.51
Average	90.47%	9.53%

Preparedness in Case of an Emergency

A total of 45.99% of the respondent only prepared emergency activities such as Disaster supply kits, stored food and water, flashlights and batteries, medical supplies, and other essential emergency kits. And about 29.73% are planning to and are in the process of preparing these materials as shown in Table 5.

Preparedness of a Barangay in an event of a disaster

A total of 90.47% believed that the barangay should have evacuation centers, Health centers, trained personnel on first aid, Disaster plans, and licensed medical professionals.

Table 4: Source of Information on Natural Disasters

Source of information	Percentage (%)
Newspaper	5.00
Television	37.97
Barangay Announcements/Seminar	15.55
Radio	7.05
Telephone	5.42
Social media	17.54
Friends	7.05
Others	4.52

Table 5: Preparedness in case of an Emergency

Have you prepared the following in case of an emergency or disaster?	YES (%)	NO (%)	ON PROCESS (%)
Safe escape plan	49.73	13.38	36.89
Designated meeting place after Disaster occurrences	48.46	26.94	24.59
Disaster supply kit	47.2	21.7	31.1
Stored food and water	45.75	24.77	29.48
Stored batteries and flashlights	39.78	28.03	32.19
Stored medical supplies	43.94	27.12	28.93
Stocked up on essential hygiene and sanitation supplies	44.67	29.48	25.86
Money	55.33	19.35	25.32
Emergency Hotlines	46.65	27.31	26.04
Plan for Evacuation	38.34	24.77	36.89
Average	45.99	24.29	29.73

Preparedness of a Barangay in an event of a disaster

In terms of willingness, a total of 42.72% of the respondents are willing to participate as volunteers with the LGU, Red Cross, and Neighboring groups in case of emergencies. 35.17% are partially and are in the process of volunteering.

Implications

The knowledge, awareness and practice of natural disasters among the selected residents of barangay San Juan Baño Arayat Pampanga about typhoons and landslides. In conclusion, the respondents were knowledgeable and aware of natural disasters. Results

show that Barangay San Juan Baño is involved in actions that specifically contribute to practices and preparedness for natural disasters. Therefore, strict implementation of rules and regulations is highly required, and cooperation and participation in every seminar conducted in the barangay about natural disaster preparedness programs with the collaboration of the LGU. It also shows the value of researching local knowledge, practices, and understanding of natural disasters. Similar findings were also found in Govindasamy's study on residents' knowledge of landslides Habibah and Vijaya, 2012. An investigation of residents' knowledge of landslide disaster issues revealed that they gave their knowledge an average score of 63% out of 100%, which is a reasonable result for locals.

Table 6: Preparedness of a Barangay in the event of a disaster

Barangay Preparedness in the Event of a Disaster	AGREE (%)	DISAGREE (%)
There is a designated Evacuation center for public safety in the barangay	99.10	0.9
Health center is available for medical purposes.	99.46	0.54
Barangay Hall and covered courts are available as an	96.39	3.61
There are trained personnel about the basics of first aid.	94.03	5.97
Disaster plans are well-designated, properly coordinated and disseminated.	94.21	5.79
There are trained and licensed medical personnel to treat illness/injuries.	95.3	4.7
Average	90.47	9.53

It matters a lot how households react to natural calamities. According to Kapucu (2008), if people aren't ready, then no one is. Sutton and Tierney (2016), provided an overview of the critical level of preparation in a home. These metrics include risk awareness, written and informal agreements, and reaction plans. They also include medical resources, life safety and property protection, and the start of the healing process. In addition, Levac et al. (2012) evaluated the literature on disaster preparedness and found that people and families are motivated to make emergency plans based on their socioeconomic and demographic characteristics.

Table 7: Willingness of the Household in case of an Emergencies

Our household would be willing to:	YES (%)	NO (%)	ON PROCESS (%)
Volunteer during a disaster event	57.69	20.43	21.88
Volunteer with the LGU	30.02	22.78	47.2
Volunteer with Red Cross	26.4	22.06	51.54
Volunteer with a neighborhood group	56.78	23.15	20.07
Average	**42.72**	**22.11**	**35.17**

Furthermore, it can be concluded that the residents in Barangay San Juan Baño, Arayat, Pampanga are highly prepared in case a disaster occurs particularly a typhoon & landslide. Preparedness is the level of readiness based on undergone planning, training, and exercises to respond to an emergency (Col, 2007). A well-prepared home may significantly lessen the effects of disasters (Leelawat, et al, 2013). It is believed that strengthening local preparation is an essential part of an effective reaction and recovery (Levac J, et al., 2012). Investigating a household's preparedness for dealing with natural disasters is vital. When a crisis happens, families must be accountable for own needs as well as those of their neighbors (Basabe, 2013).

It can be inferred that the respondents are ready to help in the event of a crisis, particularly in the LGU. The government is crucial in aiding the community's preparedness for some calamities. The fundamental duties of the local government in assisting the community during a disaster were articulated by Kusumasari, et al. (2010). On the other hand, people' desire to assist government agencies with disaster prevention, self-rescue and mutual rescue activities, and involvement in neighborhood catastrophe reduction efforts. The public's willingness to help the government after a disaster is generally positive, and participants are generally willing to provide disaster aid.

Recommendations

The study recommends providing seminars and alert systems especially on natural disasters for the entirety of the residents of barangay San Juan Baño Arayat Pampanga as their target audience for the community to gain more knowledge about natural disasters.

Due to the results obtained from the study, the researcher recommends to do the following suggestion:

- Conducting and providing seminars on alert systems checking and monitoring of Mount Arayat through the collaboration of the MDRRMO and PENRO.
- Preparedness to establish safe areas in barangay for different types of emergencies.
- Show each family member how and where to shut off utilities (water, gas, electricity).
- Learn about the signs and warning systems in the community (sirens, text messages, symbols/terms used in weather forecasts).

REFERENCES

Basabe, Pedro. Hyogo Framework for Action 2005–2015. *Encyclopedia of Natural Hazards*. 2013. DOI: 10.1007/978-1-4020-4399-4_180

Habibah Lateh, Vijaya Govindasamy. Residents awareness towards landslide disaster In Penang, *International Journal of Scientific and Engineering Research*. *International Journal of Scientific & Engineering Research*. 2012, 3(4), 1-7.

Kusumasari, B.; Alam, Q.; Siddiqui, K. Resource capability for local government in managing disaster. *Disaster Prevention and Management: An International Journal*. 2010, 19(4), 438–451. https://doi.org/10.1108/09653561011070367

Leelawat, N.; Mateo, C. M. R.; Gaspay, S. M.; Suppasri, A.; Imamura, F. Filipinos' views on the disaster informa-tion for the 2013 Super Typhoon Haiyan in the Philippines. *International Journal of Sustainable Future for Human Security*.2014, 2(2), 16-28.

Levac, J.; Toal-Sullivan, D.; O'Sullivan, T.L. Household emergency preparedness: a literature review. *J Community Health*. 2012, 37(3):725-33. doi: 10.1007/s10900-011-9488-x. PMID: 21984406.

Mulyasari, F.; Takeuchi, Y.; Shaw, R. Implementation toolsfor disaster education. *Commun Environ Disaster RiskManag*. 2011, 7, 137–51.

Smith, K. Environmental hazards: assessing risk andreducing disaster. London: Routledge publisher, 1993.

Torani, S.; Majd, P.M.; Maroufi, S.S.; Dowlati, M.; Sheikhi, R.A. The importance of education on disasters and emergencies: A review article. *J Edu Health Promot*. 2019, 8:85.

Sutton, J.N.; Tierney, K.J. Disaster preparedness: concepts, guidance, and research. Report prepared for the Fritz Institute Assessing Disaster Preparedness Conference Sebastopol, California, November 3 and 4, 2006, Tyson Brown, National Geographic Society.

Warner, K.; van der Geest, K. Loss and damage from climate change: local-level evidence from nine vulnerable countries. *Int. J. Global Warming*. 2013, 5 (4), 367–386.

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Leaf Litter Arthropods in the Gallery Forest of Jos Zoological Garden, Jos, Plateau State, North Central Nigeria

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ABSTRACT

Arthropods are an important and the most diverse component of terrestrial ecosystems and they occupy a wide variety of functional niches. Consequently, during the rainy season of September to October 2019, a study on the species composition of leaf litter arthropods in relation to some soil physicochemical parameters was conducted in the Gallery forest of the Jos Zoological Garden. Arthropods found in leaf litter were gathered using pitfall traps. Standard techniques were used to determine the physic-chemical characteristics of the soil. A total of 965 arthropods were collected, representing 4 Classes, 12 Orders, 30 Families, 36 Genera, and 39 Species. There was a significant difference ($P<0.05$) in the abundance of leaf litter arthropods in comparison to arthropod taxa, with Insecta accounting for 89.01% of the total, followed by Hymenoptera (48.08%), Formicidae (47.56%), and Camponotus pennsylvanicus (40.41%) as the most abundant taxa. The amount of organic matter, pH, temperature, and soil moisture all have an impact on the diversity and quantity of leaf litter arthropods. The quantity and variety of leaf litter arthropods depend on the availability of food, suitable microhabitats, and favorable soil conditions. Therefore, it is advised that the management of Jos Zoological Garden prohibit all anthropogenic activities.

INTRODUCTION

Arthropods are essential components of the marine, freshwater, terrestrial, and avian ecosystems (Rupert et al. 2004) and play key roles in food chains, population dynamics, and community structure (Latif et al. 2009). Arthropod species make up over 80 % of all known living animal species, with estimates ranging from 1,170,000 to 5 to 10 million (Odegaard, 2000). Cuticle, a non-cellular substance released by the epidermis, makes up the exoskeletons of arthropods (Rupert et al. 2004). The procuticle is the collective name for the exocuticle, which is made up of chitin and chemically hardened proteins, and the endocuticle, which is made up of chitin and unhardened proteins (Schmidt-Rhaesa et al. 1998). A flexible cuticle covers the joints between limb segments and between body segments (Rupert et al. 2004). A distinguishing characteristic of Ecdysozoa (arthropods, tardigrades, onychophorans, nematodes, and related taxa) is ecdysis or moulting, which characterizes the process of shedding the exterior integument, the cuticle (Schmidt-Rhaesa et al. 1998). Growth, progress toward an adult body plan, and body part regeneration are all facilitated by moulting (Drage, 2016). A few species of crustaceans and insects can reproduce by parthenogenesis, particularly when the conditions are right for a "population explosion." The majority of arthropods, however, reproduce sexually, and parthenogenetic species frequently switch to sexual reproduction when environmental conditions deteriorate (Smith, 2014). According to Rupert et al. (2004), most arthropods lay eggs. Most often, the small nauplius larvae that hatch from crustaceans have three segments and pairs of appendages (Rupert et al. 2004). Arthropods can act as infectious pathogen carriers or vectors. (Duvallet et

al. 2018), yet other arthropod species are crucial to our survival, giving us access to things like food, clothing, medicine, and protection from hazardous critters as well as helping to maintain ecological equilibrium (Myers, 2001). Healthy soil contains leaf litter, dead leaves, twigs, and pieces of bark that have fallen to the ground. This dead organic matter offers a wide variety of creatures the ideal habitat (Lin, 2012). Invertebrates, with arthropods having the biggest abundance, make up the majority of the live organisms found in leaf litter. The need to gather data on the species composition of leaf litter Arthropods in conservation areas like the Gallery Forest of Jos Zoological Garden stems from the fact that sound information on leaf litter composition must be incorporated into management practices if ecosystems are to be managed properly by the next generation.

MATERIALS AND METHODS

Study Area

The investigation was carried out in the Gallery Forest of Jos Zoological Garden from September to October of 2019.

Techniques for Collection, Identification, and Quantification of Arthropods

Twenty pitfall traps were distributed throughout the Gallery Forest of the Jos Zoological Garden. The sampling method involved placing traps at intervals of 50 meters along a transect for a period of 72 hours. Giving all Arthropods an equal chance to be ensnared is the goal. After 72 hours, arthropods were harvested. Arthropods were collected and stored in 70% alcohol and glycerol after being freed of plant detritus. Arthropods were transported to the laboratory for sorting, identifying, and categorization. A colored atlas and identification keys from Castner (2000) and Shattuck (2000) were used to identify, organize, and classify each sample of arthropods into groups, orders, families, genus, and species.

Determination of Soil Physicochemical Parameters

The soil temperature was measured by excavating the ground (approximately 5 cm), inserting a thermometer, waiting 5 minutes, and then taking the measurement. Following weighing and the subsequent calculation, 20 g of soil samples were placed in an ovum at 100°C for 24 hours. The moisture content was then calculated as follows:

$$\% \text{ of soil moisture content} = \frac{W1-W2}{W1} \times 100$$

Where w_1-w_2 is loss in weight; w_1 is initial weight

In a 500 ml beaker, 20 g of processed soil samples were placed. 20ml of distilled water was added to it and stirred; then allowed to stand for 30min. It was occasionally stirred with a glass rod. A calibrated pH meter's electrode was put into the partially settled slurry, and the meter's screen displayed the pH. A modified version of Walkley and Black's (1934) approach was used to calculate the soil organic matter.

Statistical Analyses

R Console software was used to analyze the data (version 3.2.2). The relative abundance of leaf litter arthropods with respect to classes, orders, and families was compared using Pearson's Chi-square test. Statistics were judged to be significant for P-values under 0.05.

RESULTS

In total, 965 arthropods were collected and identified, representing 4 Classes, 12 Orders, 30 Families, 36 Genera, and 39 Species. (Table 1). The most prominent species of identified arthropods were *Camponotus pennsylvanicus*, *Tipula* spp.., and Alphitobius spp (Table 1). As shown in Table 1, the species with the lowest species richness were *Brachycybe* spp., *Gromphadorhina portentosa*, *Blatella lituricollis*, *Clivina impressefrons*, *Galerita* spp., *Podabrus pruinosis*, *Episyrphu*s spp., *Triatoma protracta*, *Triatoma sanguisuga* and *Dipogon subintermedius*. When compared to class, the number of leaf litter arthropods varied significantly ($\chi2$= 2134.3, df = 3, P 0.0001) as shown in Figure 1. As illustrated in Figure 1, the results showed that the class Insecta was the most numerous, with 859 (89.01%). According to Figure 2, the Order Hymenoptera had the most individuals with 464 (48.08%), followed by the Order Coleoptera with 154 (15.95%), and the Order Plasmidesmida with just 1 (0.10%). As a result, there was a significant variation in the number of leaf litter arthropods according to Orders ($\chi2$= 2705.5, df = 12, P 0.0001). As indicated in Figure 3, the Formicidae family had the highest population density with 459 (47.56%) individuals, while the Andrognalidae, Alaberidae, Blatellidae, Cantharidae, Pompilila, Syriphidae, Tenthredinoidea, and Tetrigidae families had the lowest density with 1 (0.10%) each. As a result, there were significant differences in the abundance of leaf litter arthropods according to family ($\chi2$= 6633.6, df = 29, P 0.0001).

Table 1: Species Checklist of Leaf Litter Arthropods from Gallery Forest of Jos Zoological Garden

Class	Order	Family	Common Name	Species	Total	Percent (%)
Arachnida	Aranea	Lycosidae	Wolf spider	*Lycosidae* spp	15	1.55
		Pholcidae	Daddy long legs	*Pholcus phalangioides*	4	0.41
		Sicariidae	Brown recluse spider	*Loxosceles reclusa*	80	8.30
Crustacea	Isopoda	Platyarthridae	Pill bug	*Armadilllidium vulgare*	4	0.41
Diplopoda	Plasmidesmida	Andrognalidae	Feather millipede	*Brachycybe* spp	1	0.10
	Spirostreptida	Spirostreptidae	Giant African millipede	*Archispirostreptus gigas*	2	0.21
Insecta	Blateria	Blaberidae	Madagascar hissing cockroach	*Gromphadorhina portentosa*	1	0.10
		Blatellidae	Blatellid cockroach	*Blatella lituricollis*	1	0.10
	Coleoptera	Carabidae	Ground beetle	*Stenolophus ochropezus*	9	0.93
			Vivid metallic ground beetle	*Chlaenius scapularis*	7	0.73
			Red ground beetle	*Clivina impressefrons*	1	0.10
			False bombardia beetle	*Galerita* spp	1	0.10
		Cantharidae	Soldier beetle	*Podabrus pruinosis*	1	0.10
		Staphylinidae	Devil's coach horse beetle	*Staphylinus olens*	30	3.11
			Rove beetle	*Staphylinus aethiops*	2	0.21
		Tenebrionidae	Darkling beetle	*Alphitobius* spp	103	10.67
	Dermaptera	Anisolabididae	Ring legged earwig	*Euborelia annulipes*	48	4.97
	Diptera	Calliphoridae	Oriental latrine fly	*Chrysomya megacephala*	4	0.41
		Drosophilidae	Vinegar fly	*Drosophila melanogaster*	6	0.62
		Fannidae	Latrine fly	*Fannia scalaris*	12	1.24
		Muscidae	House fly	*Musca domestica*	2	0.21
			Muscid shoot fly	*Antherigona reversura*	2	0.21
			Unidentified	Unidentified	8	0.83
		Syriphidae	Hover fly	*Episyrphus* spp	1	0.10
		Tipulidae	Crane fly	*Tipula* spp	108	11.20
	Hemiptera	Cydnidae	Burrower bug	*Pangaeus bilineatus*	2	0.21
		Nabidae	Damsel bug	*Nabis roseipennis*	2	0.21
		Reduviidae	Western bloodsucking conenose bug	*Triatoma protracta*	1	0.10
			Eastern bloodsucking conenose bug	*Triatoma sanguisuga*	1	0.10
	Hymenoptera	Formicidae	Carpenter ant	*Camponotus pennsylvanicus*	390	40.41
			Sugar ant	*Camponotus consobrinus*	42	4.40
			Slender twig ant	*Tetrasponera allaborans*	2	0.21
			Fire ant	*Solenopsis geminate*	23	2.38
			Mystrium ant	*Mystrium rogeri*	2	0.21
		Pompilila	Spider wasp	*Dipogon subintermedius*	1	0.10
		Tenthredinoidea	Saw fly	*Tenthredo mesomela*	1	0.10
		Vespidae	Paper wasp	*Polistes* spp	3	0.31
	Lepidoptera	Erebidae	Oak moth	*Phoberia atomaris*	4	0.41
	Orthoptera	Gryllidae	Field cricket	*Gryllus campestris*	25	2.60
		Tetrigidae	Black sided pygmy grasshopper	*Tettigidea lateralis*	1	0.10
	Unidentified				12	1.24
				Total	965	
				Percent (%)		100

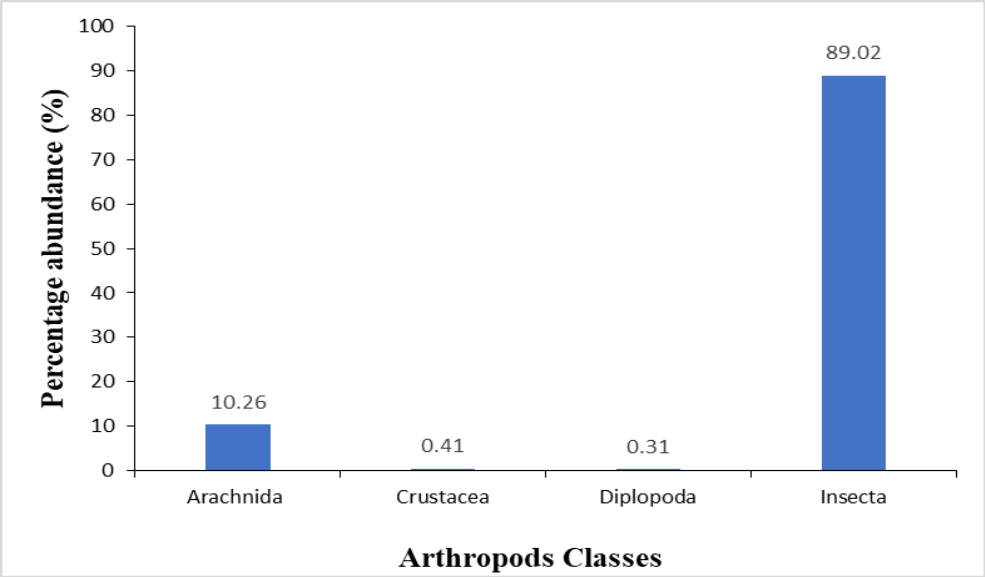

Figure 1: Class-specific percentage abundance of leaf litter arthropods

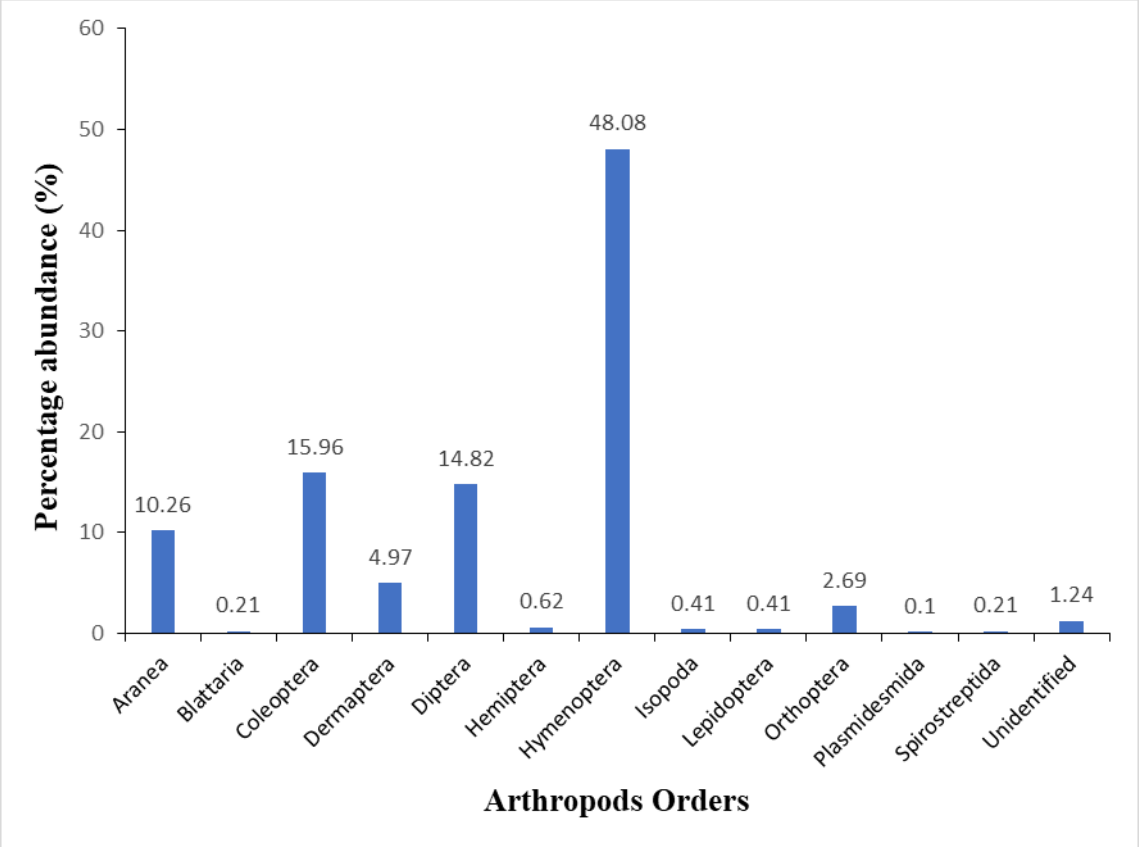

Figure 2: Order-specific percentage abundance of leaf litter arthropods

As demonstrated in Table 2, over the four-week study period, the soil physic-chemical parameters in the Gallery Forest of the Jos Zoological Garden varied over time. The physic-chemical parameters that were recorded and their related abundances are shown in Table 2 in the order that they were recorded. The first measurement was taken at the third collection of leaf litter arthropods, the second measurement at the seventh collection of leaf litter arthropods, and the final measurement at the tenth collection of leaf litter arthropods. When the soil's physic-chemical characteristics were originally measured, they showed a pH of 7.36 (slightly alkaline), a temperature of 22°C, 2.02% organic matter, and a moisture content of 36.70%.

The maximum abundance ever observed was 643 leaf-litter arthropods, which were gathered under all of these conditions. The soil physic-chemical parameters revealed a reduction in the second measurement. It showed that the soil had a pH of 7.01 (slightly alkaline), was 18°C, had 1.75% organic matter, was 24.10% moist, and had 195 leaf litter arthropods in total. These conditions led to the collection of 127 leaf litter arthropods, the lowest abundance ever seen. A total abundance of 965 leaf litter was produced by the soil's mean values for pH, temperature, organic matter, and moisture content, which are 7.11, 20°C, 1.89%, and 27.10%, respectively. As indicated in Table 2, the relationship between soil moisture, soil pH, and the quantity of leaf litter was direct (soil moisture dropped as soil pH declined).

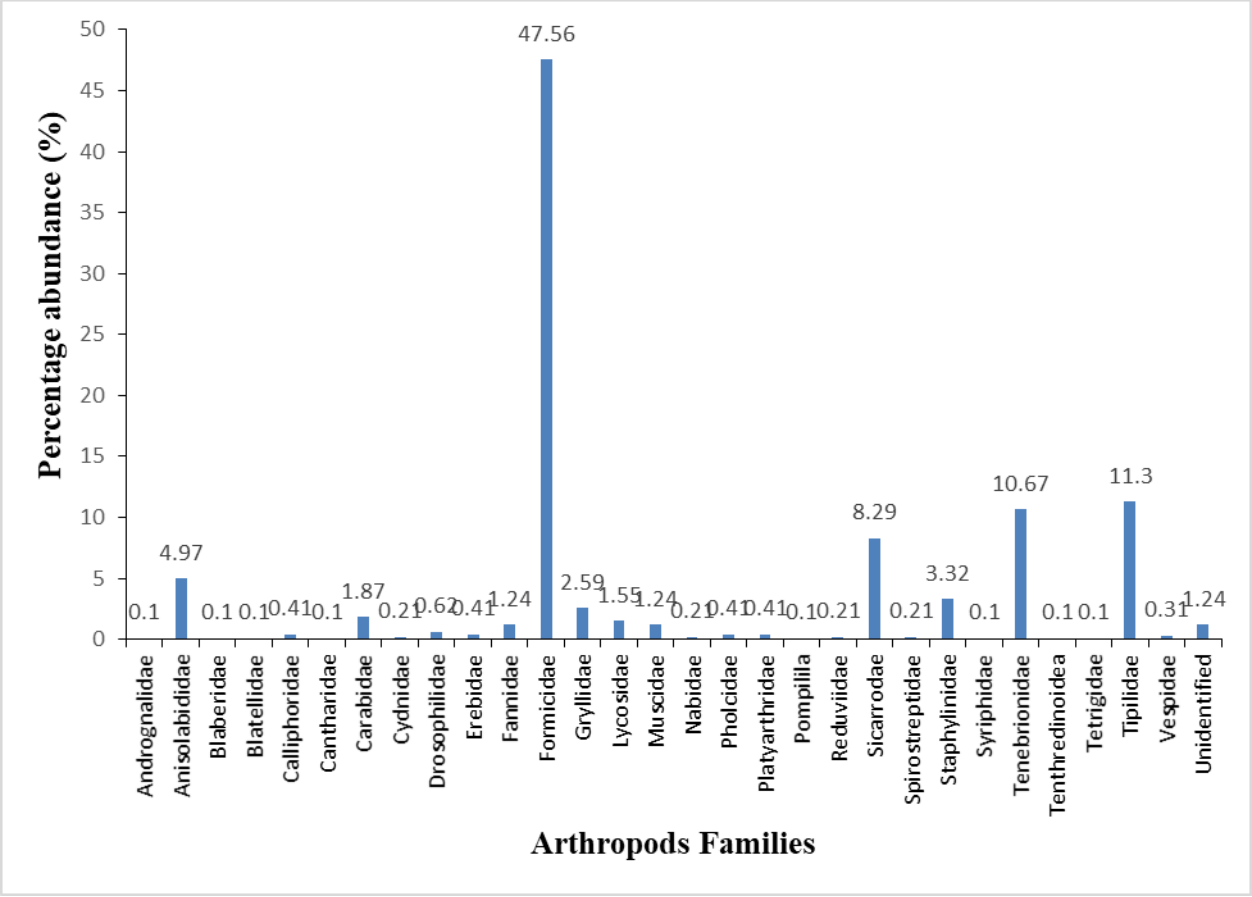

Figure 3: Family-specific percentage abundance of leaf litter arthropods

Table 2: Soil Physicochemical Factors on Abundance of Arthropods in Jos Zoological Garden, Jos.

Mean Soil Physicochemical Factors				
Soil pH	**Soil Temperature (°C)**	**Soil Organic Matter Content (%)**	**Soil Moisture Content (%)**	**Leaf litter Arthropod's Abundance**
7.36	22.00	2.02	36.70	643
7.01	18.00	1.75	24.10	195
6.91	20.00	1.89	20.55	127
Mean=7.11	Mean=20.00	Mean=1.89	Mean=27.10	Total=965

DISCUSSION

Arthropods are essential to the stability and operation of terrestrial ecosystems (Njila et al. 2022). In this study, arthropods that live in leaf litter were classified into four classes, twelve orders, and thirty families. The habitat, microclimate, and food availability in the leaf litter as well as the protection from predators and harsh weather conditions afforded by the leaf litter can be linked to the 36 genera and 39 species that were collected and identified in this study (Table 1). According to Njila et al. (2022) investigation, many arthropods use the leaf litter layer as a habitat because it provides them with food, a refuge from the elements, and protection from predators, all of which increase their population. In this

study, the high abundance of *Camponotus pennsylvanicus*, Tipula species, and Alphitobius species (Table 1) was likely caused by these detritivores' attraction to the fermented byproducts of decomposing leaf litter as they drank these liquids for the purpose of feeding, C. pennsylvanicus, Tipula species, and Alphitobius species congregate at this stage of the decomposition process when the leaf litter begins to ferment. They absorb their liquid meal via their mouthparts. Since no immature forms were found during the survey and some Tipula species have been reported to lay their eggs on fermented material (Njila et al. 2014), the existence of these insects was attributed to their affinity to liquid food (Perez and Barrion-dupo, 2013). Triatoma protracta, Triatoma sanguisuga, Dipogon subintermedius, Tenthredo mesomela, and Tettigidea lateralis were the least common arthropods in this study, while Galerita species, Podabrus pruinosis, Episyrphus species, Blatella lituricollis, Clivina impressefrons, and Gromphadorhina portentosa were the most common (Table 1). Because they are opportunistic predators, the presence of these arthropods may only be temporary (Njila and Hadi, 2015). The torrential rains at the time of sampling may have contributed to these extremely low levels. Many arthropods appear to have avoided the leaf litter due to the recent severe rains. The arthropods might have looked for areas to reside that were drier or they might have been washed away by rain. The variability of the microhabitats and the availability of food in the leaf litter, as well as the canopy provided by trees covering the leaf litter in the gallery forest of the Jos Zoological Garden, could be responsible for the considerable difference in the abundance of leaf litter arthropods in relation to Class, Order, and Family (Figures 1, 2, and 3) observed in this study. This result corroborates the findings of Njila et al. (2022) which showed that mature forests with a closed canopy are more likely to host a diversified and rich fauna than forests in an early successional stage. Insecta and Hymenoptera were also found to be the most abundant taxa of ground dwelling arthropods associated with two habitat types in the Jos Zoological Garden Jos Plateau state, North central Nigeria (Njila and Hadi, 2015). This study's noticeably high abundance of members of the family Formicidae is consistent with observations obtained by Cheli et al. (2010) while studying the community of ground-dwelling arthropods on Peninsula Valdes in Patagonia, Argentina. According to Cheli et al. (2010), the colonial nature of the Formicidae means that when they are collected in an area, they are typically captured in relatively large numbers. This supports the Formicidae's hegemonic position in a habitat. The Gallery forest's soil pH was primarily alkaline (Table 2). This has a favorable correlation with the abundance and variety observed. This is in keeping with the findings of Hamilton (2015) who linked the richness and abundance of arthropod species to alkaline soils, and with the findings of Njila et al. (2022), who found that arthropods prefer alkaline soil to acidic soil in Gallery forest soils. The high rate of litter decomposition, increased microbial activity, and water dilution potential with increasing moisture content were all factors that contributed to the soils' alkaline nature and supported Leonardo (2006) findings regarding the decomposition and micro-arthropod abundance in soil and litter in a Southern Appalachian wetlands complex. All of the soil in the Jos Zoological Garden's Gallery woodland had low temperatures (Table 2). However, Table 3 shows that the Gallery Forest of the Jos Zoological Garden has the highest soil temperature observed and the largest arthropod abundance. This is likely because, at warmer temperatures, arthropods reproduce and mature more quickly, which increases their abundance. This is in line with Kiritani's (2006) assertion that some insects may produce more generations as a result of increased temperatures likely stimulating adult reproduction. In general, the weather during the study period and the shade given by the trees in the Gallery Forest may be blamed for the low temperature of the soils. The other significantly lower temperatures that revealed lower arthropod abundances may be because of the lower temperatures' effects on metabolism and reproduction. This is corroborated by research by Block et al. (1990), which showed that as ambient temperatures drop near the low end of the arthropod species' thermal range, each individual's total metabolism declines and their ability to move becomes increasingly constrained. The Gallery woodland of the Jos Museum Zoological Garden had a low amount of soil organic matter (Table 2). The quantity and variety of arthropods that were collected were adversely affected by this. Due to excessive rainfall during the study period, the soil may have been washed away, and the Gallery Forest of the Jos Zoological Garden's predominant tree species may also have contributed to the low proportion of soil organic matter. This is consistent with the findings of Wiwatwitaya and Takeda (2005), who linked seasonal fluctuations in soil arthropod abundance, and the findings of Funderburg (2001), who stated that soils that have grown under forest vegetation typically have comparatively low levels of organic matter and that there are at least two explanations for these levels: trees create a lot smaller root mass per acre than grass plants, and trees do not die back and decay every year. However, it is crucial to remember that soil organic matter typically excludes surface plant litter, or new vegetal waste (Njila et al. 2022). The Jos Zoological Garden's Gallery Forest

had high soil moisture levels throughout. The highest level of soil moisture observed had the most leaf litter arthropods (Table 2). Thus, there was a correlation between this and the high number of leaf-litter arthropods. This is consistent with the finding of Sylvain et al. (2014) that increased soil moisture increased the abundance of practically all taxa (nematodes and arthropods) in their study. This is further reinforced by the research of Njila et al. (2022), who found that places with high levels of moisture in the leaf litter are regarded as refuges for desiccation-intolerant species and permit continued reproduction (abundance) and foraging activity. The significant amount of rain that fell during the sampling period could be blamed for the high soil moisture content. However, the frequent flooding of the pitfall traps caused by the continuous rain throughout the study period limited the collection of arthropods in the traps, which in turn reduced the number of leaf litter arthropods that could be gathered.

CONCLUSION

Within the Gallery Forest of the Jos Zoological Garden, there were considerable differences in the species diversity and richness of leaf litter arthropods. In the absence of human activities like cattle grazing and the continuous deforestation there, the Gallery Forest may host a large variety of leaf litter arthropods. In this study, it was discovered that carpenter ants (Camponotus pennsylvanicus) of the Class: Insecta, Order: Hymenoptera, and Family: Formicidae was the most predominant taxon. The majority of the colonies of C. pennsylvanicus in the forest were discovered in decomposing wood. As a result, their presence might be considered a key bio-indicator of the forest's health. The Jos Zoological Garden's Gallery Forest was also studied for its soil physic-chemical parameters, including soil moisture, temperature, pH, and organic matter. High soil moisture content and an alkaline soil pH favored the abundance of leaf litter arthropods, whereas low soil temperature and low soil organic matter content was unfavorable to the abundance of leaf litter arthropods as a direct consequence.

REFERENCE

Block, W., Baust, J.; Franks, F.; Johnston, I.; Bale, J. Cold tolerance of insects and other Arthropods. Biological Sciences (series B). Philosophical Transactions of the Royal Society of London. 1990, 326 (1237), 613- 633.

Castner, J. L. Photographic atlas of Entomology and Guide to insect Identification. Feline Press Gainesville U.S.A Inc. 2000, 74-223 pp..

Cheli, G.H., Corley, J.C.; Bruzzone, O., del Brio, M., Martinez, F.; Roman, N. M.; Rios I. The ground-dwelling arthropod community of Peninsula Valdes in Patagonia,Argentina. *J. Insect Sci*. 2010, 10:1-16.

Drage, B. H. Patterns in Palaeontology. Palaeontology [Online]. 2016. Vol 6, Pp.1-10. (Accessed April 2, 2016). Retrieved from https://www.palaeontologyonline.com/articles/2016/arthropods-moulting.

Duvallet, G.; Bonlanger, N.; Robert, V. Arthropods: Definition and Medical mportance. Skin and Arthropod Vect. 2018, 2: 29-54.

Funderburg, E. What does organic matter do in soil? Noble Research Institute Publication, 2001; pp 7-8. Retrieved from https://www.noble.org/news/publications/ag-news-and-views/2001/august/What -does Organic-matter-do-in-soil/ (accessed August 24, 2001)

Hamilton, F. Phenology and diversity of Arthropod communities in leaf litter. Theses and Dissertations. 1242. 2015. Retrieved from http://scholarworks.uark.edu/etd/1242 (accessed May 4, 2015)

Kiritani, K. Predicting impacts of global warming on population dynamics and distribution of arthropods in Japan. Popul. Ecol. 2006, 48; 1:5–12.

Latif, M.A.; Rahman, M. M.; Islam, M.R.; Nuruddin, M.M. Survey of Arthropod biodiversity in the Brinjal field. *J. of Ento*. 2009, 6(1):28-34.

Leonardo, K. Decomposition and microarthropod abundance in litter and soil in a Southern Appalachian wetlands complex. Proceedings of the National Conference on undergraduate research. 2006. Asheville, North Carolina pp. 56-77.

Lin, K. What lurks in the leaf litter? Seasonal Science. 2012. Retrieved from: https://www.scientificamerica. Com/article/bring-science home-leaf-litter-biodiversity. (Accessed March 24, 2012)

Myers, P. The animal diversity web (online). 2001. Accessed at https://animaldiversity.org(accessed August 2, 2001)

Njila, H.L; Mwansat, G.S; Imandeh, G.N.; Onyimba, I.A. Abundance and distribution of adult and juvenile stages of soil microarthropods along the Western Bank of river Benue in Adamawa State North-Eastern Nigeria. *Afric, J. Nat, Sci*. 2014, 17, 37 – 47.

Njila, H. L. and Hadi, S. M. Survey of Ground Dwelling Arthropods associated with two habitat types in the Jos Museum Zoological Garden Jos Plateau State,

North Central Nigeria. Eth. *J. Environ. Stud. & Manage*. 2015. 8(3), 272-282.

Njila, H.L.; Salihu N.I.; Ombugadu, A. Species composition of leaf litter arthropods in the gallery forest of the jos wild life park, *Jos Plateau State J. Res. Wildl. Environ*. 2022, 14(3), 109 – 115.

Ødegaard, F. "How many species of arthropods? Erwin's estimate revised." (PDF), *Bio. J. Linnean Society*, 2000, 71 (4), 583–597.

Perez, J. J.; Barrion-dupo, A.A. Arthropod community structure during the early stages of leaf litter decomposition. *Asian J. Biol.* 2013, 4(1). Retrieved from http://ejournals.ph/form/cite.php?id=1475. (Accessed February 4, 2013)

Rupert, E.E.; Fox, R.S.; Barnes, R.D. Invertebrate Zoology (7th ed.) 2004, 518-539 pp..

Schmidt-Rhaesa, A.; Bartolomaeus, T.; Lemburg, C.; Ehlers, U.; Garey J.R. The position of the arthropoda in the phylogenetic system. *J. Morphol*. 1998, 238: 263-285.

Shattuck, S.O. Australian ants, their biology and Identification. CSIRO Publishing, 2000, 226, 54 pp..

Smith, M.R. Hallucigenia's onychophoran-like claws a case for Tactopoda. Nat. 2014, 514 (7522), 363-366.

Sylvain, Z.A.; Wall, D.H.; Cherwin, K.L.; Peters, D.P.C., Reichmann, L.G.; Sala, O.E. Soil animal responses to moisture availability are largely scale, not ecosystem dependent: insight from a cross-site study. Glob. Change Biol. 2014, 20, 2631– 2643.

Walkley, A.J.; Black, I.A. Estimation of soil organic carbon by the chromic acid titration method. Soil Sci. 1934, 37, 29-38.

Wiwatwitaya, D.; Takeda, H. Seasonal changes in soil arthropod in the dry evergreen forest of north-east Thailand, with special reference to Collembolan communities. *Ecol. Res*. 2005, 20(1), 59-70.

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Performance of Maize (*Zea mays*) Under Different Sowing Methods and Intra-Row Spacing

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ABSTRACT

The experiments were conducted to investigate the effects of sowing methods and intra-row spacings on some agronomic characteristics of the crop, including plant height, stem diameter, leaf area index, number of rows/ear, number of seeds/ row, number of grains per Ear, 1000-grains weight and grain yield (t.ha-[1]), were conducted using the cultivar Hudeiba I, seasons 2019/20 and 2020/21. The experimental design was a randomized complete block design in a split plot arrangement with three replications. The main plot was sowing methods (drilling, ridging, and terrace). Subplots were intra-row spacing of (10, 15, 20, 25, and 30 cm). Sowing methods and intra-row spacing had significant effects on plant height, number of seeds per ear, and grain yield. Row spacing had non-significant effects on stem sickness, number of rows per cob, and 1000-grain weight. Intra-row spacing at 20 cm gave the highest grain yield (6.99 t.ha-1) and the same intra-row spacing 20 cm combined with the ridging sowing method gave the maximum grain yield, so they achieved (8.33 t.ha-[1]), and intra-row spacing 10 cm with drilling sowing method were gave the highest plant height in both two seasons, they were achieved 190.13 cm. It's clear that plant height increased with the decrease in intra-row spacing. Stem diameter decreased with the decrease in intra-row spacing. Intra-row spacing (10 cm) in combination with the terrace sowing method produced the lower grain yield (3.53 t.ha-[1]).

INTRODUCTION

Determination of the optimum plant density and in combination with appropriate agronomic practices is an important component of crop production package for maximizing productivity. Maize (Zea mays L.) is a member of the grass family, Poaceae (Gramineae); it's the world's widely grown highland cereal and primary staple food crop and animal feed in many developing countries (Kandil, 2014). It is the third most important staple food crop both in terms of area and production after wheat and rice in the world (Yearbook, 1995). Maize demand is projected to increase by 50% worldwide` and by 93% in sub-Saharan (FAO, 2015, Temesgen, 2019). In the many countries becoming the main food crop, especially in part of Africa and Asia countries. Maize has become a staple food in many parts of the world, with total production surpassing that of wheat or rice (Ali, 2019). Maize is also known as corn, domesticated by the indigenous people of South Mexico before 10,000 years ago (Ali, 2019). The rapidly increase demand for maize is driven by increase demand for direct human consumption in the world as a staple food crop (Ghimire et al. Kandil, 2014), this made many researchers, research centers and countries focus on this crop in order to fill any potential food gap in the world, whether through direct consumption or through animal and poultry feed. Where increasing grain yield per unit area and increasing the corn are the best solution to

decrease the gap between consumption and production from feed and forage. Among the good agricultural practice to achieve this goal is to define the best row and intra-row spacing. Decreasing intra-row spacing decreased the number of inflorescences per plant, leaf area, shoot dry weight and grain yield per plant but increased plant height (Kandil, 2014). In other crops, early sowing dates with low density and high irrigation levels increased growth period and reduced competition, so increased production potential of Amaranth (Kandil, 2014, Yarmia et al. 2011).

Although maize was a non-major crop in Sudan, but in the past few years the need for it has grown, as it is used in livestock and poultry feed, in addition to use it in other food industry and biofuel (ethanol). Maize optimum cultural practices should be determined to satisfy increasing demand for the crop. Also, its production is greatly affected by varying planting density than other members of the grass family because of its monoecious floral organization, its low tillering cognition to fill the gap among plants, and the presence of synopsis ontogeny punctuation (Ali et al. 2017).

In fact, Sudan has great potential for animal production, ranking first in the Arab World. In Sudan, area cropped with maize amounts to 126 thousand acres (121,500 Feddan), about 51000 ha-1, which is 82% of that of 2013 (FAOSTAT, 2016). It's becoming the fourth most important, after wheat, sorghum, and millet. It is grown mainly as a food and feed crop (both forage and grain). Also it's of minor importance; it is only grown on in River Banks, in small batches, and in the "Jobraka" system of farming around houses in rural areas, in irrigated schemes, and in modern irrigation systems in Khartoum and River Nile States (Ali, 2019).

The establishment of an adequate plant density is critical for the utilization of available growth factors such as water, light, nutrients, and carbon dioxide and to maximize grain yield. Decreasing the distance between neighbor rows at any particular plant population has several potential advantages. It reduces competition among plants within rows for light, water, and nutrients due to a more equidistant plant arrangement (Tesfaye, 2020).

Growth and grain yield of maize is more affected by variations in hill spacing than other members of the grass family. Too wide spacing leads to low plant density per unit area and reduces ground cover, whereas too narrow spacing is related to intense competition between plants for growth factors (Tesfaye, 2020). The low yield of crops has been partly attributed to inappropriate plant density, planting time, and pest pressure (weeds, diseases and insect pests) (Gobeze et al, 2012). Determination of optimum plant population, adapted varieties and appropriate agronomic practices are important components of the maize production package for maximizing productivity. Successful production of any crop depends on the application of production inputs that will support the environment as well as agricultural production, these inputs include; adapted varieties, plant population, soil tillage, fertilization, weed, insect and disease control, harvesting, marketing and financial resources. Maize crops are characterized as low tillers, this poses that population density should be manipulated to compensate for the spaces created by the low tillering character; therefore, studying plant densities will be of vital importance. Many cultural practices like optimum sowing methods, intra-row spacing, and suitable varieties which achieve economical yield are also crucial for farmers and producers to increase their returns, change lifestyles, and increase the investment capital of producers and investors. The increase in maize crop yield adds up to the satisfaction of the growing demand of the increasing livestock and poultry industry.

The experiments were conducted to adapt the best cultural practices that increase maize production in Sudan, especially in Khartoum north area. Therefore, the overall objective of this study investigated a new cash and food crop, test the effects of sowing methods, and intra-row spacing on a variety of maize (Hudeiba I) for the growth, yield, and yield components of the crop.

MATERIALS AND METHODS

Description of the experiment

Two experiments were conducted at the experimental farm of the College of Agricultural Studies, Sudan University of Science and Technology, Shambat, Khartoum North, Sudan, to investigate the effects of three sowing methods (drilling, ridging, and terrace), and five intra row spacing's (10, 15, 20, 25 and 30 cm) on some agronomic characters of plants using the cultivar Hudeiba I, seasons 2019/20 and 2020/21. The area suited in the low land, River Nile, which lies between Latitude 15˚ 40̍ N and longitude 32˚32̍ E, evaluated 380 m above Sea level (GoI, 2018). During two consecutive seasons (2019/20 and 2020/21) to investigate the proper sowing method with the relation of intra-row spacing of maize, variety (Hudeiba I), using a Randomized Complete Block Design in a split-plot arrangement, keeping sowing methods as main plots and intra-row spacing as sub-plots, plant populations of these intra-row spacings at all sowing methods are (10.0, 6.67, 5.0, 4.0 and 3.33 plants m-1) respectively (Table 1), the plot measuring size is 12

m2 (4 rows× 3 m) with three replications (Table 1), (drilling sowing method was leveled the four ridges and seeds were sown in four lines, the terrace sowing method was combined every two ridges together to compose one terrace and seeds were sown at the sides of any terrace). The spacing of 1.0 m and 1.5 m were left between plots and blocks, respectively.

Table 1: Combination of Treatments and Descriptions

No	SM× Intra-row spacing	Plot area (m^2)	Plant density/ m^{-1}
1	SM1 IRSP1	12 m^2	10.0
2	SM1 IRSP2	12 m^2	6.67
3	SM1 IRSP3	12 m^2	5.00
4	SM1 IRSP4	12 m^2	4.00
5	SM1 IRSP5	12 m^2	3.33

SM= Sowing Methods (1= Drilling (Flat), 2= Ridging, 3= Terrace), IRSP = Intra-row Spacing (1= 10, 2= 15, 3= 20, 4= 25 and 5= 30 cm).

Climate

The climate according to Shambat Metrological station, is described as tropical semi-arid, with the maximum annual rainfall ranging between 160- 180 mm, occurring from July to September. Relative humidity ranges between 31- 51% during the wet season and 12-27% during the dry season. Mean maximum and minimum temperatures in Khartoum North are 41.7˚C and 15.3˚C respectively. Winter season from Nov. – Mar. and is relatively cool and dry. The summer season is hot and dry.

Sowing methods and time

The experiments were sown on the 4th week of Nov. during both seasons. Sowing was done manually. Pumping water thefrom river Nile is common; in addition, underground water is used as supplementary irrigation the when river pump station was failed, especially in the second season. First irrigation was given after 15 days after the sowing in the first season and 7 days in the second season. For the 1st month field was shallowly irrigated at 7 interval days, while after a month till to tasselling and silking irrigation 10 days intervals were applied deeply by a furrow system, and at a critical time at tasselling and silking stage field was irrigated by 5 days interval to initiate flowering and silking, most of the time irrigation has been done after noon to avoid loses of water from the field by evaporation.

Land preparations

Land was well prepared (soil was plowed with a disc plow to uproot the previous crop, followed by disc harrow, cross harrow, and leveling and finally ridging operation), all these operations were done by a tractor. After that, the field was divided into plots. Drilling, and terrace were done manually after dividing the soil and then two seeds per hole were sown manually the last end-Nov, thinning to a single plant per each hole was done when seedlings produced four real leaves.

Plant material

The open-pollinated variety of grain maize (Zea mays L.) used in this study was obtained from Agricultural Research Corporation (ARC), Hudeiba station. The experiments were conducted to study the effects of sowing methods, and intra-row spacing on maize variety namely: Hudeiba I.

Soil classification

Soil of Shambat is well-drained loamy clay, non-saline, non-sodic, and classified predominantly as arid sols with pockets of Vertisols formed on old alluvium deposits, and Entisols on recent alluvium and aeolian deposits, with pH ranging from 7.71 to 7.91 (Gol, 2018, Hamadtou, 2016, Osman, 2021).

Fertilization

Phosphorus fertilizer in the form of DAP (Diammonium phosphate 18% N and 46% P2O5) at the recommended dose of 100.0 kg. ha-1 this equivalent (9 kg N and 46 kg P2O5) and half of the recommended dose of Nitrogen fertilizer in the form of Urea 46% N 250.0 kg ha-1, this equivalent (115.0 kg N) were added uniformly to all plots manually at the time of the sowing and the rest half of N-fertilizer was added after 35 days (5 weeks) from the first irrigation during both seasons.

Herbicides

Herbicide 2-4-D (2-4-dichloro-phenoxyacetic acid) 4.0 L. ha-1 was applied manually by Knapsack to protect the crop from broad leaves in the second season only.

Insecticides

Amidocloprid (N-{1-[(6-Chloro-3-pyridyl) methyl]-4, 5-dihydroimidazol-2-yl} nitramide) 1.50 L/ha-1 was applied manually by Knapsack, to control the Armyworms

Mythimna Spp. (Lepidoptera: Noctuidae) appeared during both seasons.

Plant height (cm)

Plant height was measured from six randomly pre-tagged plants from the net plot area and then their height was measured from the soil surface to the point where the tassel starts to branch with a meter rod at physiological maturity.

Stem diameter (mm)

Stem diameter was measured at 30 cm over the soil surface using the vernier caliper to determine the plant thickness and effects of sowing methods and intra-row spacing.

Leaf area

Leaf area per plant and leaf area index was recorded at 50% milk stage by measuring the leaf length and maximum leaf width of three leaves (top, middle, and bottom) per plant from six randomly pre-tagged plants from each net plot, the average of the three leaves was multiplied by the total number of leaves per plant and the area was adjusted by a correction factor 0.75 (i.e. 0.75× leaf length× maximum leaf width) as described by (Francis et al. 1969). The leaf area index was determined as the ratio of leaf area per plant divided by the respective ground area occupied by the plant.

Ear length

Ear length was recorded from six pre-tagged plants and measured their ear height from the attached of stalk level to the node bearing the top useful ear with a meter rod at physiological maturity.

Ear diameter

Ear diameter was recorded also from the same six ears taken from the net plot area (The same ears from which the length was taken), and then their diameter was measured at the middle of the ear with an vernier caliper; the mean was recorded as an ear diameter.

Number of rows/ear

The number of rows per ear was counted with the average number of rows in six ears from the same six pre-tagged plants, where the number of rows from six ears was counted and divided by their number.

Number of kernels/ row (KR)

Number of kernels per Ear (KR) was recorded from the six pre-tagged plants.ears taken from the same six pre-tagged plants.

Number of kernels/ ear

Number of kernels per ear were recorded by multiplying the total number of rows per ear and the number of kernels per row was recorded from the same six ears taken from the net plot area (The same ears from which the lengths and thickness were taken) in the net plot area after harvest and the average was recorded.

1000-kernels weight (GW)

Thousand kernels were counted from randomly taken ears after shelling by (manual counted). Then, thousand kernels weight was recorded from weighed thousand kernels using sensitive balance and adjusted to 12.5% moisture level.

Grain yield (GY)

Grain yield per plot was recorded using electronic balance and then adjusted to 12.5% moisture and converted to hectare basis.
The trend of data collected during two seasons was found similar, so the data was averaged.

Statistical analysis

The data was subjected to analysis of variance (ANOVA) using Statistical Analysis System (Statistix10, 2013) version 10.0.1.5 Software using proc GLM procedure. Duncan's multiple range tests and LSD was used to separate significantly differing treatment means after treatment effects were found significant at P≤ 0.05.

RESULTS AND DISCUSSIONS

Analysis of variance showed a significant differences among sowing methods, intra-row spacing and interactions of both variables were obtained from leaf area index (LAI), number of kernels per row, and grain yield in the combined results of two years, all results were shown in (Tables 2- 4).
Plant height (cm):
Analysis of variances of plant height showed no significant affected due to the main effects of sowing method, but highly significant at (P>01) of intra-row spacing and significant at (P>05) of combined analysis of sowing methods with intra-row spacing, the highest plant height (190.13 and 181.73 cm) were obtained from an interactions of drilling and ridging sowing methods with 10 cm intra-row spacing, respectively, while the lowest (139.20 and 134.20 cm) were recorded from interactions

of terrace sowing method combined with 25 cm intra-row spacing followed by interactions of drilling sowing method combined with 30 cm intra-row spacing, (Table 2).

Plant height was increased with decreased of intra-row spacing (increase in plant population from 3.33 to 10.0 plants.m-1), and these might be due to competition among plants about growth factors (moisture, nutrients, solar radiation and wind), these results agreed with (Gondal et al. 2017), they found that plant height was increased with increasing seed rate and decreasing row spacing. (Snider et al, 2012), reported that the effects of seeding rate on the plant height to be significant but contrasting effects at different sites. The intra-row spacing of 10 cm resulted in the highest plant height among all intra-row spacings and interactions among sowing methods; the lower plant height (134.20 cm) was obtained from drilling sowing method and interaction with 30 cm intra-row spacing. Also (Azam, 2007), reported that various varieties of maize have genotypic differences for plant height where the tallest plant height (145 cm) was recorded for variety Cargill 707 and the shortest plant height (134 cm) was recorded for variety Baber.

Stem diameter (mm)

Analysis of variances of stem diameter showed significantly (p>01) affected by intra-row spacing but sowing methods and interaction between sowing methods and intra-row spacing had no significant effects. The highest stem diameter (20.3 mm) was determined at interaction of drilling sowing method with 30 cm intra-spacing, while the lowest stem diameter (15.3 mm) was recorded at interaction of drilling and ridging sowing methods with 15 cm intra-row spacing, terrace sowing method was achieved the highest stem diameter (17.3 mm), while the sowing methods, and both were get 17.1 mm stem diameter, also 30 cm intra-row spacing was resulted the maximum (19.9 cm) stem thickness over the all other intra-row spacings (Table 2). These results may due to the fact that higher seed rate directly results in higher stems density and a higher stem density resulting in decrease in stem diameter due to the obvious interplant competition due to narrower of holes between plant to plant. These results were in line with (Schmitt and Wulff, 1993, Werf et al 1995) they reported that increase in seed rate from 5 kg ha-1 to 15 kg ha-1 resulted in a significant decrease in stem diameter while increased the stem density. Higher plant density produces thin stemmed plants that tend to lodge Kashiwagi et al, 2008; Venuto and Kindiger, 2008).

Table 2: Effects of sowing methods and intra-row spacing on growth parameters (PH, SD and LAI) of maize

Treatments	Plant height (cm)	Stem diameter (mm)	LAI (cm)
IRSP1 (10 cm)	179.76a	1.57c	4.74d
IRSP2 (15 cm)	170.62ab	15.6c	5.70c
IRSP3 (20 cm)	164.30b	16.1c	6.99b
IRSP4 (25 cm)	151.31c	18.5b	5.07ab
IRSP5 (30 cm)	145.96c	19.9a	4.86a
L. S.	*****	*****	*
LSD (0.05)	***4.19***	***0.04***	***0.07***
SM1 (drilling)	165.11a	17.1a	3.63ab
SM2 (ridging)	171.28a	17.1a	3.99a
SM3 (terrace)	150.77a	17.3a	3.28b
L.S.	***N.S.***	***N.S.***	**
LSD (05)	***10.86***	***0.06***	***0.14***
SM1 IRSP1	190.13	15.7	5.13
SM1 IRSP2	166.40	15.3	5.93
SM1 IRSP3	181.10	16.3	7.27
SM1 IRSP4	153.73	17.7	4.80
SM1 IRSP5	134.20	20.3	5.03
SM2 IRSP1	181.73	15.7	5.57
SM2 IRSP2	180.20	15.3	6.40
SM2 IRSP3	172.33	1.60	8.33
SM2 IRSP4	161.00	18.7	4.83
SM2 IRSP5	161.13	19.7	5.60
SM3 IRSP1	167.40	15.7	3.53
SM3 IRSP2	165.27	16.0	4.77
SM3 IRSP3	139.47	16.0	5.37
SM3 IRSP4	139.20	19.3	4.57
SM3 IRSP5	142.53	19.7	3.93
L. S	*	***N.S.***	*
LSD (0.05)	***7.74***	***0.06***	***0.13***

IRSP = Intra-row Spacing (10, 15, 20, 25 and 30 cm), SM= Sowing Methods (1= Drilling (Flat), 2= Ridging, 3= Terrace), L. S= level of significant. * Significant at 0.05%, ** significant at 0.01%., N.S. Not significant, LSD: Least Significant Different.

Leaf area index

Analysis of variance showed a highly significant at (P < 0.01) affected by way of sowing methods and significant at (P> 0.05) affected by two ways (intra-row spacing and interactions of sowing method with intra-row spacing). Therefore, analysis and combined analysis of variance depicted that the maximum leaf area index (8.33 and 6.99) were obtained from interactions of the intra-row spacing 20 cm× ridging sowing method and intra-row spacing 20 cm, respectively (5.0 stalk. m-1 plant density), whereas the minimum leaf area index (3.53 and 3.28) were attained from combination of the terrace sowing method× 10 cm intra-row spacing (10.0 stalk. m-1 plant density) and terrace sowing method, respectively (Table 2).

In this study, it's clear that leaf area index was increasing with increasing the intra-row spacing till to 20 cm intra-row spacing and decreasing again, the possible reasons for the highest leaf area for ridging sowing method at the medium intra-row spacing (20 cm) might be due to the optimum conditions and ability of plant to uptake its sufficient needs from soil solution and solar radiation interception. These results were agreed with (Ngugi et al, 2013), he mentioned that lower plant population got more nutrients and water compared to higher population, thus contributed increased leaf area unlike high plant population density that reduced that reduced low leaf area of maize decreased. Similarly (Tesfaye, 2020), reported that the main effects of both intra, inter-row spacing and their interactions on leaf area were significant ($P < 0.05$), also he found that the leaf area per plant was increased with increasing inter and intra-row spacing.

Ali et al., 2017; Zhang et al. 2007 and Borra's et al. 2003 reported that a less leaf area index (LAI) duration could have resulted in response to increased plant population in the field due to more leaf senescence rate during grain filling. (Ali et al. 2017) mentioned that photosynthetic efficiency, growth and development in maize are greatly related to the effect of canopy architecture on the vertical distribution of light within the plants canopy. The optimum plant density is one of the ways of increasing the capture of solar radiation within the canopy. However, the efficiency of the conversion of intercepted solar radiation decreases with a high plant population density because of mutual shading in the plants in the field (Ali et al. 2017; Zhang et al. 2006).

Number of rows per Ear

The effects of sowing methods (SMs) and intra-row spacing on the means of number of the rows per ear were presented in (Table 3). Statistical analysis showed no significant differences among the number of rows per ear affected by sowing methods and intra-row spacing. However, the ridging sowing method (SM2) scored a higher level of rows per ear and achieved 13.49 over the drilling and terrace sowing methods and they scored 13.40 and 13.15 respectively.

The maximum number of rows/ear (14.27) was recorded from the interactions of the ridging sowing method with 20 cm intra-row spacing, followed by the interaction of the terrace sowing method with 30 cm intra-row spacing, was achieved (14.07 cm). These results were agreed with (Ibrahim et al. 2019), they found that the ridging sowing method scored higher rates of ear number , number of seeds/ ear, number of seeds per row and hay yield, also mentioned that the increase in intra-row spacing from 20 cm to 25 cm significantly increase number of row/ ear, 100 seed weight and grain yield.

Table 3: Effects of sowing methods and intra-row spacing on yield components (RE, KR and KE) of maize

Treatments	Number of rows/ear	Number of kernels/row	Number of kernels/ Ear
IRSP1 (10 cm)	13.50a	26.98bc	363.86b
IRSP2 (15 cm)	12.96a	27.44b	355.81b
IRSP3 (20 cm)	13.51a	30.52a	414.22a
IRSP4 (25 cm)	12.91a	26.36cd	339.98b
IRSP5 (30 cm)	13.87a	25.93d	359.40b
L. S.	***N.S.***	**	**
LSD (0.05)	***0.25***	***0.33***	***10.15***
SM1 (drilling)	13.40a	26.78a	358.26
SM2 (ridging)	13.49a	29.35b	397.05
SM3 (terrace)	13.15a	26.21b	344.65
L.S.	***N.S.***	**	*
LSD (05)	***0.33***	***0.33***	***10.51***
SM1 IRSP1	13.00	27.20	353.27
SM1 IRSP2	12.67	27.67	350.90
SM1 IRSP3	13.40	29.77	399.03
SM1 IRSP4	13.93	25.27	351.90
SM1 IRSP5	14.00	24.00	336.20
SM2 IRSP1	13.60	27.87	379.03
SM2 IRSP2	13.47	28.33	381.23
SM2 IRSP3	14.27	33.93	484.14
SM2 IRSP4	12.60	28.07	354.20
SM2 IRSP5	13.53	28.53	386.63
SM3 IRSP1	13.87	25.87	359.27
SM3 IRSP2	12.73	26.33	335.30
SM3 IRSP3	12.87	27.87	359.47
SM3 IRSP4	12.20	25.73	313.83
SM3 IRSP5	14.07	25.27	355.37
L. S	***N.S.***	**	***N.S.***
LSD (0.05)	***0.56***	***0.50***	***18.21***

IRSP = Intra-row Spacing (10, 15, 20, 25 and 30 cm), SM= Sowing Methods (1= Drilling (Flat), 2= Ridging, 3= Terrace), L. S= level of significant. * Significant at 0.05%, ** significant at 0.01%., N.S. Not significant, LSD: Least Significant Different.

Number of kernels per row

The effects of sowing methods and intra-row spacing on number of kernels per row were presented in (Table 3). Statistical analysis showed highly significant differences among the mean of number of kernels per row and it was affected by three ways of sowing methods, intra-row

spacing and interactions of SMs with intra row spacings. However, 20 cm intra-row spacing was achieved the highest number (30.52) of kernels per row while the 30 cm intra-row spacing was scored the lowest number of kernels per row (25.93). Moreover ridging sowing method (SM2) scored the higher level of kernels per row and achieved the 29.35 over the drilling and terrace sowing methods and they were achieved 26.78 and 26.24 respectively. The interaction effects of these cultural practices, ridging sowing methods with 20 cm intra-row spacing were achieved the highest number of kernels per row, achieved 33.93 while the lowest number of kernels per row were achieved by drilling and terrace sowing method methods with (25 and 30 cm) intra-row spacing respectively, they were scored 25.27 number of kernels per row. These results may due to the optimum conditions of the 20 cm intra-row spacing with ridging sowing method, crop was uptake the sufficient required from the soil nutrients and moisture and optimum distance between plants to intercepts their needs from solar radiation for good photosynthetic.

Number of kernels per ear

Number of kernels per ear contributes to the economic yield and represents the productive efficiency of any cereal crop or crop variety (Kebede, 2019).

Number of kernels per ear was highly significant ($p < 0.01$) affected by the main effects of intra-row spacing, significant ($P > 0.05$) affected by sowing methods (SMs) and there were no significant effects by interactions among the experimental variables. The highest number of kernels per year (484.14, 414.22) was recorded at interactions of ridging sowing with 20 cm intra-row spacing followed by the 20 cm intra-row spacing, while the lowest number of kernels per ear (313.85, 335.30) was recorded under interactions of terrace sowing method with 25 cm and 15 cm intra-row spacing respectively (Table 3). This variation might be due to the fact that widely spaced plants encountered less interplant competition than closely spaced plants and thus exhibited better growth that contributed to more number of kernels per ear. These results agreed with (Mukhtar et al., 2012) reported that wider spacing (17.50 cm) produced higher number of kernels per ear (717.00) while narrower spacing (10 cm) gave lower number of grains (540.30). In same line also (Eskandarnejada, 2013) reported that wide inter-row spacing of 30 cm produced more number of kernels per ear than that 20 cm plant spacing.

1000-kernels weight

The effects of sowing methods and intra-row spacing on means of 1000-kernel weight were shown in (Table 4). The main effects of intra-row spacing were highly significant ($P < 0.01$) on thousand kernel weight. However, the sowing methods and their interactions were not significant with increase intera-row spacing, thousand kernels weight increased, where the highest thousand kernels weight (325.72 g) was recorded at the 20 cm intra-row spacing, whereas, the lowest (235.0 g) was recorded at the 25 cm intra-row spacing. The highest 1000-grain weight 358.0 g was recorded at interaction of 20 cm intra-row spacing combined with ridging sowing method. The parameter of increase in 1000-grain weight was reflected in the grain yield increase confirming its contributive factor for grain yield.

Thousand kernel weights were increased with increasing of intra-row spacing till to 20 cm and decreased again, this might be due to the optimum condition to assimilate partitioning between higher numbers of kernels used in connection with the decreased interplant competition that lead to increased plant capacity, for utilizing the environmental inputs (solar radiation interception, wind and soil aeration) addition to agronomic practices with additives like fertilizers and water in building a great amount of metabolites to be used in developing new tissues and increasing its yield components. These results were agreed with (Kandil et al., 2017), reported that maize hybrids i.e. Varieties have different response to agronomic characters and grain yield. Also (Alias et al., 2010; El-metwally, 2011) showed a significant difference between plant heights, number of ears/ plant, LAI, number of seeds/ row, grain weight/ ear and grain yield. (Fernandez et al., 2012) reported that single-row planting at low plant populations produced the highest grain weight.

Grain yield

Grain yield was shown in (Table 4). Statistical analysis showed a significant ($p > 0.05$) affected by the interactions of the sowing method with intra-row spacing. Accordingly, the highest grain yield (8.33 ton. ha-1) was obtained in a combination of the ridging method with 20 cm intra-row spacing, while the lowest grain yield (3.53 ton. ha-1) was obtained from the terrace sowing method in combination with the narrowest intra-row spacing 10 cm.

The possible reason for the lowest grain yield at the narrowest spacing might be due to the presence of competition of plants per unit area for solar radiation interception, moisture, available nutrients and other sources in the soil. This indicated that high plant

population per unit area that could not get better available growth factors like moisture, nutrients, light, and space could not offset the grain yield obtained from high plant population per unit area.

Table 4: Effects of sowing methods and intra-row spacing on yield components (1000 Kernels weight and grain yield) of maize

Treatments	1000-Kernels. wt (g)	Yield. T.ha^{-1}
IRSP1 (10 cm)	236.7b	4.74c
IRSP2 (15 cm)	242.44b	5.70b
IRSP3 (20 cm)	325.72a	6.99a
IRSP4 (25 cm)	235.00b	5.07c
IRSP5 (30 cm)	243.00b	4.86c
L. S.	*****	*****
LSD (0.05)	***8.22***	***0.15***
SM1 (drilling)	252.90a	5.63b
SM2 (ridging)	265.20a	6.35a
SM3 (terrace)	251.60a	4.43c
L.S.	***N.S.***	*****
LSD (05)	***7.39***	***0.07***
SM1 IRSP1	237.67	5.13
SM1 IRSP2	245.33	5.93
SM1 IRSP3	324.50	7.27
SM1 IRSP4	218.33	4.80
SM1 IRSP5	238.67	5.03
SM2 IRSP1	240.67	5.57
SM2 IRSP2	240.67	6.4
SM2 IRSP3	358.00	8.33
SM2 IRSP4	245.33	5.83
SM2 IRSP5	241.33	5.60
SM3 IRSP1	231.67	3.53
SM3 IRSP2	241.33	4.77
SM3 IRSP3	294.67	5.37
SM3 IRSP4	241.33	4.57
SM3 IRSP5	249.00	3.93
L. S	***N.S.***	*****
LSD (0.05)	***12.79***	***0.26***

IRSP = Intra-row Spacing (10, 15, 20, 25 and 30 cm), SM= Sowing Methods (1= Drilling (Flat), 2= Ridging, 3= Terrace), L. S= level of significant. * Significant at 0.05%, ** significant at 0.01%., N.S. Not significant, LSD: Least Significant Different.

Previous research reveals indicated that plants grown on wider spacing absorb more nutrients and solar radiation for improved photosynthesis and hence produce better grain yield on an individual basis, but yield per unit area reduced due to a thin and low plant stand on unit area. (Ibrahim and Elhassan, 2019), mentioned in the conclusion study that among the three sowing methods ridge method scored the highest rates of the majority of the measured characters. As far as the Intra-row spacing 30 cm and 40 cm scored the highest levels of almost all measured characters.

Within the three varieties used, the variety113 gave highest levels of all measured attributes. The combination of (drilling) Flat× 40 cm× V113 and (drilling) Flat ×30 cm× V113 of the interaction between the three treatments during the first season and the combination of (drilling) Flat× 20 cm V113 during the second season gave the highest levels of yield in Kg.ha-1.

Conclusion and Recommendation

From these findings, we are recommending the following ridging sowing method and 20cm intra-row spacing in this area and variety.

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REFERENCES

Ali, A. Inter-and intra-row and plant spacing impact on maize (*Zea mays* L.) growth and productivity: a review. *International Journal of Advanced Science and Research*. 2017, 2(1), 10–14.

Ali, I.E.EM. Effect of Sowing Methods, Intra-row spacings' on growth, yield and yield components of three Maize (*Zea mays* L.) varieties, at Gash Scheme, Sudan. Sudan University of Science and Technology, 2019.

Alias, M.A.H.A.; Bukhsh, R.A.A.; Malik. A.U.H.S.; Ishaque, M. Agro-physiological traits of three maize (*Zea mays* L.) hybrids as influenced by varying plant density. *Journal of animal and plant Science*. 2010, 24, 34–39.

Azam, S. Effect of plant population on maize hybrids. *Journal of Agricultural and Biological Science*. 2007, 2(1), 104–111.

Barr'as, L..; Maddanni, G., Otegui, M. Leaf senescence in maize hybrids: plant population, row spacing and kernel set effects. *Field Crops Research*. 2003. 82(1), 13–26.

El-Metwally, E., Behavior of some maize hybrids cultivated with different plant densities. Journal of Plant Production, 2011. 2(3), pp. 479-490.

Eskandanejada, S.; Khorasani, K. S.; Bakhtiari, S.; Heidaria, A. Effect of row spacing and plant density on yield and yield components of sweet corn (*Zea mays* L.). *Journal of Crop Science*. 2013. 13(1), 80–88.

FAO, The state of food and agriculture–social protection and agriculture: breaking the cycle of rural poverty. 2015.

FAOSTAT, Production database from the Food and Agriculture Organization of the United Nations. 2016.

Fernandez, C.J.; Fromme, D.D.; Grichar, W.J. Grain sorghum response to row spacing and plant populations in the Texas Coastal Bend Region. *International Journal of Agronomy*. 2012, 2012, 1-6.

Francis, C.; Rutger, J.N.; Palmer, A.F.E. A rapid method for plant leaf area estimation in maize (Zea mays L.) 1. *Crop science*. 1969. 9(5), 537–539.

Ghimire, K. Full season maize varietal research in western hills of Nepal (2004-2006). In Proceedings of the 25th National Summer Crops Research Workshop on Maize Research and Production in Nepal held in June. 2007, 21–23 pp.

Gebeze, Y. L.; ceronio, G. M.; Van R.L.D. Effect of row spacing and plant density on yield and yield component of maize (*Zea mays* L.) under irrigation. *Journal of Agricultural Science and Technology*. 2012, 2(2B), 263.

Gol, H.D.A.A.D. Evaluation of seed filling problems of some hybrids and open pollinated Sunflower (*helianthus annuus* L) cultivars, as affected by Pollination and sowing dates. Ph.D thesis, College of Agricultural Studies, Sudan University of Science and Tecnology. 2018, 1-97.

Gondal, M. Effect of seed rate and row spacing on grain yield of sorghum. *SAARC. Journal of Agriculture*. 2017, 15(2), 81–91.

Hamadtou, G.A.F. Effect of organic, Inorganic fertilizer and bio fertilizer on growth, yield and quality of rice (*Oryza sativa* L.) under Sudan conditions. PhD thesis, College of Graduate Studies, Sudan University of Science and Technology. 2016, 1-100.

Ibrahim, M.B.I.E.; Idries, A.E..; Elmusharaf, A.K.A.; Ahmed, B.A.M.; Alhussein, E.A. Effect of sowing methods and Intra-row spacing on growth and yield of three varieties of Maize (Zea mays L.) at Gash scheme, Sudan. *International Journal of Applied and Pure Science and Agriculture*. 2019. 5 (3), 3–29.

Kandil, A.; Aharief, A.; Abozaid, A., Maize hybrids yield as affected by inter and intra row spacing. *International Journal of Environment, Agriculture and Biotechnology*. 2017, 2(2), 238714.

Kandil, E. Determine independent population density for each maize hybrid (Zea mays L.). International Proceedings of Chemical, Biological and Environmental Engineering (IPCBEE). 2014. 79, 30–35 pp.

Kashiwagi, T. Improvement of lodging resistance with QTLs for stem diameter in rice (*Oryza sativa* L.). *Theoretical and applied genetics*. 2008, 117(5), 749–757.

Kebede, M.B., Effect of inter and intra row spacing on growth, yield components and yield of hybrid maize (*Zea mays* L.) varieties at Haramaya, Eastern Ethiopia. *American Journal of Plant Sciences*. 2019. 10(9), 1548–1564.

Mukhtar, T. Yield and yield components of maize hybrids as influenced by plant spacing. *J. Agric. Res*. 2012. 50(1), 59–69.

Ngugi, K. Anthesis to silking interval usefulness in developing drought tolerant maize. *Journal Of Renewable Agriculture*. 2013. 1(5), 84–90.

Osman, M.M.A. Land suitability evaluation of some sileit projects soils Khartoum North. M.Sc thesis, College of Graduate Studies, Sudan University of Science and Technology. 2021, 1-51 pp.

Schmitt, J.; Wulff, R.D. Light spectral quality, phytochrome and plant competition, *Trends in Ecology & Evolution*. 1993. 8(2), 47–51.

Snider, J.L.; Raper, R.L.; Schwab, E.B. The effect of row spacing and seeding rate on biomass production and plant stand characteristics of non-irrigated photoperiod-sensitive sorghum (*Sorghum bicolor* (L.) Moench). *Industrial crops and Products*. 2012. 37(1), 527–535.

Temesgen, T. Effects of Varieties and Intra Row Spacing on Yield of Maize (Zea mays L) Under Supplementary Irrigation in an Arid Region of Western Ethiopia. *Advances in Applied Sciences*. 2019, 4(2), 44.

Tesfaye, T.A.G. Effect of intra and inter row spacing on yield, yield components and growth parameter of hybrid Maize at Mettu, South Western Ethiopia. *Journal of Environment and Earth Science*. 2020. 10, 1, 16- 22.

Venuto, B., and Kindiger, B., Forage and biomass feedstock production from hybrid forage sorghum and sorghum–sudangrass hybrids. Grassland science, 2008. 54(4), pp.189–196.

Werf, H.M.; Van der, Wijlhuizen, M.; De Schutter, J. Plant density and self-thinning affect yield and quality of fibre hemp (*Cannabis sativa* L.). *Field Crops Research*. 1995. 40(3), 153–164.

Yarnia, M., Effect of planting dates and density in drought stress condition on yield and yield components of Amaranth cv. Koniz. *Advances in Environmental Biology*, 2011, 1139–1150.

Yearbook, F.P., Roma: FAO, 1995. v. 49.

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Botanic Plant Resources as Insect Pests Administrator of Field Crops

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ABSTRACT

Owing to growing public awareness and concern about the adverse effects of pesticides have necessitated the need to look for eco-friendly, safer, and effective organic methods of pest control. The best solution for this is to follow indigenous traditional ways of pest control by using plants, which have been once prevalent all over the world. But with the advent and use of modern synthetic pesticides, these botanicals more or less vanished. The successful utilization of botanicals can help to control many of the world's destructive insect pests of crops. The botanical pesticides could be divided into the 1st generation including nicotine, rotenone, sabadilla, ryania, pyrethrum, and plant essential oils; while the 2nd generation comprises synthetic pyrethroids and azadirachtin, as well as potential new botanicals. Botanical pesticides may affect insect nerves, while others may affect the molting process. Different botanical formulations have been reported from time to time showing pronounced insecticidal activity, repellence to pests, oviposition deterrence, adult emergence inhibition, ovicidal, larvicidal, pupaecidal activity, and feeding deterrence based on their contact toxicity and fumigation effects. Thus, managing of crop pests using plant secondary metabolites can be more easily integrated into agro-ecologically sustainable crop production systems.

1. INTRODUCTION

Nowadays, insect tormenter management must go about the economic and ecological consequences of the employment of aggressor management measures. Sustained struggles against harmful insects for exploitation of artificial and oil-derivative molecules have created perverse secondary effects (mammalian toxicity, insect resistance, and ecological hazards). The diversification of the approaches inherent in Integrated Pest Management (IPM) is critical for higher environmental protection (Sarwar, 2013a; 2019a; Sarwar et al., 2021).

Biological control has less practical application because of its dependence on environmental conditions (Sarwar, 2014; Sarwar and Salman, 2016). Hence, biochemical control is the most effective controlling measure in large-scale crop protection (Sarwar et al. 2005; Ahmad et al. 2011) resulting in being friendly to pollinators (Sarwar, 2020).

Among the choice ways, the utilization of plants, and insecticidal allele chemicals seems to be promising. Aromatic plants and their essential oils, are among the foremost economical botanicals. Their activities are manifold and they induce chemical and topical toxicity similarly as antifeedant or repellent effects. They are harmful to adults, however, conjointly inhibit replica. Although mechanisms depend upon phytochemical patterns and do not seem to be acknowledge, this widespread variety of activities is a lot and more being thought of for each industrial and household uses, whereas in essential oils are presently thought to be a brand-new category of ecological merchandise for controlling of insect pests (Sallam et al., 2009; Sarwar and Salman, 2015a).

Green pesticides, also called ecological pesticides, are pesticides derived from organic sources, which are considered environmentally friendly. Of the present

concept of green pesticides, some rational attempts have been made to include substances such as plant extracts, hormones, pheromones, and toxins from the organic origin and also to encompass many aspects of pest control (Sarwar, 2015a; 2016a). More than 2500 plant species belonging to 235 families have been found to possess the characteristic properties required for an ideal botanical insecticide. Natural crop protectants or products are used as powder formulations or liquid or oil formulations (Karunamoorthi, 2012).

2. Botanicals Used to Control Different Insect Pests

The results of pesticidal and phytochemical screenings of a number of higher plants based on traditional knowledge have strongly indicated that plants are endowed with pesticidal properties that can be harnessed cheaply for use in agriculture and related fields (Sarwar, 2015b).

A field experiment has been conducted to test a synthetic insecticide and insecticidal properties of four selected plant origin materials against Helicoverpa species on chickpea crop. After treatment, counts for larval mortality and percentage of pods infestation showed that over all least pods infestation percentage and higher seed yield in treated crops have been significantly different than the untreated plants. However, as it is evident from the data the synthetic product gave the best results than all the sets of natural products for the parameters studied (Rajput et al., 2003).

Studies on the effect of pyrethroid (ripcord 0.5%) and different concentrations of neem (Azadirachta indica) seed extract on parasitoid Trichogramma chilonis (Ishii) (Hymenoptera: Trichogrammatidae) are conducted. Among different concentrations of neem seed extract (4,2,1,0.5 and 0.25%), the highest mortality (68.29%) of Trichogramma has been recorded with 4% neem seed extract and the lowest (35.83%) with 0.25% neem seed extract. Overall, the highest mortality (97.52%) of Trichogramma has been recorded with ripcard. It can be concluded that neem seed extract of less than 4 % concentration can be included in IPM to protect T. chilonis as biological control agent (Khan, 2011).

It has been contemplated to evaluate the efficiency of the botanical pesticide A. indica and its comparison with synthetic chemicals against gram pod borer Helicoverpa armigera (Hubner) (Fig. 1) on chickpea crop. Interestingly, the beneficial effects of all tested insecticides have been noted on plant stand. Results from the present investigations displayed that although both the botanical and synthetic insecticides contributed in reducing the pest population, yet the synthetic chemicals are still the first line of defense against the ravages of insects and can be used freely when any insect outbreak occurs (Sarwar, 2012).

Of particular economic significance among the plants is Rhododendron mole G. Don. The finely ground powder when applied as spray in suspension or as dust has been highly active against aphids, pentatomids and leaf-beetles as well as against caterpillars (Okwute, 2012).

The study has been reported the insecticidal property of botanicals and their potential as organic pest control agents for field management of aphid *Myzus persicae* (Sulzer) (Homoptera Aphididae) on canola Brassica napus L. (Brassicaceae). The effectiveness of four botanical pest control agents such as, tobacco (Nicotiana tabacum L.), garlic (*Allium sativum* L.), goosefoot (*Chenopodium album* L.), and *Aloe vera* L., has been assessed through foliar applications on canola (B. napus) crop. The A. vera (Aloeaceae) and to a greater extent *N. tabacum* at 10 % concentration have been the most effective botanicals and rated parallel for effectiveness in the treated crop, and resulted in the least aphid's damage and enhanced yield across all the seasons followed by *C. album* and *A. sativum* relative to the untreated control (Sarwar, 2013b).

Fig. 1. Gram pod borer

The genus Piper (family Piperaceae) is probably one of the most studied botanicals. With over 1000 species, about 112 genera have been screened for pesticidal activity and over 611 active compounds isolated and identified from various parts of the species. Perhaps, of great significance are extractives from Piper guineense, Piper longum and Piper retrofractum, which are known to be active against the garden insects. In these experiments, piperine has shown to be a synergist rather than an insecticide in crude extracts (Okwute, 1992).

The research has assessed the potential trade-offs of using pesticidal plant extracts on legume crop yields and the regulating ecosystem services of natural pests enemies. The application of six established pesticidal plants (*Bidens pilosa*, *Lantana camara*, *Lippiaja vanica*, *Tephrosia vogelii*, *Tithonia diversifolia* and *Vernonia amygdalina*) have been compared to positive and negative controls for their impact on yields of bean

(Phaseolus vulgaris), cowpea (*Vigna unguiculata*) and pigeon pea (*Cajanus cajan*) crops, and the abundance of key indicator pest and predatory arthropod species. Analysis of field trials showed that pesticidal plant treatments often resulted in crop yields that have been comparable to the use of a synthetic pesticide (lambda-cyhalothrin). The best-performing plant species have been *T. vogelii*, *T. diversifolia*, and *L. javanica*. The abundance of pests has been very low when using the synthetic pesticide, whilst the plant extracts generally have a higher number of pests than the synthetic but lower numbers than observed on the negative controls. Beneficial arthropod numbers have been low with synthetically treated crops, whereas the pesticidal plant treatments appeared to have little effect on beneficials when compared to the negative controls (Tembo et al. 2018). The outcomes of this research suggest that using extracts of pesticidal plants to control pests can be as effective as synthetic insecticides in terms of crop yields while tri-trophic effects have reduced, conserving the non-target arthropods that provide important ecosystem services such as pollination and pest regulation.

An outline of different botanical pesticides and their effects on various insect pests has appeared in Table 1.

Table 1. Native botanical sprays used to control insect pests in crops

Botanical	Target pests
Neem (*Azadirachta indica*) leaf extract	Defoliators and sucking pests
Garlic (*Allium sativum*) extract	*Spodoptera litura* (leaf-eating caterpillar), *Helicoverpa armigera* (fruit borer), and other lepidopteran pests
Garlic-Chilli (*Capsicum annum*) extract	*Helicoverpa armigera* (fruit borer), *Spodoptera litura* (leaf-eating caterpillar), *Leucinodes arbonalis* (Brinjal fruit & shoot borer), *Amsacta albistriga* (red-headed hairy caterpillar)
Datura (*Datura stramonium*) plant extract	Tea mosquito bugs, thrips, jassids, aphids
Calotropis (*Calotropis gigantean*) leaf extract	Termites
Lantana (*Lantana camera*) leaf powder	Aphids
Lantana leaf extract	Beetles, leaf miners, defoliators
Mixed leaves extract	Defoliators like *Spodoptera litura*, semi loopers
Eucalyptus (*Eucalyptus globules*) leaf extract	Jassids, aphids, scales
Adathoda (*Adathoda vesica*) leaf extract	Defoliators and sucking pests
Multiple plants leaf extract	Major pests and diseases
Nicotine (Nicotiana tabacum)	Aphids, thrips, caterpillars, mites, bugs, fungus gnat, leafhoppers
Rotenone (Lonchocarpus spp., Derris eliptica)	Bugs, aphids, potato beetles, spider mites, carpenter ants, bean leaf beetle, cucumber beetles, leafhopper, red spider mite
Ryania (Ryania speciosa)	Codling moths, potato aphids, onion thrips, corn earworms, silkworms, caterpillars, thrips, beetles, bugs, aphids
Sabadilla (*Shoenocaulon officinale*)	Grasshoppers, codling moths, armyworms, aphids, cabbage loopers, squash bugs, bugs, blister beetlesflies, caterpillars,potato leafhopper
Pyrethrum (*Chrysanthemum cinerariaefolium*)	Crawling and flying insects such as cockroaches, ants, mosquitoes, termites, caterpillars, aphids, leafhoppers, spider mites, bugs, cabbage worms, beetles
Essential oils	Caterpillars, cabbage worms, aphids, white flies, land snails
Neem products	Armyworms, cutworms, stemborers, bollworms, leaf miners, caterpillars, aphids, whiteflies, leafhoppers, psyllids, scales, mites and thrips
Citrus trees (d-Limonene, Linalool)	Fleas, aphids, mites, paper wasps, house crickets, dips for pets
Baobab chacal (*Adenium obesum*)	Cotton pests, particularly the larvae of bollworms Heliothis sp.)
Synthetic pyrethroids	Caterpillars, aphids, thrips

3. Botanicals and their parts used

Plant parts selected for botanicals show variations in their activities as shown in the study of Kabir and Muhammad (2010). When cowpea seeds are treated with powders of different parts of A. indica (leaf and stem bark powders) and the seed oil, the order of activity against *Callosobruchus maculatusis* found to be seed oil > leaf powder > stem bark powder. The study also proved that the insecticidal compound azadirachtin is found in fruits, bark, and leaves of the tree, but seeds have the highest concentration. Sometimes, the dust is made from the seeds and the active components are lacking in the other plant parts (roots, bulbs, stems, and leaves). It is

interesting that the toxic constituents actually become more powerful after storage, for instance, in the case of sabadilla, also known as cevadilla, derived from the seeds of the sabadilla lily (Schoenocaulon officinale). The various plant parts like leaf, bark, seed powder, clove, fruit, flower, rhizome or oil extracts are used as an admixture to control insect pests as given in Table 2. The variations in the chemical composition of botanicals due to season, location or plant part also affects their pesticidal activity (Burt, 2004). Hence, it is strongly recommended to standardize the plant products before their application and commercialization.

Table 2. List of plants and their parts used for evaluation of pesticide activities

Common name	Scientific name	Family	Part use
Fingerroot	*Boesenbergia pandurate* Schltr.	Zingiberaceae	Rhizome
Belamcanda chinensis	*Kaempferia parviflora* Wall.	Zingiberaceae	Rhizome
Peacock ginger, resurrection lily	*Kaempferia pulchra* (Ridl.) Ridl	Zingiberaceae	Rhizome
Smith. Wild ginger, Martinique ginger	*Zingiberzer umbet* (L.)	Zingiberaceae	Rhizome
Ginger	*Zingiber officinale* Roscoe.	Zingiberaceae	Rhizome
Phlai, cassumunar	*Zingiber montanum* (Koenig) Link	Zingiberaceae	Rhizome
Kha, galingale, galangal	*Alpinia galangal* (L.) Swartz.	Zingiberaceae	Rhizome
Turmeric	*Curcuma longa* L.	Zingiberaceae	Rhizome
Curcuma	*Curcuma xanthorrhiza* Roxb.	Zingiberaceae	Rhizome
Lemongrass	*Cymbopogon citratus* Stapf.	Gramineae	Leaf
Leech lime	*Citrus hystrix* DC.	Rutaceae	Leaf
Ho-ra-pa, sweet-basil, basil	*Ocimum basilicum* Linn.	Labiatae	Leaf
Hairy basil	*Ocimum canum* Linn.	Labiatae	Leaf
Holy basil, sacred basil	*Ocimum sanctum* Linn.	Malvaceae	Leaf
Horseradish tree	*Moringa oleifera* Lam.	Moringaceae	Leaf
Sugar apple	*Annona squamosal* Linn.	Annonaceae	Leaf
Guava	*Psidium guajava* Linn.	Myrtaceae	Leaf
Red river gum, Murray red gum	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae	Leaf
Jackfruit tree	*Artocarpus heterophyllus* Lam.	Moraceae	Leaf
Cha-plu	*Piper sarmentosum* Roxb.	Piperaceae	Leaf
Orange jessamine, satin-wood	*Murraya paniculata* (L.) Jack.	Rutaceae	Leaf
Kitchen mint, marsh mint	*Melissa officinalis* L.	Lamiaceae	Leaf
Kassod tree, siamesesenna	*Cassia siamea* (Lam.)	Fabaceae	Leaf
Neem	*Azadirachta indica* A. Juss.	Meliaceae	Leaf, fruit
Garlic	*Allium sativum* L.	Lilliacea	Clove
Chilli	*Capsicum annum* L.	Solanaceae	Fruit
Datura	*Datura stramonium* L.	Solanaceae	Leaf, fruit
Calotropis	*Calotropis gigantea* (L.) R. Br. Ex	Apocynaceae	Leaf, flower
Lantana	*Lantana camera* L.	Verbenaceae	Leaf, flower
Eucalyptus	*Eucalyptus globulus* Lab.	Myrtaceae	Leaf
Nerium	*Nerium oleander* L.	Apocynaceae	Leaf
Althea	*Althaea officinalis* L.	Malvaceae	Leaf, root
Visnaga	*Ammi visnaga* L.	Apiaceae	Fruit
Peppermint	*Mentha pipermita* L.	Labiatae	Leaf, flower
Spearmint	*Mentha spicata* L.	Lamiaceae	Leaf, flower
Acacia	*Acacia arabica* Lam.	Fabaceae	Flower, fruit
Capsicum	*Capsicum frutescens* L.	Solanaceae	Fruit
Castor bean	*Ricinus communis* L.	Euphorbiaceae	Fruit
Thymue	*Thymus vulgaris* L.	Lamiacae	Leaf
Marjoram	*Majora nahortenis* L.	Lamiacae	Leaf
Chamomile	*Matricaria chamomile* L.	Asteraceae	Flower
Pelargonium	*Pelargonium graveolens* Her.	Geraniaceae	Herbs
Pomegranate	*Punica grataum* L.	Punicaceae	Pomegranate peel

4. Resources of Botanical Pesticides and Their Mode of Action

At present, there are four major types of botanical products used for insect control (pyrethrum, rotenone, neem, and essential oils), along with three others in limited use (ryania, nicotine, and sabadilla). Additional plant extracts (garlic oil, Capsicum oleoresin) are seen in limited (low volume) regional use in various countries (Sarwar and Sarwar, 2022).

The botanical pesticides could be divided into two generations: the 1st generation includes nicotine, rotenone, sabadilla, ryania, pyrethrum, and plant essential oils; while the 2nd generation comprises synthetic pyrethroids and azadirachtin, as well as potential new botanicals as stated by Regnault-Roger et al. (2005) in the book: Biopesticides of plant origin.

4.1. The first-Generation Botanical Pesticides

The first-generation pesticides are organic compounds known as botanicals primarily used during the prior times.

4.1.1. Pyrethrum

Pyrethrum is the powdered, dried flower head of the pyrethrum daisy, Chrysanthemum cinerariaefolium (Asteraceae). The flowers are ground to a powder and then extracted with hexane or a similar nonpolar solvent; and removal of the solvent yields an orange-colored liquid that contains the active principles (Glynne-Jones, 2001). These are three esters of chrysanthemic acid and three esters of pyrethric acid. Among the six esters, those incorporating the alcohol pyrethrolone, namely pyrethrins I, and II, are the most abundant and account for most of the pesticidal activity. The modern synthetic pyrethroids bear a little structural resemblance to the natural pyrethrins and their molecular mechanism of action differs as well.

The insecticidal action of the pyrethrins is characterized by a rapid knockdown effect, particularly in flying insects, and hyperactivity and convulsions in most insects. These symptoms are a result of the neurotoxic action of the pyrethrins, which block voltage-gated sodium channels in nerve axons. Pyrethrins exert their toxic effects by disrupting the sodium and potassium ion exchange process in insect nerve fibers and interrupting the normal transmission of nerve impulses. Pyrethrins insecticides are extremely fast acting and cause an immediate “knockdown” paralysis in insects. Despite of their rapid toxic action, however, many insects are able to metabolize (break down) pyrethrins quickly. After a brief period of paralysis, these insects may recover rather than die. To prevent insects from metabolizing pyrethrins and recovering from poisoning, most products containing pyrethrins also contain the synergist, piperonylbutoxide (Rattan, 2010).

4.1. 2. Nicotine

An alkaloid nicotine obtained from the foliage of tobacco plants (Nicotiana tabacum) and related species, has a long history as an insecticide. Nicotine and two closely related alkaloids, nornicotine and anabasine, are synaptic poisons that mimic the neurotransmitter acetylcholine. As such, they cause symptoms of poisoning similar to those seen with organophosphate and carbamate insecticides (Regnault-Roger and Philogène, 2008). In both insects and mammals, nicotine is an extremely fast-acting nerve toxin. It competes with acetylcholine, the major neurotransmitter, by bonding to acetylcholine receptors at nerve synapses and causing uncontrolled nerve firing. This disruption of normal nerve impulse activity results in rapid failure of those body systems that depend on nervous input for proper functioning. In insects, the action of nicotine is fairly selective and only certain types of insects are affected.

4.1.3. Rotenone

Rotenone is one of several is flavonoids produced in the roots or rhizomes of tropical legumes, Derris, Lonchocarpus and Tephrosia. Most rotenone used at present comes from Lonchocarpus and is often called cube root. Extraction of the root with organic solvents yields resins containing as much as 45 % totalrotenoids. Studies indicate that the major constituents are rotenone (44 %) and deguelin (22 %) (Cabizza et al. 2004). Rotenone is a mitochondrial poison, which blocks the electron transport chain and prevents energy production (Hollingworth et al. 1994). As a pesticide, it is considered a stomach poison because it must be ingested to be effective. Rotenone is a powerful inhibitor of cellular respiration, the process that converts nutrient compounds into energy at the cellular level. In insects rotenone exerts its toxic effects primarily on nerve and muscle cells, causing rapid cessation of feeding. Death occurs several hours to a few days after exposure.

4.1.4. Sabadilla

Sabadilla is a botanical pesticide obtained from the seeds of the South American lily *Schoenocaulon officinale*. In purity, the active principles, cevadine-type alkaloids, which are remarkably similar to that of the pyrethrins, despite their lack of structural similarity (Isman, 2006). In insects, sabadilla’s toxic alkaloids affect nerve cell membrane action, causing loss of nerve cell membrane action, producing loss of nerve function, paralysis, and death. Sabadilla kills insects of some species immediately,

while others may survive in a state of paralysis for several days before dying (Sarwar, 2021).

4.1.5. Ryania

Ryania is obtained by grinding the wood of the Caribbean shrub Ryania speciosa (Flacourtiaceae). The powdered wood contains < 1 % ryanodine, an alkaloid that interferes with calcium release in muscle tissue. It is used to a limited extent by organic apple growers for control of the codling moth Cydia pomonella (Fig. 2). Ryania is a slow-acting stomach poison. Although it does not produce rapid knockdown paralysis,it does cause insects to stop feeding soon after ingesting it (Weinzierl, 2000).

Fig. 2. Codling moth

4.1.6. Plant Essential Oils

Steam distillation of aromatic plants yields essential oils, which are since long been used as fragrances and flavorings in the perfume and food industries, respectively, and more recently for aromatherapy and as herbal medicines (Abd El-Aziz and El-Hawary, 1997; Buckle, 2003). Plant essential oils are produced commercially from several botanical sources, many of which are members of the mint family (Lamiaceae). The oils are generally composed of complex mixtures of monoterpenes, biogenetically related phenols, and sesquiterpenes. Examples include 1,8-cineole, the major constituent of oils from rosemary (Rosmari nusofficinale) and eucalyptus (Eucalyptus globus); eugenol from clove oil (Syzygiuma romaticum); thymol from garden thyme (Thymus vulgaris); and menthol from various species of mint (Mentha species) (Isman, 2008). Interest in the oils has been renewed with an emerging demonstration of their fumigant and contact insecticidal activities to a wide range of pests (Abdallah et al., 2004). The rapid action against some pests is indicative of a neurotoxic mode of action, and there is evidence interference with the neuromodulator octopamine by some oils and with GABA-gated chloride channels by others (El-Hosary, 2011).

As broad-spectrum pesticides, both pollinators and natural enemies are vulnerable to poisoning by products based on essential oils. On the other hand, plant oils have harmless effects on predacious mites (Sarwar, 2017). Contact and fumigant insecticidal actions of plant essential oils have been well demonstrated against stored product pests (*Acanthoscelides obtectus*). Knockdown activity and lethal toxicity via contact has been demonstrated in the American cockroach (*Periplaneta americana*), the German cockroach (*Blattella germanica*), and the housefly (Musca domestica) (Rice and Coats, 1994).

Certain essential oil monoterpenes are competitive inhibitors of acetylcholinesterase. The modes of action of limonene and linalool in insects are not fully understood. Limonene is thought to cause an increase in the spontaneous activity of sensory nerves. The central nervous system may also be affected, resulting in additional stimulation of motor nerves. Massive over stimulation of motor nerves leads to rapid knockdown paralysis. Constituents of essential oil like citronellal, thymol, and α-terpineol are most effective as feeding deterrents against tobacco cutworm (Fig. 3) *Spodoptera litura* synergism, or additive effects of the combination of monoterpenoids from essential oils are reported against *S. litura* larvae (Hummelbrunner and Isman, 2001).

Fig. 3. Tobacco cutworm

4.2. The Second-Generation Botanical Pesticides

The second-generation pesticides are largely included synthetic organic compounds against pests.

4.2.1. Synthetic Pyrethroids

The evolution of this class of compounds has since yielded a vast array of molecules, some with greater lipophilicity, extremely low water solubility, and

considerable persistence because of the use of single or multiple halogen atoms. Synthetic pyrethroids are generally recognized as neurotoxicants that act directly on excitable membranes. These compounds induce intense repetitive activity in sense organs and in myelinated nerve fibers. In the lateral-line sense organ, this repetitive activity increases with cooling, a phenomenon that may be related to the negative temperature coefficient of toxicity of pyrethroids in insects (Sarwar and Salman, 2015b).

Pyrethroids are also known to cause prolongation of the sodium current together with repetitive activity in nerve fibers of invertebrates (Henk et al. 1982). It has been suggested that the sodium channel in the nerve membrane is the major target site of pyrethroids. Other results showed that these compounds modify sodium channel gating in a strikingly similar way and reduce selective rate of closing of the activation gate.

4.2.2. Neem Products (Azadirachtin)

Two types of botanical pesticides can be obtained from seeds of the neem tree (*Azadirachta indica*) (Meliaceae) (Fig. 4). Neem oil, obtained by cold-pressing seeds, can be effective against soft-bodied insects and mites (Sarwar, 2019b), but is also useful in the management of phytopathogens. Apart from the physical effects of neem oil on pests and fungi, disulfides in the oil likely contribute to the bioactivity of this material (Dimetry, 2012).

More highly valued than neem oil are medium polarity extracts of the seed residue after removal of the oil, as these extracts contain the complex triterpene azadirachtin. Neem seeds actually contain more than a dozen azadirachtin analogs, but the major form is azadirachtin and the remaining minor analogs likely contribute little to the overall efficacy of the extract. Seed extracts include considerable quantities of other triterpenoids, notably salannin, nimbin, and derivatives thereof. The role of these other natural substances has been controversial, but most evidence points to azadirachtin as the most important active principle (Isman, 2002). Neem seeds typically contain 0.2–0.6 % azadirachtin by weight, so solvent partitions or other chemical processes are required to concentrate this active ingredient to level 10–50 % seen in the technical grade material used to produce their products (Sallena, 1989).

Azadirachtin has two profound effects on insects. At the physiological level, azadirachtin blocks the synthesis and release of molting hormones (ecdysteroids) from the prothoracic gland, leading to incomplete ecdysis in immature insects. In adult female insects, a similar mechanism of action leads to sterility. In addition, azadirachtin is a potent antifeedant to many insects.

Fig. 4. ***Azadirachta indica***

4.2.3.Melia Extracts

The remarkable bioactivity of azadirachtin from the neem tree (A. indica) led to the search for natural pesticides in the most closely related genus, Melia. Seeds from the chinaberry tree Melia azedarach (Fig. 5), contain a number of triterpenoids, the meliacarpins that are similar but not identical to the azadirachtins, and these also have insect growth regulating bioactivities (Kraus, 2002).

The M. azedarach growing in Argentina lacks meliatoxins, but produces triterpenoids (most notably meliartenin) that are strong feeding deterrents to insect pests and could prove useful for pest management (Carpinella et al., 2003). The Melia toosendan (Fig. 6), is a tree considered by most taxonomists to be synonymous with M. azedarach. An extract of its bark contains a number of triterpenoids based on toosendanin, a substance reported to be a stomach poison for chewing insects. Later studies suggest that this substance acts primarily as a feeding deterrent, but can also serve as a synergist for conventional insecticides (Feng. et al., 1995).

When M. toosendan came under scientific scrutiny, an investigation of the east African Melia volkensii (Fig. 7) demonstrated bioactivity in insects from seed extracts of this species. The active principles in *M. volkensii* include the triterpenoids alannin, also a major constituent of neem seed extracts, and some novel triterpenoids such as volkensin. Collectively these function as feeding deterrents and stomach poisons with moderate efficacy against chewing insects (Rembold and Mwangi, 2002). Neem products are complex mixtures of biologically active materials, and in insects, neem is most active as a feeding deterrent, but in various forms it also serves as a repellent, growth regulator, oviposition (egg deposition) suppressant, and sterilant, or toxin. As a growth regulator, neem is thought to disrupt normal development interfering with chitin synthesis (Salama and Sharaby, 1988).

Fig. 5. Melia azedarach

Fig. 6. Meliat oosendan

Fig. 7. Melia volkensii

4.3. Potential new Botanicals

There are unlimited numbers of botanicals have potential for future commercialization as a biorational alternative to control the potential threat of insects in crops.

4.3.1. Annonaceous acetogenins

The acetogenin class of polyethers is found exclusively in the Annonaceae family of plants. Annonaceous acetogenins are an important group of long-chain fatty acid derivatives found exclusively in the plant family Annonaceae. Tetrahydrofuranoid acetogenins have been found to have potent pesticidal and feeding deterrent activities against a diverse variety of pests such as mosquito larvae, spider mites, aphids, Mexican bean beetle, striped cucumber beetle, blowfly larvae and nematodes. A new acetogenin called 'asimicin' has been isolated and is typical of the subject class of useful compounds: A quantitative liquid chromatography/tandem mass spectrometry method is established for the quality control of the annonaceous acetogenins in the extracts of the pawpaw tree Asimina btriloba (L.) Dunal (Annonaceae) (Fig. 8) (Gu et al. 1999). Novel member named asimicin Included within this class of compounds has been isolated from the bark and seeds of the pawpaw tree *A. triloba*.

Fig. 8. Asimina triloba

Botanical pesticides have been traditionally prepared from the seeds of tropical Annona species, members of the custard apple family (Annonaceae). These include the sweetsop (Annona squamosa) (Fig. 9) and soursop (*Annona muricata*) (Fig. 10), which are important sources of fruit juices. Detailed investigations in have led to the isolation of a number of long-chain fatty acid derivatives, termed acetogenins, responsible for insecticidal bioactivity. The major acetogenin obtained from seeds of *A. squamosa* is annonin I, or squamocin (Johnson et al. 2000). A simicint reduces the rate of oxygen consumption by fourth instar *Ostrinia nubilalisas* measured with a constant volume manometer.

Fig. 9. Annona squamosa

These compounds are slow-acting stomach poisons, particularly effective against chewing insects such as lepidopterans and the Colorado potato beetle

(Leptinotarsa decemlineata) (Fig. 11) (Johnson et al., 2000).

Fig. 10. Annona muricata

Fig. 11. Colorado

4.3.2. Polyesters of sugars

There are polyesters of sugars which include sucrose and sorbitol octanoates. The sugar or sucrose esters naturally occurring in the foliage of wild tobacco (*Nicotiana gossei*) (Fig. 12) are pesticidal to certain soft-bodied insects such as whitefly and mites (Buta et al. 1993). The glandular trichomes of wild tobacco contain complexes of either glucose or sucrose esters (sometimes both). These leaf surface lipids have biological activity against insects and microorganisms. This product is a contact pesticide that kills small insects and mites through suffocation (by blocking the spiracles) or disruption of cuticular waxes and membranes in the integument leading to desiccation.

There are other polyesters of sugars and including sorbitol octanoates. They are also isolated from the poisonous hairs on the tobacco leaves which hitherto are assumed to contain nicotine, a popular insecticide. When insects are contaminated by rubbing, they cause death of the insects by a dehydration process and rapidly degrade to harmless sugars and fatty acids. These polyesters are known to be effective against a variety of farm and domestic insect pests and the deadly parasitic Varroa mite, which usually settles on the back of honey bees (Sarwar, 2016b).

Fig. 12. Nicotiana gossei

5. Botanicals Mode of Actions

Knowing about the mode of action is integral to improving the quality and sustainability of a product. For understanding how pesticides work (their mode of action), it is necessary to understand how the pests targeted systems normally function. Another reason to understand the modes of action of pesticides is to prevent the development of pesticide resistance in the target pests. Using pesticides with the same mode of action contributes to this problem by killing the susceptible pests and leaving only those with resistance to the entire class of pesticides that work through similar mechanisms (Sarwar and Salman, 2015c; Sarwar, 2016c). Botanical pesticides can be grouped according to their mode of action or the way a pesticide destroys or controls the target pest. This is also referred to as the primary site of action. For example, one insecticide may affect insect nerves, while another may affect molting (El-Wakeil, 2013). There are many modes of actions for various botanical pesticides as shown in Table 3.

6. Biotechnology for Natural Product Synthesis

Currently, there has been a growing interest in research concerning the possible use of botanicals as alternatives to synthetic insecticides. Many higher plants produce economically important organic compounds such as oils, resins, tannins, natural rubber, gums, waxes, dyes, flavors and fragrances, pharmaceuticals, and pesticides. The generation of mutants is a tool available for increasing of natural product diversity. Furthermore, global society is demanding natural products and rejecting synthetic chemicals for all possible uses including crop protection. Although the search continues with increasing intensity, finding new and more useful products would not have matched the effort without the support of biotechnology. Although the most powerful approach is genetic

manipulation, other techniques such as mutagenesis, breeding and protoplast fusion, and the relatively old biotechnology of plant tissue culture are very useful. These also include even more simple approaches such as optimizing culture conditions and the design of fermenters. The combination of technologies together with innovative ideas has already increased the production level of already existing natural products and expanded the diversity of products obtainable from biological sources (Hettiarachi, 2011; Roohi et al. 2019; Noreen et al. 2021). Therefore, there is a need for more intensive research on optimizing the production of already identified bioproducts, with simultaneous research efforts on new product formation.

Table 3. Mechanism of action by plant-origin pesticides

Insect system	Mechanism of action	Compound	Plant source
Cholinergic system	Inhibition of acetylecholinestrase (AChE)	Essential oils	*Azadirachtin indica*, *Mentha* spp., *Lavendula* spp.
	Cholinergic acetylcholine nicotinic receptor agonist/ antagonist	Nicotine	*Nicotiana* spp., *Haloxylonsa licornicum*, *Stemona japonicum*
Gamma-aminobutyric acid (GABA) system	GABA-gated chloride channel	*Thymolsil phinenes*	*Thymus vulgaris*
Mitochondrial system	Sodium and potassium ion exchange disruption	Pyrethrin	*Crysanthemum cinerariaefolium*
	Inhibitor of cellular respiration (mitochondrial complex I electron transport inhibitor (METI)	Rotenone	*Lonchocarpus* spp.
	Affect calcium channels	Ryanodine	*Ryania* spp.
	Affect nerve cell membrane action	Sabadilla	*Schoenocaulon officinale*
Octopaminergic system	Octopaminergic receptors	Essential oils	*Cedrus* spp., *Pinus* spp., *Citronella* spp., *Eucalyptus* spp.
	Block octopamine receptors by working through tyramine receptors cascade	Thymol	*Thymus vulgaris*
Miscellaneous	Hormonal balance disruption	Azadirachtin	*Azadirachtin indica*

Obviously, these results have equally established that plants belonging to certain families of vegetation are more likely to possess pesticidal activity. Thus, these upshots will serve as useful guides in the collection of plants for laboratory research studies and field trials.

CONCLUSION

The insecticides of plant origin could be exploited for the development of novel molecules with highly precise targets for sustainable insect pest management. Different types of plant preparations such as powders, solvent extracts, essential oils, and whole plants have been reported for their insecticidal activity against insect pests including their actions as fumigants, repellents, anti-fee dents, and insect growth regulators. Finally, it came to know through this chapter the identification of the botanicals, their corresponding plant, their parts used, and targeted pest. From the assignment, we can easily say that many field crops can be controlled from the potential threat of insects through the use of botanicals, and the use of botanicals is important and effective indeed.

Some newer plant-derived products and their application technologies deserve proper attention for use in the control of infestations of food commodities infested by different species of insect pests. Botanical pesticides (essential oils, flavonoids, alkaloids, glycosides, esters, and fatty acids) have various chemical properties and modes of action and affect insects in different ways namely; repellents, feeding deterrents, antifeedants, toxicants, growth retardants, chemosterilants, and attractants.

The conclusion can also be drawn that the botanical mixtures could form the basis for a successful formulation and commercialization of bio-pesticides in developing countries, where low agriculture inputs are in vogue. In several countries, such plants are readily available in the local markets all around for farmer's use to protect their crops. Since the materials are used in ethnobotany for the treatment of various ailments, they are safe, cheap, easily biodegradable, and technologically and environmentally friendly. They could provide valuable alternatives to synthetic insecticides in the management of insect pests of field crops in limited resource farmer's farms. Further studies are required to ascertain their optimum mixture levels and spraying schedules for optimum crop yield.

Although the search continues with increasing intensity, finding new and more useful products would not be possible without the support of biotechnology.

REFERENCES

Abd-El-Aziz, E.S.; El-Hawary, F.M.A. Inhibitory effects of some essential oilson the development of the cotton leafworm, *Spodoptera littoralis* (Boisd.). *J. Egypt German Soc. Zool.* 1997, 22: 117–130.

Abdallah, S.A.; Barakat, A.A.; Badawy, H.M.A.; Soliman, M.M.M. Insecticidal activity of different wild plant extracts against Aphis craccivora Koch. *Egypt J. Biol. Pest Control*. 2004, 14: 165–173.

Ahmad, N.; Sarwar, M.; Khan, G. Z.; Tofique, M.; Salam, A. Efficacy of some plant products and synthetic chemicals to manage the outbreak of Mealy Bug (*Maconellicoccus hirsutus*) in Cotton. *Journal of Agriculture and Biological Sciences*. 2011, 3 (1): 16-21.

Buckle, J. Clinical aromatherapy: Essential oils in practice. Churchill Livingstone, *Edinburgh*. 2003, 416.

Burt. S. Essential oils: their antibacterial properties and potential applications in foods- A review. *Int. J. Food Microbiol*. 2004, 94: 223–253.

Buta, J.G.; Lusby, W.R.; Neal, J.W.J.; Waters, R.M.; Piuarelli, G.W. Sucrose esters from *Nicotiana gossei* active against the greenhouse whitefly, Trialeurodes vaporatiorwll. Phytochemistry. 1993, 22: 859–864.

Cabizza, M.; Angioni, A.; Melis, M.; Cabras, M.; Tuberoso, C.V.; Cabras, P. Rotenone and rotenoids in cube resins, formulations, and residues on olives. *J. Agric. Food Chem*. 2004, 52, 288–293.

Carpinella, M.C.; Defago, M.T.; Valladares, G.; Palacios, S.M. Antifeedant and insecticide properties of a limonoid from *Melia azedarach* (Meliaceae) with potential use for pest management. *J. Agric. Food Chem*. 2003, 51: 369–374.

Dimetry, N.Z. Prospects of botanical pesticides for the future in integrated pest management programme (IPM) with special reference to neem uses in Egypt. Arch. *Phytopathol. Plant Prot*. 2012, 45, 1138–1161.

El-Hosary, R.A. Evaluation of some essential oils against *Sesamia cretica* Led. under field conditions. *J. Am. Sci.* 2011, 7: 563–568.

El-Wakeil, N. E. Botanical pesticides and their mode of action. *Gesunde Pflanzen*. 2013, 65 (4), 125–149.

Feng, R.; Chen, W.; Isman, M.B. Synergism of malathion and inhibition of midgut esterase activities by an extract from *Melia toosendan* (Meliaceae). Pestic. Biochem. Physiol. 1995, 53: 34–41.Glynne-Jones, A. Pyrethrum. Pestic Outlook. 2001, 12, 195–198.

Gu, Z.M.; Zhou, D.; Lewis, N.J.; Wu, J.; Johnson, H. A.; McLaughlin, J.L.; Gordon, J. Quantitative evaluation of *Annonaceous acetogenins* in Monthly Samples of Pawpaw (*Asimina triloba*) Twigs by liquid chromatography/electrospray Ionization/ tandem mass spectrometry. *Phytochem. Anal.* 1999, 10, 32–38.

Henk, P.M.; Vijverberg, J.M.; Zalm, V.D.; Bercken J.V.D. Similar mode of action of pyrethroids and DDT on sodium channel gating in myelinated nerves. *Nature.* 1982, 295, 601–603.

Hettiarachi, S. Biotechnology: a Tool for natural product synthesis. In: Natural products in plant pest management, N.K. Dubey (Ed.). CAB International. 2011, 263-279.

Hollingworth, R.; Ahmmadsahib, K.; Gedelhak, G.; McLaughlin, J. New inhibitors of complex I of the mitochondrial electron transport chain with activity as pesticides. *Biochem. Soc. Trans*. 1994, 22: 230–233.

Hummelbrunner, L.A.; Isman, M.B. Acute, sublethal, antifeedant, and synergistic effects of monoterpenoid essential oil compounds on the tobacco cutworm, *Spodoptera litura* (Lepidoptera: Noctuidae). *Journal of Agriculture and Food Chemistry*. 2001, 49: 715-720.

Isman, M.B. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annu Rev Entomol*. 2006, 51: 45–66.

Isman, M.B. Botanical insecticides: for richer, for poorer. *Pest Manag. Sci.* 2008, 64: 8–11.

Isman, M.B. Insect antifeedants. pestic outlook. 2002, 13, 152–157.

Johnson, H.A.; Oberlies, N.H.; Alali, F.Q.; McLaughlin, J.E. Thwarting resistance: *Annonaceous acetogenins* as new pesticidal and antitumor agents. In: Cutler SJ., Cutler, J.G. (Eds.). Biological active natural products: pharmaceuticals. Boca Raton, CRC Press. 2000, 173–83.

Kabir, H.Y.; Muhammad, S. Comparative studies of seed oil extract, leaves and stem bark powders of *Azadirachta indica* Linn (Meliaceae) on adults *Callosobruchus maculatus* (Coleoptera Bruchidae). *Biosci. Res*. 2010, 22 (6): 345–350.

Karunamoorthi, K. Medicinal and aromatic plants: A major source of green pesticides/Risk-reduced pesticides. *Med. Aromat Plants*. 2012, 1: e137.

Khan, M.H., Sarwar, M.; Farid, A.; Syed, F. Compatibility of pyrethroid and different concentrations of neem seed extract on parasitoid *Trichogramma chilonis*

(Ishii) (Hymenoptera: Trichogrammatidae) under laboratory conditions. *The Nucleus*. 2010, 47 (4), 327-331.

Kraus, W. Azadirachtin and other triterpenoids. Neem Found, Mumbai. 2002, 39–111.

Noreen, A., Sarwar, M.; Babar, H.S. Biotechnological trends in insect pests control strategy. In: Biopesticides in organic farming: recent advances. L. P. Awasthi (Ed.). CRC Press, Boca Raton. 2021; 333-339.

Okwute, S.K. Plant-derived pesticidal and antimicrobial agents for use in agriculture: A review of phytochemical and biological studies on some nigerian plants. *Journal of Agric. Sci. and Technol.* 1992, 2 (1), 62-70.

Okwute, S.K. Plants as potential sources of pesticidal agents: A review. In: Pesticides - Advances in chemical and botanical pesticides, R.P. Soundararajan (Ed.). Intech, 2012, 207-232.

Rajput, A.A.; Sarwar, M.; Bux, M.; Tofique, M. Evaluation of synthetic and some plant origin insecticides against *Helicoverpa armigera* (Hubner) on chickpea. *Pakistan Journal of Biological Sciences*. 2003, 6 (5): 496-499.

Rattan, R.S. Mechanism of action of insecticidal secondary metabolites of plant origin. *Crop Prot*. 2010, 29: 913–920.

Regnault-Roger, C.; Philogène, B.J.R.; Vincent, C. Biopesticides of plant origin. Lavoisier, Paris. 2005; 313.

Rembold, H.; Mwangi, R. Melia volkensii Gurke. Neem Found, Mumbai. 2002, 827–832.

Rice, P.J.; Coats, J.R. Insecticidal properties of monoterpenoid derivatives to the house fly (Muscidae) and red flour beetle (Tenebrionidae). *Pestic. Sci.* 1994, 41, 195–202.

Roohi, A.; Wali, Q.; Sarwar, M.; Naeem, M.; Zia, M.B.A.A. Comprehensive overview of transcription factors (WRKY, NAC and BZIP) in plants. *International Journal of Biosciences*. 2019, 14 (1), 495-509.

Salama, H.S.; Sharaby, A.M. Feeding deterrence induced by some plants in *Spodoptera littoralis* and their potentiating effect on Bacillus thuringiensis Berliner. *Internat. J. Tropical Insect Sci*. 1988, 9: 573–577.

Sallam, A.A.; Volkmar, C.; El-Wakeil, N.E. Effectiveness of different bio–rational insecticides applied on wheat plants to control cereal aphids. J. Plant Dis. Prot. 2009, 116: 283–287.

Sallena, R.C. Insecticides from neem. In: Amason IT, Phllogene BJR, Morand P. (Eds.) Insecticides of plant origin. American Chemical Society, Washington, DC. 1989; 213.

Sarwar, M. Competency of natural and synthetic chemicals in controlling gram pod borer, *Helicoverpa armigera* (Hubner) on chickpea crop. *International Journal of Agricultural Sciences*. 2012, 2 (4), 132-135.

Sarwar, M. Integrated pest management (IPM) - A constructive utensil to manage plant fatalities. *Journal of Agriculture and Allied Sciences*. 2013a, 2 (3): 1-4.

Sarwar, M. The Inhibitory properties of organic pest control agents against Aphid (Aphididae: Homoptera) on Canola *Brassica napus* L. (Brassicaceae) under field environment. *International Journal of Scientific Research in Environmental Sciences*. 2013b, 1 (8), 195-201.

Sarwar, M. The propensity of different larval stages of lacewing *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) to control aphid *Myzus persicae* (Sulzer) (Homoptera: Aphididae) evaluated on Canola *Brassica napus* L. Songklanakarin. *Journal of Science and Technology*. 2014, 36 (2), 143-148.

Sarwar, M. The killer chemicals for control of agriculture insect pests: The botanical insecticides. *International Journal of Chemical and Biomolecular Science*. 2015a, 1 (3), 123-128.

Sarwar, M. Information on activities regarding biochemical pesticides: an ecological friendly plant protection against insects. *International Journal of Engineering and Advanced Research Technology*. 2015b, 1 (2), 27-31.

Sarwar, M. A potent folklore of botanical plant materials against insect pests together with their preparations and applications. Sky Journal of Biochemistry Research. 2016a, 5 (4): 58-62.

Sarwar, M. Mites- The tiny killers to push honeybee colonies into collapse and integrated pest management. *International Journal for Research in Applied Physics*. 2016b, 1 (7), 12-21.

Sarwar, M. Potential uses of synergists in insecticides resistance management accompanied by their contributions as control agents and research tools. *Chemistry Research Journal*. 2016c, 1 (3), 21-26.

Sarwar, M. Predatory mites (Acari: Phytoseiidae) culturing for their releasing. Lap Lambert Academic Publishing, Saarbrucken, Germany. 2017, 140 pp.

Sarwar, M. Multiple integrated pest management (ipm) and area-wide management (AWM) approaches for Insect pests of Chickpea Cicer arietinum (L.) Walp Crop. In: Handbook of Chickpeas: Nutritional Value, Health Benefits and Management, Albert T. Lund and Noah D. Schultz (Eds.). Nova Science Publishers, Inc., New York. 2019a; p. 237-263.

Sarwar, M. Biology and ecology of some predaceous and herbivorous mites important from the agricultural perception. In: Pests Control and Acarology, Haouas, D. and Hufnagel, L. (Eds.). IntechOpen Ltd., London, UK. 2019b, 29.

Sarwar, M. Essential services by pollen vectors to ecosystem impacted by incidents of pesticides toxicity alongside pollinators protection and conservation. *Journal of Environment Protection and Sustainable Development*. 2020; 6 (2), 48-56.

Sarwar, M. Biopesticide weapons against agricultural Mite Pests. In: Biopesticides in organic farming: recent advances. L. P. Awasthi (Ed.). CRC Press, Boca Raton. 2021, 323-330.

Sarwar, M.; Salman, M. Success stories of eco-friendly organically acceptable insecticides as natural products discovery. *International Journal of Materials Chemistry and Physics*. 2015a, 1 (3), 392-398.

Sarwar, M.; Salman, M. The paramount benefits of using insecticides and their worldwide importance in food production. *International Journal of Bioinformatics and Biomedical Engineering*. 2015b, 1 (3), 359-365.

Sarwar, M.; Salman, M. Insecticides resistance in insect pests or vectors and development of novel strategies to combat its evolution. *International Journal of Bioinformatics and Biomedical Engineering*. 2015c, 1 (3), 344-351.

Sarwar, M.; Salman, M. From production to field application methodology of generalist predator green lacewing, *Chrysoperla carnea* [Stephens] (Neuroptera: Chrysopidae). *International Journal of Zoology Studies*. 2016, 1 (1), 35-40.

Sarwar, S. and Sarwar, M. Scope of botanical pesticides in storage insect pests management. In: Principles of Organic Farming, L. P. Awasthi, S. Das & S. Pattanayak (Eds.). I. K. International Pvt. Ltd. New Delhi, India. 2022; p. 251-274.

Sarwar, M.; Ali, A.; Ahmad, N.; Tofique, M. Expediency of different botanical products intended for managing the population of rice stem borers. Proce. 25th Pakistan Conger. of Zoology, March 1-3, Sindh Agriculture University, Tandojam. 2005, 25: 15-23.

Sarwar, M. H., Sarwar, M. F., Khalid, M.T.; Sarwar, M. Pesticides exposure impacts on human health and need for Biopesticides in Organic Farming. In: Biopesticides in Organic Farming: Recent Advances, L. P. Awasthi (Ed.). CRC Press, Taylor & Francis, Boca Raton. 2021, 39-45.

Tembo, Y.; Mkindi, A.G.; Mkenda, P.A.; Mpumi, N.; Mwanauta, R.; Stevenson, P.C.; Ndakidemi, P.A.; Belmain, S.R. Pesticidal plant extracts improve yield and reduce insect pests on legume crops without harming beneficial arthropods. *Front. Plant Sci*. 2018, 9: 1425.

Weinzierl, R.A. Botanical insecticides, soaps, and oils. In: Rechcigl JE, Rechcigl NA (Eds.) Biological and biotechnological control of insect pests. Lewis Publishers, Boca Raton. 2000, 101–121.

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Traditional and Biocultural Potential of Toko Plant (*Livistona jenkinsiana* Griff) in East Siang District, Arunachal Pradesh

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ABSTRACT

A brief study was conducted in Mirku, Napit, Balek, and Takilalung villages of East Siang district, Arunachal Pradesh. The district has diverse forest ecosystems that provide both economic and social benefits for local people. *Livistona jenkinsiana* Griff (locally called Toko by the Adi tribe), is a plant species that provide both economic and social benefits for the local community and it also has traditional and cultural significance within the community. Male and female members engaged in toko plantations were chosen as the respondents of the study. Using personal interviews; questionnaire-based data were collected. Based on the village and forest survey, it was observed that toko in good numbers in varying habitats viz, jhum lands, morang, home gardens, and around paddy fields. The Adi tribe in the area planted toko as an agroforestry component. The overall establishment cost is relatively less compared to other plantations in the region. (Such as orange and pineapple). Women play a significant role in the conservation of this species. The number of bio-culturally important products made out of the leaves and fruits of toko.

INTRODUCTION

Livistona jenkinsiana Griff is a species of palm of the family Arecaceae. It was first described by William Griffith in 1845 from the collection made in 1842 by Major Francis Jenkins from Nowgaon, Assam; the type specimen is still available in the National Botanical Garden of Belgium (Barfod et al., 2010).

It is a palm with large fan-shaped leaves on spiny petioles, thereby commonly known as a fan palm. It is very similar to L. speciosa in its leaves and the downward curving spines on the petioles of its leaves, but it is distinguished from this species by its fruit color (laden- blue vs turquoise-iridescent), by its fruit being wider than long vs longer than wide, and by the branching of its infructescence which is to the third- order rather than the fourth. It is a tall, fan- shaped, singly growing palm, height of up to 10 meters but at maturity it may reach more than 10 meter. Leaves palmate, long up to 480 cm, petiole 340 cm tall, blade or lamina size across 250 cm, split after two-third distance from the base of lamina, segment number 80 to 94, erect at the apices, lamina externally rounded, grayish green abaxially, green adaxially, petiole 30cm thick, 61 cm width, petiole with two types spines along margins, decreasing in density toward distal end, arranged alternately with long 30cm tall, after short, 10 cm tall, recurved, tip pointed, both are brown in color. L. jenkinsiana is a plant of tropical regions, though it can be grown in more or less frost- free temperate and subtropical climates. It is found in areas of high rainfall, which can be with or without a distinct dry season. Grow best in a sunny, moist, but well drained position found in the wild mainly on sandy loam (Sourav et al., 2020).

Secondary metabolites such as phenols, flavonoids and anthocyanins produced in the plants as a part of self defense from pest and disease attacks, are having various health benefits. These bio-active compounds are receiving considerable importance due to their various

health benefits such as anti-allergic, anti- carcinogenic, anti- inflammatory, anti- proliferative, antiviral, cardioprotective and vasco protective (Bhargav et al., 2018; Ganeshpurkar and Saluja, 2017).

Livistona jenkinsiana Griff is an endangered and threatened species in the Indian continent and globally too. Livistona species has a wide distribution; distributed in Africa, South Arabia, South East and Eastern Asia, Malaysia and Australia, China and Thailand (Barfod et al., 2010).

Datta and Rawat (2003) observed foraging of mature fruit by hornbills in northeast India. More recently, Payum (2018) in his study found a number of volatile and non-volatile compounds from the fruit of Livistona jenkinsiana Griff with various health benefits. The ethanol extract of L. jenkinsiana fruit contain forty three compounds out of which 22 compounds have been reported to be useful and biologically active against number of health problems like anticancer, antioxidant, prevention of uric acid formation etc. Out of the 43 compounds, Trehalose occupied 40% of the TIC (Total ion chromatogram) peak area percentage, trehalose is an energy source and also a protectant against the effects of freezing or dehydration, an attractive ingredient in food, health and beauty and pharmaceutical products (Payum, 2018).

Northeastern region of India is considered one of the biodiversity hot spots and abode of the Indian cultural diversity and repository. The tribal people of Arunachal Pradesh use natural resources in almost all aspects of their life. For instance, the food they eat is collected from the forest and the house they stay in is also constructed by using materials collected from the forests. Livistona jenkinsiana Griff; an endangered and threatened species is used in many useful purposes. Such as the use of stalk as firewood, fencing construction and ropes. Use of trunk in floor of local house, as the pillar and also in fencing construction. Fruits consumed raw or cooked (Singh et al. 2020).

Figure 1: *Livistona jenkinsiana* Griff.

Study area

The study was carried out in the East Siang district of Arunachal Pradesh (Figure1), situated at the eastern foothills of the Himalayas at 155 meters above sea level. The district lies in the coordinates approximately between 27°43'' and 29°20'' North latitudes and 94°42'' and 95°35'' East longitude. East Siang district occupies an area of 4,005 square kilometers (1,546sq mi). It is inhabited by the Adi community; the district is a wild mountainous area and presents a remarkable topographical variety. (Source: https://en.m.wikipedia.org/wiki/East_siang_district- year- 2022).

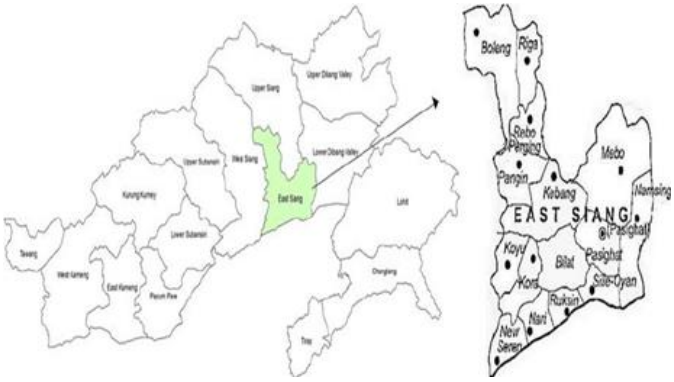

Figure 2: Distribution of Species in East Siang district

Climate

The East Siang district has a cold mountainous climate in the north while a tropical climate exists in the south. Where winter temperature drops up to 7°C and summer temperature goes up to 36°C. December and January are the coldest months and July – August are the hottest months. The District receives exceptionally heavy monsoons with an average rainfall of 31.34mm which equals nearly 25mm a day. (Source: http:cgwb.gov.in/District Profile/Arunachal/East%20Siang.pdf- year - 2022).

Demography

According to the 2011 census East Siang district has a population of 99,214. This gives it a ranking of 615th in India (out of a total of 640). The district has a population density of 27 inhabitants per square kilometer (70/sq mi). Its population growth rate over the decade 2001-2011 was 13.33%. East Siang has a sex ratio of 962 females for every 1000 males and a literacy rate of 73.54%. (Source: https://eastsiang.nic.in/east-siang-district-at-a-glance/- year - 2022).

Topography

The topography is characteristically rugged due to lofty, haphazardly arranged ranges and deep valleys criss-crossed by a number of rivers and streams spreading along the southern slopes of the eastern Himalayas to the western slope of the Potkoi hills and around the huge valley of mighty river Brahmaputra. (Source: https://en.m.wikipedia.org/wiki/East_siang_district - year - 2022).

METHODOLOGY

The study was carried out in four villages of East Siang district, Arunachal Pradesh namely Mirku, Napit, Balek and Takilalung during 2021-2022, based on the surveys and questionnaire method in which information provided by the common local people was collected and further interpreted. The questions were on the establishment, management, harvest, capital investment, labour input, sale and economic returns from the toko plantations.

RESULTS

The study areas were inhibited by the Adi community, the community posses a strong base of traditional knowledge about the forest structure and ecosystem function. The State's local communities have a large role to play where more than 80 percent of forested areas are private lands. Livistona jenkinsiana Griff is known by various names with local tribals such as, Toko, OW/ Yoak by Nyishipeople; Taa- ck by Adi tribe; Tokou; Tokouby Assamese; Talai nyom, Purbong by Lepchasof Sikkim. It is commonly known as the Assam Fan palm. In the course of family property sharing, it is taken into account and is inherited as an ancestral property.

Distribution and Status of L. jenkinsiana Griff.

The tree endemic to Northeast India grows up to an elevation of 1,100m. It is usually encountered in nature in tropical evergreen forests and sub-tropical broad leaved forests. Though the species is found almost throughout Arunachal Pradesh, the larger concentration is towards the central and eastern parts of the state, particularly in Upper Subansiri, West Siang, Upper Siang and East Siang districts (study area).Apart from its natural occurrence (in morang forest of Adi and other tribes too), it is largely Cultivated by the local people in their jhum land / community lands, home Gardens and around paddy fields.

As per the survey conducted in the study area the occurrence of toko in different habitats of the following villages was found to be; (i) Mirku, 1300 toko trees in jhumlands, 250 in morang forest, 80 in home gardens and 75 around paddy fields. (ii) Napit, 1700 toko trees in jhumlands, 400 in morang forests, 120 in home gardens and 90 around paddy fields. (iii) Balek, 3000 toko trees in jhumlands, 600 in morang forests, 100 in home gardens and 120 around paddy fields. (iv) Takilalung, 3100 in jhumlands, 670 in morang forests, 200 in home gardens and 110 around paddy fields (Figure3).

Relatively, more number of toko trees were observed in the jhumlands of Takilalung and Balek villages, because of the topography of jhum lands, soil fertility and being rural areas, most of the people were more involved in rural livelihood activities for their subsistence. Also both the village territories were larger than the other two villages viz, Mirku and Napit. The overall status of L. jenkinsiana Griff in the study area is abundant.

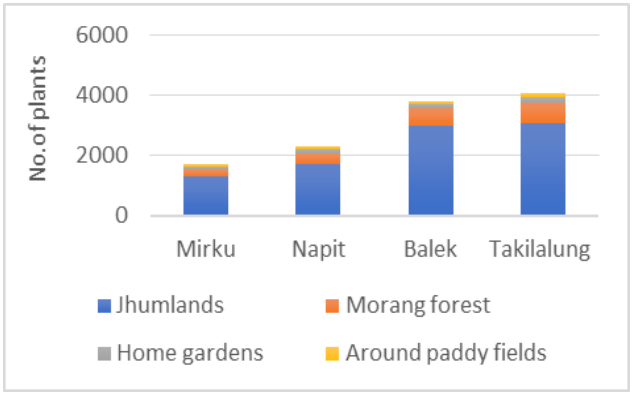

Figure 3: Number of Toko trees in studied villages

Natural Regeneration

Natural regeneration occurs by means of the seeds. Profuse regeneration can be seen in the vicinity of mature fruiting trees along partially open moist slopes. The seeds fallen over the ground or carried over by birds and squirrel - like animals or dropped on the soil during winter months start germinating in good habitats with pre monsoon showers in April – May and establish to form plants. However, the survival percentage is very low due to cattle damage and adverse ecological factors. Despite this, natural regeneration is usually observed in Morang forest as gregarious patches.

Artificial regeneration

Propagation by seeds is the easiest, cheap and most conventional method. Seeds can be gathered from during November - December when they are fully ripe. Freshly harvested seeds are used for sowing. The seeds are extracted from fleshy fruits by depulping, or removing the peal. This can be done manually or fruits can be kept in water or in soak-pits for a couple of days by which time slight rooting of fruit peal takes place and then it becomes easy to remove the peals by gentle mashing and washing.

Seed treatment

Freshly collected seeds are kept in basket wrapped with banana leaves or ekkam-pat (Phyrium pubinerve) for one month in order to loosen the tough impermeable seed coat. It can be otherwise eaten as chutney. Seed coats can be alternatively loosened by burying in soil wrapped with gunny bags.

Generally these seeds are not eaten. The clean seeds are broadcasted in the jhum field in the Month of April by using a digging stick (Dao), with a uniform spacing of about4m.The seeds can be sown in mother beds or directly in the polythene bags. The seeds should not be sown too deep in the soil and sowing at 2-3 cm depth is found to be ideal. Germination takes place after about 50-60 days of sowing. Sometimes germination may get delayed depending upon the sowing month and winter severity. However, by the month of April germination will take place. Thus, if seeds are sown in December it may germinate only in April next. Seed germination is up to 90-95% germination. Seedlings can be picked up sufficiently early in one leaf stage for transplanting them into polythene bags without causing damage to roots or adjacent seedlings. After picking out, it is good to give profuse watering. The seedlings are initially kept under shade and watering is done as and when required. A single watering per day is sufficient. When seedlings get established in the polybags, after 2-3 months they can be kept in open beds. Usually, this will be the rainy months and can thus avoid watering. Seedlings are comparatively hardy and devoid of disease and pests. They can, however, be monitored for weed infestation and cattle (Mithun, goat and cows) browsing. This initial growth of seedlings is slow and takes about 12-15 months in the nursery to attain plantable size (Table1). Similarly, seedlings can also be obtained and transplanted into polythene bags from the areas of gregarious regeneration, where otherwise the seedlings are destined to die.

Table 1: Procedure for seed treatment & raising seedlings

Seed sown	2-3 cm deep
Germination	After 50-60 days
Germination percentage	90-95%
Transfer of seeds to polythene bags	After 2-3 months
Growth of seedling to plantable size	12-15 months

Plantation technique

Planting is done when seedlings are about 18 months old at a spacing of 4m x 4m during May-June with the beginning of the rainy season. Adi people use closer spacing up to (2.5 x 2.5m) in hill Slopes when they grow toko as mono plantation (Table2). This helps in saving manpower for watering and also for assuring a better survival rate. Seedlings can be transplanted in any other month provided the soil has enough moisture for its establishment. The pits of 45x45x45 cm in size are made, weathered and filled with a rich mixture of soil, sand and farm yard manure at the time of planting (Figure3). After, planting, it is better to prune some of the basal leaves which encourages leaf production and reduces transpiration loss.

Obnoxious weeds like Mikania, Eupatorium, and Ageratum etc. tend to over topple the seedlings and hinder the establishment. Weeding ensure better survival and growth of plants. It has been observed that trunk formation starts after 4 years of planting and leaf production is at a rate of 1-2 leaves per month with an average of 10-12 leaves a year (Table3). The local practice of pruning the leaves and splitting the fiber cover helps in better growth and leaf production.

Table 2: Plant spacing of toko depending on the nature of the plantation

Site	Plant spacing	Planting season
Jhumlands (as mono plantation)	2.5m x 2.5m	May – June
Jhumlands (as agroforestry component)	4m x 4m	May- June

Table 3: Average leaf production from single toko plant

Leaf production per month (single tree)	Average leaves a year
1-2	10 - 12

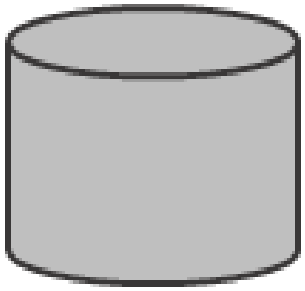

Figure 4: 45 x 45 x 45cm size pith

Traditional agroforestry

Toko can also be planted as an agroforestry or shade/ nursery tree species with other crops. It does not produce much shade as the stem is branchless and leaves occur at the top only, therefore, seasonal crops and vegetables can easily be grown below toko trees.

The Adi tribe in study areas was observed to follow the following agroforestry combination with the toko Tree: toko + ginger, toko + tea, toko+ orange (toko is taken as living fence crop), toko + tuber crops engin and singe-engin (sweet potato and tapioca) and t oko + maize (for initial 4-5 years) Table4.

At the time of establishing jhum lands, after the slash and burn of the forest, the first plantations of toko around the boundary of the field and in between as intercrop is also made. Following these traditional models of agroforestry, farmers are able to utilize the available spaces in between the two trees of toko. These models are adopted according to the slope of topography, nature of crops (shade loving) and the basic needs of the farmers. Usually in first 6 years of new jhum land establishment, crops intercropping are followed more.

Table 4: Traditional Agro-forestry components with Toko.

Toko +	*Ginger*
	Tea
	Orange
	Tuber crops; engine & Singe- engine (sweet potato and Tapioca).
	Maize
	Leafy vegetables.

Manure and fertilizers

Application of organic manure like oil cake dust, bone meal and fish meal are useful for hastening seedling growth. It decomposes slowly in the soil releasing the essential nutrients to growing plants for longer periods. Well rotten cow dung is also good manure but too much use of this manure is harmful and it invites termites and other pests. The manure should be applied before the growing season, i.e., at the end of colder months or just before the monsoon.

Plantation Cost

The overall establishment cost is relatively less as compared to other plantation establishments in the region (such as orange and pineapple). Seedlings may be collected from the natural stands or can be obtained from the fruits sold in the local markets at the rate of Rs. 50, 5 portions of such fruits gives sufficient seeds for establishing plantation of 1 acre. For planting an acre of plantation 3 laborers employed for Rs.600/day. The plantation requires weed management 3-4 times a year for which 4 laborers employed at the rate of 400 (Table5).

Table 5: Estimates of Total Establishment Cost of toko plantation (in Rs/Acre)

Nature of Costs	**Estimated cost (in Rupees)**
Seedling Cost	300
Plantation weed management	6400
Planting cost	1800
Total establishment Cost	8,500

Cow dung is preferred for manure if required; cow dung worth Rs. 100 is enough for 1 acre of plantation. At the time of harvest 3 laborers employed at the rate of Rs.600/day. Transportation cost of leaves to the market @ Rs.1200, the average cost of operation and maintenance incurred per acre is shown in Table 6.

Table 6: Average cost of operational and maintenance incurred per Acre

S.No.	**Nature of Cost**	**Amount (in Rupees)**
1.	Total Labour cost	3,400
1a.	Harvest & collection	1800
1b.	Plantation weed management	1600
2.	Manures & fertilizers	100
3.	Transport Costs	1200
	Total costs	4,700

Pests and diseases

Generally, no serious pests or diseases have been observed in the toko plant. However, some Insects attack the green leaves and fruits of the plants sporadically in some localities.

Sometimes, borer attack is seen in older stems which can be controlled by spraying insecticides. The major problem faced in establishing the plantation is cattle grazing/ browsing particularly by Mithun.

Harvesting

The fan-shaped leaves are harvested from a mature tree. Generally, while harvesting, only 2-3 leaves are left in the palm excluding the tender leaves. It is harvested after the

full moon to avoid termite and pest attack. There is a popular belief among Adis that the pre full moon days are not good for harvesting as those harvested will be vulnerable to pest attack and cause damage to the trees. The leaves are harvested on every alternate year. Generally, harvesting of toko at large scale is done by the indigenous institution called Mila. Male harvests the leaves, while female after making the bundles skillfully carry it. In this institution, male members of close relatives assembled together and help to toko plants owner for harvesting leaves and carrying it.

Drying and curing of leaves

After harvesting, the petioles of leaves are cut off leaving a small portion intact with the leaf blade then both the right and left flanks are folded to the same side of the leaf, arranged systematically, and stacked to dry. Over each stack some weight is given at the top to cure it and prevent it from crumpling during drying.
It is kept as long as the leaves turn completely brown only then it is used for roofing.

Economics of Toko leaves

The leaves are bundled and traded. Generally, each bundle has 40-45 leaves and sold or bartered with other tribes. In the villages, 50 leaves of toko are sold at Rs 70-90, while same numbers after trading in nearby local market (like Pasighat), the toko owners sale it in Rs 150-200 (Table 7).A single leaf may vary from Rs 2-6 depending upon conditions of market and season of leaves availability.

Table 7: Price of toko leaves bundle in village & local market

Leaves per bundle	Price in villages	Price in local market
40-50	Rs.70-90	Rs. 150-200

Good yield can be obtained for up to 35-40 years. The older palms bear small-sized leaves and it becomes difficult and risky to climb the older trees for the collection of leaves. Therefore, older trees are removed by felling.
The Adi community have experienced that the productivity of toko leaves is found always better in the Jhum land than in home gardens and around the paddy field. In the ideal situation, from 625 tree plants/ha, 10 leaves and a total 6,250 can be harvested. After deducting the labor and transportation charges, the net benefit is obtained every alternate year which may continue for over 30 years (Table 8). Additional income can be obtained by the sale of seeds and seedlings.

Table 8: Leaves harvested per hectare in the ideal situation

Toko plant/ ha.	No. of leaves harvested per tree	Total harvested leaves per hectare	Years of production
625	10	6250	30 years.

Biocultural uses

A number of products are made out of toko leaves and fruits, which had great cultural, food and Livelihoods values for Adi tribe. Using tender leaves of Toko, Botok (rain cover) is made. Botok is used to cover the back during the rainy season in fields, fishing etc. Botari (cap) is worn during ploughing of fields. The basket like item is also made from the leaves of toko.
The leaves are an integral part of using them to pack the meat and wild games during the special occasions like Solung, Etor and Aran festivals of Adi. The petioles are used in making mat.
Using leaves of toko, Hut (chang ghar) and Poyup (small hut in jhum land) are made. Leaves are used after proper drying as a roofing material for local houses. The leaves of kitchen room are said to last for 10 years or so, while leaves of other rooms for 4-5 years.
Leaves are used for covering tops of doolies (palanquins) and boats and making hand fans. Mid rib of the leaves is used to make coarse broom. Plants are largely used in nursery as overhead shade. The leaves are also used as the item to cover the burial places, and the store bin of community grain banks. These palms are also planted as an ornamental and avenue plants. Fibrous sheaths are used for making ropes; for making winter resistant shields for shoulder bags (tali). New soft shoots are sometimes eaten as vegetables. Pericarp of ripe fruits, which are blue in colour are eaten raw or as salad. Fruits are also used after the fermentation as chutney.
Dried peel of fruit contain good amount of oil and thus powder is now being used as mixing Items with the leaves of ongerc (Zanthoxylum rhetsa), ongin (Clerodendrum colebrookianum), and bangko (Solanum spirale) to use as chutney. Nut is edible and used as masticator; as a substitute for areca nut. The cut stems are used as temporary log bridges to cross over village streams and as posts of temporary structures.

Gender, conservation and knowledge variability

From seed collection to the plantation of toko, women play a pivotal role and contribute 80-95%. Only in those practices, where hard physical labor is required male folk contribute from 60%. As per the survey conducted in the study area, the contribution of men and women was

observed as, Seed collection (female-83%, male- 17%), seed soaking (female- 90%, male- 10%),nursery preparation (female-80%, male-20%),seed sowing (female- 95%, male- 5%), nursery care (female-82%, male- 18%), transplanting (female- 83%, male-17%), plantation (female-79%, male-21%), training & pruning (female-23%, male-77%), harvesting (female-20%, male-80%), curing of leaves (female-35%, male-65%), trading & marketing (female-85%, male-15%) (Figure5). This shows that women of Adi community have a significant role in the Conservation of toko tree populations. Males harvest the leaves from the toko tree, while females carry the load of bundles of Toko leaves. It could be learned that except for the practices of training and pruning of trees, harvesting skills of leaves and curing the leaves for use, women were significantly higher in all the toko related practices. Further, there was a difference in the knowledge of young, middle and old aged Adi community members on the conservation practices relating to the toko tree. It indicates that elders of the Adi community have more knowledge about toko tree which is helpful in conservation of this tree species.

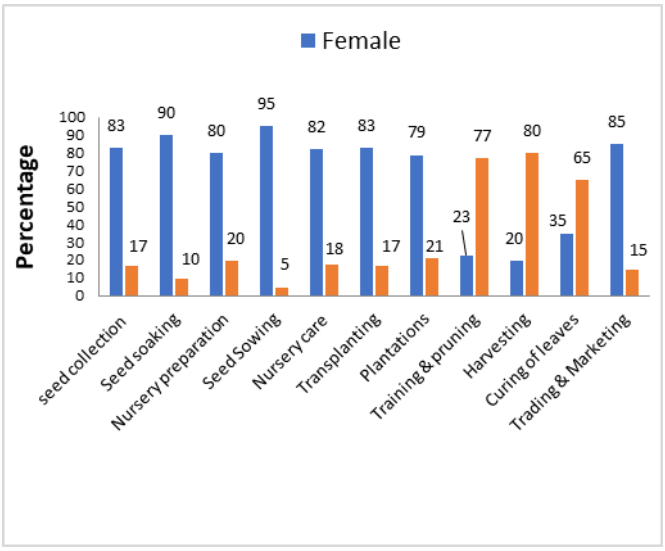

Figure 5: Gender role in conservation of toko tree

DISCUSSION

Arunachal Pradesh, being the largest state of Northeast India, harbours great number of plant species that are endemic to the region. The diversity and endemism of the state have kept in the category of biodiversity hot-spot. Though in the recent past in the Red Data Book of Indian plants (1987) a number of plant species are being listed as rare, endangered and threatened species because of increasing threats from anthropogenic and other natural factors. In the list of threatened species, L. jenkinsiana Griff has also been mentioned. However, as per the survey conducted in the study area, it was observed that there is no dearth of toko plants population. It can be endangered and threatened in other regions like Assam, but not in Arunachal Pradesh according to the study.

Singh et al. (2010) observed that toko is good in numbers in jhum lands, Morang, home gardens and around paddy fields, conserved by the adi community in East Siang District, Arunachal Pradesh by adopting closer plant spacing (2.5x 2.5m) in hill slopes when they grow toko as mono plantation. However, based on our village and forest survey in the study area it was found that some plantations had wider plant spacing varying up to 4 meters. The present survey of the study area found active participation and contribution of women in toko plantation in number of practices such as seed collection, seed sowing, planting, curing of leaves, trading and marketing shows that our observations are in line with the earlier observations made by Singh et al., 2010. In the year 2009-2010, L. jenkinsiana Griff was one of the major food items for the Asiatic black bear cubs (Dasgupta et al., 2015).

In the present study, it was observed that toko being a multipurpose tree has a variety of use and plays an integral role in the tribal Adi community, from the use of leaves as

thatching material , fruits, fibers, ropes, fire woods, different products such as; hand fans, mats, Botari, Botok, tali and cultural significance too. It provides income generation to the toko planters by selling the leaves in nearby local markets, like Pasighat. After harvesting, the leaves are arranged systematically and stacked to dry. Once the leaves have dried properly they are bundled and traded, each bundle has 40-45 leaves and is sold for Rs.150-20, which is at par with regarding the toko plant being an integral part of the Adi tribe earlier observed by Singh et al., 2010.

As per a survey conducted in the study area, it was observed that the survival percentage of naturally regenerating seeds was very low due to cattle damage and adverse ecological factors. However, natural regeneration was observed in morang forest as gregarious patches. Also, toko is planted as an agroforestry tree species with other crops, less manure is required and generally, no serious pests and diseases were observed this concedes with the earlier observations made by Singh et al. (2010).

CONCLUSION

Toko is a multipurpose tree; a number of products are made out of its leaves and fruits, which have great cultural, food and livelihood values for the Adi tribe. It finds its habitat in jhum lands, Morang forest (broad leaved forest) and to some extent in the home gardens

under subtropical climate. The seeds of toko are dispersed and carried over by the squirrels and birds. Due to the damage caused by animals in the seeds, the natural germination percentage is relatively low. However, germination is maintained by the Adi tribe through its traditional treatment after pruning in ekkam leaves. Apart from monoculture, the conservation of toko is encouraged by adopting the traditional agroforestry models by the Adi tribe. The higher plant population was observed in jhum land, because of its good productivity and people's preference according to the topography as well as toko has been observed to be a cross-culturally important species and an integral part of Adi tribe. Though inputs required for conservation promotion of toko are learned to be very less, however, the net income is of considerable percentage but not competitive in comparison to other cash crops. Because of labour-intensive jobs required for generating incomes from toko, younger people do not prefer to plant the toko. Therefore, more people are interested in planting high-cash crops such as oranges, pineapple, and others to have more economic gain. This discourages the conservation intensity of the toko tree. The conservation of Toko on an individual level and decreasing percentage of collective management seem to be caused by the disintegration of joint family to nuclear family and aggravated by the privatization of natural resources among the Adi tribe.

However, the conservation of toko in Morang forest provides a permanent reservoir for the use of its genetic resource to multiply later on in emergency conditions. The conservation of toko is primarily done by the women folk and variability in the knowledge required for it was noticed across the ages. Many studies indicate that indigenous institutions (kebang), traditional knowledge (TK), and TK nurturing institutions play a significant role in the conservation of indigenous biodiversity.

Toko is a bio-culturally important tree species and is being conserved across habitats and cultures. There is no dearth of the plant population of Toko in the study areas. It can be endangered and threatened in other regions like Assam, but not in Arunachal Pradesh.

The community with their TK and indigenous institutions (kebang) conserves this tree species at a large scale since it is an integral part of their life support system. Special attention is required to integrate the younger generation of the community with their better incentives so that the conservation intensity of Toko could be improvised at a larger scale. Further, the community needs training and research support on toko to enhance the plant population, but it is only possible when toko is well integrated with its rational use through value addition in its products (handicrafts, house construction material, food products from fruits etc.), proper market channels and controlled harvesting. There might be few biological threats against this species that need to be studied further to understand the complete status and issues around toko tree species in Arunachal Pradesh.

REFERENCES

Barfod, A.S., Dowe, J.L., Suksathan, P. Major Jenkins Fan palms in Thailand. PALMS, 2010, 54 (3), 109-18.

Bhargav, V., Kumar, R., Shivashankara, K.S., Rao, T.M., Dhananjaya, M.V.,Sane,A., Bharathi, T.U., Venugopalan, R., Roy, T.K. Diversity of flavonoids profile in China aster (Callistephus chinensis (L.) Nees) genotypes. Ind Crops Prod. 2018, (111), 513-519.

Datta, A. and Rawat, G.S. Foraging pattern of sympatric Hornbills during the nonbreeding season in Arunachal Pradesh, northeast India. Biotropica, 2003, (35), 208-218. https://doi.org/10.1111/j.1744-7429.2003.tb00280.x

Dasgupta, S., Choudhury, P., Ashraf, N.V.K., Bhattacharjee, P.C. and Kyarong, S. Food preferences of rehabilitated Asiatic black bearcubs in lowland tropical forests of northeast India. Asian Journal of Conservation Biology 2015, 4(1), 20-25.

Ganeshpurkar, A. and Salija, A.K. The farmacological potential of Rutin. Saudi Pharm. J. 2017, 25(2), 149-164.

Payum, T Chemical Composition and Ethnobotany of Livistona jenkinsiana Griff: An Endangered Thatching Palm Tree of Eastern Himalayas. Pharm. J. 2018, 10(6), 1202-1207.

Singh, R.K., Kumar, A., Singh, A., Singhal, P. Evidence that cultural food practices of Adi women in Arunachal Pradesh, India, improve social – ecological resilience: insights for Sustainable Development Goals. Ecological processes 2020, 9(29), pp19. https://doi.org/10.1186/s13717-020-00232-x.

Singh, R.K., Srivastava, R.C., Adi Community and Mukherjee, T.K.. Toko –patta (Livistonia lenkinsiana Griff): Adi community and conservation of culturally important endangered tree species in eastern Himalaya. Ind. J. T. K. 2010, 9(2), 231-241.

Sourav, Md. S.H., Anwar, K.B. Arenga westerhoutii and Livistona jenkinsiana Griff., two new species of wild palms for Bangladesh. *Trop. P. R.* 2020, 7(2), 374 - 378.

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Estimating Economic Efficiency Levels and Identifying Its Determinants for Milk Producers' Households in North Shewa Zone, Oromia Region, Ethiopia

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ABSTRACT

This study aimed to estimate economic efficiency levels and identify its determinants for milk producers' households in North Shewa Zone, Oromia Region, Ethiopia. Three stages random sampling technique was used to select 400 sample farmers. The data were analyzed using descriptive statistics and an econometrics model. The result of the stochastic frontier model showed significant and positive elasticity of lactation cow, green forage, and crop residue. The estimated mean values of technical, allocative, and economic efficiency were 58%, 77.6%, and 44.7% respectively. The yield gap due to technical inefficiency was 9.6 liters per cow per day. A two-limit Tobit model result shows that education, amount of concentrate feed used, grazing land, type of breed, and frequency of extension contact contributed significantly and positively to technical efficiency. Moreover, total land, dairy farm experience, dairy membership, and type of breed affect allocative efficiency significantly and positively while the amount of concentrate feed used had a significant and negative effect on allocative efficiency. Economic efficiency is also affected significantly and positively by education level, total land, grazing land, type of breed, and frequency of extension contact. To improve the efficiency level of farmers, due attention should be given to the use of concentrate feed, improving feed availability, adequate and proper management of grazing land, and using of improved breed and dairy cooperatives.

INTRODUCTION

Ethiopia has the tenth-largest livestock inventory in the World. The country has the largest number of livestock, more than any other country in Africa. Ethiopia leads with a staggering 60.39 million cattle, while Tanzania, in the second position, has an estimated total of 33.9 million cattle (Africa Census, 2020). Though Ethiopia has a large livestock inventory, the productivity of cattle remains low.

According to Central Statistical Agency (CSA) (2020), there are around 7.56 million dairy cows in Ethiopia. Of

these, 15.04 million are milking cows. On average, each cow produces 1.48 liters of milk daily. Nathaniel et al. (2014) indicated that dairy inputs and service provisions are still at the infant stage and the development of improved dairy cows is limited in the country. The increase in milk production may have come mostly from the increased number of cows rather than increased productivity. Nega and Simeon (2006) indicated the inefficiency among smallholder dairy producers due to the inefficient use of scarce resources. Understanding the existence of inefficiency and different factors contributing to the inefficiency by farmers and policymakers helps to improve efficiency with a view to bringing a desired change in the sector. However, most efficiency studies in agricultural economics focus on technical efficiency, which is just one component of overall economic efficiency. Focusing only on technical efficiency (TE) understates the benefits that producers could from improvements in overall performance. Unlike technical efficiency, research done on economic efficiency, especially in milk production is limited. In addition, many empirical studies did not consider yield gaps because of technical inefficiency among milk producers.

North Shewa Zone, Oromia Region in Ethiopia has milk production potential, and the demand for milk and milk products has been increasing while output is not able to meet the higher demand. Moreover, there is an output difference among dairy producers. Dairy producers have little knowledge of how to use minimum cost (cost efficiency) in the study area. Therefore, knowledge about the level of economic efficiency of smallholder milk production and the underlying socio-economic and institutional factors causing inefficiency may help to assess the opportunities for increasing milk production. Additionally, to the best of knowledge, no studies have been conducted in the area of economic efficiency (EE) of milk production, especially in the study area. Hence, there is a need to fill the existing knowledge gap by addressing issues related to technical, allocative efficiency (AE), and EE of smallholder milk production in the study area by providing empirical evidence on smallholder milk producers. Therefore, the objective of this study was to estimate economic efficiency levels and identify the determinants for milk producer households in North Shewa Zone, Oromia Region, Ethiopia.

METHOD AND MATERIALS

Study Area

This study was conducted in the North Shewa Zone of Oromia Regional state, Ethiopia due to its high potential in milk production. It has a total of 13 districts and is bordered on the South by Oromia Special Zone Surrounding Addis Ababa, on the South West by West Shewa, on the North by the Amhara Region, and on the South East by East Shewa.

Samplin g Techniques and Sample Size Determination

Three stages of random sampling procedures were employed to draw a representative sample. In the first stage, four districts, Degem, Wuchale, Debra Libanos, and Girar Jarso, out of 13 milk producing districts in the zone, were purposively selected. In the second stage, two kebeles from each district, with a total of eight kebeles from four sampled districts, were selected purposively due to their high dairy production potential. In the third stage, 400 sample farmers were selected using a simple random sampling technique based on probability proportional to the size of milk producers in each of the eight selected kebeles. The sample size was determined by using the formula provided by Yamane (1967).

Accordingly, the sample size for the study is determined based on the following formula:

$$n = \frac{N}{1 + N(e)^2} = \frac{37243}{1 + 37243(0.05)^2} = 400 \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, n = sample size (including the non-response rate of 1%), N = Total milk producers in the study area, and e = Level of precision considered.

Table 1: Sample size distribution

No.	Name of sampled district	Total household milk producers	Sampled household	Proportion (%)
1	Degem	5570	60	15.00
2	Wuchale	13880	149	37.25
3	Debralibanos	4273	46	11.50
4	Girarjarso	13520	145	36.25
Total		37243	400	100

Source: North Shewa Livestock and Fishery Development Office (2020)

Types, Sources, and Methods of Data Collection

The research is accomplished using primary and secondary data sources, which are qualitative and quantitative in nature. The primary data necessary to achieve the designed objectives were obtained from sample households through a structured questionnaire for sampled households and a checklist for focus group discussion and key informants interviews. Secondary data was collected from relevant sources such as articles, proceedings, journals, CSA, and district annual reports which were vital to the study.

Data measurement

i. Output variable: It is defined as the actual quantity of milk produced and measured in liters (L) during the 2020 production year by sample households. This is a dependent variable of the production function taken as a continuous variable.

ii. Input variables: Defined as the total inputs used by sample household in the production of milk namely: lactation cow (number), labor (Man-day), Green forage (beli), and crop residue (beli) in the 2020 production year (1beli=1kg).

iii. Dependent variables: The dependent variables for this study are; TE, AE, and EE scores of milk production obtained from the stochastic frontier function.

iv. Inefficiency variables

1. Sex: This is a dummy variable that was measured as 1 if the household head is male and 0, otherwise.

2. Education: It is a continuous variable that is defined as the education level of the sample household head. This variable was measured in terms of years of schooling.

3. Concentrate: the total amount of concentrate used by sampled households to produce milk in quintals (Qt).

4. Total land: refers to the total area cultivated (owned, shared, or rented in) land that the sample household managed during the 2020 production year measured by a hectare (ha).

5. Extension: The frequency of extension agents contacting farmers and vice versa, measured by the number of contact per production year.

6. Grazing land: it refers to the total grazing land area allotted by the sample household for cow milk production during 2020 that was measured in ha.

7. Type of breed: It is a categorical variable that takes a value of 1 if the farmers use local breed, 2 if the farmers use both local breed and cross-breed, and 3 if the farmers use cross-breeding cows.

8. Dairy experience: It is a continuous variable and refers to the total years that the household participated in milk production, which is measured in years.

9. Distance: It is defined as the distance of the nearest market from the house of the household head in walking minutes.

10. Membership: It is the dummy variable that takes a value of 1 if the sampled farmer is in a dairy cooperative member and 0 otherwise.

11. Feeding method: It is a dummy variable equal to 1 for the farm that uses the total mixed ratio (TMR) and 0 if the farm uses the pasture feeding method.

12. Housing System: It is a dummy variable that takes 1 for farms that use free stall housing and 0 otherwise.

Method of Data Analysis

Descriptive statistics

Descriptive statistics such as mean, minimum, maximum, percentages, frequencies, and standard deviation or standard error were applied to describe demographic, socio-economic, farm characteristics, institutional characteristics, and distribution of efficiency levels of milk producers in the study area. After coding and feeding the collected data into the computer, STATA version 15 was used for the analysis.

Econometric analysis

Specification of an econometric model

Coelli et al. (1998) recommended that the Stochastic Frontier Production Function (SFPF) is more appropriate than DEA and deterministic models in agricultural applications, especially in developing countries, where measurement errors generally influence the data are generally influenced by measurement errors and the effect of weather, disease, and pests play a significant role. Some researcher argues that Cobb-Douglas functional form has advantages over the other functional forms in that it provides a comparison between the adequate fit of the data and computational feasibility. It is also convenient in interpreting the elasticity of production and it is very parsimonious with respect to degrees of freedom and it is convenient in interpreting elasticity of production.

In addition, the Cobb-Douglas production function is attractive due to its simplicity and because of the logarithmic nature of the production function that makes econometric estimation of the parameters a simple matter. The translog production function is more complicated to estimate the parameters having serious estimation problems. One of the estimation problems is as the number of variable inputs increases, the number of parameters to be estimated increases rapidly. Another problem is the additional terms require cross-products of input variables, thus making a serious multicollinearity problem (Coelli, 1995). Therefore, this study used stochastic production frontier to estimate the TE, AE, and EE levels of smallholdermilk-producing farmers in the study area.

Following Aigner et al. (1977) and Meeusen and Van den Broeck (1977), the general functional form of the stochastic frontier model for this study is specified as follows:

$$Y_z = f(X_z;\beta_z) + \varepsilon_z \quad \ldots\ldots (2)$$

Where z = 1, 2, 3... n; Yz represent the observed milk output level of the zth sample farmer; f (Xz; βz) is the convenient frontier production function (e.g. Cobb-Douglas or Trans log); Xz denotes the actual input vector by the zth farmer; βz stands for the vector of unknown

parameters to be estimated; εz is a composed disturbance term made up of two error elements (Vz and Uz) and n represents the number of farmers who will involve in the survey.

The stochastic frontier functional approach requires a priori specification of the production function to estimate the level of efficiency. Among the possible algebraic forms, Cobb-Douglas and trans-log functions were the most popularly used models in the most empirical studies of agricultural production analysis. Therefore, the Cobb-Douglas production function was adopted for this study. Thus, the Cobb-Douglas frontier function was specified as follows:

$$Y_z = AX_1^{\beta 1}X_2^{\beta 2}..X_n^{\beta n} \ldots\ldots(3)$$

The linear form of Cobb-Douglas production functions for this study was defined as:

$$\ln(Y_z) = \beta o + \sum_{j=1}^{4} \beta_j \ln X_{jz} + \varepsilon_z \ldots\ldots(4)$$

$$\ln(Y_z) = \beta o + \beta 1 \ln(LACTATION\ COW) + \beta 2 \ln(GREEN\ FODDER) + \beta 3 \ln(CROP\ RESEDUE) + \beta 4 \ln(LABOR) + \varepsilon_z$$

$$\mathcal{E}_z = V_z - U_z$$

Where, ln denotes the natural logarithm (i.e., base e); j represents the number of inputs used; z represents the zth farm in the sample; Yz represents the observed milk output of the zth sample farmer; Xjz denotes zth farm input variables used in milk production of the zth farmer; β_0 represent intercept; β_1-β_4 stands for the vector of unknown parameters to be estimated and represent elasticity of milk production; Ɛz is a composed disturbance term made up of two error elements (Vz and Uz); the symmetric component (Vz) is assumed to be independently and identically distributed as random errors with zero mean and variance N (0, σ2v), which captures inefficiency as a result of factors beyond the control of farmers and Uz proposed to capture inefficiency effects in the production of milk.

Assuming that the production function in equation (4) is self-dual. Cobb Douglas), the dual cost function of the Cobb-Douglas production function can be specified as:

$$lnC_z = \alpha_0 + \sum_{j=1}^{4} \alpha_j lnW_{jz} + \alpha_j lnY^* + V_z + U_z \ldots\ldots(5)$$

Where z refers to the zth sample farm; j is the number of inputs; Cz is the minimum cost of production; Wjz denotes input prices of z th farm; Y* refers to milk output in litre; α's are parameters estimated; Vz denotes random variables assumed to be independent and identically distributed random errors with zero mean and variance and Uz denotes non-negative random variables which are assumed to account for cost inefficiency and assumed to be independent and identically distributed random errors with zero mean and variance.

Sharma et al. (1999) suggest that the corresponding dual cost frontier of the Cobb-Douglas production functional form in equation (5) can be rewritten as:

$$C_z = C(W_z, Y^*, \alpha) + \varepsilon_z \qquad z=1, 2, 3\ldots..n$$

The economically efficient input vector of the zth farm Xze is derived by applying Arega and Rashid (2005) and substituting the firms input prices and adjusted output level, a system of minimum cost input demand equation can be expressed as:

$$\frac{\partial C_z}{\partial W_z} = X_z^e (W_z, Y^*; \alpha) \ldots\ldots(6)$$

We can define the farm-specific TE in terms of observed milk output (Yz) to the corresponding frontier milk output (Y*) using the existing technology.

$$TE_z = \frac{Y_z}{Y^*} = \frac{f(X_z;\beta)\exp(V_z - U_z)}{f(X_z;\beta)\exp(V_z)} = \exp(-U_z) \ldots\ldots(7)$$

The cost efficiency of an individual farm is defined in terms of the ratio of the observed cost (C) to the corresponding minimum cost(C*) given the available technology. That is, cost efficiency (CE):

$$C_E = \frac{C}{C^*} = \exp(U) \ldots\ldots(8)$$

Where the observed cost (C) represents the actual production cost whereas the minimum (efficient) cost (C^*) represents the frontier total production cost or the least total production cost level.

The farm-specific AE is defined as the ratio of minimum total production cost (C*) to the actual observed total production cost (C).

$$AE_z = \frac{1}{C_E} = \frac{C^*}{C} \ldots\ldots(9)$$

Following Ali et al. (2012), the EE index was derived from equations (8) and (9) as follows:

$$EE_z = AE_z x TE_z \ldots\ldots(10)$$

Determinants of inefficiencies

In this study, the Tobit regression model was used, which is specified as:

$$y_z^* = \beta_0 + \sum_{k=1}^{12} \beta_k X_{kz} + U_z \ldots\ldots(11)$$

Where: y_z^*, a , a latent variable representing the efficiency scores of farm z (TE, AE and EE); β_o intercept; β_kunknown parameter; Xkz are demographic, institutional, socio-economic and farm-related variables which are expected to affect TE, AE and EE; k is a number of explanatory variables that affect TE, AE and EE and Uz are an error term that is independently and normally distributed with mean zero and variance σ^2.

Denoting y_z as the observed variables:

$$y_z = \begin{cases} 1 & \text{if } y_z^* \geq 1 \\ y_z^* & \text{if } 0 < y_z^* < 1 \\ 0 & \text{if } y_z^* \leq 0 \end{cases} \quad \ldots\ldots(12)$$

Likelihood ratio statistic

Aigner et al. (1977) proposed the log likelihood function for the model in equation (3) assuming normal distribution for the technical inefficiency effects (Uz). They expressed the likelihood function using λ parameterization, where λ is the ratio of the standard errors of the non-symmetric to symmetric error term (i.e. λ= σ U/ σ v). According to Bravo and Pinheiro (1997) gamma (γ) can beformulated as:

$$\gamma = \frac{\lambda^2}{1+\lambda^2} \ldots\ldots(13)$$

In this study, the likelihood ratio test was conducted to select the appropriate functional form that best fits the data. The value of the generalized likelihood ratio (LR) statistic to test the hypotheses that all interaction terms, including the square specification, is equal to zero (H0: βjz=0) was calculated as follows.
Following Greene (2003) the hypothesis tests were conducted using the log-likelihood ratio (LR) statistics, λ which is defined in equation (14):

$$LR(\lambda) = -2\ln\left[L(H_0)/L(H_1)\right] = -2\left[lnL(H_0) - lnL(H_1)\right] \ldots\ldots(14)$$

Where: LR= Generalized log-likelihood ratio
L (H_o) = Denotes the likelihood function value under the null (Ho)
L (H_1) = Denotes the likelihood function value under the alternative hypothesis (H_1)

This value was compared with the upper 5% point for the χ^2distribution and the decision was made based up on the model result. If the calculated χ^2 value is less than the tabulated upper 5 percent point of the critical value, we accept the specified null hypothesisis at a 5 percent level of significance.

Milk yield gap

Yield gap is the difference between yield potential and actual farmers' yields over a given spatial or temporal scale (Ittersum et al. 2013). The study measured the milk yield gap to determine how much milk output is lost because of inefficiency variation among milk-producing farmers in the study area. From the stochastic model defined in equation (15), TE of the zth farmer was estimated as follows.

$$TE_Z = \frac{Y_Z}{Y_Z^*} = \frac{f(Xz;\beta)\exp(Vz-Uz)}{f(Xz;\beta)\exp(Vz)} = \exp(-Uz)$$

Then solving for Y_Z^*, the potential milk output (liter/cow/day) of each sample household is represented as:

$$Y_z^* = \frac{Y_z}{TE_z} = f(Xz;\beta)\exp(Vz) \ldots\ldots(15)$$

TEz= technical efficiency of the zth sample household in milk production

Y_Z^*= the frontier or potential output of the z^{th} sample household in milk production in liter/cow
Yz=the actual or observed output of the z^{th} sample household farmer in milk production in liter. Hence, milk yield gap (liter/cow/day) =potential yield (liter/cow/day)-actual yield (liter/cow/day).

Thus, Milk Yield gap = Y_Z^*- Yz……………………………………………………………………(16)

RESULTS AND DISCUSSIONS

Descriptive Statistical Results

Table 2 below shows that about 10.75% of the sample households were female-headed and the remaining 89.25% were male-headed. It was understood that female-headed households in rural areas in Ethiopia face more challenges in dairy production and marketing compared with their male-headed counterparts. This is partly due to cultural barriers and their busy schedules as they are engaged in domestic, reproductive, and community roles. Moreover, from the total sampled household, 2.5%, 50%, and 47.5% are using local, both local and cross breed and cross breed milking cows in the study area respectively. This indicates that the majority of the sampled household use both crossbreed and local as well as crossbreed only. Table 2 also illustrates that 69.5% of the sampled household use free stalling while 30.5% do not use free stalling. The result shows that most of the sampled farmers use free stalling in which cows are "free" to move around to eat, drink and rest wherever they like. These barns provide easy access to feed and clean water, as well as shade and protection from inclement weather which in turn increase the productivity of the milking cow. The feeding method is important to improve the productivity of the milking cows there by the associated efficiency would increase than pasture feeding method. The study shows that from the sampled household, 76% use total mixed ratio while the rest 24% not use. The finding implies that most of the sampled milk producers use total mixed ratio in the study area. Related with dairy membership, around 75.25% of the sampled households are not participating in dairy

member while 24.75% are participating in dairy cooperative member. This indicates that the majority of the sampled household in the study area are not participate in dairy membership. Farmer who participates in dairy cooperative can get different information, training, market access and etc. this leads them to become more efficient than who do not participate in dairy cooperative member.

Table 2: Descriptive statistics of dummy variables

Variables	Description	Frequency	Percent
Sex	Male	357	89.25
	Female	43	10.75
Type of breed	Local	10	2.5
	Both	200	50
	Cross	190	47.5
Housing system	Not	122	30.5
	Free stall	278	69.5
Feeding method	Not	96	24
	Total mixed ratio	304	76
Dairy membership	Not member	301	75.25
	Member	99	24.75

Source: Own computation (2020)

In Table 3 below the descriptive statistics of total land, grazing land, amount of concentrate feed used, frequency of extension contact, distance of the from home to the nearest market and Total livestock owned were discussed.

Land is the main resource needed by the milk producers to earn their livelihoods. Farmers use most of their land for crop production. The average total land of the sampled milk producers' was about 2.24 ha (Table 3). The result implies that households in the study area have relatively larger land size compared to that of the national average of farmers in Ethiopia which is 1.2 ha. If total land increases, dairy cows gets more outputs from crop production (stover of sorghum, teff, wheat, fababean, and etc) to feed their cows.

Grazing land is the main resource needed by the farmers to feed their livestock (like milking cow) which is the main source of feed by providing different fodder, grasses and etc. The average total grazing land of the sampled milk producers was about 0.48 ha with a minimum of 0 ha and 3ha (Table 3). Farmer who has large grazing land has the opportunity to get high yield of milk than the others in the study area since grazing land provides feed for lactation cows.

Concentrate is one of the types of feed used in most of milk producers in the study area which is used to increase the production and productivity of lactation cow. The study indicates that, on average, the sampled farmers use 20.58qt of concentrate feed for cows per lactation period with a minimum of 0 (not used) and maximum of 1300qt (Table 3). This implies that most dairy farmers in the study area use concentrate feed for their milking cows as feed to get more milk productivity per day and per lactation period.

Extension work in the study area focuses on the provision of general advisory services on major dairy production practices (such as proper feeding system, housing system, veterinary services on timely and how farmers manage their milking cows day to day), and also give how the farmers become dairy cooperative member to get different information especially on the price of milk. Development agents have been giving extension services in their respective field of specializations. They are required to advice and follow up their farmer's dairy farm. The survey result also indicated that frequency of extension contact in 2019/20 production year(lactation period) was on average about 4.34 with the maximum contact of like 24 times and minimum 0 times (no contact) times per lactation period (Table 3).

Distance is the time span required to reach the nearest market from homestead of the milk producers farmers and is essential variable in explaining the capacity of the farmers' performance. And it refers to how long time it takes (in walking minutes) for a dairy farmers to sell their milk and buy different inputs such as concentrate feed. It is an important variable due to the fact that as the farmers' home located far from nearest market, there would be limited access to get inputs easily and on timely which is very important in dairy production. Moreover farmers whose house is near to the market can easily get information on price of milk and provide also their product to the market in a short period of time. The study illustrate that distance from home to the nearest market in man walking minute was on average 45.84 with the maximum 180 minutes and minimum 1 minutes in the study area (Table 3).

Given a mixed farming system in the study area, livestock has imperative contribution for household income and food security. This income is very important especially to buy feeds for milking cows. The type of livestock kept by sampled farmers includes cow, oxen, bull, horse, mule, donkey, calf, goat, and heifer. Among others, oxen power is the major input in crop production process serving as a source of draft power which at the end produce different crop by products that is used as fodder for milking cows. On average, the livestock holding of the sampled farmers in the study area was 4.69TLU per household with a

minimum of 0 (no livestock other than milking cows) and a maximum of 17.77 in TLU (Table 3).

Table 3: Descriptive statistics of continuous variables

Variable description	Mean	Std. Dev.	Minimum	Maximum
Family size(AE)	3.86	1.63	1	9.05
Education (year of schooling)	3.69	3.84	0	15
Dairy farm experience(years)	14.96	10.73	1	60
Total land(ha)	2.24	1.72	0.125	10
Grazing land(ha)	0.48	0.46	0	3
Amount of concentrate feed used(qt)	20.58	77.68	0	1300
Frequency of Extension(number)	4.34	14.29	0	24
Distance from home to market(minute)	45.84	31.75	1	180
Total livestock owned (TLU)	4.69	2.67	0	17.77

Source: Own computation (2020)

Inputs used for milk production and cost function

The production function for this study was estimated using four input variables. On average, sample households produced 4989.03 lit of milk per lactation period, which is the dependent variable in the production function. The number of lactation cows, by sample households during the study, ranged from 1 to 9 with an average number of 2.94. On average, the amount of human labour, green forage, and crop residue used by the sampled milk producers was 717.45 man day (MD), 202.3 qt, and 38.2 qt respectively(qt=quintals). Among the various cost factors of production, the cost of lactation cow accounted for the highest share (56112.5 birr). Following the cost of lactation cow, the cost of labor takes a major share out of the total cost of production which is 21523 birr. Besides, the cost of crop residue takes the smallest share (3152.56 birr) out of the total cost of milk production (Table 4).

Econometric Results

Hypothesis Testing

The first null hypothesis tested was test for the selection of the appropriate functional form for the data; Cobb-Douglas versus Translog production function. The functional form that can best fit the data was selected by testing the null hypothesis. The result indicated that the null hypothesis was accepted and Cobb-Douglas functional form best fits the data. The second null hypothesis tested was the test for the existence of the inefficiency component of the composed error term of the Stochastic Frontier Model (SFM). This is made in order to decide whether the traditional average production function (OLS) best fits the data set as compared to the stochastic frontier model selected for this study. The result showed that the SFPF was an adequate representation of the data. The third null hypothesis is explored that farm-level technical inefficiencies are not affected by the farm and farmer-specific variables, and/or socio-economic variables included in the inefficiency model. The result indicated that the null hypothesis is rejected in favor of the alternative hypothesis that explanatory variables associated with the inefficiency effect model are simultaneously not equal to zero. Hence, these variables simultaneously explain the difference in efficiency among sampled farmers (Table 5).

Table 4: Summary statistics of variables used to estimate milk production and cost function

Variable	Unit	Mean	Std. Dev.	Minimum	Maximum
Milk output per lactation	Liter	4989.03	5161.66	300	48000
Lactation cow	Number	2.94	2.03	1	9
Labor	(MD)	717.45	410.76	54	3078
Green forage	*Beli*	202.30	1243.97	2	24300
Crop residue	*Beli*	38.20	59.74	1	560
Cost of lactation cow	Birr	56112.5	63394.22	8000	320000
Cost of labor	Birr	21523	12322.82	1620	92340
Cost of green forage	Birr	18676.63	106405.1	160	2065500
Cost of crop residue	Birr	3152.56	3775.36	97.5	42000

Source: Own computation (2020)

Parameter estimates of the SFPF model and cost function

The maximum likelihood estimate of the parameters of the SFPF for milk producers in the North Shewa Zone was presented in Table 6. The results of the model showed the input elasticity for each input in the SFPF. Among four

input variables analyzed in the stochastic frontier model, the parameter for lactation cow and crop residue were found to be significant at 10%, as hypothesized as well as green forage was found to be significant at 5%. The parameter estimate for labor turned out to be insignificant. The insignificance of the estimated coefficients for labor implies that the use of this input has no significant effect on milk production in the study area.

Table 5: Generalized likelihood ratio tests of hypothesis for the parameters of the SFPF

Null hypothesis	Df	LR	χ^2 value at 5%	Decision
$H_0 = \beta_{zj} = 0$	10	15.46	18.31	Accept H_0
$H_0 = \gamma = 0$	1	10.04	3.84	Reject H_0
H_0: $\delta_0 = \delta_{1=}\delta_{2=}..\delta_{12} = 0$	12	149.38	21.03	Reject H_0

Source: Own computation (2020)

Table 6: MLE for the parameters of the SFPF

Variables	Parameter	Coef.	Std. Err.
Intercept	β_0	7.645	0.527
Ln lactation cow	β_1	0.109*	0.062
Ln labor	β_2	0.101	0.074
Ln green forage	β_3	0.062**	0.084
Ln crop residue	β_4	0.074*	0.039
Variance parameter:			
$\lambda = \sigma_{u/}\sigma_v$		1.33	0.173
Gamma (γ)		0.64	

Note: ** and * refers to 5% and 10% significance level, respectively.

Source: Model output (2020)

The SFPF model results reveal that the estimated positive and coefficient of lactation cow (0.109), green forage (0.062), and crop residue (0.074) were found to be significant and positive at 5% (green forage) and10% (lactation cow and crop residue) probability level. This indicated that lactation cows, green forage, and crop residue were the most important determinant inputs of milk production in the study area. This suggests that a one percent increase in lactation cow for milk production, all things being equal, would lead to an increase of 0.109% in the output of milk production. In the same way, on average a one percent increase in the quantity of green forage and crop residue, milk output would increase by 0.062% and 0.074% respectively.

The diagnostic statistics of the inefficiency component reveal that sigma squared (σ^2) was statistically significant at 5% which indicates the goodness of fit, and the correctness of the distributional form assumed for the composite error term. The ratio of the standard error of U (σ_u) to the standard error of V (σ_v), known as lambda (λ), is 1.33. Based on λ, gamma (γ) which measures the effect of technical inefficiency in the variation of observed output can be derived (i.e.$\gamma = \lambda^2/([1+\lambda^2])$) (Bravo and Pinheiro, 1997). The estimated value of gamma (γ) was 0.64 which indicates that 64% of the total variation in milk output from the frontier is due to technical inefficiency among sample farmers in the study area and 36% of the variation in output from the frontier is due to random noise or random error (beyond the control of the farmers).

The dual frontier cost function derived analytically from the stochastic production frontier shown in Table 6 is given by:

$$lnCz = 1.9186 + 0.0113lnW_{1jz} + 0.0261lnW_{2jz} - 0.0141lnW_{3jz} - 0.0301lnW_{4jz} + 1.0043lnY^*.$$

Where C_z is the minimum cost of production of the z^{th} sample farmers; W_{jz} denotes input prices of z^{th} farm; Y* refers to milk output in liter.

Efficiency scores and their distribution

The MLE results of the stochastic frontier production functions are estimated for the individual farm level TE, AE, and EE independently for sample smallholder farmers. The model output presented in Table 7 indicates that the mean TE of sample farmers was about 0.580 with a minimum level of 0.156 and the maximum level of 0.842. This means that if the average farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, then the average farmer could realize 31.12% derived from (1-0.580/0.842)*100 increased milk output by improving TE with existing inputs and technology, using the resource at their disposal in an efficient manner without introducing other improved or external inputs and practice.

In addition, Table 7 shows that the average AE of the sample farmers was about 0.776 with a minimum of 0.299 and a maximum of 0.979. This shows that farmers are not allocatively efficient in producing milk. Hence, a farmer with an average level of AE would enjoy a cost saving of about 20.74% derived from (1 – 0.776/0.979)*100 to attain the level of the most efficient farmer. Similarly, the mean EE of the sample farmers was 0.447 implying that there was a significant level of inefficiency in the production process. That is the producer with an average EE level could reduce the current average cost of production by 44.81% which is derived from (1-0.447/0.810)*100 to achieve the potential minimum cost level without reducing output levels. It can be inferred that if farmers in the study area were to achieve 100% EE, they would experience substantial production cost savings of 44.81%. This low

average level of EE was the total effect of both technical and allocative inefficiencies.

Table 7: Estimated TE, AE and EE scores

Types of efficiency	Mean	Std. Dev.	Min	Max
TE	0.580	0.141	0.156	0.842
AE	0.776	0.148	0.299	0.979
EE	0.447	0.133	0.102	0.810

Source: Model output (2020)

The distribution of the TE scores showed that about 47% of the sample households had TE scores of 0.6 to 0.799. 11% of the households' TE scores fell in the range of 0.2-0.399. On average, households in this cluster have room to enhance their milk production at least by 42%. Out of the sample households, only 2% had a TE score of greater than 0.8. This implies that about 98% of the households can increase their production at least by 20%. The AE distribution scores indicated that about 59.25% of milk producers operated above 0.8 efficiency level. The distribution of EE scores also implies that 51.75% of the household heads have an EE score of 0.4-0.599. This also indicates the existence of substantial economic inefficiency than technical and allocative inefficiency in the production of milk during the study period in the study area (Table 8).

Table 8: Distribution of TE, AE, and EE

Efficiency range	TE		AE		EE	
	Frequency	%	Frequency	%	Frequency	%
<0.2	3	0.75	0	0	15	3.75
0.2-0.399	44	11	1	0.25	124	31
0.4-0.599	157	39.25	77	19.25	207	51.75
0.6-0.799	188	47	85	21.25	53	13.25
0.8-0.999	8	2	237	59.25	1	0.25

Source: Model output (2020)

Yield gap due to technical inefficiency

Yield gap analysis is an essential tool to measure to what extent the production could be increased if all factors are controlled. Using the actual output values of the predicted TE indices, the potential output was estimated for each household in milk production per cow per day. Hence, the mean level of the actual and potential milk yield per cow per day was 10.1 liter /cow/day and 19.7 liter /cow/day, respectively. Using the t-test method, the mean difference of the actual and the potential yield was found to be statistically significant at a 1% level of significance. Therefore, the average milk yield gap that is lost due to technical inefficiency, which was the mean difference between the actual (10.1 liter/cow/day) and the potential output (19.7lit/cow/day) was, 9.6lt/cow/day (Figure 1). This indicates that there is room to boost milk production on average by 9.6 liter/cow/day with the existing level of input use. On average, the money value of milk output that was lost due to technical inefficiency (yield gap) was 153.6birr/cow/day, since the value of 1lt of milk is 16 Ethiopian birr.

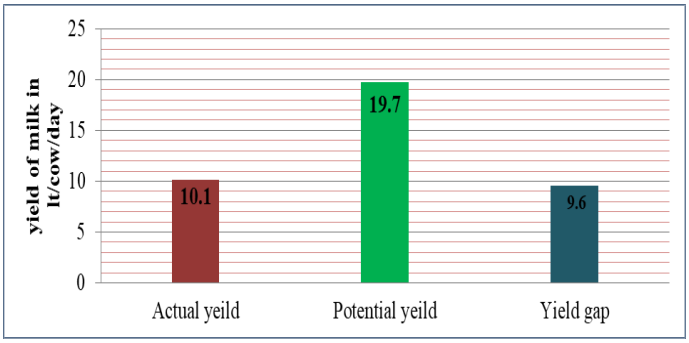

Figure 1: Distribution of actual and potential level of milk output

Source: Own computation (2020)

Determinants of inefficiencies

The result of two- limit Tobit model (Table 9) for each significant variable and its marginal effects of change in explanatory variables (Table 10) on TE, AE, and EE were discussed as follows.

Educational

The findings of the study show that education affected TE and EE of milk producers significantly and positively at 1% significance level. The positive sign implies that more educated farmers tend to be more efficient in milk production than the less educated in the study area. This is due to the fact thatbetter-educatedd household heads can use dairy technology easily and are able to apply technical skills imparted to them. Aone-yearr increase in the educational level of the household head increases the probability of a farmer being technically efficient and economically efficient by 0.34% and 0.01%, and the mean values of technical and economic efficiencies by about 0.92% and 0.97% with an overall increase in the probability and levels of technical and economic efficiencies by 1%, and 0.98%, respectively. The result agreed with the finding of Al-Sharafat (2013).

Total land

The result indicated that total land was a positive and significant effect on AE and EE at a 1% level of significance as expected. This implies that, total land is an important factor in influencing the level of AE and EE in the production of milk or positively contributes to AE and EE

of milk production in the study area. This implies that households who have more land were relatively better in AE and EE. A unit increase in total land (ha) would increase the probability of the farmer being AE and EE by about 1.09% and 0.01% and the expected values of AE and EE by about 0.94% and 0.86% with an overall increase in the probability and levels of AE and EE by 1.13% and 0.87%, respectively.

Dairy experience

Experience significantly and positively affected AE of sampled households at 10% level of significance, which is in line with the hypothesis made. The possible reason is that having more experience and knowledge of on dairy production methods, would increase the probability of the farmers to participating in dairy production. The more dairy production experience, the higher the likelihood of accumulating physical and social capital. The accumulation of physical and social capital can offer farmers' better exposure and capacity to produce more dairy production. The study result revealed that, a one-year increase of experience in dairy farming would increase the mean values of AE by about 0.04% with an overall increase in the probability and the level of AE by about 0.04%. The finding of this study agrees with the earlier research finding of Al-Sharafat (2013).

Dairy membership

It was found to have a significant and positive effect on AE 10% significance level. The result indicates that the sample farmers who participated in dairy members were more efficient than others. This is because farmers who participate in dairy cooperatives can get different knowledge, information, training, and market access. Moreover, the computed marginal effect result also shows that, a change in the dummy variable, dairy member from (0 to 1), would increase the probability of the farmer being allocatively efficient by about 4.35% and the expected values AE by about 3.22% with an overall increase in the probability and levels of AE by 3.92%.

Amount of concentrate used

The result revealed that, the amount of concentrate feed used by sampled households affected TE positively and significantly at 1% and affect AE negatively and significantly at 5%. This may be due to the fact that concentrated feed provide different nutrients for milking cows which increase the productivity of lactation cow. But the price of this feed is become increasing due to this, farmers may fail to allocate (minimize) the cost of this feed. Furthermore, the computed marginal effect result shows that, a unit increase in concentrate (qt) would increase the probability of TE and decrease the probability of AE by 0.01% and 0.01% and increase mean values of TE and decrease the mean values of AE by 0.02% and 0.01% with an overall increase in the probability and the level of TE and decrease an overall AE by about 0.02% and 0.02% respectively. This is in line with the research results of Amlaku et al. (2013).

Grazing land

Grazing land significantly and positively affected both TE and EE of the sampled households' at1% level of significance, which is in line with the hypothesis made. The possible reason is that having more grazing land provides more feed for the milking cows which results increase in milk output. It is the main resource needed by the farmers to feed their livestock which is the main source of feed by providing different fodder and grasses. A unit increase of grazing land would increase the probability of a farmer being both technically and economically efficient by 1.97 % and 0.04% and the mean values of TE and EE by about 5.58% and 3.92% with an overall increase in the probability and the level of TE and EE by about 5.85% and 3.96% respectively.

Type of breed

The result indicated that type of breed was a positive and significant effect on TE at 5% and AE and EE at 1% level of significance respectively as expected. This implies that, cross breed is an important factor in influencing the level of TE, AE and EE in the production of milk or positively contributes to TE, AE and EE of milk production in the study area. Breeds are believed to be genetically improved which makes them more efficient than local breeds. A change from local to cross breed milking cows increases the probability of a farmer being TE, AE, and EE by 0.85%, 8.69% and 0.07% and the mean values of technical, allocative and economic efficiencies by about 2.33% ,7.54% and 7.61% with an overall increase in the probability and levels of technical, allocative and economic efficiencies by 7.53% , 9.02%, and 7.69 %, respectively. The result is in line with previous studies by Mekdes (2017).

Frequency of extension contact

The result showed that the variable had positive sign and significant effect on TE and EE at 1% level as expected. The reason is that farmers who had more frequency of extension; could lead them to improvements in resource allocation, facilitates practical use of modern techniques and use inputs in appropriate way during dairy production. A one times increase in frequency of extension of household head increases the probability of a farmer being technically efficient by 0.17% and the

mean values of technical and economic efficiencies by about 0.46% and 0.42% with an overall increase in the probability and levels of technical and economic efficiencies by 0.5% and 0.42%, respectively. The finding is in line with the study of Fita et al. (2013).

Table 9: A two-limit Tobit regression results of determinants of TE, AE and EE

Variables	Parameters	TE		AE		EE	
		Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Const	δ_0	0.4261***	0.0479	0.4517***	0.0430	0.4517***	0.0430
Sex	δ_1	0.0272	0.0203	0.0029	0.0215	0.0221	0.0178
Education	δ_2	0.0102***	0.0017	0.0026	0.0018	0.0098***	0.0015
Total land	δ_3	0.0008	0.0038	0.0120***	0.0040	0.0087***	0.0033
Experience	δ_4	-0.0003	0.0006	0.0012*	0.0006	0.0004	0.0005
Membership	δ_5	-0.0246	0.0150	0.0422*	0.0159	0.0061	0.0131
Concentrate	δ_6	0.0002***	0.0001	-0.0002**	0.0001	0.0001	0.0001
Grazing land	δ_7	0.0595***	0.0139	-0.0129	0.0147	0.0397***	0.0122
Type of breed	δ_8	0.0257**	0.0118	0.0960***	0.0125	0.0770***	0.0103
House system	δ_9	-0.0051	0.0091	0.0094	0.0096	0.0010	0.0080
Type of feeding	δ_{10}	-0.0052	0.0153	0.0248	0.0162	0.0130	0.0134
Extension	δ_{11}	0.0051***	0.0080	0.0005	0.0017	0.0042***	0.0014
Distance	δ_{12}	-0.0002	0.0031	0.0000	0.0022	-0.0002	0.0002

Note: ***, ** and *sign represents significance at 1%, 5% and 10% levels, respectively.
Source: Model output (2020)

Table 10: Marginal effects of change in explanatory variables

Variables	Marginal effect of TE			Marginal effect of AE			Marginal effect of EE		
	$\partial E(y)$	$\partial E(y^*)$	$\partial[\varphi(Z_U) - \varphi(Z_L)]$	$\partial E(y)$	$\partial E(y^*)$	$\partial[\varphi(Z_U) - \varphi(Z_L)]$	$\partial E(y)$	$\partial E(y^*)$	$\partial[\varphi(Z_U) - \varphi(Z_L)]$
Sex	0.0268	0.0249	0.0074	0.0027	0.0022	0.0025	0.0220	0.0218	0.0004
Education	0.0100	0.0092	0.0034	0.0025	0.0021	0.0024	0.0098	0.0097	0.0001
Total land	0.0007	0.0007	0.0002	0.0113	0.0094	0.0109	0.0087	0.0086	0.0001
Experience	-0.0003	-0.0002	-0.0001	0.0011	0.0009	0.0011	0.0004	0.0004	0.0000
Membership	-0.0242	-0.0224	-0.0073	0.0392	0.0322	0.0435	0.0061	0.0060	0.0000
Concentrate	0.0002	0.0002	0.0001	-0.0002	-0.0001	-0.0002	0.0001	0.0001	0.0000
Grazing land	0.0585	0.0538	0.0197	-0.0121	-0.0101	-0.0117	0.0396	0.0392	0.0004
Type of breed	0.0253	0.0233	0.0085	0.0902	0.0754	0.0869	0.0769	0.0761	0.0007
House system	-0.0050	-0.0046	-0.0017	0.0089	0.0074	0.0085	0.0010	0.0010	0.0000
Type of feed	-0.0051	-0.0046	-0.0017	0.0234	0.0197	0.0208	0.0130	0.0129	0.0002
Extension	0.0050	0.0046	0.0017	0.0005	0.0004	0.0005	0.0042	0.0042	0.0000
Distance	-0.0002	-0.0002	-0.0001	0.0001	0.0001	0.0001	-0.0002	-0.0002	-0.0000

Note: ∂E(y)/(∂X j) (total change), ∂E(y^*)/(∂X j)(expected change) and (∂[ϕ(Z U)-ϕ(Z L)])/(∂X j) (change in probability).
Source: Model result (2020).

CONCLUSION AND RECOMMENDATION

Conclusion

The study estimated efficiencies using the stochastic production frontier model. The findings indicated that that the number nnumber of lactation cows, green forage and, crop residue were significant determinants of production level. The study also found that farmers can increase milk production by 42% without increasing inputs if they were technically efficient, reduce the current cost of inputs by 22.4% with cost minimization way and improve EE by 55.3% when resources are used

efficiently. The positive and significant variables namely; education, total land, dairy experience, dairy membership, amount of concentrate feed, type of breed, and frequency of extension in the present study imply that they play a great role in enhancing the efficiency and productivity of milking cow. An important conclusion coming from the analysis is that, milk producers in the study area are not operating at full TE, AE and EE levels which implies that there is an opportunity for milk producers to increase output at existing levels of inputs and minimize cost without compromising yield with present technologies.

- artificial insemination in the study area.
- Dairy cooperatives should be encouraged by the concerned body like woreda, zonal and regional governments.
- The study revealed that the number of lactating cows, green forage and crop residue was found to be highly significant hinting that these are the most critical input to increase milk production and productivity. So that producers and policymakers should use this opportunity to alleviate the existing level of food deficiency & poverty that is to say in designing development policy specifically for improving milk production.
- Adequate and proper management of grazing land should be done by the farmers and concerned body.

Conflict of interest

All authors declare that there is no any conflict of interest regarding the publication of this manuscript.

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Recommendations

The result of the study provides information and got some policy recommendations to policymakers and extension workers as follows:

- Regional government should have the responsibility to keep on the provision of education, and adequate extension services in this area so that farmers can use the available inputs more efficiently under the existing technology.
- The livestock office should give great attention on the cross variety of cows by using

REFERENCES

Africa census. Livestock census statistics on the African continent, 2020.

ncy and productivity analysis. Kluwer Academic Publishers, Boston, Dordrecht/London, 1998, 134-249 pp.

Fita, L.; Trivedi, M.M.; Patel, A.M.; Tassew, B.; Joshi, C.G. Determinants of technical efficiency of the dairy farmers in Ada'a district of Oromia State, Ethiopia.

Aigner, D.J.; Lovell, K.CA.; Schmidt, P.S. Formulation and estimation of stochastic models. *Journal of Econometrics*. 2013, 6 (1), 21-37.

Ali, A.A.; Imad, E.E.; Yousif, A.K. Economic efficiency of wheat and Faba bean production for small scale farmers in northern state, Sudan, 2012. *The Journal of Animal & Plant Sciences*. 22 (1), 215-223.

Al-sharafat, A.J. Technical efficiency of dairy farms: A stochastic frontier application on dairy farms in Jordan. *Journal of Agricultural Science*. 2013, 5(3), 45-53.

Amlaku, A.S.; Johann; Maria, W. Innovation and technical efficiency in the smallholder dairy production system in Ethiopia. *Journal of Agricultural Science and Technology*. 2013, 3, 151-164.

Arega, D.; Rashid, M.H. The efficiency of traditional and hybrid maize production in eastern Ethiopia: An extended efficiency decomposition approach. *Journal of African Economics*. 2005, 15 (1), 91-116.

Bravo-ureta, B.E.; Pinheiro, A.E. Technical, economic, and allocative efficiency in peasant farming: evidence from the Dominican Republic. *The Developing Economies*. 1997, 3 (1), 48–67.

Central Statistical Agency (CSA). Federal democratic republic of Ethiopia central statistical agency agricultural sample survey 2020/21. Volume Ii Report On livestock and Livestock Characteristics (Private Peasant Holdings), Addis Ababa.

Coelli, T.J. Recent Developments in frontier modeling and efficiency measurement. *Australian Journal of Agricultural Economics*. 1995, 39 (3), 219-245.

Coelli, T.J.; Rao, D.SP.; Battese, G.E. An Introduction to efficie

Iranian Journal of Applied Animal Science. 2013, 59-65.

Greene, W.H. Econometric Analysis, 5th Ed. Prentice Hall, Upper Saddle River, Newjersey, 2003.

Ittersum, M.K.; Cassman, K.G.; Grassini, P.; Wolf, J.; Tittonell, P.; Hochman, Z. Yield gap analysis with

local to global relevance review. *Field Crops Research*. 2013, 143, 4-17.

Meeusen ; Van Den Broeck, J. Efficiency estimation from cobb-douglas production functions with composed error. *International Economic Review*, 1977, 18 (1), 435-444.

Mekdes, G. Technical efficiency of commercial dairy farms; the case of Sululta District, Oromia regional state of Ethiopia, 2017.

Nathaniel, M.; Raphael, M.; Tsehay, R. Akke van der, Z. Jan van der, L. White gold: Opportunities for dairy sector development collaboration in East Africa centre for development innovation. Wageningen UR, 2014.

Nega, W.; Simeon, E. Technical efficiency of smallholder dairy farmers in the central Ethiopian highlands. in Proc. *International Association of Agricultural Economists,* Conference, Gold Coast, Australia, 2006,, 12-18.

Sharma, K.R. Leung, P.; Zaleski, H.M. Technical, allocative and economic efficiencies in Swine production in Hawaii: A Comparison of Parametric and Nonparametric Approaches. *Agricultural Economics*, 1999, 20 (1), 23-35.

Yamane, T. Statistics: An introductory analysis, 2nd Edition, New York, 1967.