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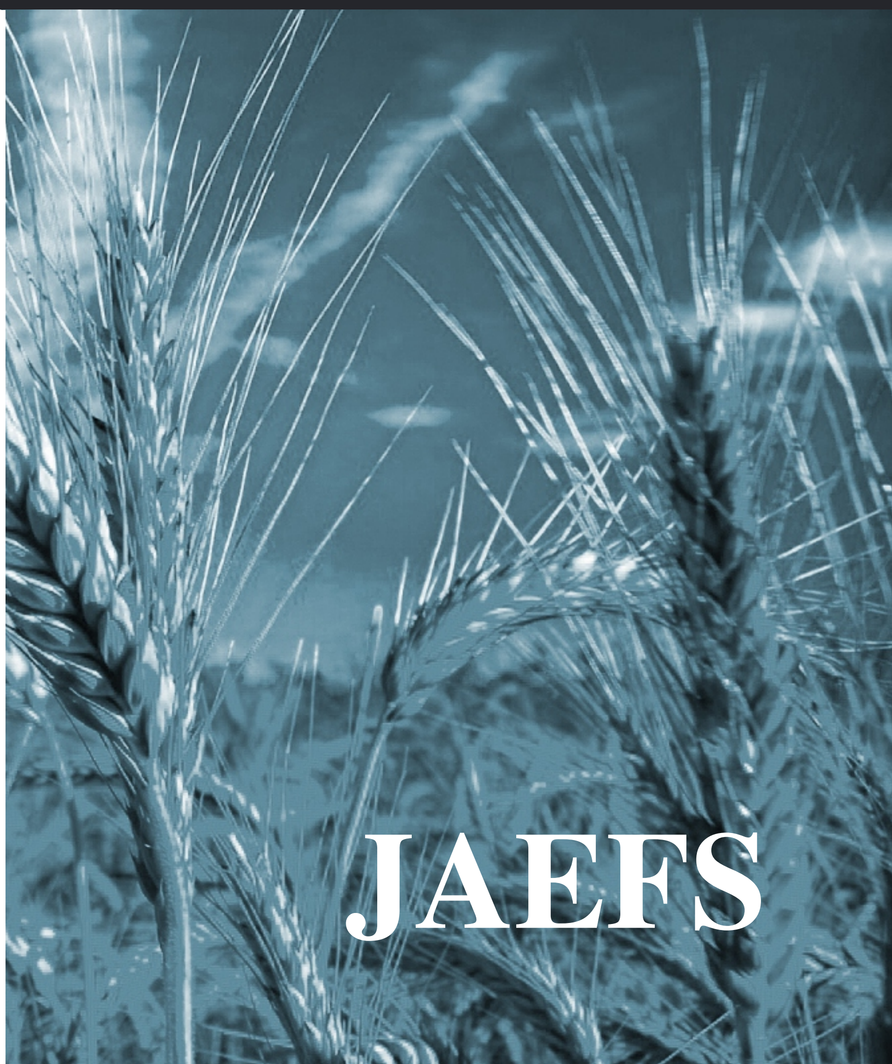

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Contents

Research Articles

Review Articles

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Research Article

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A SWOT Analysis of Nepalese Agricultural Policy

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Abstract

Agriculture, which generates two-third of the employment and one-third of the GDP in Nepal, is an important sector since Nepal is a small, landlocked country with low income. The government enacted the National Agriculture Policy in 2004 (NAP-2004) as an umbrella policy in the agricultural sector to guide all sectoral policies coming in the future. The paper has examined NAP-2004 by using the Strength, Weakness, Opportunity and Threat (SWOT) analysis technique. For the analysis, secondary data, the publications of the government and the international organizations as well as peer-reviewed articles were reviewed. The strength and weakness were analyzed by using nine different indicators. The results of the paper will be instrumental for improvement of the agricultural policy.

Keywords: SWOT, Agriculture Policy, Nepalese

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Introduction

Nepal is a small, landlocked, agricultural country which is sandwiched between China and India. It has an area of 147,181 square kilometers and a population of 28 million with the growth rate of 1.35% (CBS, 2015). Regarding the fact that agriculture in Nepal contributes to one-third of the GDP and provides employment opportunity to almost two-thirds of the population (MoF, 2016), it is an important economic activity in Nepal.

Nepal is geographically divided between mountains (35%), hills (42%) and terai (23%). The cultivated agricultural land of Nepal is three million hectares, whereas the uncultivated agricultural land is one million hectares. On the other hand, only 1.4 million (up to 2012/13) hectares of agricultural land is irrigated (MoAD, 2015). Nepal produces many agricultural commodities due to the diversity created by altitudinal variation (60 – 8,848 masl) and geography (UN, 2013). The Ministry of Agricultural Development publishes the annual statistics of 119 agricultural commodities (MoAD, 2015) and farmers still practice mixed crop and livestock integrated farming in every agro-ecological region of the country (FAO, 2010a).

Unlike Japan where average farm size is increasing (OECD, 2009), the average farm size in Nepal is continuously decreasing and has reached to 0.516 hectares by 2011/12 (CBS, 2013). Around 97 % of the agricultural holdings in Nepal are less than 2.0 hectares (CBS, 2013). Moreover, one forth of the total population lives below the poverty line and per capita GNI is just $730 (ADB, 2016). The rate of fertilizer consumption, which has increased from 57 kg / ha by 2012-2013 to 97 kg / ha by 2014-2015, is still low (MoF, 2016). The increase in fertilizer consumption is supported by government grants and stable price for the last few years (MoF, 2016). The share of agriculture in total exports is 28%, while the share in total imports is 20% (TEPC, 2017).

To guide the agricultural sector in Nepal, the government launched the “National Agriculture Policy, 2004” (NAP-2004) in the background of the World Trade Organization and the commitments of Millennium Development Goal (FAO, 2010a). The paper attempts to analyze the policy in the framework of “Strength, Weakness, Opportunity and Threats (SWOT) Analysis”. The SWOT analysis is a planning and strategic positioning tool (Maratovna, 2014) which enables the planners to have a better understanding of enhancing the strengths to achieve the possible, available opportunities and overcoming the weaknesses and threats (Helms and Nixon, 2010).

Objective

The objective of the study is to assess the influencing factors of the National Agriculture Policy- 2004 and take them into consideration. The specific objectives of the study are:

- Evaluating the strengths and weaknesses of the NAP-2004
- Assessing the opportunities and threats of the NAP-2004

Materials and Methods

The NAP-2004 (in Nepali and English Language) was accessed from the web portal of Nepal Law commission (www.lawcommission.gov.np). Similarly, the secondary data has been collected from various government reports and websites. Likewise, the peer reviewed articles and publications from international organizations working in the field of agriculture and economic policy were reviewed to categorize the policy options laid down by the NAP-2004.

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Originally, a SWOT matrix was devised for strategic positioning and giving an advice to business entity, but it can be extended to be extensively used in other areas, too (Sica, et al., 2015). A conceptual framework has been developed to categorize the NAP-2004 into endogenous and exogeneous factors. Endogenous factors are further classified into the strengths and weaknesses, while exogeneous factors are classified into the opportunities and threats. Table 1 describes the details of each factor.

Result and Discussion

For the better comparison the strengths and weaknesses of the NAP-2004 have been categorized into nine sub-headings, namely "Policy Objective", "Inclusiveness", "Competitiveness", "Cooperation", "Modernization", "New concepts", "Environment and sustainability", "Monitoring and Structure" and "Policy Option". The same category enables to have insight in particular issue, which contrasts strength and weakness. Since a policy has wider implication, various categories can have both strength and weakness due to limited internalization or imperfect accommodation of the issues. The result has been discussed accordingly into four sections: as the Strengths, Weaknesses, Opportunities and Threats.

i. Strengths

a. Policy Objective: The policy objectives of the agricultural policy are categorized into three parts as the objectives related to the farmers, consumers and society at large (OECD, 2008). The objectives related to the farmers aim to increase both the production and productivity of agriculture, as well as increasing the competitiveness in the regional and world markets through the commercialization and development of a competitive agriculture system. Similarly, the objective related to the society deals with the environment and sustainability issues and it aims to conserve, promote and utilize the natural resources, environment and biodiversity. Considering the policy objective of the OECD, the NAP- 2004 is enough in creating the objectives related to the farmers and society but does not satisfy the consumers in the field of fair price. Nevertheless, food quality, food safety and quarantine system were some consumer related issues taken into consideration at the policy levels, rather than as an objective.

b. Inclusiveness: The NAP-2004 has a special section for the target group, which has been identified as Dalit, oppressed, marginalized farmers and farm labors. Eight policy options which consist of the access to land, the provision of a land bank, loan, special facilities to small-scale irrigation, the assurance of food availability, the priority of the access to food, transportation interest and the provision of a "Food and Nutrition Safety Net" have been envisioned for the target group by the government. Likewise, farmers having less than four hectares of land have been identified as "resource-poor farmers". On the other hand, enhancing the participation of female farmers to 50% in response to the 35% target of the Ninth Period Plan (1997-2002) and providing mobile training to female farmers were also expressed in the NAP-2004 (FAO, 2010a). Moreover, devolution in the agricultural programme and a bottom-up approach have been adopted to make the NAP-2004 more inclusive. The provision of participatory implementation and monitoring have been made and the National Agricultural Resource Center has been envisioned in each development region.

c. Competitiveness: The second objective of the NAP-2004 is aimed at increasing the commercialization and competitiveness. Considering small holding sizes which contribute to low output and high costs of production (UN, 2013), large production packets have been proposed to address the market demand and to be benefited from economies of scale. The diversification toward high value-added crops is important for the competitiveness which has been observed in recent years (UN, 2013). Double Track system was introduced to be used in governmental farms where local community and private sector participate at the optimal level. Considering market demand, promotion of organic farming and regulation on GMOs have been devised.

Table 1. Definitions of SWOT factors from a trans-disciplinary interpretation

		Business/Management	Policy perspective
Endogenous Factors	Strengths	Characteristics of the business / the project to stay ahead of the game.	Both the characteristics and policy options provide an advantage. The policy options address both the current and upcoming problems.
	Weaknesses	Characteristics that are a disadvantage for the business/project.	Characteristics which are a disadvantage for the policy. The policy option that cannot address the existing and upcoming issues. Similarly, such options have a negative impact on the success of the policy.
Exogeneous Factors	Opportunities	Elements that the project can exploit to its advantage	Exogenous factors which will be beneficial for the success of the policy if carefully grasped.
	Threats	Elements in the environment that can cause trouble for the business / project	Exogenous factors which will pose a risk to the failure of the policy and cannot be controlled by the policy itself.

Adopted from "Ecosystem services-based SWOT analysis of protected areas for conservation strategies" (Scolozzi, *et.al*, 2014)

Special training of young, educated and unemployed people about commercialization of agricultural products with the provision of the access to loan has been proposed to increase competitiveness.

Likewise, provision of the assurance of improved agricultural inputs, market information system, contract farming, fee-based agriculture extension (if possible), focusing on the development of high value added agricultural products in rural areas and strengthening the quarantine system can be considered as the strengths of the NAP-2004 to boost the competitiveness. Strengthening the quarantine system is important because trans-boundary diseases are a big problem not only for the access to markets, but also for domestic plants, animals and humans (MoAC, 2010).

d. Cooperation: The NAP-2004 has focused on the cooperation among the government agencies, private sectors, nongovernmental organizations, cooperatives, international organizations and universities. It is a strength of the NAP-2004.

e. Modernization: Increasing the agricultural productivity through irrigation and other supports is a key challenge in Nepal since it requires increasing the investments in rural infrastructure like irrigation, rural roads, and markets (ADB, 2009; Schwab, *et.al*, 2015; Haefele, *et.al*, 2014). Thus, the assurance of improved inputs, such as seeds, fertilizers, irrigation, rural roads and electrification and training of the young, educated and unemployed people living in the rural areas has been proposed for modernization. The introduction of agriculture and livestock insurance is another strength of the NAP-2004 for the modernization of Nepalese Agriculture. The provision of quality control, regulations and well-equipped wholesale markets for agricultural products will all help for modernization.

f. New Concepts: Some of the concepts introduced in the NAP-2004, such as the agriculture and the double track system in governmental farms are the new practices that are currently implementing. Land banks, cooperative-based industrialization and participatory biodiversity park are the other new practices, which are yet to be realized. Moreover, gene banks and in situ conservation are the other strengths of the NAP-2004.

g. Environment and Sustainability: Some policies, such as discouraging Nepalese farmers from using agro-chemicals in agriculture as well as medicines and hormones in livestock production and promoting the use of organic fertilizers are the environment friendly options. Furthermore, the commitment to the conservation of biodiversity and promotion of agro-forestry are the other strengths of the NAP-2004. With respect to the various agricultural practices, geographical conditions and other problems, such as increased soil erosion, lower fertility of soil, diminished biodiversity, increased pollution of ground water and eutrophication that become a threat to the sustainability of upland farming system in Nepal, agroforestry is a good option to counteract such practices (Schwab, Schickhoff, & Fischer, 2015).

h. Monitoring and Structure: A monitoring system which involves the stakeholders is a strong point of the NAP-2004. The provision of multi-level committee for participatory and coordinative program planning, implementation and monitoring made the NAP structurally strong.

i. Policy Option: One of the very strong points of the NAP-2004 is that it has established itself as an umbrella policy for the agricultural sector. Acknowledging the extent of agriculture, an agro-industry development policy as well as the commodity and subject- specific policies are taken into account by the NAP-2004.

ii. Weaknesses

a. Policy Objective: The policy objective was stated by the OECD regarding the consumers is lacking in the NAP-2004. The concept of "fair price" is not mentioned in the NAP-2004. Regarding the fact that governmental capacity has a significant influence on providing quality service to the producers and consumers, there is the need to increase the competency, motivation, professionalism, etc. (MoAC, 2010; FAO, 2010a). However, these issues are totally ignored by the NAP-2004. Moreover, governance which is an important aspect in receiving better output (MoAC, 2010; MoAD, 2014) cannot be visualized in the NAP-2004.

b. Inclusiveness: Even though the NAP-2004 was designed to be as inclusive as possible, this could not be actually realized since "poverty reduction", which cannot be extracted from the policies for target groups, is not a determining factor in the NAP-2004. In this connection, the formulation and successful implementation of a labor policy to encourage labor-intensive agriculture can be a better option for the Nepalese rural development (Joshi & Maharjan, 2008)

c. Competitiveness: Although the NAP-2004 explained global competition in the background, the policy fails realize global competition to a large extent. Due to the opportunity created by geographical diversity, Nepal produces large numbers of agricultural commodities and livestock. However, Nepalese agriculture suffers from high costs of production (MoAC, 2010) which the NAP-2004 failed to overcome. Furthermore, the ratio of technical manpower to farm family is 1:2500 in the crop sector. As a result, the government adopted the group approach (Shrestha, 2011) to change this ratio, even after whose adoption the ratio will be 1:100, still unsatisfactory to provide the quality extension services and to increase the competitiveness. There was more than a 12 % net increase in forests since 1996 because cropland was abandoned for migration, resulting in fragmented families, a higher proportion of elderly people for land management and higher household incomes. However, the increase in household incomes is not used for agricultural development (Schwilch, et al., 2017).

As a matter of fact, Nepal cannot produce all agricultural commodities in a competitive-way and the agricultural policy should identify priority commodities which cannot be found in the NAP-2004. There was more than a 12 % net increase in forests since 1996 because cropland was abandoned for migration, resulting in fragmented families, a higher proportion of elderly people for land management and higher household incomes. However, the increase in household incomes is not used for agricultural development (Schwilch, et al., 2017). As a matter of fact, Nepal cannot produce all agricultural commodities in a competitive-way and the agricultural policy should identify priority commodities which cannot be found in the NAP-2004.

d. Cooperation: Even though the NAP-2004 has focused on cooperation among several agencies, there is ambiguity on the roles of the private sector and cooperatives which may lead to confusion and contradiction on implementation.

e. Modernization: Regarding ensuring improved and quality inputs, the NAP-2004 failed to explain how it will ensure it. The connection between farm and market is not clear. Most farmers suffer from a longer and strong chain of brokers, leading to farmers earning less money and consumers paying more. Similarly, logistic improvement, which is another important part of modernization, was not considered sufficiently. The promotion of agricultural mechanization was not mentioned in the NAP-2004, even though most farmers still use locally made agricultural equipments and tools (UN, 2013). In consequence, the government introduced a separate policy, namely "Agriculture Mechanization Promotion Policy, 2014". However, the use of jargons like "Scientific Land Use" and "Appropriate Technology" creates difficulties during implementation.

f. New concept: The NAP-2004 has not included some of the new agricultural concepts which can be unavoidable in the near future. For example, agro-tourism or leisure agriculture, which is a combination of agricultural production and modern tourism, has been developing rapidly (Zhang and Feng, 2013). Urban agriculture and small-scale agriculture like kitchen garden and roof-top gardening, which can helpful in achieving food and nutrition security, were also neglected (FAO, n.d.). Likewise, smart farming and protected agriculture are some promising technology in agriculture which has not internalized by NAP-2004.

g. Environment and Sustainability: Climate change is not taken in consideration sufficiently in the NAP-2004, which poses a great threat to the whole agricultural system. The contradiction between the promotion of high input farming and organic agriculture prevents the NAP from being a sound policy.

h. Monitoring and Structure: Implementation and monitoring by the same organization is against the principle of independent monitoring. In this respect, participatory monitoring becomes one of the weaknesses of the NAP-2004. Moreover, no justification has been provided for the provision of agricultural research and development fund within the same organization.

i. Policy option: The NAP-2004 has successfully established itself as an umbrella policy for Nepalese agriculture. However, it failed to explain the status of policies enacted before itself, namely the National Seed Policy 2000, National Tea Policy 2001, National Fertilizer Policy 2002 and National Coffee Policy 2003.

iii. Opportunities

In addition to various, positive, endogenous factors, there are several, positive, exogeneous factors which may lead to the success of the NAP-2004. These potentials are discussed hereunder.

- The growing interest of youth and private sector in agriculture creates a conducive environment for agricultural development. Similarly, farmers, entrepreneurs and traders are organizing gradually (FAO, 2010b).
- In every policy document, the government has prioritized agriculture as the top choice of the nation. Nevertheless, budget allocation for agriculture, which is around 3%, still does not match with this priority (MoAC, 2010) and is not adequate to promote the anticipated growth rate and to ensure the food security (Wagle, 2016).
- The revolution on Information Communication Technologies (ICTs) is another opportunity for the success of the NAP-2004. If government successfully grabs this chance, it can overcome the setback of group approach.
- Several sectoral policies, such as – "Agribusiness Promotion Policy, 2006", "Agro-biodiversity Policy, 2006", "Dairy Development Policy, 2008", "Floriculture Promotion Policy, 2012", "Poultry Policy, 2012", "Rangeland Policy, 2012", "Agriculture Mechanization Promotion Policy, 2014" and "Beekeeping Promotion Policy, 2016", made good opportunity to NAP-2004 are introduced to assist the NAP-2004 (MoAC, 2010).
- Increasing foreign cooperation also became a positive external factor for the success of the NAP-2004.
- Growing concern over the "food security" has created a favorable environment for the success of the NAP-2004.

iv. Threats

Despite various opportunities, the NAP-2004 has been surrounded by several threats. They are discussed hereunder.

- Global trading system has posed a severe threat to the success of the NAP-2004. Lowering traffic decreases competitiveness of domestic product accompanying with high cost of production (MoAC, 2010).
- Rapid changes in the preference, quality and standards of consumers also pose a threat to Nepalese agriculture. Small and resource-poor farmers cannot keep pace with the change of preference, quality and standards demanded by the consumers.

- Nepalese agriculture is highly dependent on weather conditions, a situation which is supported by the variation in the agricultural growth rate. The average rate of agricultural growth which was 3.3 % in 1997-2001 periods became 2.67 % in 2002-2007 periods (ADB, 2009). As a result, climate change is the greatest exogeneous factor threatening the agricultural sector.
- Policy inconsistency is another threat for the success of the NAP-2004. It emphasizes increasing the production by ensuring inputs like the chemical fertilizers. However, the demand for chemical fertilizers in Nepal is far behind the supply and the supply of fertilizers decreased from 38,950 MT in 2002/03 to 25,169 MT in 2007/08 after the withdrawal of subsidy (MoAC, 2010).
- A lack of "funnel system" (centralized funding mechanism) in agricultural development may pose a threat to the success of the NAP-2004. Without funnel system development activities cannot ensure alignment with NAP-2004.
- Being a landlocked country, unrestricted supply of inputs matters a lot to achieve the desired pace of growth. In this connection, Nepal has already faced several trade and supply restrictions along southern border which had restricted growth severally.
- Due to the sanitary and phytosanitory measures (SPS) and the technical barriers on trade (TBT) of the World Trade Organization (WTO), small and resource-poor farmers face severe problems to comply with these set standards.
- The agricultural policies of the neighbouring countries also threaten the NAP-2004. Heavy subsidies to the farmers of neighbouring countries, directly hamper the competitiveness of Nepalese agriculture
- Cross-sectoral interaction and improving coordination among inter-sectoral ministries are the key challenges (ADB, 2009) in Nepal which is also threating the success of NAP-2004.

Conclusion

As a result of the economic growth and globalization, increase in food consumption, diversification of the diet away from traditional food and decline in the share of food in household expenditure are expected. Thus, a sound agricultural policy should foresee the future along with addressing these current issues. However, the policy-making processes in Nepal are highly complex and they are influenced by political, social and economic environment to a great extent. Considering these factors, the NAP-2004 has achieved to overcome some of the constraints in Nepalese agriculture and can be classified as a good agricultural policy. Nevertheless, limited considerations on climate change, global trading system, innovation in agriculture, ensuring competitiveness, reducing poverty and providing fair prices both for the farmers and the consumers and higher dependency on other sectoral policies are the serious setbacks of the NAP-2004.

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Correlation and path coefficient analysis for grain yield and its attributing traits of maize inbred lines (*Zea mays* L.) under heat stress condition

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Abstract

Heat stress during the flowering, pollination and grain filling periods affect maize grain yield and its attributing traits. Twenty maize inbred lines were evaluated in alpha lattice design with two replications under heat condition during spring season from February to June, 2016 at Rampur, Chitwan, Nepal. Meterological data showed maximum mean temperature (46.2–43.28°C) and minimum (30.52-30.77°C) in with relative humidity 37.05 to 49.45% inside the tunnel during in April-May which coincided with the flowering, pollination and grain filling periods. The data were analyzed statistically to study the correlation and path coefficient. The analysis of variance showed that all the lines were significantly different from each other for all traits anthesis silking interval, SPAD chlorophyll and leaf senescence, tassel blast, leaf firing, plant and ear height, leaf area index, ear per plant, cob length and diameter, number of kernel ear^{-1}, number of kernel row^{-1}, number of kernel row, silk receptivity, shelling percentage, thousand kernel weight and grain yield. Grain yield had positive and significant phenotypic correlation with silk receptivity, shelling percentage, cob length and diameter, number of kernel ear^{-1}, number of kernel row^{-1}, number of kernel row, SPAD chlorophyll, thousand kernel weight and significant and negative correlation with tassel blast, anthesis silking interval, leaf area index, leaf firing. Path analysis revealed that of thousand kernel weight, shelling percentage, number of kernel ear^{-1} and silk receptivity exerted maximum positive direct effect on grain yield. Therefore, selection of genotypes having maximum thousand kernel weight, shelling percentage, silk receptivity and number of kernel ear^{-1} and shorter anthesis silking interval, no leaf firing and tassel blast is pre-requisite for attaining improvement in grain yield under heat stress condition.

Keywords: Maize (*Zea mays L.*), Heat stress, Correlation, Path analysis, Coefficient

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Introduction

Maize being nutritionally animportant crop has multiple functions in thetraditional farming system; being used as food andfuel for human beings andfeed for livestock andpoultry. In Nepal, it is grown in 8,91,583 ha producing 2.2 million tons, with an average yield of 2500 kg ha^{-1} (MOAD, 2016). The reasons for low maize yield in Nepal are high temperature, drought, stalk rot infestation, maize borer and shoot fly infestation, poor crop management, high input rates and use of low quality, substandard seed.

Heat and drought stress have emerged as a common problem worldwide which can reduce maize crop productivity (Ali et al., 2015). Heat stress in the flowering and grain filling periods due to elevated temperatures drastically affect crop productivity. A record drop in maize production was reported in many maize-growing areas of the world (Van der Velde et al., 2010). It is predicted that maize yield might be reduced up 70 % due to increasing temperatures (Khodarahmpour et al., 2011). A report of the Asian Development Bank warns that if the current trends persist until 2050 major food crop yields and food production capacity of south Asia will significantly decreases by 17% for maize,12% for wheat and 10% for rice due to climate change induced heat and water stress.

Maize crop yield potential grown in terai is always at risk from important biotic and abiotic stresses which limit crop production. Now day's heat stress is one of key abiotic stress with high potential impact on maize crop growth and development and eventually on productivity. Various plant organs, in a definite hierarchy and in interaction with each other are involved in determining crop yield under stress (Barnabas et al., 2008). The response of maize crop to climate depended on the genetic and physiological make up of variety being grown and interaction with prevailing climatic condition. Therefore, incomparasion to agronomic management genetic management of heat stress tolerance genotypes would be low economic input technology that would be readily acceptable to resource's –poor, heat affected and small land holding farmer (Saxena and Toole, 2002).

Transitory or constantly high temperatures cause an array of morph-physiological, anatomical and biochemical changes in plants, which eventually affects plant growth and development, and lead to a drastic reduction in biological and economic yield (Commuri and Jones, 2001). The correlation studies measure the associations between yield and other traits. Path coefficient analysis permits the

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separation of correlation coefficient into direct and indirect effects. Therefore, the present investigation was carried out to determine the association of traits with grain yield through correlation coefficient and direct and indirect effect of a set of variables through path analysis under heat stress condition in maize.

Materials and Methods

The research was conducted at National Maize Research Program (NMRP) of Rampur, Chitwan during spring season from February 24, 2015 to July 2016, geographically located at 27º 37' North Latitude and 84 º 29' East longitude at an altitude of 225 meter above sea level. This site contains only sandy loam soil with acidic reaction. This research location is characteristics of subtropical climate. The plant materials were collected from National Maize Research Program (NMRP). The list of inbred lines along with pedigree information included in the study is presented in Table 1.

Field experiment was conducted in alpha lattice design. There were two conditions: normal and plastic house (for heat stress), each condition replicated twice. Each replication comprised four blocks consisting of five plots each. Each plot was 3 meter in length 0.6 meter wide. Each plot had one row with spacing 20 cm between rows, inter block gap was 0.5 m was maintained. Each plot contained single row with spacing 60×20 cm and consisted 15 hills, each of two seed were sown, one of whose seedling were removed at the six leaves stage. The dose of chemical fertilizer applied was 120:60:40 kg NPK per hectare. Fertilizer were applied prior to sowing at rate of 60 kg N ha^{-1}, 60 kg P and 40 kg K ha^{-1} and additional side dressing of 30 kg N ha^{-1} were applied at the two times in six leaves stage and knee high stage of maize. The irrigation was done three important stage, knee high stage, tasseling stage and milking stage. To created heat stress condition maize study half of field was controlled heating imposed using two plastic (120gsm) houses were used two week just prior to the onset of reproductive period up to the crop harvesting. Maximum mean temperature 46.2°C in April in heat stress condition whereas as normal condition was 37.23°C and similarly for May month in maximum mean temperature was 43.28°C whereas in normal condition 34.54°C at time of flowering, pollination and grain filling periods as shown in Table 2. Partial opening top side of tunnel was done for control relative humidity inside tunnel to avoid any possible disease outbreak.

Data Collection

Data on days to50% anthesis, days to 50% silking and ears per plot, leaf firing, tassel blast, leaf senescence were recorded on plot basis. Whereas, ear height (cm), number of kernel ear^{-1}, number of kernel row, number of kernel row^{-1}, SPAD reading, leaf area index, silk receptivity, thousand kernel weight (g)and shelling per cent were recorded on five selected representative plants. The sample cobs were shelled, cleaned and grain weight and shank weight were recorded to calculate the shelling percent. Thousand kernel weight was measured by counting 1000 grains from the bulk of each plot after shelling and weighed in grams after the moisture was adjusted to 15%. Anthesis-silking interval (ASI) was calculated by subtracting the number of days taken for 50% anthesis from the number of days taken to 50% silk emergence.

Table 1. Names and pedigree information of maize inbred lines used for heat stress research at NMRP Chitwan (2016).

S.N	Maize Inbred Lines	Pedigree	S.N	Maize Inbred Lines	Pedigree
1	NML-2	CML-430	11	RL–101	UPAHAR-B-20-2-3-1-1
2	RML–4	CA00326	12	RML–24	CA00304
3	RML–32	CA00320	13	RML–40	CML-427
4	RML–95	PUTU-17	14	RML–57	CLQG6602
5	RML–86	PUTU-20	15	RL–107	UPAHAR-B-20-2-4-3-1
6	RML–17	CML-287	16	RML–20	CA-34503
7	RML–96	AG-27	17	RML–76	CLRCYQ007
8	RL–105	UPAHAR-B-20-2-4-1-1	18	RML–7	CML-413
9	RL–111	UPAHAR-B-31-1-1-1-1	19	RML–91	PUTU-19
10	RML–115	PUTU-17	20	RL–140	POOL-21-12-1-2-2-1-1

Table 2. Weather data recorded in NMRP, Chitwan during Experimental period (24th Feb to June 2016).

Months	Maximum Temperature (°C)	Minimum Temperature (°C)	Mean (°C)	Relative Humidity (%)
Feb	26.98	12.38	19.68	81.29
March	32.05	17.55	24.80	65.82
April Normal	37.23	23.83	30.53	56.36
April Stress	46.20	32.52	39.36	37.05
May Normal	34.54	22.16	28.35	67.72
May Stress	43.28	30.77	37.03	49.45
June	33.99	24.90	29.44	78.32

Source: National Maize Research Program (NMRP), NARC, Chitwan

Leaf area index was calculated by total leaf area divided by land area and multiply by correction factor (0.75). Silk receptivity was recorded by total number of fertilized grains per ear divided by number of potential grain per ear. Leaf firing was obtained by the counting the number of plants that showed leaf firing symptoms in the total number of plants in a particular plot and was expressed in percentage. Tassel blast was obtained by the counting the number of plants that showed tassel blast symptoms in the total number of plants in particular plot was expressed in percentage. Grain yield (kg/ha) at 15% moisture content was calculated using fresh ear weight with the help of the below formula:

$$\text{Grain yield}\left(\frac{kg}{ha}\right) = \frac{F.W.\left(\frac{kg}{plot}\right) \times (100 - HMP) \times S \times 10000}{(100 - DMP) \times NPA}$$

Where,
F.W. = Fresh weight of ear in kg per plot at harvest
HMP = Grain moisture percentage at harvest
DMP = Desired moisture percentage, i.e. 15%
NPA = Net harvest plot area, m^2
S = Shelling coefficient, i.e. 0.8

This formula was also adopted by Carangal et al. (1971) and Shrestha et al. (2015) to adjust the grain yield (kg ha^{-1}) at 15% moisture content. This adjusted grain yield (kg ha^{-1}) was again converted to grain yield (t ha^{-1}).

Statistical Analysis

The data recorded on different parameters from in heat stress field were first tabulated and processing in Microsoft excel (MS- Excel, 2010), then subjected to restricted maximum likelihood (REML) tool in GenStat to obtain ANOVA. Correlation coefficients of different traits were carried out using the formula given by Steel and Torrie, (1980) by using SPSS program. Path analysis carried out by using MS- Excel.

Results and Discussion

Maximum mean temperature 46.2°C in April in heat stress condition whereas as normal condition was 37.23°C and similarly for May month in maximum mean temperature was 43.28°C whereas in normal condition 34.54°Cmeans mean temperature 8-9°C higher in plastic house at time of flowering, pollination and grain filling periods as well as there was no drought due to plot was irrigated when the surface began dry and all other factor were kept constant, the only stress led to difference between the normal and stress treatment was assumed to be due to heat stress. Analysis of variance was performed for all traits. Analysis of variance of mean square comparison described significant difference among 20 maize inbred lines for traits as shown in Table 3 and 4.

Anthesis-silking interval (ASI)

In present study, significant increases the ASI under heat stress as compared to normal condition was observed. Mhike et al., (2012) also reported similar result significant increases the ASI in maize under heat stress might be silking delay i.e due to at rise in temperature (+30C), pollen shedding starts much ahead of silks emergence while silking is delayed, so that silking period does not correspond to anthesis/tasseling, resulting in poor synchronization of flowering. Cicchino et al (2010) reported mechanisms of increases anthesis silking interval under heat stress condition causes reduction in essential nutrients as well as all other factors like pollen viability, increase silking day known as silk delay. Edmeades et al., (1993) reported association of short anthesis-silking interval with increased partitioning of assimilate to the ear at flowering and supply of nitrogen to the developing ear a cause of improved performance of genotypes under stress environment.

Leaf firing and Tassel blast

Leaf firing of the flag leaf and one or two adjacent leaves was observed after severe heat waves that occurred when the tassel tissue was about to emerge from the leaf whorl. Thus occurrence of tassel blastinfluences the occurrence leaf firing under heatstress condition due increase in cell injury leads to release of reactive oxygen species complexes and leakage of electrolytes which leads to chlorosis, and death of the tissue under high temperature. Chen et al., (2010) also reported that under high temperature stress condition leaf firing reduces photosynthetic apparatus which lead to reduction in grain yield. Maize pollen viability decreases with exposure to temperatures above 35 °C (Dupuis and Dumas, 1990). Dass et al., (2010) reported that high temperature can delay anthesis and damage most of tassels resulting in little or no pollen production and increasing the occurrence of male sterile plants in field.

SPAD chlorophyll and leaf senescence

In heat stress condition, leaf sensensedue to increase in cell injury leads to release of reactive oxygen species complexes and leakage of electrolytes which leads to chlorosis, and death of the tissue, leading to inappropriate production of assimilates which are required for proper growth. Crafts-Brandner et al., (2002) reported reduced content of chlorophyll might cause a drastic reduction in the efficiency of the photosynthetic machinery of crop plants due to reduction in activation of rubisco enzyme alters rate of ribulose-1,5-biphosphate regeneration by disruption of electron transport and inactivation of oxygen evolving enzymes of PS II. Plant senescence is a common physiological phenomenon which leads to drying of the leaves but in heat stress phenomenon proceeds at faster rate moving towards the flag leaf by destroying the chlorophyll content. Guendouz et al., (2012) reported that plant having high chlorophyll content showed slow leaf senescence and produces maximum yield under heat stress condition. Renu et al., (2004) reported that plant having heat tolerant was characterized by less cell injury percentage under heat stress condition.

Plant and Ear Height

Effect of heat stress was most prominent on plant and ear height reduction might be result of the effect of heat stress on internal –nodal elongation. This research finding was supported by (Weaich et al., 1996 and Cairns et al., 2012).

Leaf area index (LAI)

Leaf area index of the decreases was observed after severe heat waves due to leaf growth pattern of maize increases in rang of temperature 0-35ºC with decline at 35-40ºC. Leaf area expansion is of great importance for light interception and for photosynthesis; it varies with the quantity of assimilates allocated to the production of leaves and the ratio of the leaf area produced per unit of leaf dry matter. Heat stress causes translocation of the photosynthetic products cannot fully match the increased rates of carbon fixation under the prevailing conditions, this results in the thickening of the existing leaves and the formation of thicker new leaves, and therefore in a sharp decrease of leaf area in the pre-anthesis period. It can also be noted that the LAI is maximum at tasselling or later and further slight decrease in leaf area is attributed to the senescence of the old (thinner) leaves, so that the younger thicker leaves remain on the stand a and longer growing cycle and normally a higher LAI and determine the overall LAI value. This finding was agreement with earlier finding reported by (Danalatos et al., 1994). Karim et al., (2000) also noted that leaf area and day time leaf expansion rate were good thermo tolerance trait of tropical maize under heat stress condition.

Ear Per Plant (EPP)

Significant increases in the frequency of barrenness in high temperature due reduction in average ears per plant was observed. It is attributed to the fact that different vegetative and reproductive organs undergo active growth at the same stage, which incurs competition for assimilates among organs. Rattalino Edreira et al., (2011) finding was agreement with earlier finding reported as changes in distribution of assimilates might be cause for reduced reproductive growth, particularly ears per plant. Cicchino et al., (2010b) reported thatsimilar findings has been reported in previous studies in maize crop exposed to high temperature at flowering stage.

Number of kernel per ear (NKE^{-1})

A number of factors could be responsible for reduction in number of kernels ear^{-1} under heat stress condition. Duke and Doehlert, (1996) and Rattalino Edreira et al., (2011) finding was agreement with earlier finding reported as number of kernel per ear reduces due to reduced pollen viability and receptivity of silk, increased frequency of kernel abortion, decreased cell division in endosperm, reduced sink capacity of developing kernels, reduced starch grain number and overall starch synthesis, increased soluble sugar accumulation, duration of grain filling, kernel development and enzyme activities. Cicchino et al., (2010b) reported similar finding that stress in pre-anthesis stress leading to barrenness in plants, while absorption of fertilized structure and reduced ear growth rate lead to reduction in kernel number and ultimate affect crop yield. Moser et al., (2006) reported that stress before and immediately after pollination may lead to failure of number of kernel development ear. Hussain et al. (2010) also reported that, number of rows cob^{-1}, number of kernels row^{-1} and yield per plant were much reduced in spring season due to heat stress.

Silk Receptivity

Pollen shed may occurs for up to 2 weeks but usually lasts for 5 to 8 days with peak shed by about days 3.Silk can grow 2 to 3 inch per day and maximum growth by 3 and 4 days after first silk. Silk longevity is around 10 days and maximum up to 14 days but under heat stress condition desiccate the prematurely will appear as erratic pattern of fertilization along the ear with most fertilized ovule located at the base. A number of factors could be responsible for reduction in number of silk receptivity under heat stress on corn kernel set, seasonal pollen production, silk elongation pattern and duration of silk receptivity. The seasonal pollen production determine kernel per plant at pollen densities less than 3000 pollen grain per silk. It was found that a minimum pollen shed density per exposed silk is required to achieve maximum kernel set and grain yield reported by (Westgate et al., 2003). Silk receptivity can be drastically reduced by as much as 80% during high temperatures due tosudden pollen shedding over a very short time (Fonseca et al., 2005). Anderson et al., (2004) found that kernel set and yield stability are impacted by variation among hybrid for silk elongation and senescence. Campos et al., (2004) suggested that selection based on performance in multi- environment trials increased grain yield under drought trough increase yield potential and kernel set, rapid silk exertion and reduced barrenness through at lower rate than under optimal condition.

Shelling percentage

Rowhani et al., (2011) reported that significant variation in shelling percentage under heat stress condition might be associated with lower grain yield traits such as pollen viability and fertilization under high temperature. This was because of grain filling period was most sensitive to heat stress as reported by (Thompson,1986).

Thousand Kernel weight (TKW)

Rise in temperature beyond 30°C impacts the activity of *Rubisco* in maize, which in turn reduces photosynthesis and ultimately decreases grain filling period and grain size (Steven et al., 2002). Kernel weight is influenced by source-sink relationships during grain fill with increased kernel weight being caused by irradiance level, grain-fill duration, and plant and kernel growth rate (Gambinet et al., 2006). The reduction of thousand kernel weight in agreement with findings (Abendrothet et al., 2011).

Grain Yield

Maize yields have been shown to have an optimum growing temperature of 29 °C and 30 °C, respectively; temperatures above this threshold result in yield decreases (Schlenkerand Roberts, 2009). The major effect of high temperature is embryo abortion, which is related to the inhibition of photosynthesis and the subsequent reduction in assimilates available to developing kernels. Exposure to temperatures above 30 °C damaged cell division and amyloplast replication in maize kernels which reduced the size of the grain sink and ultimately yield (Commuri and Jones, 2001). The of the yield decrease up to 100%, larger than those estimated in previous studies (Lobell and Field, 2007; Schlenker and Roberts, 2009). Lobell and Field, (2007) showed maize yields decreased 8.3% per 1°C rise without any complicating effect due to water stress. Khodarahmpour et al., (2011) observed reduction of grain yield up to 70% under heat stress might be due to low pollen viability, silk receptivity and longer ASI duration in heat stressed condition.

Correlation Analysis

The grain yield had positive and significant phenotypic correlation with silk receptivity, shelling percentage, cob length and diameter, number of kernel ear^{-1}, number of kernel row ear^{-1}, number of kernel ear^{-1}, SPAD chlorophyll, and thousand kernel weight whereas it was significant and negative correlation with tassel blast, anthesissilking interval, leaf area index, leaf firing under heat stress condition as shown in Table 5. Khodarahmpourand Choukan, (2011) reported similar finding in a study of fifteen inbred line under heat stress condition reported that grain yield had positive and significant correlation with number of kernel ear^{-1}, no of kernel row, no of kernel ear^{-1}, 1000-grain weight, and cob diameter. Kaur et al., (2010) reported similar result significant negative association leaf firing and tassel blast with grain yield under heat stress. Cairnset al.,(2012) reported significant correlation between grain yield and ASI and SPAD reading was negatively correlated. Krasensky, J., and Jonak, C. (2012) reported similar result for significant positive for association between chlorophyll content and grain yield under drought stress. Betran et al.,(2003a) reported similar result for SPAD chlorophyll content and

EPP with grain yield under drought stress but relation of EPP was found non-significant.

Path Coefficient Analysis

Direct effect of thousand kernel weight (0.786), shelling percentage (0.552), number of kernel ear^{-1} (0.448), silk receptivity (0.279),leaf area index (0.058) on grain yield had highest positive value as compared to all other traits such as ear per plant (0.011)exerted positive direct effect on yield based on direct effect in path analysis but it is non-significant correlated with grain yield hence may not be statistically considerable. El-Badawy et al., (2011) reported similar result highest positive direct effect of 100 grain weight on yield per plant in maize. Krishnaji et al., (2017) found similar result high positive direct effect of shelling percentage and number of kernel per ear under heat stress condition. Jawaria Azhar, J., RamzanandAhmad, R.M. (2016) reported similar result high positive direct effect of thousand kernel weight on grain yield under heat stress condition in maize. Similarly correlation coefficient of SPAD chlorophyll, cob diameter, cob length, Number of kernel row ear^{-1}, number of kernel row were positiveand significant with grain yield while there direct effects on grain yield were negative. But negative direct effects of these traits were nullified by their positive indirect contribution via other yield components. Similarly correlation coefficient of leaf area index was negative and significant with grain yield while there direct effects on grain yield were positive. But positive direct effects of these traits were nullified by their negative indirect contribution via other yield components. On contrary, some characterof anthesis silking interval and tassel blast exerted positive direct effect on grain yield. However positive direct effect of these traits was nullified by their negative indirect contribution via other yield components. Thousand kernel weight showed the highest positive indirect contribution towards grain yield via shelling percentage (0.4960), number of kernel per ear (0.381), silkreceptivity (0.260), anthesis silking interval (0.126),ear height(0.0380) and leaf firing (0.015). However, it showed negative indirect effect via tassel blast, leaf senescence, SPAD chlorophyll, leaf area index, ear per plant, cob diameter and length, number of

Table 3. Mean square comparison for different traits in 20 inbred lines of maize under high temperature stress at NMRP, Rampur, Chitwan (2016).

Source of vaiance	df	ASI	LF	TB	LS	SPAD	EH	LAI	EPP
REP.Block	6	0.76ns	29.58ns	10.36ns	0.98ns	8.45ns	24.38ns	0.03ns	0.015ns
Inbred line	19	2.96*	251.3*	369.75**	473.03**	80.83*	264.92**	0.5*	0.16*
Error	13	0.69	92.58	105.7	0.26	29.45	29.34	0.107	0.03

Table 4. Mean square comparison for different traits in 20 inbred lines of maize under high temperature stress at NMRP, Rampur, Chitwan (2016).

Source of vaiance	df	SR	CD	CL	NKRE	NKE	NKR	SP	TKW	GY
REP.Block	6	2.46ns	0.07ns	0.14ns	0.07ns	0.521ns	0.52ns	2.11ns	91ns	189.9ns
Inbred line	19	465.98**	4.10**	69.13**	63.3**	86.83**	86.84**	465.98**	39025**	169314**
Error	13	12.96	0.06	0.798	0.23	1.118	1.11	12.96	100	743

Table 5. Pearson's Correlation coefficient among different traits under heat stress condition at NMRP, Rampur (2016).

	ASI	LF	TB	LS	SPAD	EH	LAI	EPP	SR	CD	CL	NKRE	NKE	NKR	SP	TKW
ASI	1															
LF	.546*	1														
TB	.641**	.328	1													
LS	-.442	-.113	-.031	1												
SPAD	-.555*	-.607**	-.474*	-.063	1											
EH	.109	-.054	.389	-.051	-.386	1										
LAI	.345	.101	.474*	.021	-.238	.508*	1									
EPP	.094	-.137	.052	-.140	-.282	.251	-.161	1								
SR	-.788**	-.723**	-.714**	.195	.617**	-.246	-.457*	-.093	1							
CD	-.860**	-.687**	-.686**	.317	.629**	-.311	-.411	-.039	.937**	1						
CL	-.758**	-.626**	-.761**	.320	.496*	-.260	-.339	-.026	.869**	.907**	1					
NKRE	-.852**	-.705**	-.715**	.258	.640**	-.266	-.464*	-.038	.954**	.972**	.871**	1				
NKE	-.682**	-.748**	-.714**	.117	.513*	-.153	-.396	-.052	.953**	.853**	.831**	.884**	1			
NKR	-.848**	-.710**	-.745**	.234	.648**	-.333	-.488*	-.038	.956**	.968**	.873**	.987**	.887**	1		
SP	-.763**	-.630**	-.605**	.292	.572**	-.236	-.463*	-.180	.945**	.883**	.803**	.910**	.846**	.901**	1	
TKW	-.854**	-.668**	-.743**	.340	.609**	-.330	-.446*	-.047	.932**	.982**	.937**	.978**	.850**	.975**	.898**	1
GY	-.726**	-.692**	-.679**	.167	.560*	-.237	-.445*	-.132	.980**	.896**	.857**	.917**	.941**	.917**	.963**	.904**

Values are significant difference at 5 % level of significance (*) and highly significant at 1 % level of significant (**), ASI= AnthesisSilkinginterval,LF %= leaf firing%,TB= Tassel blast,LS=Leaf senescence,SPAD=SPAD chlorophyll,EH=Ear height,PH=Plant height,LAI= leaf area index,EPP= Ear per plant,SR%= Silk receptivity,CD=Cob diameter,CL=Cob length,NKRE=Number of kernel per row,NKE=Number of kernel per Ear,NKR=Number of kernel per row,SP%= Shelling percentage, TKW=Thousand kernel weight(g),GY=GrainYield(Kg ha^{-1}).

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Table 6. Direct (diagonal) and indirect effects of different traits on grain yield.

	ASI	LF	TB	LS	SPAD	EH	LAI	EPP	SR	CD	CL	NKRE	NKE	NKR	SP	TKW
viaASI	**0.022**	-0.081	-0.095	0.065	0.082	-0.016	-0.051	-0.014	0.116	0.127	0.112	0.126	0.101	0.125	0.113	0.126
via LF	-0.012	**-0.022**	-0.007	0.003	0.014	0.001	-0.002	0.003	0.016	0.015	0.014	0.016	0.017	0.016	0.014	0.015
viaTB	0.062	0.032	**0.096**	-0.003	-0.046	0.037	0.046	0.005	-0.069	-0.066	-0.073	-0.069	-0.069	-0.072	-0.058	-0.072
viaLS	0.077	0.020	0.005	**-0.173**	0.011	0.009	-0.004	0.024	-0.034	-0.055	-0.055	-0.045	-0.020	-0.041	-0.050	-0.059
viaSPAD	0.047	0.052	0.040	0.005	**-0.085**	0.033	0.020	0.024	-0.053	-0.054	-0.042	-0.054	-0.044	-0.055	-0.049	-0.052
viaEH	-0.013	0.006	-0.045	0.006	0.044	**-0.115**	-0.058	-0.029	0.028	0.036	0.030	0.031	0.018	0.038	0.027	0.038
viaLAI	0.020	0.006	0.027	0.001	-0.014	0.029	**0.058**	-0.009	-0.026	-0.024	-0.020	-0.027	-0.023	-0.028	-0.027	-0.026
viaEPP	0.001	-0.001	0.001	-0.002	-0.003	0.003	-0.002	**0.011**	-0.001	0.000	0.000	0.000	-0.001	0.000	-0.002	-0.001
viaSR	-0.220	-0.202	-0.199	0.054	0.172	-0.069	-0.128	-0.026	**0.279**	0.262	0.243	0.267	0.266	0.267	0.264	0.260
viaCD	0.202	0.161	0.161	-0.074	-0.148	0.073	0.097	0.009	-0.220	**-0.235**	-0.213	-0.228	-0.200	-0.227	-0.207	-0.231
viaCL	0.056	0.046	0.056	-0.024	-0.036	0.019	0.025	0.002	-0.064	-0.067	**-0.073**	-0.064	-0.061	-0.064	-0.059	-0.069
viaNKRE	0.243	0.201	0.204	-0.074	-0.182	0.076	0.132	0.011	-0.272	-0.277	-0.248	**-0.285**	-0.252	-0.281	-0.259	-0.279
viaNKE	-0.305	-0.335	-0.320	0.052	0.230	-0.069	-0.177	-0.023	0.427	0.382	0.372	0.396	**0.448**	0.397	0.379	0.381
viaNKR	0.358	0.300	0.314	-0.099	-0.273	0.140	0.206	0.016	-0.403	-0.408	-0.368	-0.416	-0.374	**-0.422**	-0.380	-0.411
via SP	-0.422	-0.348	-0.334	0.161	0.316	-0.130	-0.256	-0.099	0.522	0.488	0.444	0.503	0.467	0.498	**0.552**	0.496
via TKW	-0.671	-0.525	-0.584	0.267	0.479	-0.259	-0.351	-0.037	0.733	0.772	0.737	0.769	0.668	0.766	0.706	**0.786**
SUM	-.726**	-.692**	-.679**	0.1674	.560*	-0.237	-.445*	-0.132	.980*	.896*	.857**	.917**	.941**	.917**	.963**	.904**

kernel row per ear and number of kernel per row respectively. Shelling percentage exhibited had positive indirect contribution on grain yield via thousand kernel weight, number of kernel per ear, silk receptivity, ear height, leaf firing and anthesis silking interval. However, it showed negative indirect effect via tassel blast, leaf senescence, SPAD chlorophyll, leaf area index, ear per plant, cob diameter and length, number of kernel row per ear and number of kernel per row respectively. Number of kernel per ear exhibited had positive indirect contribution on grain yield via thousand kernel weight, shelling percentage, silk receptivity, anthesis-silking interval, ear height, and leaf firing. However, it showed negative indirect effect via tassel blast, leaf senescence, SPAD chlorophyll, leaf area index, ear per plant, cob diameter andlength, number of kernel row ear^{-1} and number of kernel row^{-1}respectively. Silk receptivity exhibited had positive indirect contribution on grain yield via thousand kernel weight, shelling percentage, anthesis silking interval, ear height, and leaf firing. However, it showed negative indirect effect via tassel blast, leaf senescence, SPAD chlorophyll, leaf area index, ear per plant, cob diameter and length, number of kernel row ear^{-1} and number of kernel row^{-1}respectively.The negative correlation between grain yield and anthesis silking interval, tassel blast and leaf area index indirect influence via thousand kernel weight and shelling percentage, silk receptivity and number of kernel ear^{-1}.This traits needs consideration, because direct effect these traits positive in direction. The positive correlation between grain yield and SPAD chlorophyll, cob diameter, cob length, number of kernel row^{-1} and number of kernel row indirect influence via thousand kernel weight and shelling percentage, silk receptivity and number of kernel ear^{-1}. This trait needs consideration, because direct effect these traits negative in direction.

Conclusion

In present investigation, SPAD reading, cob diameter and length, thousand kernel weight, silk receptivity, shelling percentage, number of kernel ear^{-1} with minimum tassel blast, leaf firing, shorter anthesis-silking interval were most yield determinative traits as revealed from correlation analysis and hence simultaneous selection for these trait might brining an improvement in maize grain yield under heat stress. Beside the correlation analysis inter se association also provide huge support on these traits from all other yield components. Path analysis using grain yield as dependent variable revealed that of thousand kernel weight, shelling percentage, number of kernel ear^{-1}, silk receptivity exerted maximum positive direct effect on grain yield and these trait could be relied upon for selection of genotypes to improve grain yield. On contrary, some character via anthesis silking interval and tassel blast exerted positive direct effect on grain yield. However positive direct effect of effective theses trait were nullified by their negative effects through other components traits thousand kernel weight, shelling percentage, silk receptivity and number of kernel ear^{-1} which ultimately resulted in to highly significant negative correlation with grain yield.

Hence indirect selection through other component characters with which these two traits exhibited negative indirect effects can be recommended so as to bring improvement in grain yield. Thus selection of genotypes having maximum thousand kernel weight, shelling percentage, silk receptivity and number of kernel ear^{-1} and minimum anthesis silking interval, leaf firing, tassel blastis pre-requisite for attaining improvement in grain yield under heat stress condition.

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Determination of some chemical characteristics and total antioxidant capacity in apple varieties grown in Posof/Ardahan region

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Abstract

In this study, total phenolic content, antioxidant capacity, total anthocyanin content and total ascorbic acid content (in flesh+peel) of the 7 apple cultivars grown in Posof/Ardahan were measured. The total phenolic content of the three apple cultivars was higher than other cultivars. “Posofkırmızısı”, “Sarı şafran” and “Paşa” apple cultivars had the highest total phenoli ccontents (239.22, 228.81 and 222.71 mg of gallic acid equivalents/100 g offlesh+peels, respectively). Results showed that fresh apple had the highest levels for antioxidant capacity (90.32 and 114.23 µmol of vitamin C equivalents/g of flesh+peel) and total anthocyanin content (30.07 to 71.49 mg/100g), whereas lower levels were found for ascorbic acid in flesh+peels. Results covered a narrow range: 17.18–26.83 mg/100g for ascorbic acid content in flesh+peels weight of apple cultivars. As a result, that these apple cultivars have high total phenolic value and antioxidant capacity in flesh+peels. For this reason, it is suggested for consume with their peels.

Keywords: Apple, Total phenolic, Total antioxidant, Anthocyanin, Ascorbic acid

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Introduction

Apple is a member of the Malus genus of the family of Rosacea. Anatolia is one of the natural spread area of apples informed the 48 species that spread the different gene centers (Europe, the Himalayas, China, Japan, Korea and North America) (Dziubiak 2004; Ercişli 2004; Arabacı and Sevindik 2014). The apple varieties given our research are local apple varieties that propagated with grafting by local people in Posof / Ardahan region. Apple is an important fruit in terms of human health is rich in phenolic compounds and antioxidant substances (Arabacı and Sevindik 2014; Chen and Chen 2013; Vauzouret al. 2010; Williams et al. 2004). Apples are quantitatively the most consumed fruits in several countries in Europe and America. (Claire Kevers at al 2011). Apples are a good source of phenolic compounds because their consumption is widespread, and they are available in the market throughout the year. (Claire Kevers at al 2011, Wolfe et al. 2003, Eberhardt et al. 2000). In a fruit, the amount of phenolic contents can vary according to the growth period, the year of harvest, the geographic location, the storage conditions, and most importantly, genetic variation.(Claire Kevers at al 2011; Jiang et al. 2006; McGhie et al. 2005;Rossle et al. 2010; Wojdylo et al. 2008). The total extractable phenolic content has been ranged from 110 to 357 mg/100 g of fresh apple (Eberhardt et al. 2000; Podsedek et al. 2000; Wolfe et al. 2003).

One of the antioxidant is ascorbic acid, the most abundant in fruits and vegetables. Ascorbic acid in the apple is lower compared with other fruits (Arabacı and Sevindik 2014). Ascorbic acid content is reported as 2-30 mg / 100g, varies according to the cultivars of apple (Fisher 1999; Mapson 1970; Schuphan 1956). The phenolics were higher responsibility than Vitamin C for the antioxidant activity (Wolfe et al. 2003). At the same time, the content of total phenolics or others often do not directly reflect the total antioxidant capacity in fruits (Lee et al. 2003)

The aim of this research was determination of the total phenolics, total anthocyanins ascorbic acid content and total antioxidant activity of local apple varieties in Posof/Ardahan region. The obtained results can be used in the registration process of these local varieties and may be taken into consideration in the selection of parents in breeding programs.

Materials and Methods

Fruit Material

Seven varieties of apples (“Posof kırmızısı”, “Sarı şafran”, “Paşa”, “Kaburgalı”, “Uruset”, “Sütelması” and “Beyazelma”) were obtained from the Posof/Ardahan region. The fruits were collected on the harvest time and used for analysis. For the study apple fruits were not stored. Samples were transported to Isparta in icebox for analysis after harvested and the apples were analyzed directly.

Methods

In experiment, 3 samples were prepared for each cultivar. Total phenolic were detected with Folin-Ciocalteu assay. 10 g flesh+peels were centrifuged at 6000 rpm after homogenized in 40 ml ethanol solution. After, diluted (1/10) 1000 µl folin-ciocalteu and 800 µl Na_2CO_3 solution was

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added upon supernatant. After 2 h incubated examples were read at 750 nanometer wavelength in spectrophotometer. Water-ethanol mixture was used as blank. Gallic acid is used as a standard in the calculation (Arabacı and Sevindik 2014)

For total anthocyanin analysis, 10 g flesh+pees were homogenized in methanol solution that 1% HCL included. Samples were filtered with filter paper after a night standing. Supernatant were incubated in tampon solution (pH 1.0 and pH 4.5). Samples were read against the blank at 530 and 700 nanometer wavelengths. Results were calculated using siyanidin- 3-galactoside molar absorbtivit coefficient (Arabacı and Sevindik 2014)

For ascorbic acid analysis, fruit juice samples were obtained by pureed and filtered. Samples were homogenized by centrifuge. 400 µLokzalic acid (0.4% 0.4) and 4.5 ml 2,6-diklorofenolindofenol solution were added upon supernatant. Data were read against the blank at 520 nanometer wavelengthin spectrophotometer (Arabacı and Sevindik 2014).

Antioxidant capacity was determined using DPPH method. Fruit juice samples were obtained by pureed and filtered. Samples were homogenized by centrifuge. 950 µl 0.1 N DPPH (1,1-diphenyl-2-picrylhydrazyl) solution was added upon 50 µl supernatant. Then it was read against the blank at 515 nm wavelength spectrophotometer (Suils et al. 2000, Bakhshiand Arakawa 2006; Rezaeiradet al. 2013, Arabacı and Sevindik 2014).

Statistical Analysis

In this research, Data were checked for normal distribution that is the precondition of parametric tests. Normal distribution and homogeneity of variance were checked by Anderson-Darling test and Bartlett's Chi-square test respectively. The difference between the average rank of the varieties were analyzed with the Kruskal-Wallis test due to abnormal distribution. Differences between varieties were analyzed by Bonferroni-Dunn multiple comparison test. Statistical analyzes were performed using Minitab 16 software package.

Results and Discussion

In this research, the total phenolic, anthocyanin and ascorbic acid contents and antioxidant activity of the flesh+peel of the seven apple varieties were determined (Table 1). The Kruskal-Wallis test was applied to data. The differences between the average rank of the varieties are statistically significant ($p<0.01$). The Bonferroni-Dunn test was applied to differences between the average ranks of the varieties and shown in Table 1. The phenolic content was found to vary from 126.42 to 239.22 mg/100 g according to the variety.

The total phenolic contents of "Posofkırmızısı" and "Sarı şafran" varieties were highest at 239.22and 228.81 mg of gallic acid equivalents/100 grespectively (Table 1, Figure 1). These values were significantly different. Other cultivarswere followed by 222.71 mg/100g for"Paşa", 190.56mg/100g for "Kaburgalı", 155.66 mg/100g for "Uruset", 140.20 mg/100g for "Sütelması" and 126.42 mg/100g for "Beyazelma"cultivars(Table 1, Figure 1). The total phenolic contents of the "Beyazelma" were significantly lowest than the other all varieties. Different researchers were informed the results for total phenolic in apple. Our data was similar this results (Vrhovseket al.16; 66-212 mg/100 g, Kevers et al. 2011; 140 to 447 mg/100 g, Wolfe et al. 2003; 159to119.0 mg/100g, Arabacı and Sevindik 2014; 46.9 to 112.2 mg/100g).

Total anthocyanin contents of "Kaburgalı" were highest at 71.50 mg/100g, followed by "Beyazelma" and "Uruset" varieties (63.21 mg/100g and 58.28 mg/100grespectively) (Table 1, Figure 2). These value differences between "Kaburgalı" were significant. "Sarı şafran", "Paşa" and "Posofkırmızısı" varieties were followed by others (34.56 mg/100g, 33.32 mg/100g and 32.44 mg/100g respectively) (Table 1, Figure 2). The differences between these three varieties were significant. Different researchers were found results that wide ranged. Arabacı and Sevindik 2014 were informed from 0.5 to 49.1 mg/100g for total anthocyanin amount of apple peels but, only one apple variety has anthocyanin (35.9 mg/100g for red colored flesh Uruset). Wolfe at al. (2003)was reported from 2.1 to 26.8 mg of cyanidin 3-glucoside equivalents/100 g of peels. Rababah et al. (2005) was determinedas 9.2 mg/kgof apple. Our data was similar this results. According to some researchers, the amount of anthocyanin is varies according to peel color of fruits. And this depends on the presence of cyanidin 3-galactoside that makes the peel red color (Wolfe at al. (2003); Awad and Jager 2000).

Table 1. Total phenolic and anthocyanin, ascorbic acid and free radical activity of apple cultivars

Variable	Total Phenolic (mg of gallic acid equivalents/100 g)		Total Anthocyanin (mg/100g)		Antiokcidant Activity (µmol of vitamin C equivalents/g)		Ascorbic Acid (mg/100g)	
Variety	Mean	Rank means	Mean	Rank means	Mean	Rank means	Mean	Rank means
Kaburgalı	190,56±0,12	11 D	71,50±0,18	20A	90,32±0,00	2 G	17,18±0,13	2 F
Posofkırmızısı	239,22±0,10	20 A	32,44±0,10	5F	114,23±0,01	20 A	19,93±0,07	12,3 C
Uruset	155,66±0,12	8 E	58,28±0,15	14 C	110,72±0,01	17 B	17,69±0,14	5 E
Paşa	222,71±0,21	14 C	33,32±0,05	8E	104,41±0,03	5 F	19,77±0,04	8 D
Sütelması	140,20±0,26	5 F	30,07±0,09	2G	106,32±0,04	8 E	19,88±0,01	12,7 C
Beyazelma	126,42±0,03	2 G	63,21±0,05	17B	107,80±0,03	11 D	26,83±0,11	20 A
Sarı şafran	228,81±0,08	17 B	34,56±0,03	11 D	109,68±0,00	14 C	24,40±0,03	17 B

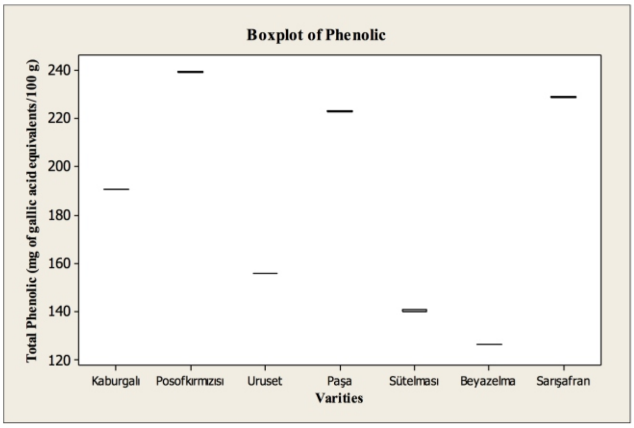

Figure 1. Boxplot of Phenolic (Means and SE Mean)

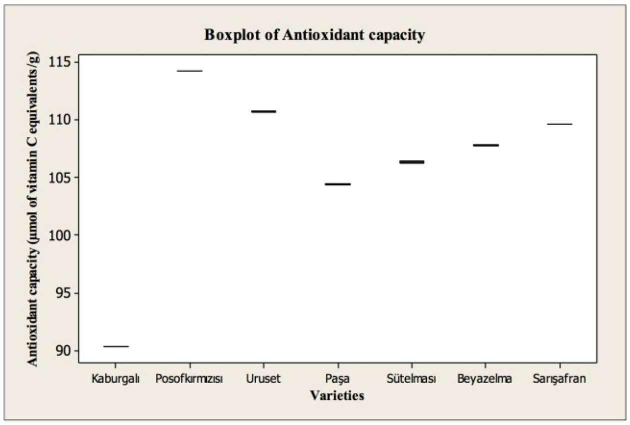

Figure 3. Boxplot of Antioxidant capacity(Means and SE Mean)

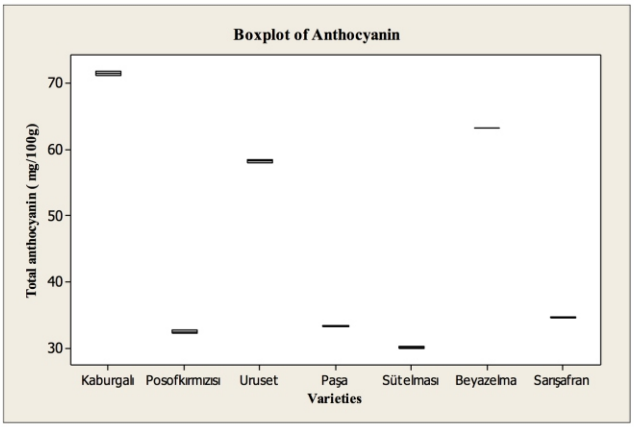

Figure 2. Boxplot of Anthocyanin (Means and SE Mean)

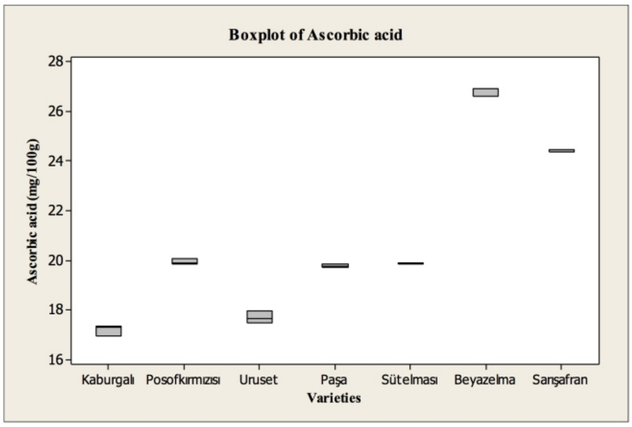

Figure 4. Boxplot of Ascorbic acid (Means and SE Mean)

In this research, ascorbic acid contents of apple varieties were shown in Table 1 and Figure 3. “Beyezelma” and “Sarı şafran” varieties were highest amount of ascorbic acid (26.83mg/100g and 24.40 mg/100g respectively). These values were significantly different. Other cultivars were followed by 19.93 mg/100g for “Posofkırmızısı”, 19.88 mg/100g for “Sütelması”, 19.77mg/100g for “Paşa”, 17.69 mg/100g for “Uruset” and 17.18mg/100g for “Kaburgalı” (Table 1, Figure 3). The differences between these four varieties were significant and significant differences are between these four varieties and the varieties which has the highest value (“Beyezelma” and “Sarı şafran”). Different researchers were informed the results for total phenolic in apple. Our data was similar this results (Szeto et al. 2002; 60 mg/100g, Arabacı and Sevindik 2014; 5.2 to 17.2 mg/100g, Kevers et al. 2011; 11.6 to 35.3 mg/100g, Gardner et al. 2000; 3.9 mikroM, Lee et al. 2003; 9.0 to 16.6 mg/100g, Miller et al 1997; 51 µmol/litreof juice). At the same time, our data were higher than many other researchers reported. The reason for this is believed to be genetic variations and effects of growth area conditions.

The antioxidant activity of “Posofkırmızısı” was highest at 114. µmol of vitamin C equivalents/g, followed by “Uruset”, “Sarı şafran”, “Beyazelma”, “Sütelası” and “Paşa” varieties (110.72, 109.68, 107.80, 106.32 and 104.41 µmol of vitamin C equivalents/g respectively) (Table 1, Figure 4). These values were significantly different. The antioxidant activity of the “Kaburgalı” (90.32 µmol of vitamin C equivalents/g) were significantly lowest than the other all varieties. Different researchers were informed the results for total phenolic in apple. Our data was similar this results (Szeto et al. 2002; 6300 4200 µmol/kg fresh wet wt, Arabacı and Sevindik 2014; 21.7-57.8%, Kevers et al. 2011; 1101-4917 µmolTE/100 g FW, Van der Sluis et al. 2001; IC50: 5.8-8.0 g of fw/L, Lee et al. 2003; 116.22 mg of VCEAC/100 g, Rababah et al. 2005; 17.7 mM TE/kg).

Conclusion

As a result, that these local apple cultivars have high total phenolic, anthocyanin and antioxidant capacity in flesh+peels. It is known, positive effect on human health of these substances. For this reason it is suggested for consume with their peels.

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Research Article Int J Agric Environ Food Sci 2(4):135-138 (2018)

Investigation of pesticide ruins by LC-MS/MS and GC-MS chromatography in sweet fennel seed (*Foeniculum vulgare* Mill.)

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Abstract

The aim of present study was to investigate the effects of the pesticide residues on the seeds of sweet fennel, Foeniculum vulgare Mill. cv. Dulce, grown by good agricultural practices. The sweet fennel was grown in Tefenni town of Burdur provience in South Western Part of Turkey. The residue analyses were done by GC-MS/MS and LC-MS/MS chromatographies. Total 186 active substances in used pesticides during the cultivation period were analyzed by LC-MS/MS chromatography meanwhile 116 active substances of pesticides by GC-MS/MS chromatography device were analyzed in sweet fennel seed. This study was conducted in years of 2012 and 2013 consecutively. Detectable pesticide residues have not been measured in the samples.

Keywords: Fennel, Pesticides, Residues, Chromatography, Burdur

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Introduction

Fennels (*Foeniculum vulgare* Mill. var. *Dulce*) are members of Apiaceae (Umbelliferae) family and their synonyms in Turkey are "rezene, raziyane, arapsaçı, irziyan and mayana". The origion of these spice plantsis reported to be Western Asia and Mediterranean Countries (Davis, 1982; Uzun et al., 2012). "Sweet fennels" (*Foeniculum vulgare* Mill. var. dulce) that are grown artificially as well, are spice plants (Baydar, 2005; Ceylan, 1997) found naturally in Northern, Southern and Western regions of Turkey (Davis, 1982) and are grown in limited areas of cities such as Bursa, Denizli, Gaziantep, Manisa and Antalya (Anonymous, 1999). "Hot fennels" are found wild in the Northern Anatolia region (Ordu and Trabzon) of Turkey (Zeybek, 1960; Baytop, 1999; Akgül, 1993).

While a great amount of fennel seeds was produced in Turkey, they are consumed in internal market, and the rest is being exported (Anonymous, 1999). Fennels shared about 4.2 % of Turkey's Medical Plant Export in 2008 and 1.915 tonnes of products were exported for 3.739.000 $ while 266 tonnes were imported for 386.000 $. 10 tonnes of fennels had been processed and as a response, 200 kg's of volatile oil had been obtained (Anonymous, 1999). Furthermore, rate of volatile oil obtained from fennels that are traded should not be under 1.5%. The 2% infusion obtained from seeds of fennels, whose leaves are known as wound healing and stems are known as diuretic, is known as gas removing and milk enhancer and was reported to be effective as spasms solvents and secreolytically effective (Baytop, 1999; Ernst, 2001). In addition, fennels have production license as herbal drugs by the Ministry of Health (Özçelikayet al., 1997). Fennels' launched medical forms are used for some diseases such as aches, swelling, gas pains and spasms of stomach and intestines and upper respiratory tract discharges (e.g: Flu) (Czygane, 1989; Weib, 1991).

Volatile oil and some other components produced by fennel seeds are used for food and medicine sectors and perfumes and cosmetics sectors (Baytop, 1994). There is a need for the determination of pesticide residues on fennel seeds and bringing these findings into the economy which serve a rewarding purpose for Turkey, as a developing country. Pesticides are used as protectors in agriculture and their overuse and misuse cause permanent toxic effect in nature. Their misuse cause acute and chronical diseases on people and cause environmental pollution. Although restriction shave taken place for pesticide use, harvest of premature products and introduction of these products to markets before the correct time resulted for pesticides to take place as residues in the food chain. Residues on earth are observed to pollute spring waters and drinking waters by the effects of rains and etc. When pesticides are misused, they may lead to many kinds of diseases for animals more than the plant itself, which pesticides are applied on, and this situation may go as far as death for animals. Active substances of pesticides are known to cause acute toxic and genotoxic effects on people (Anonymous, 2014). When analyzing the pesticide residues over the standards developed by Worlds Health Organization (WHO) and Food Agriculture Organization (FAO) highly sensitive analytical devices such as GC-MS/MS and LC-MS/MS are used (Ersoy et al., 2011a; Ersoy et al., 2011b). In this study, pesticide residues on fennel seeds that grown in Tefenni Town of Burdur city were analyzed.

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Materials and Methods

In this study, the seed materials obtained from fennel plants grown by a farmer in Teffeni town of Burdur city during 2012- 2013. Examples were gathered approximately 1 month later the harvest. As the purpose, 1 kg seed samples from 10 different sacks in the farmer's fennel stock were gathered and mixed. 15g of seed samples were studied for extractions for 3 times revealingly. Pesticides given in Figure 1 and 2 are searched in the examples of fennel seeds, which are the materials. All extraction studies and residue analysis of the samples were done at the Directorate of Food Control Laboratory of İzmir, connected The Food, Farming and Livestock Ministry.

All the solvents and chemicals (water, acetonitrile, methanol, formic acid, acetic acid, ammonium formate) used as mobile phases in sample extractions were chosen in accordance to a profound quality. Pesticide standards are prepared at least a 90% rate of purity. Extractions and clearance of the samples are generalized in accordance with AOAC (International Official Methods of Analysis) methods (AOAC, 2007).

Examples' Preparation for Analysis

15 g samples were homogenized in a mechanical shredder. Other similar samples of the same sample were put into same processes separately. Sample amounts that put into extraction were taken from these homogenized samples after weighing.

Extraction of Examples

Whole samples were homogenized with steel blenders by shredding and 5g of sample from the main sample were weighed and mixed with 10ml of water and 15ml of acetonitrile with 1% acetic acid and strongly shaked for 1 minute. Afterwards, 6 g of waterless magnesium sulfate ($MgSO_4$) and 1.5 g's of Sodium Acetate ($C_2H_3NaO_2.3H_2O$) was added into falcon tubes and after being shaked for 1 minute, centrifuged for 5 minutes at 4000 rpm rate. As the next step, 8 ml of samples from the previous examples' high phases were collected for the cleaning process and transported into 15 ml falcon tubes and mixed with 1.2 g of waterless $MgSO_4$ and 0.4 g's of PSA and centrifuged for 5 minutes at 4000 rpm rate, once again. Later, the high phase was transported into vials and kept in a freezer until the device evaluations. As the last injections into LC-MS/MS and GC-MS/MS devices were conducted and residue rates were determined. Chromatographically conditions of LC-MS/MS and GC-MS/MS devices are explained on Table 1 and Table 2 in detail.

3 Hydroxy carbofuran+Carbofuran; Acephate; Acetamiprid; Aclonifen; Aldicarb+sulfone+sulfoxide; Allaxydim Na; Amitraz+Metabolitleri ;Anilofos ;Atrazine ;Atrazine Desethyl; Azadirachtin; Azoxystrobin;Azyprotryn; Benalaxyl; Bendiocarb; Benfurocarb; Benomyl+Carbendazim; Bensulfuron methyl; Boscalid;Bromacil; Bromuconazole; Butocarboxim;Butylate ;Carbaryl;Carbosulfan;Carboxin;Carfentazone ethyl; Chlofentezine; Chlorbromuron; Chlorfenvinphos; Chloridazon; Chlormequat chloride; Chloroxuron;Chlorpyrifos;Chlorpyrifos methyl;Clodinafop propargyl ester;Clomazone;Coumachlor; Coumaphos;Cyanazine;Cycloate; Cymoxanil; Cyproconazole ;Cyprodinil; Demeton S methyl sulfoxide; Diazinon;Dibrom; Diclorvos (DDVP); Dicrotophos; Diethofencarb; Difenoconazole; Dimefox; Dimetha chlor; Dimethenamid;Dimethoate+Omethoate; Dimethomorph;Diniconazole; Dioxacarb; Diphenamid; Dipropetryn;Diuron; Dodine; Epoxiconazole; Ethion; Ethirimol; Ethoxyquin;Etrimfos;Famoxadone; Fena midone; Fenazaquin; Fenhexamid; Fenoxaprop; Fenoxycarb; Fenpiclonil; Fensulfothion; Fenuron; Fluquin conazole; Flurochloridone; Flutriafol;Fonofos; Formothion; Furathiocarb; Haloxyfop toxyethyl; Haloxyfop methyl; Heptenephos; Hexythiazox; Imazalil; Imazaquin;Imidocloprid; Indoxacarb ;Iodosulfuron methyl sodium; Iprodion; Iprovalicarb; Isopruton;Kresoxim methyl; Lenacil;Malaoxon;Malathion; Mecarbam;Mefenpyr diethyl;Mephosfolan;Mesosulfuron methyl; Metalaxyl+Metalaxyl; Metamitron; etazachlor; Metconazole; Methacrifos; Methamidophos; Methidathion; Methiocarb; Methomyl+Thiodicarb; Metolachlor; Metoxuron; Metribuzine; Metsulfuron methyl; Mevinphos;Molinate; Monocrotophos; Monolinuron; Myclobutanil;Nicosulfuron;Oxamyl;Paraoxon Ethyl;Parathion ethyl;Parathion ethyl; Pencycuron;Phentoate; Phosalone; Phosmet;Phosphami don; Phoxim; Picloram; Pirimicarb; Pirimiphos ethyl; Pirimiphos methyl;Pirimisulfuron methyl; Prochloraz; Profenefos; Profoxydim; Promecarb; Prometryn; Propachlor; Propamocarb; Propaquizafop; Propazine; Propiconazole; Propoxur; Propyzamide;Proquinazid; Prosulfuron; Pymetrozine;Pyraclostrobin; Pyrazop hos;Pyrazosulfuron; Pyridaben; Pyridaphention; Pyriproxyfen; Quizalofop P ethyl;Rimsulfuron;Spinosad; Spiroxamin; Temefos; Tepraloxydim; Terbufos; Terbuthylazine; Terbutryn; Tetrachlorvinphos;Thiabendazole; Thia cloprid;Thiamethoxam;Thiophonate ethyl; Thiophonate methyl; Tolyfluanide; Tralkoxydim; Triadimefon+Triadimenol; Triallate; Triasulfuron; Triazophos; Trifloxystrobin; Triflumizole; Triflusulfuron methyl; Triticonazole; Tulfotep; Vamidothion; Vernolat; Zoxamide

Figure 1. Active substances examined in fennel seed examples on LC-MS/MS device (Detection Limit: 0,010-0,050 µg/kg)

1-3 Hexachlorobutadiene; Acetochlor; Alachlor; Aldrin+Dieldrin; Alpha BHC;Alpha+Beta+Endosulfan sülfat; Azinphos methyl; Azobenzene; Beta BHC; Bifenthrin; Bitertanol; Bromophos ethyl;Bromophos methyl; Bromopropylate; Bupirimate;Buprofezin;Cadusafos;Captan;Chlorfenapyr;Chlorfenson;Chloroneb; Chlorpropam; Chlorthal dimethyl; Chlorthalonil; Cis+Trans Chlordane; Cyfluthrin; Cypermehtrin + isomers; Cyromazine; Delta BHC; Deltamehtrine; Demeton-S-methyl; Desmethrine; Dialifos; Dichlofluanid;Dicofol; Dinobuton; Disulfoton;Disulfoton sulfone; Disulfoton sulfoxide; Ditalimphos; Endrin; Endrin aldehit; Endrin keton; EPN; Ethalfluralin; Ethiofencarb; Ethofumasate; Ethoprophos; Etoxazol; Fenamiphos; Fenarimol; Fenchlorfos; Fenitrothion; Fenpropathrin;Fenson; Fenthion; Fenvalerate+Esfenvalerate;Flamprop methyl;Flucythrinate; Fluotrimazole; Flusilazole; Folpet; Fuberidazole; Heptachlor + isomers; Hexachlorobenzene (HCB); Hexaconazole; Iodofenfos; Isazofos; Isodrin; Isopropalin, Lambda Cyhalothrin; Lindane (Gamma BHC);Linuron; Methoxychlor;Nuarimol;Ofurace;Oxidixyl; Oxyfluorfen; Pebutale; Penconazole; Pendimethalin; Pentachloroanilin; Pentanachlor; Permethrin; Phorate; Piperonyl butoxide;Procymidone;Propanil;Propargite; Prothiofos; Pyrimethanil; Pyrimidifen;Quinalphos; Quinomethionate; Quinoxyfen; Quintozene;Rabenzazole; Resmehtrin; Simazine;Sulprofos;Taufluvalinate;Tebuconazole;Tebufenpyrad; Tecna zene;Tefluthrine; Terbacil;Tetraconazole;Tetradifon; Tetrasul; Thiobencarb; Thiometon; Tolclofos Methyl; Total DDT; Trichlorfon; Trifluralin; Vinclozolin

Figure 2. Active substances examined in fennel seeds examples on GC-MS/MS device (Detection Limit: 0,010-0,050 µg/kg)

Table 1. Chromatographic Working Conditions of LC-MS/MS

LC	Agilent 1200/Binary		
MS/MS	Agilent 6410		
Mobile Phase	5 mM Amonium Formate &Water + Acetonitrile		
Mobile Phase Flow	0,6 ml/min		
Column	Eclipse XDB-C18; 3,5µm; 4,6*150mm		
Gradient	Time (min)	%A	%B
	0	85	15
	5	85	15
	20	10	90
	30	0	100
The Column Oven	25°C		
Injection Capacity	3 all		
MS Gas Temperature	350°C		
MS Gas Flow	12 l/min		
Nebulizer Pressure	40 psi		
Capillary	4000 V		
MS1 / MS2 Temperature	100°C / 100°C		
Bowl Vacuum	2,3 Torr		
High Vacuum	$8,79*10^{-6}$ Torr		
Delta EMV	400		

Table 2. Chromatographic Working Conditions of GC-MS/MS

Gas Chromatography	7890A			
Mass Detector	7000A			
Column	HP-5MS, 15 m, 250µm, 0.25µm			
Injection Volume	PTV Injektion, 5µl			
Carrier Gas, Flow	Helium (high purity)			
Mode of Operation	SIM			
PTV Temperature Program		Increase °C/min	Temperature (°C)	Time (min)
	Start		60	0,5
	Level 1	200	250	10
	Level 2	50	60	4
Oven Temperature Program		Increase °C/min	Temperature (°C)	Time (min)
	Start		50	0,75
	Level 1	25	150	0
	Level 2	3	200	0
	Level 3	8	280	15
Pressure	26,2 psi			
Vent Flow	100 ml/min			
Inlet	280°C			

Results and Discussion

The findings amount in the study are considered on an average of 3 repetitions of each example in accordance with the "Turkish Food Codex (TGK) Rescript of Maximum Residue Limits of Pesticides Permitted to be Found in Livestock (Official Newspaper: 21.01.2011-27822; Rescript No: 2011/2). Each residue limits of TGK for each pesticide example are given in the tables, separately. In the residue limits of fennel seed examples' examinations, where high-previsioned devices such as GC-MS/MS and LC-MS/MS were used, 186 active substances of pesticides in LC-MS/MS device and 116 active substances of pesticides at GC-MS/MS device were analyzed. In this study conducted during the years of 2012 and 2013, any analyzable residues were not observed in the examples of both years.

Ersoy et al., (2011a), in the study they conducted to analyze the pesticide residues on strawberries and table grape examples gathered from the markets of Konya area, found that, there is 34, 33 and 47 µg/kg (tolerate value 20 µg/kg) rate of Imazalil in the example of wet grapes; and there is 337 and 433 µg/kg Benomyl-Carbendazim (tolerate value 300 µg/kg) on 2 examples on wet grapes. In the study they conducted, in the wet grape examples on which they studied, the product without any pesticide residues is 38%, the product with 1 kind of pesticide residues is 10%, the product with 2 kind of pesticide residues is 20%, the product with 3 kind of pesticide residues is 10%, the product with 4 kinds of pesticide residues is 11%, the product with 5 pesticide residues is 9%, the product with 6-7 kinds of pesticide residues is 2% of all the examples. They determined the strawberry examples as 70% is without any pesticide residues and 30% is with pesticide residues, over-limit pesticide residues and with the use of forbidden chemicals.

Kurt et al. (2011), studied the spice and other spice kinds' exportation between the years of 1900 -2009. They reported that fennel have a role of 5% (27.7 million kg's) in exportation and 9% (3.46 million kg's) in spice importation of Turkey's spice trade.

Abou-Arabet et al., (1999), in the study they conducted, analyzed pesticide residues on 303 different examples of 20 different medicinal plants spices in Egypt and among these; hibiscus, dill, celery, tea, cumin and chamomile are taking place. Their findings showed that malathion is the superior pesticide residue on the analyzed examples. They reported that dimetohate rate on cumin and camomile examples passed the permitted limit (MPLs). On chamomile examples, lindane, aldrin, dieldrin, DDT, clordane and rates have passed the maximum limits (MPLs). They reported that when medical plants boiled in water, the residues cannot be analyzed; when the plants drown into water, the pesticide residues move into the liquid extract.

Abou-Arab (1999) in his study, study on the pesticide residues on tomatoes and tomato products in Egypt.He determined the average HCB, lindane, dieldrin, heptachlor epoxide and DDT sorts' levels in the following order 0.009, 0.003, 0.006, 0.008 and 0.083 mg/kg and he reported that he did not found any pesticide residues in ketchup and tomato paste. He suggested that tomatoes contain the highest level of HCB, lindane, dieldrin and DDT in their cuticular and sub-cuticular tissues. He underlined the importance of washing them with water and/or detergent solution to decrease the pesticide rate to the lowest level and cooking (As the tomato paste production process) them helps to eliminate the pesticide residues from tomatoes.

Santamaria et al., (1999), in their study they conducted in Bari (Italy), studied on 327 different examples from 26 different fresh vegetable kinds that contain nitrate and oxalate. Their findings suggested that the vegetables whose leaves are edible (celery, parsley, spinach, etc.); contain higher levels of nitrate than vegetables whose bulbs, tubers and shoots are edible. They found high level of oxalate in spinach and chard. They reported that the daily intake of nitrate is determined as 71 mg's by the national nutrition institute and as they reported, with chard and lettuce intake this value line is passed 30%.

Abou-Arab and Abou Donia (2001), in the study they conducted, studied pesticide residues, heavy metals and aflatoxin components on medical plants (peppermint, chamomile, fennel, cumin, etc) used on both children and grown ups. Examples were collected from different markets in Egypt. As a result, while malathion, dimethoate, and profenofos were found in high levels on most of the analysed examples; aldrin, dieldrin, chlordane and lindane were found in lowest levels. Chlorpyrifos, parathion, diazinon and endosulfan were not found in analysable levels.

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Conclusion

Tefenni/Burdur district is one of the most important regions in terms of organic production in our country. The use of pesticides in the region is reasonable. Our analysable residues were not observed in the examples of both years. This is good result for good agricultural practices. According to these results, organic farming can be applied in the region.

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Review Article

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The role of herbivore-induced plant volatiles (HIPVs) as indirect plant defense mechanism in a diverse plant and herbivore species; a review

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Abstract

When plants are attacked by herbivores, they release plant volatiles called herbivore-induced plant volatiles (HIPVs) to the environment to communicate with higher trophic levels. HIPVs play different ecological roles such as plant-plant interaction, plant-herbivore interaction, tritrophic interaction and other related interactions. Attractiveness of HIPVs to natural enemies in a tritrophic interaction varies depending on species diversity. Under natural and multiple cropping systems, tritrophic interaction is expected to be more complex than single tritrophic interaction with one species per trophic level. In complex tritrophic interaction, diversity of different trophic levels affects attractiveness of HIPVs to natural enemies. From plant diversity point of view, HIPVs mixture emanating from herbivore-damaged multiple plant species are reported to affect behavioral responses and foraging behavior of natural enemies under laboratory and field conditions. Similarly, from herbivore diversity point of view, in nature, plants are commonly attacked by more than one herbivore species. Constituents of HIPVs vary between plants infested by multiple and single herbivore species and this affects the behavioral responses and foraging behavior of natural enemies. This paper reviews recent findings on the role of HIPVs as indirect plant defense in systems with simple tritrophic interaction, and in diverse plants species and diverse herbivore species.

Keywords: Herbivore-induced plant volatiles (HIPVs), Tritrophic interaction, Natural enemies, Herbivores, Species

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Introduction

In co-evolution, plants and insets have evolved a variety of deleterious and beneficial interactions (Maffei et al., 2007). In plant-insect herbivore interaction, plants are threatened by potentially hostile insect herbivores. On the other hand, plants are far from being passive victims of these attackers (Dicke et al., 2009; Das et al., 2013). They have evolved multitude of defense systems that protect them from being overeaten by the herbivores (Kessler and Baldwin, 2002; Heil and Karban, 2010). These could be either direct or indirect defense systems (War et al., 2015).

Direct plant defenses involve any plant traits such as spines, thorns, trichomes, primary and secondary chemical metabolites or proteinase inhibitors that affect the susceptibility to and/or the performance of attacking herbivores and thus increase plant fitness in environment with the herbivores (Kessler and Baldwin, 2002). Indirect plant defenses involve plant traits or adaptations such as provision of shelter or alternative food sources (e.g. extrafloral nectar) (Turlings and Wackers, 2004; Kost and Heil, 2006; Choh and Takabayashi 2010) or release induced plant volatiles upon herbivore infestation that result in the recruitment and sustenance of natural enemies such as predators and parasitoids that attack the herbivores (Dicke et al., 1988; Dick et al., 1990a; Turlings and Tumlinson, 1992; Yan et al., 2005; Tatemoto and Shimoda, 2008).

When plants are attacked by herbivores, they release induced plant volatiles from leaves or other parts to the environment to communicate with higher trophic levels that attack the herbivores and such defenses are called indirect plant defenses (Pare and Tumlinson, 1999). When attacked by herbivores, plants release much greater quantities or produce *de nevo*, of low molecular weight volatiles which are called herbivore-induced plant volatiles (hereafter called HIPVs) that attract natural enemies of the herbivores (Drukker and Sabelis, 1990; Yu et al., 2010). They are released from the site of herbivore feeding and/or systematically from undamaged parts distal to the feeding site (Turlings and Tumlinson, 1992; Rose et al., 1998). Numerous arthropod natural enemies exploit the HIPVs to locate and feed on their preys or parasitize their hosts (Dicke and Sabelis, 1988; Turlings and Wackers, 2004; Das et al., 2013; Dicke, 2015). To date, plethora of investigations have explored the attractiveness of HIPVs to natural enemies such as predators (such as Dicke and Sabelis, 1989; Tatemoto and Shimoda, 2008; Haftay and Nakamuta, 2016 a, b) and parasitoids (Turlings et al., 1990; Van Poecke et al., 2001; Yu et al., 2010).

In addition to attracting natural enemies to the food source, HIPVs could arrest them to remain on the plants (Uefune et al., 2012). Uefune (2012) reported that the parasitic wasp *Cotesia vestalis* Haliday (Hymenoptera: Braconidae) had a longer residence time on plants treated with an attractive blend of four volatiles (*n*-heptanal, sabinene, α-pinene and (*Z*)-3-hexenyl acetate) which are

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induced from *Plutella xylostella* Linnaeus (Lepidoptera: Plutellidae) larvae-infested cabbage plants.

HIPVs may comprise compounds from different groups such as terpenoids, green leaf volatiles (GLV), phenylpropanoids/benzenoids, and aromatic compounds like indole and methyl salicylate (MeSA) (Dicke, 2009). These groups of HIPVs are synthesized through different biosynthetic pathway in different compartments of plant cells (Pare and Tumlinson, 1999; Das et al., 2013) and are regulated by phytohormones such as jasmonic acid, salicylic acid, and ethylene (Ozawa et al., 2000; Menzel et al., 2014a). The attractiveness of HIPVs to natural enemies varies depending on species diversity of different trophic levels in a given environment. Under natural conditions, though different from place to place, the interaction among different trophic levels is expected to be complex. For instance, in fields with diverse plant species, the plant volatiles released to the environment is expected to be with greater diversity both quantitatively and qualitatively. On the other hand, a plant species could be attacked by multiple herbivores which might result change in response of plants in releasing HIPVs compared to attack by single herbivore species. Recent studies show that in systems with diverse plant species, herbivore species or both affect release of HIPVs quantitatively and qualitatively, and in turn the response of natural enemies (Haddad et al., 2011; Moreira et al., 2012; Haftay and Nakamuta, 2016a, b). These findings are recent advances in the plants-herbivores-natural enemies tritrophic interaction paradigm given that in natural and multiple cropping systems the interaction is more complicated and need further investigations by ecologists, evolutionists, naturalists etc. Therefore, the aim of this paper is to review the recent growing evidences on the role of HIPVs as indirect defense of plants in systems with simple tritrophic interaction, and in diverse plants species and diverse herbivore species.

Ecological role of HIPVs in a simple tritrophic interaction

Once HIPVs are released to the environment, they are not under the control of the plants. They might be exploited by various organisms from various trophic levels such as neighboring conspecific plants (Kost and Heil, 2006; Choh and Takabayashi, 2010) or different plant species (Baldwin et al., 2006; Pearse et al., 2013), conspecific herbivores (De Moraes et al., 2001; Carroll et al., 2008) or different herbivore species (Bernasconi et al., 1998; Robert et al., 2012), and natural enemies (Dicke and Sabelis, 1988; Yu et al., 2008; Yu et al., 2010; Zhang et al., 2012; Haftay and Nakamuta, 2016a,b). These attributes are thought to exert different selection pressures on the plant fitness (Hoballah and Turlings, 2001; Kost and Heil, 2006; Dicke and Baldwin, 2010). The ecological roles of HIPVs in a simple tritrophic interaction might result in different effects in the environment. Some of the effects are explained below.

Role of HIPVs in plant-plant interaction

One of the ecological roles of HIPVs is their involvement in plant-plant interaction. The release of HIPVs from herbivore-attacked plants might trigger responses, positive or negative effect, on the receiving plant of the same or different species. For instance, Kost and Heil (2006) found that HIPVs emitted from herbivore-infested Lima bean plants as well as a synthetic HIPV mixture resembling the natural one induces another indirect defense that is a secretion of extrafloral nectar, an alternative food source for natural enemies, in a neighboring conspecific plant. This led to the attraction of a higher cumulative number of predatory and parasitoid insects and the plants get a fitness benefit such as an increased production of inflorescences and leaves (positive effect). Similarly, Choh and Takabayashi (2010) found that uninfested Lima bean plants exposed to HIPVs attracted more predatory mites *Phytoseiulus persimilis* Athias-Henriot (Acarina: Phytoseiidae) and secreted larger amounts of extrafloral nectars than unexposed plants. They further reported that the predators survived longer when supplied with extrafloral nectar and stayed longer on uninfested plants that had been supplemented with additional extrafloral nectar. These findings imply that HIPVs play important role for plant-plant communications. It is expected that this might result in adjustment of mechanical and chemical defenses, and gene expression in the receiver plant.

Role of HIPVs in plant-herbivore interaction

HIPVs can also affect foraging behaviors of herbivores either conspecifics or heterospecifics. For example, De Moraes et al. (2001) reported that HIPVs emitted at night time from tobacco plants damaged by *Heliothis virescens* Fabricius (Lepidoptera: Noctuidae) larvae are highly repellent to and result in a lower ovipositing of eggs by conspecific adult moths. Additionally, HIPVs can repel heterospecific herbivore species. For example, Bernasconi et al. (1998) found that maize plants treated with regurgitant of the caterpillar *Spodoptera littoralis* Biosduval (Lepidoptera: Noctuidae) which induce emission of volatiles that attract natural enemies were repellant to corn leaf aphid *Rhopalosiphum maidis* Fitch (Homoptera: Aphididae). These findings are indicators for the possible use of HIPVs not only to attract natural enemies but also help the plant not to host other herbivores either conspecific or hetrospecifics. In addition to this, upon damage by herbivores, plants release toxic chemicals that is unpleasant for the herbivores. This helps the plant to avoid further damage by the herbivores. On the other hand, for some herbivore species, HIPVs could be attractive and might negatively affect the plant due to damage by the herbivore.

Role of HIPVs as indirect plant defense

Another well-established ecological role of HIPVs is their function as plant`s indirect defense by attracting arthropod natural enemies such as predators and parasitoids that attack the herbivores (Dicke et al., 1990a, b; Uefune et al., 2013; Haftay and Nakamuta, 2016a). The importance of the third trophic level for the plant indirect defense in a tritrophic plant-herbivore-arthropod natural enemy interaction was first suggested by Price and his colleagues (Price et al., 1980). This was followed by investigations on behavioral responses of natural enemies to plant volatiles emitted from herbivore-infested plants which led to the discovery of HIPVs that attract predators (Sabelis and Van de Baan, 1983; Dicke and Sabelis, 1988; Dicke et al., 1990a) and parasitoids (Turlings et al., 1990). Sabelis and Van de Baan (1983) revealed that volatiles (which they used the term "kairomones" for the volatiles) emitted from apple leaves infested by two-spotted spider mites *Tetranychus urticae* Koch (Acari: Tetranychidae) attracted the *P. persimilis* and *Metaseiulus occidentalis* Nesbit (Acarina: Phytoseiidae). Among other early works, Dicke et al. (1990a, b) revealed that, upon infestation by *T. urticae*, Lima bean plants emitted a blend of volatiles attracting the predatory mite *P persimilis* that effectively removed local populations of the spider mites. Similarly, corn plants damaged by caterpillars of *Spodoptera exigua* Hubner (Lepidoptera: Noctuidae) emitted volatiles that attracted the parasitoid *Cotesia marginiventris* Cresson (Hymenoptera: Braconidae) (Turlings et al., 1990). Since these discoveries, several behavioral and electrophysiological investigations had revealed the attractiveness of HIPVs to predators (such as Drukker et al., 1995; Zhang et al., 2009; Zhang et al., 2012) and parasitoids (e.g.: Turlings and Tumlinson, 1992; Yu et al., 2008; Yu et al., 2010). Some of the reports on the attractiveness of HIPVs from herbivore-infested plants to predators/parasitoids under laboratory and field conditions are summarized in Table 1 and Table 2 respectively.

As a result of attracting natural enemies, the plants are expected to get fitness benefit. There are reports which show plants get fitness benefits from the indirect defenses via HIPVs by attracting natural enemies. For instance, Hoballah and Turlings (2001) reported that maize plants (*Zea mays* L.) under attack by larvae of *S. littoralis* attracted *C. marginiventris* and *Campoletis sonorensis* Cameron (Hymenoptera: Ichneumonidae) which resulted higher parasitization and reduced feeding and weight gain of the host larvae. Consequently, at maturity, parasitized larvae-attacked plants produced 30% more seeds than plants attacked by unparasitized larvae did. Kost and Heil (2006) reported that exposure of plants to HIPVs which result in higher extrafloral nectar attracting more predatory and parasitoid insects and the plants increased production of inflorescences and leaves as compared to unexposed plants.

Attractiveness of HIPVs to natural enemies in systems with multiple plant and herbivore species

In a biological control system, it is crucial that the natural enemies are able to find prey-habitat location and the prey patches efficiently (Bouwmeester et al., 2003; Kaplan, 2012). Considering the higher detectability, HIPVs can be a reliable indicator of host or prey presence and their identities (Dicke et al., 1998; Cai et al., 2014) and thus predators and parasitoids utilize these volatiles for long-range prey-habitat location, and to locate host or prey in the habitat (Dicke et al., 1998). Thus, HIPVs play important roles in enhancing the efficiency of natural enemies as a biological control against insect pests in agricultural crops (Bouwmeester et al., 2003).

Most of the studies on electrophysiological and behavioral responses of natural enemies to HIPVs have focused on a single species of plant, herbivore and natural enemy tritrophic interaction. Beside to these factors, recently, evidences are accumulating beyond the simple tritrophic interaction paradigm that considers species diversity of different trophic levels (Dicke and Baldwin, 2010; Das et al., 2013). The emission of HIPVs constituents (quantitatively and qualitatively) is reported to be different based on the diversity of herbivore species (Shiojiri et al., 2001; Delphia et al., 2007) and plant species (Haftay and Nakamuta, 2016a, b). The high variability that characterizes the constituents of HIPVs as a result of these factors influence success of natural enemies in locating their prey or host. The constituents of the HIPVs emitted from diverse plant and/or plant species is different from a simple tritrophic interaction involving single species of each trophic level. Under natural conditions and multiple cropping agriculture systems, plants-herbivores-natural enemy interactions are thought to be more complex (Dicke et al., 2009). Under such condition, natural enemies should detect herbivore-infested plants within the complex environment with a diverse species of different trophic levels such as diverse plant species or herbivore species. Whether species diversity of a given trophic level contributes to a predator`s success in searching and locating of their prey in a given habitat will depend on the context in which the information is perceived by the predators or parasitoids. For instance, it has been reported that the abundances, behavioral and electrophysiological responses of predators to herbivore-damaged plants could be affected by diversity of plant and insect herbivore species (Dicke and Van Loon, 2003; De Boer et al., 2008; Haddad et al., 2011; Dicke and Baldwin, 2010).

From the plant species diversity perspective, the abundance and stability (i.e. lowered year-to-year variability) of arthropod natural enemies has been reported higher in systems with a diverse plant species or multiple cropping agriculture systems than a simplified or monoculture cropping systems (Haddad et al., 2011; Moreira et al., 2012; Haftay and Nakamuta, 2016a, b). Under such diverse plant species, natural enemies should locate their prey or host using different communication cues. The use of HIPVs is one of the communicating cues that mediate natural enemies to search a prey- or host-habitat location and to locate the prey or host within the habitat (Dicke et al., 1998).

Attractiveness of HIPVs to natural enemies in diverse plant species system

From the plant species diversity perspective, plethora of studies had revealed that the constituents of HIPVs emitted from different plant species infested by the same herbivores are different (Fortuna et al., 2013; Haftay and Nakamuta, 2016a). Because of this, it is expected that the constituents of HIPVs released to the environment from herbivore-infested multiple plant species, such as in multiple cropping system or under natural vegetation, will be a complex mixture of volatile compounds. Haftay and Nakamuta (2016a) found that multiple plant species involving tomato (*Solanum lycopersicum* L.), French bean (*Phaseolus vulgaris* L.) and sweet corn (*Zea mays* L.) infested by the polyphagous herbivore, African bollworm (*Helicoverpa armigera* Hubner, Lepidoptera: Noctuidae) released a complex mixture of HIPVs.

Recently, research findings are growing on the bottom-up influence of a mixture of HIPVs emanating from herbivore-damaged multiple host plant species on behavioral responses and foraging behavior of natural enemies under laboratory and field conditions. Under such complex mixtures of chemicals, the responses and foraging behavior of natural enemies are expected to be affected (Waschke et al., 2013, 2014; Haftay and Nakamuta, 2016a, b). Waschke et al (2013), in their review, suggested that natural enemies might use different foraging strategies under chemically complex environments which could involve avoiding, ignoring, preferring, or spatially responding to such environment depending on the benefits they gain.

For instance, Dicke et al. (2003) reported that behavior of the predatory mite, *P. persimilis* towards volatiles emitted from *T. urticae* -infested Lima bean plants was not affected by mixing with volatiles emitted from the caterpillar, *P. brassicae*-infested Brussels (*Brassica olerasceae* L.) plants both in a laboratory (except in one out of five experiment where the predator preferred volatiles from spider mite-infested Lima bean over mixed volatiles) and greenhouse experiment setup. The odor blends that were mixed have very different compositions and no overlap in compounds that are known to attract the predators. They suggested that the mixing of volatiles from caterpillar-infested Brussels

Table 1. Attractiveness of volatiles emitted from herbivore-infested plants to predators or parasitoids in laboratory experiments

Infested plants (Source of HIPVs)	Herbivores	Attracted natural enemies	References
Lima bean (*Phaseolus lunatus*)	*Tetranychus urticae*	*Phytoseiulus persimilis*[1]	Dicke and Sabelis, 1988; Dicke et al., 1990a, b; Margolies et al., 1997
Corn (*Zea mays*)	*Spodoptera exigua*	*Cotesia marginiventris*[2]	Turlings et al., 1990; Turlings et al., 1991; Turlings and Tumlinson, 1992
Brussels sprouts (*Brassica oleracea*)	*Pieris brassicae*	*Cotesia glomerata*[2]	Mattiacci et al., 1994
Broad bean (*Vicia faba*)	*Acyrthosiphon pisum*	*Aphidius ervi*[2]	Guerrieri et al., 1999
Phaseolus vulgaris	*T. urticae*	*Amblyseius womersleyi*-Kyoto[1]	Maeda et al., 1999
Cucumber	*T. urticae* or *Frankliniella occidentalis*	*Orius laevigatus*[1]	Venzon et al., 1999
Pear	*Cacopsylla pyricola*	*Anthocoris nemoralis*[1]	Drukker et al., 2000a, b
Arabidopsis thaliana	*Pieris rapae*	*Cotesia rubecula*[2]	Van Poecke et al., 2001
Barley plant (*Hordeum vulgare*)	*Rhopalosiphum padi*	*Coccinella septempunctata*[1]	Ninkovic et al., 2001
Vicia faba or *Phaseolus vulgaris*	Feeding plus oviposiotion by *Nezara viridula*	*Trissolcus basalis*[2]	Colazza et al., 2004
Strawberry	*T. urticae*	*Phytoseiulus macropilis*[1]	Fadini et al., 2010
Cucumber	*Thrips tabaci*	*Orius strigicollis*[1] *P. persimilis*[1]	Tatemoto and Shimoda, 2008
Cotton	*Helicoverpa armigera*	*Microplitis mediator*[2]	Yu et al., 2010

[1]Predators, [2]parasitoids

Table 2. Attractiveness of HIPVs to natural enemies under field conditions

HIPVs or source of HIPVs	Attracted natural enemies	References
Volatiles emitted *Psylla pyricola* -infested pear	*Anthocoris nemorum*[1], *Orius vicinus*[1], *Orius minutus*[1]	Drukker et al., 1995
T. urticae- or *F. occidentalis*-infested cucumber	*Orius laevigatus*[1]	Venzon et al., 1999
[(*Z*)-3-hexenyl acetate, MeSA, DMNT][a]	Multiple arthropod natural enemies[1,2]	James, 2003b
MeSA	*Chrysopa nigricornis*[1], *Hemerobius sp.* [1], *Stethorus punctum picipes*[1], *Orius tristicolor*[1]	James, 2003a; James and Price, 2004
13 HIPVs[a]	Multiple arthropod natural enemies[1,2]	James, 2005
[MeSA, MeJA, (*Z*)-3-hexenyl acetate][a]	Multiple arthropod natural enemies[1,2]	James and Grasswitz, 2005
MeSA	*Coccinella septempunctata*[1]	Zhu and Park, 2005
2-phenylethanol	*Chrysoperla carnae*[1]	Zhu and Park, 2005
Seven HIPVs[a]	Multiple arthropod natural enemies[1,2]	Yu et al., 2008
MeSA	*Diadegma semiclausum*[2], *Anacharis zealandica*[2]	Orre et al., 2010
3,7-dimethyl-1,3, 6-octatriene	*Microplitis mediator*[2]	Yu et al., 2010
[MeSA, (*Z*)-3-hexen-1-ol, (*Z*)-3-hexenyl acetate][b]	*Stethorus punctum picipes*[1]	Maeda et al., 2015
Allyl isothiocyanates	*Diaretiella rapae*[2]	Murchie et al., 1997; Titayavan and Altieri, 1990
Benzaldehyde	*Chrysoperla plorabunda*[1], *O. tristicolor*[1], *Stethorus punctum picipes*[1]	James, 2005
(*Z*)-3-hexen-1-ol	*Anagrus daanei*, *O. tristicolor*, *S. punctum*	James, 2005; Yu et al., 2008; Zhu et al., 1999, 2005
(*Z*)-3-hexenyl acetate	*O. tristicolor*[1], *Orius similis*[1], *Coccinella septempunctata*[1], *Anagrus* sp[1].	James, 2003a, b, 2005; James and Grasswitz, 2005; Yu et al., 2008; Jones et al., 2011
Limonene	*Harmonia axyridis*[1]	Alhmedi et al., 2010
MeSA, iridodial[b]	*Chrysopa nigricornis*[1], *Ceropegia oculata*[1]	Jones et al., 2011

[1]Predators, [2]parasitoids, [a]Applied singly, [b]applied as a mixture

plants that are not known in attracting the predator did not interfere with the attraction of volatiles emitted from spider mite-infested lima bean plants (or has been ignored by the predator) which consisted volatile compounds known to attract the predator. Because of this, the predators might have "ignored" the complex mixture which is one of the foraging strategies described by Waschke et al. (2013).

On the other hand, Haftay and Nakamuta (2016a, b) reported that polyphagous herbivores feeding on multiple host plant species with a mixture of HIPVs from the different host plant species enhanced the behavioral response and foraging behavior of a generalist predator, *Orius strigicollis* (Heteroptera: Anthocoridea). According to their findings, *O. strigicollis* preferred mixture of volatiles emitted from *H. armigera*-damaged multiple plant species to volatiles emitted from *H. armigera*-damaged single plant species under laboratory (Haftay and Nakamuta, 2016a) and field-cage conditions (Haftay and Nakamuta, 2016b). Besides, enhanced positive response of the predators to reconstituted HIPVs from multiple species than reconstituted HIPVs from single plant species was found in their laboratory and field-cage study. Moreover, the predator removes greater number of prey from multiple plant species than single plant species both under laboratory and field-cage condition. The enhanced attractiveness of mixture of HIPVs from multiple plant species to the predator shows a "preferring" type of foraging strategy as stated in Waschke et al. (2013). In this strategy, herbivore-damaged single plant species were attractive to the predator as compared to undamaged or mechanically-damaged plants. When the plants are in mixture enhanced attractiveness to the predator was found. This might suggest that "synergistic or additive" effect in attractiveness of HIPVs is found when HIPVs from two or more than two attractive plant species are mixed and offered to the predator. Another possible mechanism for the enhanced attractiveness of HIPVs from multiple host plant species to *O. strigicollis* could be explained from the perspective of resource availability in which a diverse plant species system offers shelters or greater variety and amount of prey to the predators than a single plant species which also supports the 'prefer' foraging strategy.

However, if the chemicals emitted from either of plant species is repellent to natural enemies under multiple plant species system, the natural enemies are expected to prefer attractive chemicals emanating from single plant species to mixture of chemicals emanating from multiple plant species consisting of attractive and repellent plant species. In this scenario, the complex mixture of HIPVs will have an "antagonistic effect" on the foraging behavior of the natural enemies. For instance, Gohole et al. (2003) reported that *Dentichasmias busseolae* Heinrich (Hymenoptera: Ichneumonidae), a pupal parasitoid of *Chilo partellus* Swinhoe (Lepidoptera: Crambidae), preferred volatiles from infested host plants, sorghum (*Sorghum bicolor* L.) or maize (*Zea mays* L.) to volatiles from a combination of the infested host plants and a non-host plant, molasses grass (*Melinis minutiflora* B.). They stated that the molasses grass in the combination was repellent, and thus, the parasitoid goes for the infested plants whose volatiles were attractive. This is an "avoiding" foraging strategy of natural enemies.

These different findings show that, the attractiveness of HIPVs from multiple plant species to natural enemies depends on the effect of the HIPVs from the single plant species on behavioral responses and foraging behavior of the natural enemy. In general, choosing and planting attractive plants in intercropping or multiple cropping systems is recommended to enhance the behavioral responses and foraging behaviors of natural enemies though other factors such as disease susceptibility, edaphic and environmental factors also determine the choice of plants to be used in intercropping or multiple cropping system.

Attractiveness of HIPVs to natural enemies in diverse herbivore species system

From the herbivore species diversity perspective, in nature, plants are commonly attacked by more than one herbivore species (Dicke and Van Loon, 2003; Rasmann and Turlings, 2007; Holopainene and Gershenzon, 2010; Das et al., 2013) simultaneously or sequentially. In support of this perspective, recent studies had reported that volatiles emitted from plants simultaneously damaged by multiple herbivore species affected the behavioral responses of predators (Moayeri et al., 2007; De Boer et al., 2008; Dicke et al., 2009) or parasitoids (Shiojiri et al., 2001; Vos et al., 2001; Rasmann and Turlings, 2007; Cusumano et al., 2015). Studies had found that there are variations in the constituents of HIPVs between plants simultaneously infested by multi-species herbivores and plants infested by single herbivore species (Delphia et al., 2007; Rasmann and Turlings, 2007; De Boer et al., 2008). They suggested that these variations in constituent of HIPVs might have led to the modification of behavioral responses of the natural enemies.

For example, Moayeri et al. (2007) found that the predatory mirid bug, *Macrolophus caliginosus* (Heteroptera: Miridae) showed a stronger response to volatiles emitted from sweet pepper plants (*Capsicum annum* L.) simultaneously infested with the spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) and the aphid, *Macrolophus caliginosus* Wagner (Heteroptera: Miridae) than to those emitted from plants infested by just one herbivore, irrespective of the species. In another study by Shiojiri et al (2001) found that *Cotesia glomerata* L. (Hymenoptera: Braconidae), parasitoid of larvae of *Pieris rapae* Linnaeus (Lepidoptera: Pieridae), preferred volatile blends emanating from cabbage (*Brassica oleracea* L.) simultaneously infested by diamond back moth, *Plutella xylostella* Linnaeus (Lepidoptera: *Yponomeutidae*) and cabbage white butterfly, *P. rapae* to those infested by only one herbivore species. Similarly, De Boer et al. (2008) reported that *P. persimilis* preferred volatiles induced by multi-species herbivory to volatiles induced by the larvae of beet armyworm, *Spodoptera exigua* Hubner (Lepidoptera: Noctuidae) alone or by *T. urticae* alone. They suggested that this was the predator`s reaction to the differences in the constituents of HIPVs between plants exposed to single and multiple herbivore species. This implies the variation in the constituents of HIPVs might have mediated the natural enemies to distinguish between volatiles emitted from plants exposed to a single and multiple herbivore species.

In support of these, some findings have detected differences in the constituents of HIPVs between plants infested by multiple and single herbivore species (Shiojiri et al., 2001; Rodriguez-Saona et al., 2003; Delphia et al., 2007; Moayeri et al., 2007; De Boer et al., 2008). For example, Delphia et al. (2007) reported that simultaneous feeding of tobacco plants (*Nicotiana tabacum* L.) by western flower thrips, *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) and the chewing herbivore tobacco budworm, *Heliothis virescens* Fabricius (Lepidoptera: Noctuidae)

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emitted greater amount of some volatiles such as α-humulene and caryophyllene oxide. Similarly, Shiojiri et al. (2001) found that cabbage plants simultaneously infested by larvae of *P. xylostella* and *P. rapae* emitted a different blend of volatiles compared to those infested by either of the two-herbivore species. The change in the constituents of HIPVs due to simultaneous multi-species herbivory consequently affects olfactory responses of arthropod natural enemies to HIPVs (Shiojiri et al., 2001; Moayeri et al., 2007; De Boer et al., 2008) mainly generalist natural enemies (Moayeri et al., 2007).

Other than simultaneous herbivory, plants are also frequently attacked by multiple herbivore species, which arrive at different time sequences (sequential herbivory). This might affect indirect defense of plants (Johnson et al., 2012; Menzel et al., 2014b; Wang et al., 2014) through HIPVs that attract natural enemies. Sequential herbivory by multiple herbivore species may influence indirect defense of plants in a positive, neutral or negative manner (Johnson et al., 2012; Menzel et al., 2014b). For example, Menzel et al. (2014b) reported that prior treatment of plants with oral secretions of the generalist caterpillar *Mamestra brassicae* L. (Lepidoptera: Noctuidae), as a mimic of caterpillar feeding, did not affect the attraction of *P. persimilis* to plants infested with its prey *T. urticae* (neutral effect). On the other hand, Johnson et al. (2012) reported that induced plant defense increases when above ground herbivores were feeding first followed by below ground herbivores (positive effect), whereas, the induced plant defense decreases when belowground herbivores were feeding first followed by aboveground herbivores (negative effect). In support of these findings, previous studies suggest that plants can form "memories" after sequential stressful events such as herbivory, which enable them to adjust their defense accordingly (priming), thus responding in an enhanced manner to a second stress (Johnson et al., 2012).

The difference in preference of natural enemies in diverse herbivore species might be related with the natural enemy`s prey or host preference and/or diet mixture. Single herbivore species-damaged plants might be less preferred by natural enemies compared to multiple herbivore species-damaged plants if both the herbivores are prey or host for the natural enemy. For the natural enemy, predators in particular, this can be explained by the higher profitability of finding a mixed diet (explanations about profitability of mixed diet can be found in Coll and Guershon 2002) or higher profitability in terms of accessing the most preferable herbivore species (Shiojiri et al., 2001; Moayeri et al., 2006; Xu et al., 2006; Harris et al., 2012; Ferrero et al., 2014). In case of sequential herbivory with varying arrival time, multiple factors such as priming of plant indirect defense for enhanced emission of HIPVs, predator`s prey preference and/or profitability of getting mixed diet might be playing their own roles for natural enemies to distinguish between volatiles emanating from different sequences of herbivory by the two herbivore species as well as between volatiles emanating from multi-species herbivory and single species herbivory. The various findings show that the difference in attractiveness of HIPVs emanating from multi-species herbivory can modify olfactory responses natural enemies to herbivore-damaged plants and this might be a result of different (perhaps interacting) factors such as priming of plant indirect defense, natural enemy`s prey or host preference and diet breadth.

The underlying mechanism for the variations in the constituents of HIPVs among plants exposed to single-, simultaneous and different sequences of multi-species herbivory might be phytohormone cross-talk. It has been reported that the phytohormone jasmonic acid (JA) and salicylic acid (SA) are involved in signaling and regulating HIPVs biosynthetic pathways (Ozawa et al., 2000; Menzel et al., 2014; Wei et al., 2014). JA or SA signaling pathways which modulate emission of HIPVs from plants have been reported different depending on the feeding mode of herbivores (Ozawa et al., 2000; van Poecke and Dicke, 2002; De Vos et al., 2005; Wei et al., 2014). Synergistic, additive or antagonistic effect from cross-talk between these phytohormones on emission of volatiles might occur after plants are attacked by multiple herbivore species (Arimura et al., 2011; Menzel et al., 2014; Wei et al., 2014) with different feeding habits and subsequently affect attraction to natural enemies. For example, Rodriguez-Saona et al. (2005) reported that, in tomato, simultaneous infestation of plants with caterpillars of *S. exigua* which induce the JA pathway and aphids *Macrosiphum euphorbiae* Thomas (Hemiptera: Aphididae) which induce SA pathway results in significant attraction of the parasitoid *Cotesia marginiventris* Cresson (Hymenoptera: Braconidae), a natural enemy of the caterpillars. Similarly, De Vos et al. (2005) reported that exposure of plants to simultaneous infestation by herbivores which induce different phytohormones biosynthesis pathway, results in a strong attraction of predators than volatiles from plants attacked by spider single herbivore species.

Conclusions and recommendations

From the plant species diversity point of view, it might be possible to enhance or modify the olfactory responses and foraging behavior of natural enemies using a mixture of HIPVs from different host plant species to biologically control herbivorous insect pests. As majority of the study in this review depicted, natural enemies could be more frequently found on or attracted to multiple plant species (greater plant species diversity) such as natural vegetation or polyculture cropping systems than monoculture cropping systems. Therefore, use of mixture of synthetic or reconstituted HIPVs from multiple plant species could be as one of the important component of integrated pest management (IPM). However, most of the findings yet have been carried out in a laboratory, field-cage or small field conditions. Therefore, further investigations are needed on the attractiveness of mixture of synthetic or reconstituted HIPVs from multiple plant species to natural enemies in a larger and open field by designing a mono- versus mixed cropping systems experiment. Besides, the economic benefit that can be gained by using mixture of HIPVs need further investigation.

From the herbivore species diversity point of view, attractiveness of HIPVs emanating from multi-species herbivory can modify olfactory responses and foraging behavior of natural enemies. In plant systems exposed to multiple herbivore species with the same or varying arrival time, multiple factors such as priming of plant indirect defense for enhanced emission of HIPVs, natural enemy`s prey or host preference and/or profitability of getting mixed diet might be playing their own roles for the predators to distinguish between volatiles emanating from the same or different sequences of herbivory by multiple herbivore species as well as between volatiles emanating from multi-species herbivory and single species herbivory. For more elucidation, further study on the responses of the natural enemies to synthetic HIPVs with different constituents of volatiles that correspond with the most attractive sequences of multi-species herbivory is necessary to identify the most attractive blend of HIPVs so that it can be important component of IPM. In addition, investigating the effect of natural enemy`s prey or host preference and diet mixture or their interaction on the response of natural enemies to HIPVs emitted from simultaneous or sequential multi-species herbivory might further elaborate the possible mechanisms involved in the modifying of the olfactory response and foraging behavior of natural enemies. The underlying mechanism for the variations in the constituents of HIPVs among plants exposed to single-, simultaneous and different sequences of multi-species herbivory might be phytohormone cross-talk. Whether the variations in the constituents of HIPVs among plants exposed to same or different sequences of herbivory by multiple herbivore species with different feeding habits are modulated by pathway cross-talk between JA and SA signaling need to be investigated by determining the endogenous levels of JA and SA from different treatments.

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Research Article

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Homestead tree species diversity and its impact on the livelihood of the farmers in Bangladesh

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Abstract

The study was conducted in twelve villages of four unions under Gopalpur upazila in Tangail district of Bangladesh to explore the diversity of multipurpose tree species in the homesteads and its impact on the livelihood of the farmers in 2016. Study sites were selected purposively as the location. A total of 3334 farmers of the 12 villages constituted the population of study. A sample of 12% farm families was selected based on stratified random sampling procedure. Thus 400 farmers were selected. However, 80 farmers were selected from 400 sampled farmers by using Yamane formula. Therefore, these 80 farmers constitute the sample for this study. Five percent (0.05) level of probability was used as the basis for rejection of any null hypothesis throughout the study. Data for the study were collected through personal interview by the researcher himself during 15 May to 25 December, 2016 using the interview schedule. Farmer's opinion regarding multipurpose tree species in the homesteads and its impact on socio-economic development was the dependent variables of the study. Ten characteristics are age, education, occupation, family member, farm size, homestead area, annual income, socio-economic aspects, knowledge on Multipurpose Tree Species (MPTs) in homestead agroforestry and problem confrontation constituted the independent variables of this study. Species diversity of MPTs in the homesteads agroforestry was measured by Shannon-wiener index (H). In case of all species, highest index (H) value found in Jhaoail union (H=3.017) and lowest index (H) value found in Dhopakandi union (H=2.967). Among these 75 different plant species, Akashmoni (12.53 %), Jackfruit (18.28 %), Neem (1.45%), Bamboo (3.72%), Mander (2.03%) were found as dominant trees for timber, fruit, medicinal, fodder and fuel wood species respectively. MPTs had direct impact on income of the farmers. Small farmers had average income 13.21 thousand taka, Medium farmers had average income 29.33 thousand taka and large farmers had average income 45.79 thousand taka from MPTs in homesteads.

Keywords: Diversity, Farmer, Homestead, Livelihood, Tree Species diversity

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Introduction

Bangladesh is one of the most densely populated countries in the world with a population of 152.5 million and with an annual growth rate of 1.37 (BBS, 2011). There are 32.07 million homesteads in Bangladesh and over 74% of the population lives in the rural areas. Approximately 7% area (0.53 million ha) of the total 8.4 million ha of cultivable land in Bangladesh is occupied by homesteads which is extremely productive (BBS, 2005). The forest land area of Bangladesh was reported at 11.08% in 2010(World Bank, 2011). However, the actual tree coverage area of Bangladesh is estimated only at 9.10% of the country. Most of the forests are distributed to the southeastern and southwestern region of the country. Out of 64 districts of Bangladesh, 35 have no natural forest (Bhuiyan, 1994). The situation of northern Bangladesh is even worse. Forest productivity in Bangladesh is also extremely low (0.5-2.5m3/ha/yr) for both plantation and natural forests (ADB, 1993). The FAO estimates that forest industries contribute more than US$ 450 billion to national incomes, contributing nearly 1 percent of the global GDP in 2008 and providing formal employment to 0.4% of the global labor force (FAO 2012). But alarming for us that forests are decreasing day by day. Therefore, The forests cannot meet the demand of woods of the country and observed that 90% of the fuel wood and bamboo, and 70% of timber requirement of the country were met from the 690 km^2 of homestead Agroforestry (Byron, 1984). The yield of this plantation is 7-9km^3/ha /yr (Douglas, 1982). Homestead Agroforestry is the the integration of tree, crop and vegetable on the same area of land is a promising production system for maximizing yield (Nair, 1990). Homestead represents a land use system involving purposeful management of multipurpose trees and shrubs in intimate association with seasonal vegetables (Fernandes and Nair, 1990). From the conservation point of view, homesteads are the in situ conservation sites of wide range of plant biodiversity (Mannan, 2000). The highly diversity of Multipurpose Tree Species in home garden have a wide socioeconomic and agro-ecological roles including production of food and a wide range of products such as firewood, fodders, spices, medicinal plants and avoidance of climate related hazards commonly associated with monoculture production systems. Multipurpose Tree Species in homestead forests supply 70% of timber and 90% of fuelwood and bamboo (Singh, 2000).

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In the context of the prevailing shortage of fuel wood and excessive deforestation in Bangladesh, this homestead agroforestry system needs to be strengthened (Leuschner and Khaleque, 1987). The diversity of MPTs in the homegarden associated with other organisms contribute to the formation and maintenance of soil structure, retention of moisture and nutrient levels and promotes the recycling of nutrients; which reduces ecosystem vulnerability to climate change. MPTs in homegardens of Bangladesh is a source of livelihood for many farmers. It increases income of the farmers and serve as safety net during the time of hardship and natural disaster. Farmers want to be used his farm area for maximum production. They can increase production by practicing intercropping, mixed cropping; relay cropping system under suitable MPTs. But farmers have no sufficient knowledge about effect of different MPTs on their production. Even they have no cleared idea about beneficial function of different MPTs. Majority of the farmers cultivate their homesteads by different MPTs in unplanned way. So it is necessary to give them suggestions how to make for plantation of MPTs and how to increase income. Overall it improves socio-economic condition of the farmers. There are few researches are done in this case. It is necessary to make sound plans and procedure for planting more prevalent MPTs in scientific way considering climatic condition. So the study was conducted to explore the diversity of multipurpose tree species in the homesteads and its impact on the livelihood of the farmers of Gopalpur upazila in Tangail district.

Materials and Methods

The study was conducted in twelve villages under four unions of Gopalpur upazila in Tangail district. According to population census (BBS, 2011), the total number of households of Tangail district is 202 thousand which is 1.1 percent of total households of the country and the population is 1120 thousand which is 0.93 % of the total population of the country. The density of the population is 650 per sq. km. The percentage of the male and female population is 51.16 % and 48.84 %, respectively. The average literacy rate as of the census (BBS, 2011) was 46.8%; male 50%, female 43.8% among 12 upazila of Tangail district. The study was conducted in Tangail district that consists of 12 upazilas. Among them, Gopalpur upazila was purposively selected. It consists of 10 unions. Among them, 4 unions were randomly selected. They are Hadira, Dhopakandi, Jhaoail and Hemnagar unions. 3 villages name Vadurirchor, Gonipur and Koriata from Hadira union, 3 villages name Shahapur, Ramnagar and Boroma from Dhopakandi union, 3 villages name Jawail, Moail and Patalia from Jhaoail union, and 3 villages name Natuarpara, Sonamukhi and Chaltapur from Hemnagar union were randomly selected. There are total of 3334 different homesteads in this selected area. Out of 3334 homesteads, a sample of 12%, i.e., 400 homesteads were selected by stratified random sampling method. Then finally 80 representative homesteads were selected for questionnaire survey, to find out the effect of multipurpose tree species on the livelihood of the farmers and tree diversity measurement. Final selection of homesteads had been done by using Yamane formula: $n=N/\{1+N(e^2)\}$ Where, n=Sampling size, N=Population, e=Error of precision. After selection of sampled farmers, Farmers were classified into the following groups on the basis of farm size in terms of hectare according to Abedin and Quddus (1990). In social research, the selection and measurement of variables constitute a significant task. The independent variables were: age, level of education, occupation, family size, farm size, homestead area, annual income, organizational participation, knowledge on MPTs in homestead agroforestry, and problem confrontation of the farmers. The farmer's opinion regarding the impact of MPTs in homestead agroforestry on socio-economic aspects was the dependent variable. Ultimately ten independent and one dependent variable were selected for this study. The independent variables were Age, Education, Occupation, Family member, Farm size, Homestead size, Annual income, Organizational participation and Knowledge on MPTs in homestead agroforestry. Education of a respondent was measured in terms of classes passed by him. Occupation of a respondent was measured in terms of working by him and respondent to the time of interview. It was operationally measured in terms of actual occupation. Family member of a respondent was determined in terms of the total number of members of each respondent. The family member included respondent himself, spouse, sons, daughters and other dependents. Land is the most important capital to a farmers and size influences on personal characteristic of farmer. Farm size was expressed as hectare and was computed by using the formula: Farm size = Homestead area + Own land under cultivation + Cultivated area taken under lease + ½ (Cultivated area given to others as borga + cultivated area taken from others as borga). Annual income was measured by the sum of all income sources of a farmer in a year (agricultural income like framing, cropping etc. and non-agricultural income like business, service, saving, labour, other etc.).

A score of 1 (one) was given for each thousand Taka. Organizational participation of respondents was measured on the basis of the nature of his involvement and duration of participation in different local formal and informal groups or organizations in the study area. For computing organizational participation score, the formula is Organization participation score = $\sum (A \times D)$ Where, A = Activity score, D = Duration score. Participation score was assigned in the following manner for activities of a farmer in each group or organization. Organizational participation score of respondent is obtained by adding the score according to the above mentioned formula for his activities in the respective group or organization. The farmers were asked 15 questions on different aspects of homestead agroforestry. The total assigned score on the entire question was 75. A respondent answering a question correctly obtained the full score of 5 while for partial answer he obtained partial score and for wrong answer he obtained zero score. The total score obtained by a respondent was taken as his knowledge on homestead agroforestry score. Problem was measured one way such as using of closed form of questions as shown in item number 17 of the interview schedule. The respondents were asked to give their opinion of the questionnaires along with their extent of confrontation in use of homestead agroforestry practices. As four-point scale was used for computing the problem confrontation score of a respondent. The weights were assigned 3 (three) for 'high', 2 (two) for 'medium', 1 (one) for 'low' and 0 (zero) for 'not at all'. The problem confrontation score of the respondents could range from 0 to 51. Zero indicating no problem and 51 indicating high problem confrontations. The farmers were asked to give their opinion regarding the improvement of their livelihood due to the direct or indirect contribution of MPTs in homestead argoforestry. It was measured on the basis of opinion obtained from the respondents on 18 statement containing information on the improvement of socio-economic aspect of their livelihood. A-4 point modified Liked type scale such as strongly agree, agree, disagree and strongly disagree was used to measure to extent of agreement of farmers with the statement. The score assigned to each of the scale for measuring the extent of agreement was 3, 2, 1 and 0, respectively for each of the 18 statements. Cell of the scale of individual consequence with its considering score such as 3 for 'strongly agree', 2 for 'agree', 1 for 'disagree' and 0 for 'strongly disagree'. Finally adding all the frequency count of each of the cell of the scale, the value was calculated. Species diversity is measured the total number of species within a given area under study. Species diversity can be expressed by species diversity index (both in richness and abundance of the species). The most commonly used method of species diversity is the Shanon-Wiener index: $H = -\sum PiInPi$, Where, Pi is the proportional abundance of the ith species such that $Pi = n/N$ (n is the number of individuals in the ith species and N is the total number of individuals of all species in the community). The statistical analysis is done by using SPSS program.

Results and Discussion

Demographic and socio-economic characteristics of the respondents of the study area

The age of the respondents ranged from 18 to 70 years. The respondents were grouped into three categories- young (up to 35 years), middle (36 to 50 years) and old (above 50 years) on the basis of their age. Number and percentage distribution of farmers according to their age group has been shown in the Table 1.

Table 1. Distribution of respondents according to their age

Category	Respondent (Number)	Percent	Average	Standard deviation
Young age (up to35 years)	14	17	47.36	12.16
Middle age (36 to 50 years)	35	44		
Old age (above 50 years)	31	39		
Total	80	100		

Data presented in Table 1 revealed that the majority (44 %) of the respondents were in the middle aged category, 39 % of the respondents were in the old aged and only 17 % were young aged category in the study area. The education level of the farmers ranged from 00-14 with an average of 4.5 and standard deviation of 2.96 of schooling. In this study 61.25% of the farmers had primary level education, whereas 16.25 % of them were illiterate, 20 % were of secondary level and 2.5 % were of higher level education (Table 2).

Table 2. Categorization of respondents according to their education

Category	Respondent (Number)	Percent	Average	Standard deviation
Illiterate (0)	13	16.25	4.50	2.96
Primary level (class 1 to 5)	49	61.25		
Secondary level (class 6 to 10)	16	20.00		
Higher level (above 10)	2	2.50		
Total	80	100		

Member of sampled farm households were categorized into three groups (Table 3). The categories and distribution of the respondents with their number, percent, mean and standard deviation are furnished below.

Table 3. Family member of sampled farmers

Family member (Number)	Respondent (Number)	Percent	Average	Standard deviation
Small (2-4)	25	31.25	5.4	1.93
Medium (5-6)	35	43.75		
Large (above 7)	20	25.00		
Total	80	100		

Data presented in Table 3 showed that majority of the farmers (43.75 %) belonged to medium size family, 31.25 % of the respondents had small size family and 25.00 % of them belonged to large family. The homesteads size of the farmer ranged from 0.01 - 0.27 hectare with an average of 0.069 hectare and standard deviation of 0.064. Among the farmers 22.5 % were landless and marginal, 22.5 % were small, 38.75 % were medium and 16.25 % were large. Homesteads size are given below (Table 4).

Table 4. Categorization of respondents according to their homestead size

Category	Respondent (Number)	Percent	Average	Standard deviation
Landless and marginal (up to 0.02 ha)	18	22.50	0.069	0.064
Small (0.03 to 0.05 ha)	18	22.50		
Medium (0.06 to 0.09 ha)	31	38.75		
Large (above 0.09 ha)	13	16.25		
Total	80	100		

Annual income of the farm families from MPTs ranged from Tk. 33 thousand to Tk. 550 thousand with an average 114.62 thousand having standard deviation of 82.34. The respondents are classified three categories basis on their income e.g.; low income (Tk. 33-102 thousand) category, medium income (Tk. 103-250 thousand) and high income (above Tk. 250 thousands) categories.

Table 5. Distribution of respondents according to their annual income

Category	Respondent (Number)	Percent	Average	Standard deviation
Low income	19	24	114.62	82.34
Medium income	36	45		
High income	25	31		
Total	80	100		

Data presented in Table 5 indicated that majority (45 %) of the respondents had medium income category, 31 % of the respondents had high income category and 24 % of the respondents in low income category.

Table 6. Distribution of the farmers according to their knowledge

Category	Respondent (Number)	Percent	Average	Standard deviation
Low (up to 15)	20	25.00	16.92	5.45
Medium (16-22)	38	47.50		
High (above 22)	22	27.50		
Total	80	100		

Table 6 indicated that major portion of the respondents (47.50 %) belonged to have medium knowledge while slight more than a quarter (27.50 %) had high knowledge and 25 % being under low knowledge category.

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Problem confrontation scores of the respondent farmers varied from 10-30 with mean and standard deviation were 13.45 and 3.23 respectively. In case of percent, there are 29.34% timber trees, 32% fruit trees, 17.34% medicinal trees, 10.66% fodder trees and 10.66% fuel wood trees in study area (Figure 1).

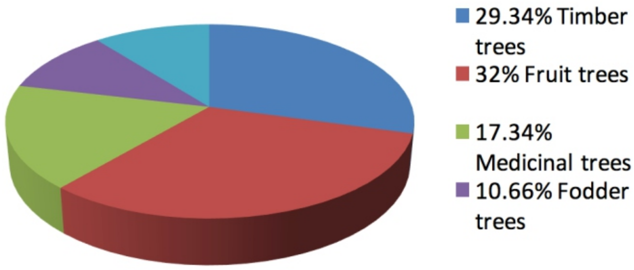

Figure 1. Percentage of fruit, timber and medicinal trees in the study area

Among 22 different timber trees, Akashmoni (12.53 %), Mahogany (8.43 %) and Eucalyptus (7.29 %) were found as dominant trees. Among 24 different fruit trees, Jackfruit (18.28 %) and Mango (14.89 %) were dominant trees. Among 13 medicinal trees, Neem (1.45%), and Bel (1.35%) were dominant trees. Among 8 fodder trees, Bamboo (3.72%)and Ipil-ipil (2.86%) were dominant trees. Among 8 fuel trees, Mander (2.03%) and Sissoo (0.48%) were dominant trees. Out of 22 timber species Mahogoni, Akashmoni and Euclyptus were found as commonly in almost 80% respondent houses area. The diversity of timber species in the study area was rich compare to medicinal, fruits. Similar type of timber species diversity was observed by Sadat (2007) in Gaibandha and he observed total 21 timber species in his study area.

Table 7. Multipurpose tree species diversity of homestead agroforestry

Sl. No.	Common Name	Scientific Name	Relative prevalence
Timber trees			
1	Akashmoni	*Acacia auriculiformis*	12.53
2	Acacia hybrid	*Acacia sp.*	0.43
3	Mahogany	Swietenia macrophylla	8.43
4	Nilotica	*Acacia nilotica*	0.58
5	Jarul	*Leagerstromia specieosa*	0.35
6	Bilati babul	*Acacia farnesiana*	0.38
7	Kalokori	*Albizia lebbeck*	0.43
8	Raintree	*Albizia saman*	0.18
9	Hijal	*Baringtonia acutangula*	0.19
10	Teak	*Tecktona grandis*	0.54
11	Debdaru	*Polyalthia longifolia*	1.43
12	Gab(Deshi)	*Diospyros peregrine*	0.30
13	Eucalyptus	*Eucalyptus camaldulensis.*	7.29
14	Pitraj	*Aphanomixis polystachya*	0.35
15	Katbadam	*Terminalia catappa*	1.36
16	Kadam	*anthocephalus chinensis*	3.66
17	Choto mahogoni	*Swietenia mahogoni*	1.09
18	Dewa	*Artocarpus lacucha*	0.21
19	Chapalish	*Artocuarpus chaplasha*	0.86
20	Bakul	*Mimosops elengi*	0.6
21	Albida	*Acacia albida*	0.4
22	Rajkoroi	*Albizia richardiana*	0.5
Fruit trees			
23	Mango	*Mangifera indica*	14.89
24	Jamrul	*Syzygium samarengense*	0.04
25	Golapsam	*Syzygium Jambos*	0.10
26	Jam	*Syzygium cumini*	0.07
27	Jackfruit	*Artocarpus heterophyllus*	18.28
28	Khejur	*Phoenix sylvestris*	0.20
29	Coconut	*Cocos nucifera*	0.03
30	Litchi	*Litchi chinensis*	0.10
31	Sofeda	*Achras sapota*	0.16
Sl. No.	**Common Name**	**Scientific Name**	**Relative prevalence**
32	Dalim	*Punica granatum*	0.06
33	Tal	*Borassus flabellifer*	0.04
34	Amloki	*Phyllanthus embelica*	0.60
35	Arboroi	*Phyllanthus acidus*	1.30
36	Papaya	*Carica papaya*	0.67
37	Ata	Annona reticulate	0.37
38	Sharifa	*Annona squamosa*	0.60
39	Leamon	*Citrus limon*	0.12
40	Guava	*Psidium guajava*	0.08
41	Boroi	Zizypus mauritania	0.10
Sl. No.	**Common Name**	**Scientific Name**	**Relative prevalence**
42	Jambura	*Citrus grandis*	0.04
43	Bilatiamra	*Spondias dulce*	0.30
44	Deshiamra	*Spondias pinnata*	0.25
45	Jalpai	*Elaeocarpus floribundus*	0.38
46	Amloki	*Phyllanthus embelica*	0.10
Medicinal trees			
47	Bohera	*Terminalia bellirica*	0.01
48	Neem	*Azadirachta indica*	1.45
49	Kadbel	*Feronia* limonia	0.02
50	Khoir	*Acacia catechu*	0.41
51	Horitoki	*Terminalia chubela*	0.01
52	Sonalu	*Cassia fistula*	0.03
53	Bel	*Aegle marmelos*	1.35
54	Tejpata	*Cinnamomum tamala*	0.45
55	Kaju badam	*Anacardium occidentale*	0.15
56	Arjun	*Terminalia arjuna*	0.90
57	Basak	*Adhatoda vasica*	0.39
58	Agar	*Apuilara agallocha*	0.03
59	Supari	*Areca catechu*	0.04
Fodder trees			
60	Ipil-Ipil	*Leucaena leucocephala*	2.86
61	Sesrakoroi	*Albizia chinensis*	0.61
62	Arhar	*Cajanus cajan*	1.43
63	Bot	*Ficus bengalensis*	0.75
64	Sajna	*Moringa oleifera*	0.43
65	Bamboo	*Bambusa spp*	3.72
66	Sil Koroi	*Albizia procera*	0.15
67	Dumur	*Ficus racemosa*	0.1
Fuel trees			
68	Mander	*Erythrina orientalis*	2.03
69	Chalta	*Dillenia indica*	0.12
70	Sissoo	*Dalbergia sissoo*	0.48
71	Tentul	*Tamarindus indica*	0.29
72	Shimul	*Bombax ceiba*	0.05
73	Jiga	*Garuga pinnata*	0.23
74	Gamar	*Gmelina arborea*	0.16
75	Khoksha	*Ficus hispida*	0.07

Total 24 fruit tree species were found in the study area. Among the fruit species Mango and Jackfruit were dominant and found up to 99% respondent houses. The diversity of fruit species in the study area was rich compare all other species. Similar type of fruit species diversity was observed by Belali (2011) in Narayangonj and he observed total 28 fruit species in Narayangonj area. And species diversity was observed by Hossain and Bari (1996) stated that the homesteads in rural Bangladesh are clustered with nearly 25 species of fruit trees and 30 species of timber, fuelwood and industrial wood trees.

Species diversity index for the Multipurpose Tree Species in the homesteads agroforestry was measured by Shannon-wiener index (H). Shannon-wiener index (H) value ranged from (2.417-3.017). Incase of timber species, highest index (H) value found in Hemnagar union (H=2.937) and lowest index (H) value found in Jhaoail union (H=2.892). Incase of fruits species, highest index (H) value found in Jhaoail union (H=2.937) and lowest index (H) value found in Dhopakandi union (H=2.918). Incase of medicinal tree species, highest index (H) value found in Jhaoail union (H=2.881) and lowest index (H) value found in Dhopakandi union (H=2.731). Incase of fodder tree species, highest index (H) value found in Hadira union (H=2.553) and lowest index (H) value found in Dhopakandi union (H=2.417). Incase of fuel tree species, highest index (H) value found in Jhaoail union (H=2.635) and lowest index (H) value found in Hadira union (H=2.421). Incase of all species, highest index value found in Jhaoail union (H=2.892). Incase of fruits species, highest index (H) value found in Jhaoail union (H=2.937) and lowest index (H) value found in Dhopakandi union (H=2.918). Incase of medicinal tree species, highest index (H) value found in Jhaoail union (H=2.881) and lowest index (H) value found in Dhopakandi union (H=2.731). Incase of fodder tree species, highest index (H) value found in Hadira union (H=2.553) and lowest index (H) value found in Dhopakandi union (H=2.417). Incase of fuel tree species, highest index (H) value found in Jhaoail union (H=2.635) and lowest index (H) value found in Hadira union (H=2.421). Incase of all species, highest index (H) value found in Jhaoail union (H=3.017) and lowest index (H) value found in Dhopakandi union (H=2.967), (Table 8).

Table 8. Species diversity index of different species

Species	Shannon-wiener index (H)			
	Hadira	Dhopakandi	Jhaoail	Hemnagar
Timber Species	2.913	2.921	2.892	2.937
Fruit Species	2.936	2.918	2.937	2.924
Medicinal Species	2.876	2.731	2.881	2.752
Fodder Species	2.553	2.417	2.432	2.475
Fuel Species	2.421	2.532	2.635	2.573
All Species	2.987	2.967	3.017	2.975

Similar type of species diversity was observed by Roy *et. al.,* (2013), The result of Shannon-Winner diversity index value was calculated highest for tree (3.39), herb (2.56) and shrub (2.48) in rural homestead garden.

Distribution of respondents according to their income from MPTs

In homestead agroforestry, Multipurpose Tree Species (MPTs) have direct impact on income of the farmers. Farmers are classified into three categories on the basis of MPTs number with standard deviation 19.42. Small farmers with MPTs number (15 – 30) have average low income 13.21 thousand. Medium farmers with MPTs number (31 – 50) have average medium income 29.33 thousand. And large farmers with average MPTs number more than 51 have average highest income 45.79 thousand (Table 9).

Table 9. Categorization of respondents according to their income from MPTs

Category	Respondent (Number)	Percent	Average income (Thousand)	Standard deviation
Small (15-30)	21	26.25	13.21	19.42
Medium (31-50)	35	43.75	29.33	
Large (above 51)	24	30	45.79	

Scores of farmers opinion regarding changes in socio-economic aspects due to homestead agroforestry ranged from 0 to 54.0 indicated no opinion and 54.0 indicated high opinion. 16.25% respondents think that MPTs in homestead agroforestry have low impact in improving socio-economic aspects. 53.75% respondents think that MPTs in homestead agroforestry have medium impact in improving socio-economic aspects. 30% respondents think that MPTs in homestead agroforestry have high impact in improving socio-economic aspects (Table 10).

Table 10. Distribution of the farmers according to their socio-economic aspect

Category	Respondent (Number)	Percent	Average	Standard deviation
Low (up to 19)	13	16.25	23.340	7.902
Medium (20 to 32)	43	53.75		
Large (above 32)	24	30.00		
Total	80	100		

Relationship

The section deals with relationship between ten selected characteristics of the farmers and the impact of multipurpose tree species in the homestead argoforestry system on the livelihood of the farmers. The variables were age, education, family member, farm size, homestead size, annual income, organnization participation, knowledge on hoemstead and problem confrontation. To explore the relationships Pearson's Product Moment Co-efficient of Correlation (r) has been used (Table 14) with description of the meaning of 'r' (Cohen and Holiday, 1982(. The relationships of the selected characteristics of the respondents and the impact of multipurpose tree species on the livelihood of the farmers have been shown in Table 11.

Table 11. Computed co-efficient of correlation (r) between farmers selected characteristics and Impact of multipurpose tree species on the livelihood of the farmers in homestead agroforestry (N = 80)

Dependent variable	Independent variables	Correlation co-efficient 'r'
Impact of multipurpose tree species on the livelihood	Age	0.322^{NS}
	Education	-0.572^{**}
	Family member	0.193^{NS}
	Farm size	0.570^{**}
	Homested size	0.301^{**}
	Annual income	0.651^{**}
	Organizational participation	0.664^{**}
	Konwledge on MPTs in homestead agroforestry	0.569^{**}
	Problem confrontation	0.813^{**}

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level, NS = Non-significant

The age of the farmers and the impact of multipurpose tree species on the livelihood of the farmers was examined against the null hypothesis as "there is no relationship between the age of of the farmers and the impact of multipurpose tree species on the livelihood of the farmers." The value of correlation 'r' was found ٠,٣٢٢ which was non-significant. The findings indicated that age of the respondents had no relationship with the impact of multipurpose tree species on the livelihood of the farmers. Aearwal (2001) also observed same relation in northern Bangladesh. The education of the farmers and the impact of multipurpose tree species on the livelihood of the farmers was examined against the null hypothesis as "there is no relationship between the eduaction of the farmers and the impact of multipurpose tree species on the livelihood of the farmers. The value of correlation 'r' in such case was found -٠,٥٧٢ which was significant at ٠,٠١ level of probability. It means that a person having more education was likely to have less impact with multipurpose tree species on his livelihood .Sudmeye *et. al.,* (2004) also observed the same result in Rongpur district. Halim and Hossain (1994) also observed the same result in Tangail district. The homestead size of the farmers and the impact of multipurpose tree species on the livelihood of the farmers was examined by testing the following null hypothesis: "there is no relationship between the homestead size of the farmers and the impact of multipurpose tree species on the livelihood of the farmers". The computed value of 'r' was found 0.301 which was significant at 0.01 level of probability. The relationship between the two concerned variables also showed positive trend. Hence, the concerned null hypothesis could be rejected. The findings indicated that homestead size of the respondents had a positive significant relationship with the impact of multipurpose tree species on the livelihood of the farmers. This implies that farmers with larger homestead size had higher level of the impact of multipurpose tree species on the livelihood of the farmers. The relation bwtween annual income of the farmers and the impact of multipurpose tree species on the livelihood of the farmers was examined by testing the null hypothesis: “there is no relationship between annual income of the farmers and their attitude towards homestead agroforestry”. The computed value of 'r' was found 0.651 which was significant at 0.01 level of probability.

Conclusion

Total 75 tree species were recorded from the study area of which 22 timber species, 24 fruit species, 13 medicinal species 8 fodder species and 8 fuel wood species. The highest diversity index value (H) for all species was found in Jhaoail union (H=3.017) and lowest index (H) value found in Dhopakandi union (H=2.967). The average size of the homestead was 0.096 ha and almost all the farmers of the study area had positive feeling towards the impact of the MPTs in homestead agroforestry. Education, occupation, farm size, homestead area, annual income, socio-economic aspects, knowledge on MPTs in homestead agroforestry and problem confrontation showed the significant results, age and family size showed the non-significant results.

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Knowledge level of vegetable growing farmers on organic production in Diyarbakır province

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Abstract

As was the case in the World, intensive input use was seen the only remedy to increase agricultural productivity so that to meet the needs for food and raw material in the second half of the last century in Turkey. Accordingly, chemical fertilizer and pesticide use were supported and encouraged. Unconscious chemical use increased the plant production but resulted in poor quality products and human health disorders. As a result of foodborn and environmental health problems, a new type of agricultural production was urged and encouraged by the conscious customers all over the World. This is called organic or ecologic farming which aims to restore the unwanted outcomes of intensive or conventional agriculture and produce healthy food to satisfy customer demands. In achieving the goals of organic production and increasing organic food production it is of great importance to unveil the knowledge level, problems and requests of the producers since culture, customs, social environment and the knowledge accumulated over years shape the agricultural production. In this study, it is aimed to reveal the knowledge level and production customs of the organic vegetable producers in Diyarbakır province. Study data was collected from the vegetable growing farmers with structured questionnaires through face to face interviews. Sample size was determined using simple randomized sampling method. In analysis of the data descriptive statistics method and Chi-Square test was employed. Study results revealed that about 61% of the respondents did not have their soils tested. It was also determined that of all respondents 81% act according to their own knowledge when covering the plant nutrient requirements of the soils as 7,5% consult their friends or neighbours and only about 2% followed the recommendations of agricultural experts. The most striking result, on the other hand, was that only about 27% of the respondents accepted that they had adequate knowledge on organic farming while the rest not.

Keywords: Organic agriculture, sources of information, vegetable growing, level of knowledge and consciousness

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Introduction

Conventional Agriculture based on the fulfilling the food demand of increasing World population resulted in intensive chemical use and one step further was the use of genetically modified seed. After figuring out that a number of diseases were foodborne, customer demands for organic agricultural products have emerged. Also, enhancement in income levels of the people parallel to the economic developments of the nations brought about changes in eating habits and patterns.

Having previously paying attention only to hygiene and freshness on the products to purchase, consumers have started to care about the quality of the products in recent years (Başak et al., 2015). Today, environmental awareness and the demand for healthy foods and other necessary consumer goods has rapidly been increasing all over the world. Gaining worldwide popularity organic Agriculture has been practicing in a number of countries with an increase in acreage and number of producers day by day.

Organic Agriculture refers to the agricultural activities towards producing healthy and high quality food and other necessary consumer goods by taking into account the ecological conditions ensuring sustainable soil fertility, preventing erosion of genetic resources and restoring the unwanted outcomes of intensive or conventional agriculture (Demir and Gül, 2004; Ak, 2002).

Although World organic agricultural product market has been growing up, US and EU member countries have still made up almost all of the market. They only import the non-grown or inadequate products from the developing countries which already challenge to take share from that rapidly growing organic food and product market (Demiryürek, 2004).

After the 1980s small scale and subsistence nature of organic farming has shifted to more commercial and market-driven production due to increasing customer demand (Turhan, 2005).

Crisis in conventional Agriculture, increasing demand for organic products, food safety concerns, encouraging government regulations, increasing environmental awareness and higher revenue are reported to be the principal reasons for the rapid growth in acreage under the organic farming (Midmore et al. 2001).

In Turkey, organic farming was firstly started with raisins and dried fig, the most important traditional export products, in 1984-85 production season and later reached up to 214 product in raw material basis according to the latest statistics (TUIK, 2018).

Although organic agricultural production is practiced as contract farming especially for foreign markets, interest and

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demand for organic products in domestic markets have increased in recent years with the supportive policies of the governments and the efforts of NGOs (Kantar et al., 2011).

The first attempt for organic production in Diyarbakır was started by one producer in wheat and cotton prodcution in a total acreage of 180 hectare in 2006 (TUIK, 2016). By the year 2016, number of producers and production acreage have reached up to 944 farmers and 523 hectares respectively (DTIM, 2016). Wheat, lentils, grape, chickpeas, pomogranate and almond are the leading organically grown agricultural products in Diyarbakır. Organic vegetable farming was firstly supported by GAP Administration within the context of "Improvement of organic farming in Lice district of Diyarbakır" Project with a budget of 288.751 ₺ (GAP, 2016). In this study it was aimed to unveil the opinions and attitudes of the vegetable growers on organic farming.

Material and Methods

The primary data was obtained from the questionnaires through face to face farmer interviews while official records of the Diyarbakır provincial directorate of Agriculture were the secondary data of the study. Study area covers the Ergani, Çınar and central districts of Diyarbakır province where organic production has been practiced. Since it was not possible to visit all producers dispersed in these districts and villages regarding the time and budget limitations, using the organic producers' records of Diyarbakır provincial directorate of Agriculture the population of the organic producers was sampled. Sample size was determined according to simple randomized sampling method, which allows all individuals in the population to be sampled equally (Newbold, 1995; Miran, 2002), and calculated according to the formula given and explained below.

$$n = \frac{N\, z^2\, p\ (1-p)}{N\ d^2 + z^2\, p\ (1-p)}$$

where,

n = Sample size

N = Total number of organic vegetable growers

σ^2_p = Variance

r = Margin of error (%7),

$Z_{\sigma/2}$ = The z-score for 95% confidence (1,96)

p = Likelihood of selecting an individual organic vegetable grower from the population (assumed to be 0,50 to obtain a big enough sample size for precision)

The sample size was calculated to be 156 growers but it was rounded up to 160 against the possibility of some incomplete, non-eligible questionnaires. In analysis of the data descriptive statistical methods and Chi-Square test were employed for the qualitative variables, or the originally quantitative but converted to qualitative variables (Püskülcü and İkiz, 1986).

The sample size was calculated to be 156 growers but it was rounded up to 160 against the possibility of some incomplete, non-eligible questionnaires. In analysis of the data descriptive statistical methods and Chi-Square test were employed for the qualitative variables, or the originally quantitative but converted to qualitative variables (Püskülcü and İkiz, 1986).

Results and Discussion

Of all age groups 31-40 (27,5%) and 41-50 (28,8%) were the most conglomerated making 56,3% of all respondents (Çizelge1). It was determined that 56,9%, 28,8% and 3,8% had primary school, secondary school and bachelor degrees respectively while 5,6% had no any degree. Also, 94,4% of the respondents stated that there was no cooperative in their villages. Only 12,5% of them had a membership to producer organizations. Whereas, farmer organizations has an important role in achieving an ecoomic and socially sustainable Agricultural production (Şahin et al., 2013).

In a similar study was it reported that 85,7%, 20,2% and 76,2% of the respondents were the members of Agricultural Credit cooperatives, Agricultural Development Cooperatives and Agricultural Sales Cooperatives respectively (Doğan, 2011).

In our study, 70% of the respondents stated that they engaged vegetable production both for family consumptions and commercial purposes as 29% were solely for family consumption and commercial respectively (Table 2).

In a study conducted in Erzurum it was noted that commercial growers adopted the organic farming more easily (Kaya ve Atsan, 2013).

The primary objective of the organic Agriculture is to prevent the use of harmful chemicals. There is a positive relationship between the level of awareness on the harmful effects of these chemicals and the adoption of oganic Agriculture by the farmers. Almost half of the respondents (49%) in the study area accepted the possibility of harmful effects of the chemicals they used in Agriculture as about 26% did not agree with these chemicals' detrimental effects. Again, 23% stated that these chemicals might be partially harmful for the environment (Table 3).

In a study conducted in Artova district of Tokat province, it was reported that 93.1% and 56,5% of the respondents admitted the harmful effects of pesticides and chemical fertilizers respectively (Kızılaslan and Kızılaslan, 2005).

It is a well known fact that unconscious, excessive and long years of chemical fertilizer use brings about salination and heavy metal accumulation, unbalanced and heterogenous plant nutrient content and poor microorgansim activity in soils, along with negative environmental impacts such as nitrogen and sulphure emission, thin ozone layer and greenhouse effects (Sönmez et al., 2008). In challenging these problems it is of vital importance to use fertilizers according to soil test results. In fact this can be accepted as an indication showing the higher level of consciousness not only in organic production but also in conventional agriculture as well. In present study, about 60% of the respondents stated that they did not have their soils tested as about one third (39%) of them employed regular soil tests (Table 4). In a study executed in Manisa province a meaningful relationship was reported between previous engagement in oganic farming and regular soil test employment (Başak et al., 2015). Moreover, in another study conducted in Kazova district of Tokat province it was dtermined that most of the agricultural producers admitted the necessity of soil testing eventhough they did not have their soils tested regularly (Olgun, 2010).

When asked how they determine the nutrient requirements of their soils, around 81% of the respondents replied that they did according to their own experiences, advices of neighbour or friends and suggestions of the Agricultural experts in respective order. Only about 7.5% of them stated that they determined according to soil test results (Table 5). This result suggests that the producers have a conventional way of thinking on Agricultural production in the study area.

The priority tool in adoption and dissemination of the organic farming among the farmers, which is a new production technique for them, is the knowledge. Although organic Agriculture is not new for Turkey, knowledge of the farmers on this production technique is limited and depends on some specific sources of information (Akın, 2008). As technology and science progress rapidly in all fields, in parallel to this progress farmer needs for knowledge and skills increase day by day. For that reason, it is of great importance to research on the information sources effective on the adoption and dissemination of the organic farming as an innovation (Kaya and Atsan, 2013).

About 76% of the respondents stated that they did not have adequate information on organic farming. Only around 23% pointed out that they had sufficient information. It is obvious from Table 6 that respondents from Ergani and Çınar districts were considerably more confident on their capability on organic farming compared to those from central district (Table 6).

Organik farming producers needs more information on the subjects of technical, marketing and regulation issues compared to conventional producers (Akın, 2008). Information sources of the farmers varies from region to region and subject to subject. Identifying the sources of information is important regarding the reliability and diffusion of the information. According to respondents their information sources were television %18. In previous studies it was reported that producers benefited from TV at the stage of awareness of innovations (Olgun, 2010). In another study conducted in KOP region it was determined that producers lacked of information and consciousness about organic farming (Üstüntaş et al., 2015).

Among the factors of primary importance is the profit expectation ranking first in making production decisions. It is directly related to crop yields and price. Of the respondents around 86 % and 13% stated that they were aware, partially aware and not aware of the lower yield but higher product prices in organic farming in respective order (Table 8). In a previous study conducted in Manisa province, 37% of the respondents pointed out that low yield in organic farming was unavoidable (Başak et al., 2015).

Conclusion

The research results show that a significant number of producers engaged with vegetable production both for domestic consumption and commercial purposes. This result has been interpreted as an advantage in adopting organic agriculture by the producers. This is because the consumption of the product produced by the producers is interpreted as an auxiliary factor in the adoption of organic farming and at the same time increasing the income from unit production. This is because producers' consumption of their own products with a peace of mind and getting higher revenue per unit product may facilitate the adoption of organic farming.

Results revealed that a significant number of producers have lacked of sufficient knowledge on organic Agriculture. The most important thing in Agricultural extension is to enhance the success of extension work through training the producers on the subjects on which they admit their incompetence. Nevertheless, farmers' low level of organization is seen as an obstacle for the adoption of organic farming. For that reason, it necessary to raise awareness and encourage the producers on starting producer unions and cooperatives.

It was revealed that respondents mostly rely on their own experiences in determination of nutrient requirements of the plants. This may be interpreted that they have a conventional way of thinking and in elimination of it extension agents working in the region should necessarily focus on the extension work on the relavant subjects when needed.

According to the results, it was found that the leading source of information on organic farming is TV, which shows the importance of using TV in Agricultural extension. Nevertheless, we interprete that it is effective in raising awareness rather than dissemination of innovations.

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Table 1. Demographic characteristics of the respondents

Age of the Respondents			Education Level of the Respondents		
Age Groups	N	%	Degree Obtained	N	%
18-20	7	4.4	Illiterate	9	5.6
21-30	23	14.3	Literate	7	4.4
31-40	44	27.5	Primary	91	56.8
41-50	46	28.8	Secondary	46	28.8
51-60	19	11.9	High	6	3.8
61 <	21	13.1	University	1	0.6
Total	160	100.0	Total	160	100.0
Cooperative existence in village of Respondents			Membership to Producer Organizations		
Response	N	%	Response	N	%
Yes	9	5.6	Yes	20	12.5
No	151	94.4	No	140	87.5
Total	160	100.0	Total	160	100.0

Table 2. Distribution of the respondents by the purposes of production

Purpose	Cinar		Ergani		Merkez		Total	
	N	%	N	%	N	%	N	%
Family consumption	11	21.2	27	31.0	9	42.9	47	29,4
Family consumption and Commercial	41	78.8	60	68.9	12	57.1	113	70.6
Total	52	100.0	87	100.0	21	100.0	160	100.0

χ^2=3,649, sd=2, p=0.161 (non-significant). Respondents from different districts did not significantly differ regarding the vegetable growing purposes.

Table 3. Opinions of the respondents on the harmfulness of the agricultural products to human health due to the chemicals they use in agricultural production

Respondent opinions	Çınar		Ergani		Central		Total	
	N	%	N	%	N	%	N	%
Harmful	30	57.7	43	49.4	6	28.6	79	49.4
Not harmful	10	19.2	26	29.9	7	33.3	43	26.9
Partially harmful	12	23.1	18	20.7	8	38.1	38	23.8
Total	52	100.0	87	100.0	21	100.0	160	100.0

χ2=6,492, df=6, p=0.165 (non-significant). Respondents from different districts did not differ significantly regarding their opinions on the harmfulness of the chemicals they used in agricultural production.

Table 4. Distribution of the respondents according to their soil testing status

	Çınar		Ergani		Central		Total	
Farmers' Soil Testing Status	N	%	N	%	N	%	N	%
Tested their soils	32	61.5	25	28.7	6	28.6	63	39,4
Never tested their soils	20	38.5	62	71.3	15	71.4	97	60.6
Total	52	100.0	87	100.0	21	100.0	160	100.0

χ^2=15.83 df=2, p=0.000 (significant). Respondents from different districts differed significantly regarding their soil testing status.

Table 5. Breakdown of the respondents by the ways of determining soil nutrient requirements

The ways of determining soil nutrient requirements	Ergani		Çınar and Central Districs		Total	
	N	%	N	%	N	%
According to my friends and neighbours	7	8.0	11	15.1	18	11.2
According to result of soil analysis	7	8.0	5	6.8	12	7.5
According to my experience	73	84.0	57	78.1	130	81.3
Total	87	100.0	73	100.0	160	100.0

χ^2=1.982, df=2, p=0.371 (non-significant). Respondents from different districts did not differed significantly regarding making decision on nutrient requirement of the soils.

Table 6. Knowledge levels of the respondents on organic agriculture

Adequacy of the respondents' knowledge on organic agriculture	Ergani		Çınar and Central districts		Total	
	Freq.	(%)	Freq.	(%)	Freq.	(%)
Adequate	23	26.4	15	20.6	38	23.8
Inadequate	64	73.6	58	79.4	122	76.2
Total	87	100.0	73	100.0	160	100.0

χ^2=0.760. df=1 p=0.457 (non-significant). Respondents from different districts did not differed regarding the adequacy of their knowledge on organic agriculture.

Table 7. Information sources of the respondents on organic farming

Sources of information	Ergani		Çınar and Central District		Total	
	N	%	N	%	N	%
I have no knowledge	59	67.8	50	68.5	109	68.1
TV	19	21.8	10	13.7	29	18.1
Others (directorates of agr., friends, etc)	9	10.4	13	17.8	22	13.8
Total	87	100.0	73	100.0	160	100.0

χ^2=3,062. df=2. p=0.213 (non-significant). Respondents from different districts did not differ significantly regarding sources of information on organic agriculture.

Table 8. Awareness status of the respondents on low yields but higher product prices in organic farming

Awareness status of the respondents	Ergani		Çınar and Central Districts		Total	
	N	%	N	%	N	%
Aware	76	87.4	62	84.9	138	86.2
Unaware	11	12.6	11	15.1	22	13.8
Total	87	100.0	73	100.0	160	100.0

χ^2=0.197. df=1. p=0.818 (non-significant). Respondents from different districts did not differ significantly regarding their awareness status on low yields but higher product prices in organic farming.

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Physical properties and organic matter content of the soils of Bade in Yobe State, Nigeria

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Abstract

The study was carried out to evaluate some physical properties of agricultural soils of Bade Local Government Area (LGA), Yobe State, Nigeria. One hundred and twenty soil samples, (0-20, 20-40, and 40-60cm depths) were randomly taken from four arable farms being cultivated for more than 30years in each of the 10 political wards of the LGA. The soil samples were analyzed for some physical properties and organic matter content using standard procedures. Results obtained showed that the soils were sandy loam in texture, slightly high bulk density (median (IQR) = 1.63Mgm^{-3}(1.60-1.65 Mgm^{-3})) with a median porosity of 39% and IQR of 38-40%. The structural stability showed that the soils are usually unstable with a mean weight diameter (MWD) (median = 0.78mm). The soil organic matter content is also very low (median =1.57gkg^{-3} and IQR (1.30-180)). Incorporation of organic residues and manure as well as conservation tillage practices to the soil will improve its physical properties and enhance productivity.

Keywords: Soil, Physical properties, Bade, Yobe

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Introduction

The most vital and essential common asset is soil. It is apparent that the production of sustenance to meet the requirement of people and animals is basically reliant upon agriculture which is dependent on soil (Lal, 1998). Soil properties vary spatially from a field to a larger scale influenced by both inherent and extrinsic factors (Cambardella and Karlen, 1999). The variation is a steady change in soil properties as a component of landforms, geomorphic components, soil forming variables and management (Boul et al., 1997).). Physical properties of soil play important role in determining soils' suitability for agricultural, environmental and engineering uses.

The plant bolster, root penetration, seepage, air circulation, maintenance of moisture, and plant nutrients are connected with the physical state of the soil; they likewise impact the chemical and biological properties of soil. (Phogat et al, 2015). The physical properties of a soil as a feature of the numerous properties of soil are vital in deciding the way in which the soil can be utilized either for agricultural and non-agricultural purposes (Mandal, 2016). Information of the physical properties of soil is fundamental for characterizing as well as enhancing soil wellbeing to achieve optimal productivity for each soil/climatic condition.

Soil structure is one of the most important properties affecting crop production because it determines the depth that roots can penetrate, the amount of water that can be stored in the soil and the movement of air, water and soil fauna and overall soil fertility (Hermavan and Cameron, 1993; Cooper, 2011). Soil structure (aggregation) results from the rearrangement, flocculation and cementation of particles and is mediated by soil organic carbon (SOC), biota, ionic bridging, clay and carbonates (Bronick and Lal, 2005). MWD as a measure of aggregate stability is an index of erosion risk, surface crust, anaerobic condition and compaction (Cooper, 2011). Furthermore Garcia et al. (2010) added that maintaining high stability of soil aggregate is essential for preserving soil productivity, minimizing soil erosion and degradation, and thus minimizing environmental pollution as well.

The transformation and movement of materials within soil organic matter pools is a dynamic process influenced by climate, soil type, vegetation and soil organisms. Soil organic matter levels commonly increase as mean annual precipitation increases and field studies have shown that temperature is a key factor controlling the rate of decomposition of plant residues and accumulation (Bot and Banites, 2005)

There is a strong growing realization that yields are limited by the physical conditions rather than plant nutrient status in the soil and that among many climatic and edaphic crop production constraints, substantial reduction in the production capacity of rainfed areas could be attributed to soil physical constraints (Indoria et al., 2016). Knowledge of the nature of soil properties existing in any area is very vital in developing management systems for these soils. In view of that, this research was carried out to determine the status of some soil physical properties and organic matter of the soils of Bade Local Government Area, Yobe State, Nigeria.

Materials and Methods

The Study Area

Bade is a Local Government Area in Yobe State, Nigeria. It has an area of 809.661 km² with a population of 139,804 (NPC, 2010). The major vegetation type is the Sahel savannah. It consists of open thorny savannah with short

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trees and grasses. The trees are about 5 to 10 m high. The LGA comprises ten (10) agricultural and political areas namely: Dagona, Gwio-Kura, Katuzu, Lawan-Fannami, Lawan-Musa, Sabon-Gari, Sarkin-Hausa, Sugum-Tagali, Usur-Dawayo, and Zango. They are predominantly farmers and mostly depend on trading of agricultural produce for livelihoods.

The study was conducted between October to November 2017 in the ten agricultural areas of Bade LGA, Yobe State, Nigeria (The areas are Dagona, Gwio-Kura, Katuzu, Lawan-Fannami, Lawan-Musa, Sabon-Gari, Sarkin-Hausa, Sugum-Tagali, Usur-Dawayo and Zango). The LGA is located between longitudes 10° 02' and 11° 11'E and latitudes 12° 48' and 12° 88' N. It is situated in the Sudan savanna ecological zone of Nigeria. The climate is characterized by high temperature and seasonal rainfall. The mean minimum temperature ranges between 10 -12°C in December/January, while the mean maximum is about 34-37°C in March-May. The mean rainfall is between 300-500 mm per annum and is unimodal and lasts mostly from June to September while the dry season starts from October to May (NEAZDP, 2015). Jalloh et al. (2011) had classified the soils of the area as Lixisols.

Soil Sampling and Handling

At each location, soil samples (N = 12) were collected from the top layer (0-20 cm) of the soil and two subsurface layers (20-40cm and 40-60 cm depths). The soil samples were collected from randomly selected cultivated farms using bucket auger, packaged and separately stored in polythene bags according to depth and location.

Laboratory Analyses

The samples were air-dried separately, ground using a porcelain pestle and mortar, and sieved through a 2 mm sieve for particle size analyses.

Particle size distribution was determined by the hydrometer method (Gee and Or, 2002). Total soil porosity was calculated assuming particle density 2.65 g cm^{-3} using the following equation (Bhogal *et al*., 2009). Total soil porosity was determined using the expression = [1- (bulk density/2.65)] 100%. Oxidizable organic carbon was determined by the Potassium Dichromate method and converted to soil organic matter using the conversion factor of 1.72 as described by Ryan *et al*. (2001)

Mean weight diameter was determined by the wet-sieving method of Le Bissonnais (1996). The mean weight diameter (MWD) was calculated as follows:

$$MWD = \sum_{i=1}^{n} x_i.w_i$$

Where: x_i is the mean diameter of the size fraction i that corresponds to the mean aperture of the adjacent sieves, and w_i is the proportion of the total sample weight remaining on each sieve after sieving.

Data Analyses

Shapiro-Wilk test for normality was applied to the data distribution among the sites, which indicated non normal distribution. The variability of the properties by location were evaluated by non-parametric test of Independent samples, where the effect was significant, pairwise comparison were carried out with Nemenyi-dunn test using 'PMCMR' package of R version 3.1.3 (R, 2017)

Results and Discussion

Particle size distribution

Table 2 presents the results of some physical properties of the soils of Bade according to the sampling locations. The soils of all the areas showed dominance of sand particles and they all belong to the textural class of sandy loam. The sand content ranged from 552.20 to 706.23 g/kg, with a median (interquartile range) of 627.70 (583.00 – 653.20 g/kg), the values at Lawan-Fannami and Sabon-Gari areas were above the 3rd quartile and only at Sugum-Tagali the value was below the 1st quartile. The silt content was higher at 378.17g/kg at Sugum-Tagali and lower at Sabon-Gari (222.33g/kg) with a median of 317.30 (IQR = 282.80 – 352.20 g/kg). Clay content also showed marked difference between the 10 locations ranging from 54.30 to 71.43g/kg, with a median of 61.90 (IQR = 55.10 – 65.80 g/kg); about 40% of the locations had values above 3rd quartile. The presence of high level of sand particle across the sampling sites recorded in the study was corroborated by findings of Ohu *et al*. (1989) for soils of Yobe and Borno States and Vonciret al. (2008) reported that the dominance of sand contents in Northern Nigerian soils is as a result of sorting of materials by clay eluviation and surface wind erosion.

Bulk density and Porosity

The bulk density value were relatively high with a median value of 1.63Mg/m^3 (IQR = 1.60 – 1.65 Mg/m^3) as shown in Table 2.this could be attributed to the soil texture and very low organic matter content of the soils. It is reported that sandy soils usually have higher bulk densities (1.3–1.7 g/cm^3), and that bulk densities greater than 1.6 g/cm^3 tend to restrict root growth (McKenzie *et al.*, 2004). Therefore practices like reduced tillage, organic manure application, crop rotation and mixed cropping should be imbibed by the farmers to decrease the high bulk density which may affect the distribution and movement of water, plant nutrients availability and even uptake by plants which may ultimately affect overall plant growth (Marshall and Holmes, 1988; Ishaq et al., 2001).

The porosity ranged between 37.67 and 39.67% with a median value of 39.00% (IQR = 38.00 – 40.00). The total porosity is typical of sandy soils as reported that the total porosity of sandy soil ranged between 30 – 45% (Phogat *et al*, 2015). The low values of porosity is a reflection of high bulk density recorded in all locations, this could be attributed to continues cultivation as reported by Malgwi and Abu (2011) indicating that continuous cultivation led to increased bulk density, reduced porosity, organic carbon, aggregate stability and water retention capacity.

Mean weight diameter (MWD) as one of the measures of soil aggregate stability is one of the key soil physical quality indicators that integrates physical, chemical, and biological information into a single measurement (Tisdall, 1996). The MWD median (interquartile range) of the soils across all sites within the LGA is 0.78 (0.60 – 1.06 mm). This result fall within unstable (0.4-0.8mm) to medium (0.8-1.3mm) category of the stability grouping of Le Bissonnais (1996). Similarly Maduakor (1991) reported that the unstable structure of these soils may be due to weak binding of the aggregates caused by low organic matter content especially in the soils formed from aeolian deposits found across the Sahel region. The soil organic matter across the LGA was low (median 1.57gkg^{-1} and IQR (1.30-1.80). Generally, the soils were low in OM, this could be attributed to low vegetative cover which is a result of low rainfall that characterize such savannas (Nyalemegbe et al., 2011). Similarly the low organic matter content of the soils in all areas could be attributed to factors such as continuous cultivation, frequent burning of farm residues commonly carried out by farmers in the area which tends to destroy much of the organic materials that could have been added to the soil (Sharu *et al*., 2013). The study area is characterized by low precipitation and high temperature, this may also contribute to low level of OM as reported to have effect on low of organic matter accumulation (Hamza and Anderson, 2010).

Soil properties as affected by depth (cm)

Physical properties of surface and sub-surface soils are presented in Table 3. The sand and clay contents showed a slight decrease with depth. The decrease in clay with depth is an indication that subsoil is more weathered than the surface, Similar results was reported on the soils of Sokoto State by Sharu *et al*. (2013). Low silt content in all the surface soils is in line with the report of Adegbenro *et al*. (2011). Bulk density and porosity showed significant differences by depth. As the bulk density increases downward the porosity decreases. This could be attributed to less organic matter and decreased aggregation and corroborates the work of Abdullah et al. (2018) whose findings showed that bulk density increased with soil depth thus, giving good porosity for soil water movement and cation exchange capacity to hold the nutrients necessary for microbial activity.

Conclusion

This study showed that the soils of Bade LGA are Sandy loam, high in bulk density, low porosity, weak structure and very low in organic matter content. In order to improve on these properties, practices such as minimum tillage, incorporation of crop residues and organic matter into soil should be encouraged.

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Table 1. Soil sampling locations (wards) in Bade LGA of Yobe State

S/no.	Wards	Latitude	Longitude	Altitude(m)
1	Dagona	12.856473	10.763133	366
2	Gwio-Kura	12.704625	11.100117	361
3	Katuzu	12.862674	11.041934	369
4	Lawan- Fannami	12.864131	11.041636	365
5	Lawan-Musa	12.891682	11.049198	366
6	Sabon-Gari	12.874008	11.030397	355
7	Sarkin-Hausa	12.864152	11.041625	334
8	Sugum-Tagali	12.813096	10.659087	373
9	Usur-Dawayo	12.875244	10.985060	359
10	Zango	12.883993	11.037897	357

Table 2. Some physical properties and organic matter content of the soils of the ten wards in Bade LGA

Wards	Sand	Silt	Clay	TC	B D	Porosity	MWD	SOM
	←	$g\ kg^{-1}$	→		$(Mg\ m^{-3})$	(%)	(mm)	$g\ kg^{-1}$
Dagona	606.50bc	330.33abc	63.17abcde	SL	1.62bc	39.33ab	0.87ab	1.60abc
Gwio-Kura	596.20cd	341.17abc	62.63abcde	SL	1.61bc	39.33ab	0.93a	1.64ab
Katuzu	616.47bc	329.23abc	54.30e	SL	1.65a	37.67c	0.58bc	1.22de
Lawan- Fannami	649.50b	293.17cd	57.33cde	SL	1.63ab	38.33bc	0.56bc	1.32cde
Lawan-Musa	653.43b	276.07d	70.50ab	SL	1.63abc	39.33ab	0.99a	1.84a
Sabon-Gari	706.23a	222.33e	71.43a	SL	1.63abc	38.67abc	0.94a	1.54abcd
Sarkin-Hausa	597.23cd	346.50ab	56.27de	SL	1.63abc	38.67abc	0.53c	1.20e
Sugum-Tagali	552.50d	378.17a	69.33abc	SL	1.60c	39.67a	1.04a	1.82a
Usur-Dawayo	619.43bc	321.83bcd	58.73bcde	SL	1.64ab	38.33bc	0.78abc	1.48bcde
Zango	636.53bc	295.13bcd	68.33abcd	SL	1.63ab	38.00c	1.09a	1.71ab
K-W ($p \leq 0.05$)	0.001	0.001	0.001		0.001	0.001	0.002	0.001
Mdn	627.70	317.30	61.90		1.63	39.00	0.78	1.57
IQR	583 - 653.2	282.8 - 352.2	55.1 - 65.8		1.60 - 1.65	38.0 - 40.0	0.60 – 1.06	1.30-180

TC = Textural class, BD = Bulk density, MWD = Mean weight diameter, SOM = Soil organic matter, K-W = Kruskal Wallis test @ 0.05 significance level, Mdn = Median and IQR = interquartile range

Table 3. Some soil physical properties and organic matter content by depth (cm)

Depth (cm)	Sand	Silt	Clay	Bulk Density	Porosity	MWD	SOM
	←	$g\ kg^{-1}$	→	$(Mg\ m^{-3})$	(%)	(mm)	$g\ kg^{-1}$
0 – 20	636.36	296.00	67.64	1.61b	39.10a	0.89	1.58
20 – 40	626.73	311.73	61.54	1.64a	38.40b	0.83	1.54
40 – 60	607.12	332.45	60.43	1.63ab	38.70ab	0.77	1.48
K-W ($p \leq 0.05$)	0.097	0.067	0.435	0.001	0.014	0.693	0.435
Mdn	627.70	317.30	61.90	1.63	39.00	0.78	1.57
IQR	583 - 653.2	282.8 - 352.2	55.1 - 65.8	1.60 - 1.65	38.0 - 40.0	0.60 – 1.06	1.30-180

MWD = Mean weight diameter, SOM = Soil organic matter, K-W = Kruskal Wallis test @ 0.05 significance level, Mdn = Median and IQR = interquartile range

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Impacts of changing climate on maize production in the transitional zone of Ghana. A case study of Nkoranza south municipality

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Abstract

This study sought to assess the challenges and opportunities that come with climate change and variability impacts on maize farming in the Nkoranza South Municipality in the Transitional Zone of Ghana. The mixed method approach was used in collecting the data. The results of the study showed that farmers had observed changes in climate in the form of decreasing rainfall, rising air temperatures and seasonal changes in rainfall pattern which were affecting their maize farming operations. The major setbacks within the area were deficit in rainy days and intermittent erratic rainfall affecting maize production. The reduction in rainfall was corroborated by data obtained from Ghana Meteorological Agency (GMet) which indicated that the dry cell between the major and minor rainy seasons was getting wetter and the two seasons were gradually merging whereas the first and last quarters of the year were getting drier for a couple of decades. The situation over the last five years had worsened as the amount of total rainfall had reduced by 22% compared to the 30year period between 1960 and 1982. The major opportunity available to farmers in the face of changing climate in this agroecological zone was cashew production. About 76.8% of the respondents had diversified into cashew farming.

Keywords: Soil, Physical properties, Bade, Yobe

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Introduction

There is now unequivocal evidence that the climate of the Earth has demonstrably warmed up since the pre-industrial era and that most of the warming over the last 50years is very likely to have been as a result of increase in Greenhouse Gases (GHGs) concentrations in the atmosphere (Intergovernmental Panel on Climate Change (IPCC), 2007).

Three major physical impacts of climate change according to IPCC (AR4) in Ghana are; temperature rise, changing rainfall regime towards a longer dry season and a varnishing wet season. Owusu *et al.,* (2008) also underscore the fact that there has been a noticeable shift in the rainfall pattern in Ghana towards a longer dry season and the disappearance of short dry spells between major and minor seasons. The Ghanaian agricultural-dependent economy has thus suffered severe economic consequences (Kyekyeku Nti, 2008).

Agriculture is the pillar of Ghana's economy providing employment to the masses in the rural areas and sustaining the vast majority of the population. Only about 0.89% of the country's arable land, equivalent to 23,657 hectares is cultivated under irrigation, benefitting only rice production [Environmental Protection Agency (EPA) 2009; Ministry of Food and Agriculture (MoFA), 2003].

According to Environmental Protection Agency of Ghana (EPA, 2000), maize yields in Ghana are low compared to that of developed countries. The national average yield is about 1.6 mt per hectare. This is primarily due to the inadequate input of fertilisers and non-existing irrigation facilities in the maize production areas (WABS consulting, 2008).

Among the staples cultivated in the country, maize has been identified as one of the most essential within the grains and cereals family [Statistical, Research and Information Directorate (SRID), 2010]. It is grown on more than, 997,661 hectares across all the various agro-ecological regions in Ghana (SRID, 2010)

Generally, high temperatures have been reported as detrimental to grain yields (Badu-Apraku *et al.,* 1982; Lobell *et al*., 2008). According to the EPA (2000), the projected percentage drop in maize yield in the transition zone ranged from 0.5 percent in the year 2000 to 6.9 percent by the year 2020 as compared to their level in 2000. The study of Lobell *et al*. (2008) indicates that each day's temperature above 30^{0}C would reduce the final yield by 1% under optimal rain-fed conditions, and by 1.7% under drought conditions. In the transition (where Nkoranza is located) and forest belts, though droughts are not the main drawback, variations in rainfall particularly deficits in the number of rainy days pose new challenges to rural livelihoods (Yaro, 2010). There is a shortening of the farming season in several places as well as a gradual waning of the secondary growing season in the transition zone (Owusu and Waylen, 2009; Yaro *et al.,* 2010).

Materials and Methods

The study was conducted in the Nkoranza South Municipality in the Brong Ahafo Region of Ghana.

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The Municipality lies within the wet semi-equatorial region of Ghana. It is located in the transitional zone between the savannah woodland of northern Ghana and the forest of the south. The Municipality lies within longitudes $1^0$10W and $1^0$55W and latitudes $7^0$20"N and $7^0$55"N (Ghana District, 2007). It shares common boundaries with Nkoranza North District to the north, Techiman Municipality to the west, Offinso North to the south and Ejura-Sekyere-Dumase to the south-east (Ghana District, 2007).

The eastern part of the Municipality is mainly characterised by savannah woodland and the southern part is principally marked by forest regrowth, made up of shrubs and grasses. It has a mean annual rainfall level ranging between 800-1200 mm, relative humidity ranging from 55-90% and average annual temperature of 26^0C (Ghana District, 2007).

Data Collection

Both primary and secondary data were used in obtaining the data. With regards to primary data, two focus group discussions were organized in two communities (Donkro Nkwanta and Aboasu). Twelve key informants were also interviewed, with at least, one coming from each community. The maize farmers were seven, two sub-chiefs, a meteorologist from GMet- Wenchi branch, an agricultural extension officer from Nkoranza South Municipal Assembly and the 2015 best farmer of the Municipality.

Secondary data consisted of meteorological data (rainfall and temperature) from GMet which covered 1960 to 2014. This data (rainfall) was divided into two trenches, 1960 to 1982 and 1988 to 2014. Some data between 1983 to 1987 were unavailable and so were not used for the analyses. Rainfall data over the last five years (2010 to 2014) as well as temperature data from 1983 to 2014 were analysed in determining current rainfall trends in the study area. Maize production data (2010-2015) was also secured from the assembly of the Municipality for analysis.

Study Design

The study relied on a questionnaire survey from selected farming communities, qualitative interview and focus group discussion (FGD) to acquire essential field data. The questionnaire survey was administered among some selected maize farming communities in the Municipality of which purposive and accidental sampling techniques were used to enhance diversity of the respondents. The purposive technique was used to obtain the farming communities; percentage of male and female farmers as respondents, and selection of key informants. The key informants were made up of the aged, chiefs, a meteorologist and an agricultural officer. Any farmer chanced upon was also given the opportunity to answer the questionnaire (Accidental sampling technique).

The questions included close-ended as well as a few open-ended questions, most of which sought information on respondent's perception on climate change and variability, farm size, variety of maize cultivated, farming system, application of fertilizer and other coping strategies meant to reduce the effects of low yields. The survey was conducted face-to-face with the respondents in different locations and in different communities. The questionnaires were read and translated into Akan (the main local language) for the respondents to answer.

In all, 12 key informants were interviewed to gain information about their views on climate change and variability impacts on maize farming in the Municipality. Seven of the respondents were maize farmers, three were elders from the chief's palace whose ages were between 65 and 73 years (the aged) and the rest were farmers. At least, one respondent came from each of the five farming communities in the study area. Apart from these key informants, one of the Municipal Agricultural Officers was interviewed. Lastly, a staff of Ghana Meteorological Agency (GMet, Wenchi branch) was also interviewed. The questions in these qualitative interviews were unstructured, but were administered with the help of an interview guide. The themes covered were similar to those in the questionnaire survey, but were more interactive and probing, seeking information on climate change and variability of the study area, adaptation of the farmers etc. with ample opportunity for the informants to provide extensive personal narratives. The interviews were done in the participants' homes or residences and were tape-recorded with their permission and later transcribed.

Two FGDs were organized at the end of the data collection in two communities. Averagely the two FGDs were made up of three females and seven male farmers. The focus groups dealt with the changing climate and variability in the area, its impacts both positive and negative on their livelihoods, their adaptive capabilities to alleviate the challenges posed by the changing climate and economic/financial assistance they received elsewhere (if any) to support themselves. All the deliberations were videoed with the permission of the discussants and later transcribed. The selection was made based on how well they answered questions during the questionnaire administration.

Results and Discussion

Demographic Information on Maize Farmers

Table 1 provides basic information about the maize farmers selected for the questionnaire survey. The respondents were made up of both male 154 (70%) and female maize farmers 66 (30%). The number of respondents was proportional to the population of each community. Sixty percent of the respondents were Bonos, 33.6% were settlers from the northern part of Ghana, 3.6% Asantes and 2.3% representing Fulanis and Ewes. Majority of maize farmers rented lands for farming accounting for 51.8%. Maize farmers who worked on their own lands were few representing 20.5%. Several of the farmers had farmlands of size greater than 2 hectares (ha). About 55.5% of the farmers had farmlands greater than 2 ha. Ninety-seven percent of respondents practised monoculture which was the dominant farming system among the maize farmers within the Municipality with 2.3% of respondents practising intercropping or mixed cropping. Eighty-seven percent of the respondents sowed *aburohoma*, a variety of maize prevalent in the Nkoranza South Municipality. Even though approved seeds like *obaatampa* and *omankwa* were available on the market, most farmers preferred the traditional variety to these new cultivars which were approved to be drought resistant and early maturing hybrids.

The percentage of farmers who applied fertilizers on their crops was 71.4%. About 17.4% of the respondents did not apply fertilizers and the famers who occasionally applied fertilizers were 10%. Most of the farmers enriched their crops with organic fertilizers.

Twenty-nine percent of the respondents had not received any formal education with only 5.5% of the respondents having attained tertiary level education. Majority of the respondents were Junior High School (JHS)/Middle school leavers representing 40.9%. Data from the survey indicated that males (8.2%)) were better educated than females. About 34.8% of the female farmers had not received formal education whiles 26.6%. of males had no formal education. A study by Khan and Ali (2013) revealed that if producers are educated, it enhances the application of best farming practices in tomato production.

Perception of Climate Change and Variability among Farmers

All farmers interviewed indicated that the pattern of rainfall in the area had changed. Of these, 78% indicated that the nature of the change was erratic. The majority (85.9%) indicated the severity of this episode was embarrassing over the past 5 years (Table 2). This had therefore made their farming operations more precarious due to the fact that there is no irrigation system in the Municipality, bringing farming activities to a near halt whenever the rain failed.

About 65.5% of the farmers admitted that unguided activities of unscrupulous chainsaw operators had led to the cutting down of trees which might have resulted in reduction in rains. On the other hand, 25.5% attributed the changes in precipitation trend to nature itself and 0.5% of respondents believed that the changes had come due to excessive emission of GHGs into the atmosphere. Another 5% of farmers also placed the blame on bush fire whereas 3.2% indicated that they did not know what had caused this change.

When they were further probed about what could be done to reverse the situation of the erratic rainfall, 64.1% responded that there should be afforestation to replace the felled trees. Others (27.7%) had the view that only God could intervene to restore the situation while some farmers (5.5%) called for bush fire control. Farmers in the FGDs disclosed that control of bush burning would allow small plants to replace logged trees although this would take a couple of years to establish. About 2.3% of respondents did not know what could be done to bring the rainfall situation back to normal whereas 0.5% also had the assurance that a ban on burning of fossil fuel would be helpful. This indicates that farmers do have some knowledge about causes of changing climate but the remedies were not within their reach due to population growth and poverty (FGDs).

With regard to temperature, when farmers were asked whether air temperatures had increased, stabilized or decreased, 86.8% *strongly agreed* that air temperatures had currently risen. It emerged from the FGDs that air temperatures had been warmer over the past 10 years and even the two cold periods (June-July and December-January) were now short lived. About 7.7% *agreed* that air temperatures had changed but not appreciably while 5.5% did not know whether temperatures had changed or not (Fig. 1). Another 86.8% of respondents had observed that the current temperatures were higher than the temperatures for the same area over the past 20yrs.

Table 1. Demographic information of farmers

Community	Gender		Farm size			Level of Education				Place of birth	
	M	F	< 2 (ha)	2-4 (ha)	>4 (ha)	None	Basic	SHS	Tertiary	Native	Alien
Aboasu (35)	28	7	34	32	34	37	46	14	3	31	69
Asoano (30)	24	6	43	37	20	30	60	7	3	90	10
D/Nkwanta (95)	57	38	49	20	31	25	59	8	8	47	53
Kyekyewere (30)	24	6	37	30	33	27	63	10	0	30	70
Kyiradeso (30)	21	9	50	30	20	33	53	7	7	30	70
Total (220)	**154**	**66**	**44%**	**27%**	**29%**	**29%**	**57%**	**9%**	**5%**	**46%**	**54%**

Table 2. Changing rainfall pattern response on the time of the changes

Changing rainfall pattern	Response on the time of the changes		Total (%)
	1-5years (%)	6-10years (%)	
Yes	85.9	14.1	100.0
Total	85.9	14.1	100.0

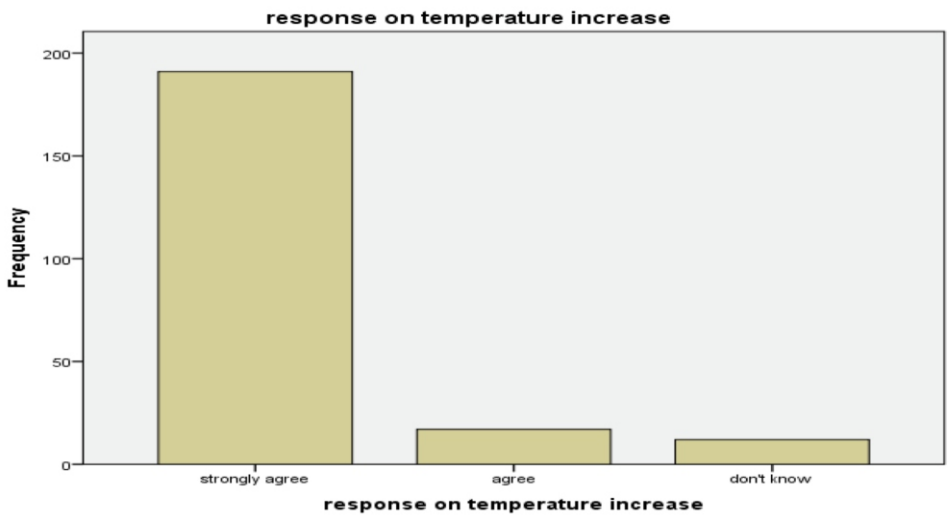

Figure 1. Farmers' perception on changing air temperatures

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Analysis of Rainfall Data of Nkoranza South Municipality (1960-2015) Depicting the Regime of Climate Change and Variability in the Study Area

Figures 2a and 2b cover the precipitation trend for the study area (Nkoranza South Municipality) from 1960-2015. 1983 to 1987 did not appear in the tables/figures because there were a lot of blank cells within this period.

Precipitation was low in the early 1960s but rose steadily in the mid-1960s, falling suddenly in the 1970s. Rainfall however progressively rose and somewhat stabilized in the mid-1970s and declined again in the early 1980s. There was no clear pattern from 1988 to 2015. It was also obvious that from 1988 to 2015, the rainfall amount hardly crossed 1000mm unlike the period between 1960-1982. This confirms what the farmers said that the current rainfall pattern is rather irregular and unpredictable.

The averages of 1960-1982 were higher than that of the present, 1988-2014 (Table 3b). From the months of January to March, the mean of 1960-82 was greater than that of 1988-2014. The farmers were right that lately, the amount of rainfall in March had drastically reduced as the amount from1960-82 (Table 3a) was well over 100mm (114.7mm) whereas the average amount for the period between 1988 and 2014 had reduced to 71.0 mm, the reason, most probably, why majority of the farmers sowed in April (79.1%). Between 1988 and 2014 rainfall averages had appreciated from April to June, with a deficit in July, rising again in August. Currently, the amount of rainfall in November has decreased to the detriment of farmers. This means that presently, crops do not receive as much rainfall as compared to 30years ago. It can also be deduced from Tables 3b and 3c that presently, August is getting wetter and the major and minor seasons are progressively merging. It is also clear that the first and last quarters of the year (January-March as well as October- December) are getting drier over the last couple of decades with the last five years the worst.

The future seems to be rather bleak looking at the trend in 1960-1982 with almost no rains in November and December (2010-2014). The average total amount of the period 2010-2014 showed a reduction of 22% over the past five years with a decline between 1960-82 (100.7) and 1988-2014 (91.9) of 6%. The month of March which was meant for planting of crops now obtained 64.5 mm (3c) of rainfall against 114.7 mm (3a) in the past buttering farmers assertion that climate had changed.

Irregularity of Rainfall

On rainfall regularity, the pattern of precipitation in the Municipality is chararcterised by uncertainty. Based on the above tables, Tables 3a-c show that the amount of rainfall in the month of August increased but figures from 2015 deviated from the trend (Table 3d). The precipitation received in the August, 2015 farming season was 0.00mm. Table 3d also showed a reduction in rainfall amounts between June and August. This phenomenon (irregularity) might have had a negative effect on maize production in 2015 resulting in the lowest yields (1.5mt/ha) of maize recorded for the Municipality in the last six years. A report by EPA (2000) indicates that even though other contributing factors exist, rising temperature and irregularity in precipitation are the major causes of the continuous reduction in maize yields. Annual rainfall for Nkoranza South Municipality since the 2008/9 farming season for the month of March had never risen above 100mm but rose to 113mm in 2015 which confirms that the nature of rains in the transitional zone is irregular. According to Stanturf *et al.,* (2011) declines in total precipitation and increasing irregular rainfall patterns make farming more hazardous, increasing the likelihood of crop failures and reducing agricultural production.

Impacts of Climate Variability and Change on Maize Production in the Municipality

The major threats of changing climate were rainfall (erratic) and rising air temperatures (FGD). The intensity of precipitation had reduced but rainy days which had declined had had a greater effect on crop yields than amount of rainfall. Over the past six years, the intensity as well as rainy days in the Municipality had varied from one year to another as shown in Table 4. The lowest amount of rainfall over the past six years (2010-2015) was in 2010 (812.3mm) with the highest in 2013 (1487.2). Some of the rainy days within the year were spread out (it rained on several days) while others were not. For instance, in 2010, the rainy days were 85 whereas in 2015, the rainy days were only 44. What can be inferred from the rainfall regime over the past six years is that the rainy days had become more inconsistent than the amount or intensity of rainfall. This confirms a study by Owusu and Waylen (2009) that more rainy days with less amount of rainfall does not have much impact on yields. The reduction in rainfall intensity in the study area was in line with a similar study by Travasso *et al.,* (2009) in Argentina which showed that there had been an observed reduction in the growing season of maize crops by 27 days, consequently causing a reduction in yields when crop yield (maize) was simulated using version 3 of Hadley Center Coupled Model (HadCM3).

There was a relationship between rainy days and maize production in the Municipality. When rainfall spread over more days, crop yields increased but when rainy days were few with large amounts of rain, crop yields dropped. For instance, in 2010, the amount of rainfall (812.3mm) was the least among the six years under review, however, average maize yields in the Municipality was 2.0 mt/ha compared to 2011, which had 1270.8mm of rainfall over 51 rainy days (Table 4). In 2011, the average yield was 1.9 mt/ha yet total cultivated area was bigger (61,231 ha) than that of 2010 (59,616 ha). The farmers who were interviewed hammered on the fact that erratic rainfall had been one of their major setbacks and 2015, for instance, was a terrible year. Rainy days had never gone below 50 days over the past six years but 2015 recorded 44 rainy days which was exceptional (Table 4). The farmers complained that in both the major and the minor seasons of 2015, the rains started late and the cessation too was early. The minor season's onset was somewhere late in September ending in mid-October which might have prevented some of the farmers from planting their seeds most likely resulting in a smaller cultivated area (42,500 ha) yielding 1.5 mt/ha in 2015 (Table 4). Fosu-Mensa (2012) reported that increased variability of precipitation, which is reflected in the high variability in grain yield, was another factor leading to the reduction of crop yields.

Opportunities Associated with Climate Change and Variability in Nkoranza South Municipality

It was observed that over the past 20years, the livelihood of the people in the Municipality had somewhat changed. According to the farmers (FGDs), some varieties of corn, yam, groundnut and cassava were fast disappearing. Table 4 summarises the benefits farmers had derived from climate variability and change. Majority of respondents (76.8%) (Table 5) said that cashew production had given them some form of relief with. About 66.9% of the cashew farmers being Bonos while 26.6% (Busanga, Dagarti, Wale, Kasena, Kusase, Gruma, Frafra) were from the three northern regions. Three major reasons respondents attributed to high rate of cashew farming were that it did not demand much time, energy and money. The other alternate form of livelihood that helped farmers adapt to the changing climate was livestock rearing as climate variability did not have any great impact on it (livestock), however, its major problem was pests and diseases (57.1%), followed by theft (33.3%). Most of the animals were reared by farmers from the North Ghana and this represented 78.9% with the Bonos accounting for 21.1%.

Conclusion

The study revealed that changes in the onset and cessation of rain coupled with intermittent dry spells had negative effects on maize farming production in the Nkoranza South Municipality, and this posed a great threat to household incomes as most farmers earned their living from farming. Vulnerability of maize production to climate change and variability in this Municipality depended on the onset of rainfall with respect to their growth stage of the crop. Maize production in the Municipality solely depended on rainfall hence its variability affected production

Cultivation of cashew has become the sole alternative form of livelihood providing income for households as maize production had become more precarious and unreliable.

The amount of rainfall had reduced drastically over the last five years to the detriment of maize farming. The major and minor seasons were gradually merging as August had become wetter over the last two-three decades with the exception of 2015. January, February, March, October, November and December were becoming progressively drier in the last 5-10 years as compared to three decades ago. This demonstrates clearly that meteorological conditions over the transitional zone would continue to alter negatively at the expense of poor-resourced maize farmers whose farming operations are dependent on rain-fed.

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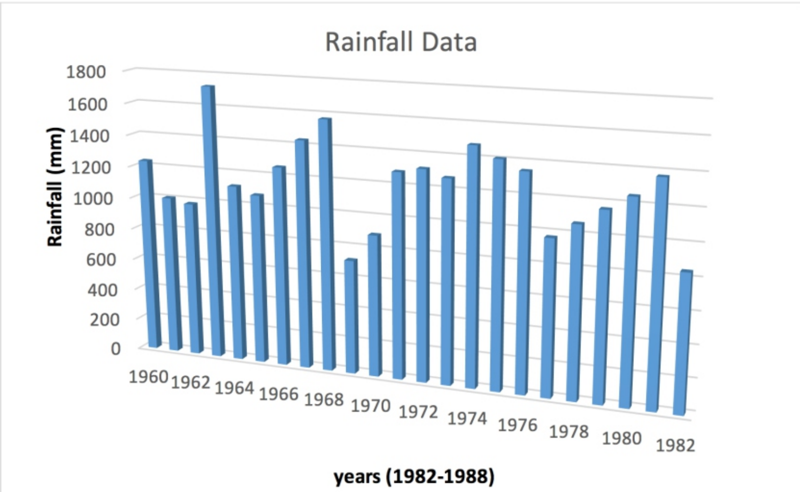

Figure 2a. Rainfall data for Nkoranza South Municipality (1960-1982) (Computed from GMet data)

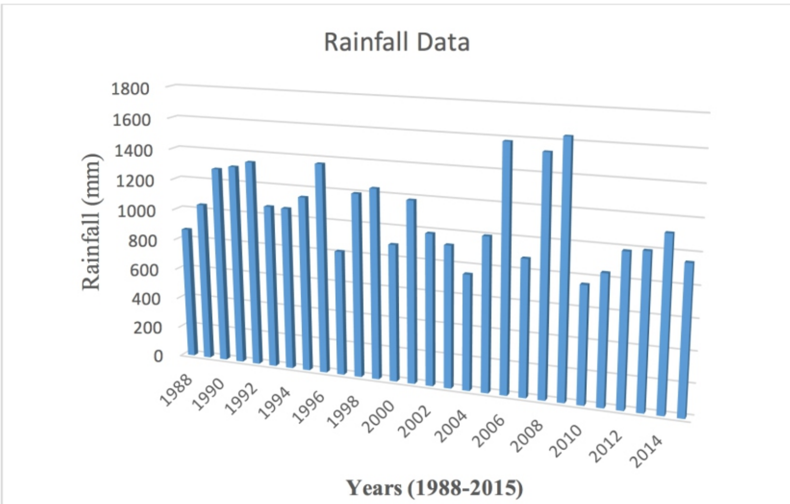

Figure 2b. Rainfall data of Nkoranza South Municipality (1988-2015) (Computed from GMet data)

Table 3a. Average monthly rainfall 1960-1982 for Nkoranza

month	J	F	M	A	M	J	J	A	S	O	N	D	total avg.
mm	10.8	46.0	**114.7**	129.8	154.0	154.0	116.6	**72.7**	192.2	169.9	37.0	11.4	**100.7**

Table 3b. Average monthly rainfall 1988-2014 for Nkoranza

month	J	F	M	A	M	J	J	A	S	O	N	D	total avg.
mm	7.1	35.1	**71.0**	148.2	159.0	174.0	97.7	**79.9**	162.1	141.1	20.7	6.8	**91.9**

Table 3c. Average monthly rainfall for the past 5yrs (2010-2014) for Nkoranza

month	J	F	M	A	M	J	J	A	S	O	N	D	total avg.
mm	5.0	34.9	**64.5**	121.0	147.5	158.8	80.8	**88.5**	138.3	90.9	8.1	0.0	**78.2**

Table 3d. Annual Rainfall Figures for 2015

month	J	F	M	A	M	J	J	A	S	O	N	D	Total avg
mm	0.0	43.9	113.0	35.3	88.3	66.1	50.1	**0.0**	214.8	160.8	86.5	0.0	**71.6**

Table 4. Rainfall and Maize production data for Nkoranza South Municipality (2010-2015)

Year	Rainfall intensity (mm)	Rainy days	Average yield (mt/ha)	Production level (mt)	Total cultivated area (ha)
2010	812.3	85.0	2.0	119232.0	59616
2011	1270.8	51.0	1.9	116338.9	61231
2012	1110.7	57.0	2.1	124452.0	59263
2013	1487.2	70.0	2.0	124899.0	62494
2014	1131.3	65.0	1.9	115250.0	60658
2015	949.0	44.0	1.5	83570.0	42500

Source: Computed from Nkoranza South Assembly data, 2015

Table 5. Response on the Time of the Changes Benefits from Climate Change Variability

Tribe	Benefits from climate change variability					Total
	Cashew production	Animal rearing	Trading	Others(oil palm, plantain, vegetable, melon)	Nothing	
Bono	85.0%	3.0%	0.8%	1.5%	9.8%	100.0%
Asante	87.5%	0.0%	0.0%	12.5%	0.0%	100.0%
Settlers from the North	60.8%	20.3%	1.4%	1.4%	16.2%	100.0%
Others(Ewe and Fulani)	80.0%	0.0%	0.0%	0.0%	20.0%	100.0%
Total	76.8%	8.6%	0.9%	1.8%	11.8%	100.0%

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Research Article   Int J Agric Environ Food Sci 2(4):171-173 (2018)

Can medical and aromatic plants be an alternative to hazelnut in the Western Black Sea Region?

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Abstract

In this study, it was investigated whether medicinal and aromatic plants can be an alternative to hazelnut cultivation, by direct interview method on 154 people living in the Western Black Sea Region (Düzce, Sakarya, Zonguldak and Bartın), which produces hazelnut by 27% of Turkey. 154 students were surveyed by using Neyman method. Likert scale was used to measure whether the medicinal and aromatic plants could be alternative to hazelnuts and the results were evaluated by SPSS method. In our study, 154 people with different professions (farmers, civil servants, workers, retired, students and unemployed), different educational levels (literacy, primary education, secondary education, high school and university) and different income levels were included in the survey. As a result of the study, 97.4% (including 92.2% of those who grow hazelnuts) want to grow medicinal and aromatic plants as an alternative to hazelnuts. 97.4% of medicinal and aromatic plants are considering to grow linden and black sesame. There are also people, at a rate of 81.8%, who think that medicinal and aromatic plants are organic and 66.2% of them also think that organic certification should be obtained for cultivation. 24.7% of them use medicinal and aromatic plants as an alternative to medicines when they are sick. As a result, medicinal and aromatic plants are important in our lives as an alternative to medicines. Considering the importance of alternative plants in the future, it is seen that in the Western Black Sea Region, even if at limited number, there is a tendency towards medical and aromatic plant farming besides hazelnut farming.

Keywords: Soil, Physical properties, Bade, Yobe

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Introduction

Turkey is the world's top hazelnut producer country, around 70% of world hazelnut production is carried out by our country. Our country has favorable ecological conditions for hazelnut production in Black Sea region. Licensed production areas that have been changed many times within the framework of hazelnut production in our country in accordance with the Law numbered 2844 on the Plan of Hazelnut Production and Determination of Planting Areas and have been restricted to 16 provinces with the last Decree of the Council of Ministers numbered 2014/7253. Four of these provinces are located in the western Black Sea region. According to the data of the Turkish Statistical Institute 2015, approximately 27% of hazelnut production is provided from the Western Black Sea region. Hazelnut is one of the rare products that are identified with the lifestyle of certain regions and geographical areas in the world and that make deep traces on the culture, social and economic structure of the people living in those regions. [Anonymous, 2016] Hazelnut is the most prominent agricultural product within the provinces of Düzce and neighboring provinces Sakarya, Kocaeli, Bolu, Zonguldak, Bartın and Kastamonu.

In this region, hazelnut farming is carried out in the land of approximately 300.000 decares and nearly 3 million farmers ' families are living through hazelnut farming (Anonymous, 2011).

It is not possible to fully define the medicinal plants. Today, the term "medicinal" and "aromatic" plants are often used together. Medicinal and aromatic plants are plants used as medicines to prevent diseases, maintain health or heal diseases. While medicinal plants are found in areas such as nutrition, cosmetics, body care, incense or religious ceremonies, aromatic plants are used to give good fragrance and taste (Anonymous, 2005). Aromatic plants are also widely used in the food, cosmetics and perfumery industry. Turkey is one of the leading countries in the trade of medicinal and aromatic plants thanks to its geographical location, climate and plant diversity, agricultural potential, wide area. This importance of Turkey is due to the fact that many plants producing herbal products that constitute the input of plant drugs, plant chemicals, food and additives, cosmetics and perfumery industries settled in developed countries are located in the flora of our country. Therefore, these plants are mostly collected from nature and marketed. Medicinal and aromatic plants are mainly collected from Aegean, Marmara, Mediterranean, Eastern Black Sea and southeastern Anatolia regions (Bayram et al., 2010).

The agricultural industry has an important place in the economic and social structure of all countries, regardless of level of development.

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The agricultural sector, which is of strategic importance, such as producing the raw material necessary for human nutrition, also provides added value for the economy and create jobs for a large mass of the population in Turkey. The appropriate ecological conditions in Turkey and the rich flora allow the cultivation of many different agricultural products (Alkan, 2006).

While looking at the West Black Sea region, it shows us that although it provides a great source of income with hazelnuts, it can also lead to different plant breeding in terms of regional characteristics. Considering the interest of people in developing Turkey against medicinal and aromatic plants, examining the potential in the region and measuring the interest of the people of the region will shed light on us.

Materials and Methods

In this study, it was investigated whether medicinal and aromatic plants can be an alternative to hazelnut cultivation, by direct interview method on 154 people living in the Western Black Sea Region (Düzce, Sakarya, Zonguldak and Bartın), which produces hazelnut by 27% of Turkey. 154 people were surveyed by using Neyman method. Likert scale was used to measure whether the medicinal and aromatic plants could be alternative to hazelnuts and the results were evaluated by SPSS method. In our study, 154 people with different professions (farmers, civil servants, workers, retired, students and unemployed), different educational levels (literacy, primary education, secondary education, high school and university) and different income levels were included in the survey. The survey was conducted by experts and participants were provided with answers to all questions.

Surwey Questions and Answers

In our study, we tried to find an answer to the question of whether medicinal and aromatic plants can be an alternative to hazelnut with the survey conducted in 154 people on people of different ages, professions, education and income levels living in the western Black Sea region (Table 1-8).

While 41.6% of the respondents were 56-65 years, 26% were 46-56 years, 16.9% were 66-75 years, and 15.6% were 45 years. The average age is 54 (Table 1).

In our study, 67.5% of the respondents are farmers and 27.3% are retirees. In total, 5.2% of workers and civil servants were included in the survey. A large part of the pensioner retired from the agricultural sector. Civil servants and workers also help agricultural workers in their families (Table 2).

When we look at the educational status of the people who are mostly farmers and participated in our survey, we see that they are 74% primary school graduates. Only 2.6% are university graduates. The level of Education remains relatively low (Table 3).

While 58,4% of respondents provide a minimum wage level of income, those who earn more than 3000 TL constitute 2.6% of the total. Most of the respondents live on the starvation line (Table 4).

Although 81% of the people in the Western Black Sea region where we carry out our survey are primary and secondary school graduates, they still go to the medicines recommended by the doctor when they are sick. While 64.9% of the respondents prefer to use only medicines when they are sick, 6.5% of the respondents prefer only medicinal plants. 26 %of them use both medicine and medicinal plants. In addition to medicine use, they use medicinal plants as a substitute which are the products they consume as tea (Table 5).

When people who participated in the survey of hazelnut growing region were asked whether they grow medicinal plants, only 24.7% of them grow medicinal plants and this plant is only Linden as the answer received (Table 6).

A large proportion of respondents wants to cultivate a medicinal plant, and this rate is a fairly high rate of 97.4%. All those who want to cultivate a medicinal plant except for the linden growers, would like to grow a black sesame (Table 7).

In our survey conducted on 154 people, when asked whether the medical and aromatic plants are organic or not, 81,8% of 154 people have been deemed to think that medical plants are organic without the certificate is concerned (Table 8).

Conclusion

As a result of our study in the western Black Sea region, a large majority of the 154 people, at the average of age 54 and mostly of primary and secondary graduates, including those of 92.2% who are growing hazelnuts want to grow medicinal and aromatic plants as an alternative to hazelnuts at the rate of 97.4%. Although the Western Black Sea region has a wide range of plant cultivation in terms of climatic properties, they consider growing linden and black sesame at 97.4% of medicinal and aromatic plants. Since Linden is already a plant grown in the region, they think that growing is suitable for them. It is also their preference to grow the black sesame not only for reason of having more benefits as medicinal plant but also the fact that there is no marketing related problems of it. People who think that medicinal and aromatic plants are organic in 81.8% are also thinking that the organic certificate in farming should be obtained at 66.2%. 24.7% use medicinal and aromatic plants as alternatives to medicines when they are sick. One in three people who participated in our survey uses it considering that it can benefit from medicinal and aromatic plants in their lives. But even if they don't use it with a benefit match, they still have to put these plants in their lives in the form of tea or oil. Although the hazelnut plant comes from the ancestors and it is the source of income for the majority of the people living in the region, people who live in the region also wants to try and grow new plants. As a result, medicinal and aromatic plants are important as alternatives to medicines in our lives. Considering the importance of alternative plants in the future, there is a tendency towards medical and aromatic plant growing in Western Black Sea Region, even if it is at limited number comparing hazelnut farming.

Table 1. Distribution of the people by age

	#	%
26-35	6	3,9
36-45	18	11,7
46-55	40	26,0
56-65	64	41,6
66-75	26	16,9
Total	154	100

Table 2. Distribution of the people by job/profession

	#	%
Farmer	104	67,5
Civil Servant	6	3,9
Worker	2	1,3
Retired	42	27,3
Total	154	100

Table 3. Distribution of the people by education

	#	%
Literacy	6	3,9
Primary Education	114	74,0
Secondary Education	14	9,1
High School	16	10,4
University	4	2,6
Total	154	100

Table 4. Distribution of the people by income

	#	%
1-1000 TL	16	10,4
1001-2000 TL	90	58,4
2001-3000 TL	44	28,6
3001-4000 TL	2	1,3
4001 TL and over	2	1,3
Total	154	100

Table 5. Distribution of the people by use when they get sick

	#	%
Medicinal Plants	10	6,5
Medicines	100	64,9
Both	40	26,0
None	4	2,6
Total	154	100

Table 6. Distribution of the people by grow medicinal and aromatic plants

	#	%
Yes	38	24,7
No	116	75,3
Total	154	100

Table 7. Distribution of the people by use when they get sick like to grow medicinal and aromatic plants

	#	%
Yes	150	97,4
No	4	2,6
Total	154	100

Table 8. Distribution of the people by medicinal and aromatic plants organic

	#	%
Yes	126	81,8
No	28	18,2
Total	154	100

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Review Article

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Extension's role and stakeholders' intervention in climate change advocacy

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Abstract

The world's agricultural system has been terribly affected by climate change and consequently the future of agriculture, its practices and productivity is hampered. Hence, this paper presents the agricultural and environmental problems associated with climate change and seeks to proffer possible solutions through the intervention of extension services and stakeholders. It focuses on the role of agricultural extension and its immense import in influencing crop production practices that will ensure sustainability and improve soil management. To effect a change in a diverging economy with critical climatic conditions, it becomes imperative that scientific, technological and conceptual policy practices that will reduce negative environmental impacts must be integrated and implemented.

Keywords: Agricultural advisory services, Agricultural production practices, Climate change, Mitigating factors

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Introduction

Recent empirical evidences have shown significant changes in agricultural systems. These changes invariably are as a result of climate change and other environmental factors. Although several research studies have been carried out, for example by (Agwu (2009), Ajetomobi (2010), Apata (2010) and others but most of their work centered on actual and projected impact of climate change, not so much work have been done on coping mechanism, adaptation and mitigations strategies. Beyond broad generalizations, the impact of climate change is more widely felt in the developing countries due to their greater vulnerabilities and lesser ability to mitigate effects on climate change (Sajjad, Yung, Ishaq, et al., 2017). Corroborating this, IPCC (2015) remarked that climate change in Africa is exacerbated by low levels of adaptation and mitigations.

Climate change often result into high frequency and intensity of extreme weather events such as high temperatures, frost, droughts, flood and storms, declining water resources and loss of biodiversity. As global temperature rises, there are changes in areas suitable for agriculture and how much of the world's land that can be used. For example, a rise in temperature in the range of 5-7^{0}C in the last 100 years has drastically altered the natural vegetation of the environment (IPCC, 2007). Other indicators of climate change are rainfall, evaporation, drought and wind. More than 95 percent of the agricultural production in sub-Saharan Africa is rain-fed (Simelton et al 2013). Yet, according to IPCC (2013) and IPCC (2014) there are uncertainty about future rainfall patterns in southern Sahara, Guinea coast and Sahel. Saul (2015) also noted that climate change is already having impact in Nigeria.

Extension Role and Its Intervention in Climate Change Advocacy

In Africa, increased demographic pressure is creating scarcity of land and reduced periods of fallow. According to Narain (1985), it was believed that there is no available technology by which the traditional farmer can adjust to the reduced fallow periods and experienced a more intensified agriculture. Up till now, the erratic nature of the weather makes cultivation and management of crops on the field difficult. In their study, Enete and Amusa (2010) highlighted the critical challenges faced by the Nigerian agriculture as is tries to adapt to climate change. The challenges are lack of requisite education, information and training necessary to adapt to climate change. A report from UNDP confirms that the level of awareness about climate change is low in Nigeria, and it was noted that if care is not taken, it will wreak havoc on the daily lives of its citizen.

Prokopy, Barrtels, Burniske and Power (2017) however found that farmers are beginning to understand that practices that worked in the past are no longer viable in the light of changing weather patterns. Therefore, attaining self-sufficiency in food production is a major problem with the present climatic and environmental condition. They also found that farmers acknowledged the impact of local climate (increasing frequency weather events driven from outside their region) on agricultural practices. This recognition they believe will provide fertile ground for agricultural extension to assist with climate change adaptation now and in the future. Hence, extension workers have an increasingly important role to play if farmers are to learn to adapt and build resilience.

Therefore, extension service providers have an enormous, significant and urgent role to play especially as the unpredictability of climate change has brought new dimension to agricultural research and development (AGRA, 2017). Extension advisory service is vested with the task of promoting the use of best practices that will assist

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smallholder farmers and communities in developing countries to be resilient and cope with the risk of weather extremities caused by climate change. Extension has as one of its major mandate to educate and disseminate information on land use systems like terracing, contouring, crop rotation, soil compacting, building soil organic matter, and conservation tillage. Extension role also include teaching on avoidance of practices that may result into flooding of farmlands, discouraging mono cropping which aggravates pests and diseases that thrive on the new intensive crops. But all these will have their roots in participatory extension approaches.

Hence, there is an extremely important role for extension service providers to play now and in the future of climate change communication. The approach to be employed must put farmers at the centre, though it requires facilitating skills, listening and teaching skills, and ability to be flexible and responsive. Unfortunately, AGRA (2017) discovered that government has tended to ignore extension's work and this is a big problem that will deter its prompt intervention in climate change related information transfer. The funding of agricultural research from federal government budget, which is always the main and now virtually the sole source of funds has also been in regression since the collapse of oil prices in the early 1980s (Enete and Amusa, 2010).

Stakeholders'role in Global Environmentally Sustainable Agriculture

The response to climate change is about more than what government can do. Industries, research institutions, universities, non-governmental organization (NGOS), private sectors, government organizations, media, communities and individuals all have a role to play. Synergy of these groups is needed to provide support for adaptation and mitigation innovation. Stakeholders' participation involves process whereby all those with a stake in the outcome of a project can actively participate in decision on planning and management. Crispino (2011) advanced that an active participation of enlightened and empowered citizen, communities and other stakeholders would be required for successful implementation of the plans. Similarly, Aloni, Daminabo, Alexander, and Bakpo (2015) affirmed a growing consensus that timely and broad based stakeholder involvement is a vital ingredient for effective environmental assessment, project planning, appraisal and development.

However, IFAD (2013) suggested an institutional policy reforms that needs to articulate a framework for private sector engagement and market access development and incorporate sustainable extension service delivery. In addition, there is need for policy frame work that will provide a suitable environment for continuity and effectiveness in agricultural programmes on climate change. More importantly, policies in the spheres of agricultural risk management, adaptation and mitigation must be adopted and implemented. Research should be based on actual farmers' activities so that its findings can be relevant and easily adoptable. It will also be expected that there is a focus on development of technologies appropriate for farmers. IFAD (2013) had recommended the need for core strategy choices that would ensure that the poor and marginalized are drawn into the policies.

And to effectively manage the impact of climate change, it may require researchers to work with other stakeholders to create a shared understanding of the issues, and develop a range of potential options. Researchers may also aim to be stakeholders in on-going and long-standing processes. Corroborating this, Prokopy, Barrtels, Burniske and Power (2017) reveals a new research approach in which agricultural stakeholders become active participants in the generation of scientific knowledge. Besides, the national government should provide an enabling environment by integrating climate change in sectoral policies to facilitate access to climate change information for decision making. In essence, for effectiveness, climate change adaptation in particular will need to take place at the local and regional level. For example, BNRCC (2017) reveals its aims to help build informed responses to climate change in Nigeria by enhancing capacity at the community, state and national level.

Torwards Resileince in Production Systems and Livelihood

Of recent, there is a growing emphasis on the constraints climate change imposed on agricultural production. FAO (2016) found evidences that climate change has already negatively affected wheat, rice, soy beans and maize yields. Climate-related crop failure is already causing economic loses and undermining food security and these are likely to become more severe as global warming continues. More food is needed in the future but climate change may mean less food production potential and the poor people will be hit the hardest. There have been predicted future economic loses and increase in risk of hunger due to climate change. Enete and Amusa (2010) asserted that the developing world already contends with chronic poverty and food crisis. CBN (2012) reported a decline in agricultural production in Nigeria from 7.2% in 2007 to 5-7 % in 2011. Amanchukwu (2015) maintained that many Nigerians even farmers are aware that climate change is severely affecting livelihood due to changes in rainfall patterns. And since climate change affects crops and regions differently, it is expected that agricultural productivity will decline because of the fluctuating weather patterns. Similarly, Akinbobola, Adedokun and Nwosa (2015) revealed the impairing effect of climate change on agricultural production. Apart from reduction in production, Apata (2016) noted that migration and relocation of some arable crop farmer is another negative effect of climate change. Hence, achieving sustainable food security in a world with a growing population, changing diets and continuously changing climate becomes a major challenge (CGIAR, 2011).

Coupled with this is another notable problem of mismanagement of the environment which invariably leads to fall in production and productivity. Decreased productivity is also as a result of the rapid population growth and decreased per capita food production.

Tackling agricultural production problems, including climate and environment induced problems, is therefore a necessary prerequisite for increasing per capita food production. However, Simmons (2004) had succinctly stated that it is not possible to deal with food insecurity unless investment in agriculture and productivity increase drastically. Hence, more attention should be paid to the climate-related production problems of farmers and efforts must be made to alleviate them.

To promote productive agriculture that conserves and enhances natural resources, partnership that links research and action for low-income agricultural producers and consumers must be practiced.

For example, rural women represent one-quarter of the world's population and they make up around 43 percent of agricultural labour force in developing countries. These women are mostly smallholder farmers who are more exposed to climate change risk than men. The nature and intensity of poverty and vulnerability to risk is also gender-specific. Hence, creating an enabling environment for agricultural production is now necessary and mandatory. There is a dire need also to mitigate the potential negative effects of environment on agricultural production. Emphasis should be laid on why we need to sustain the environment, improve and integrate management of land, water and related biological resources.

Mitigating the impacts of climate change for increased rural and agricultural production requires concerted and coordinated efforts of the extension agents, stakeholders, government and the farmers. The mitigation measures have to do with limiting and controlling climate change (Saul, 2015). Drastic changes in farming practices will remarkably reduce the negative effects of climate change on agricultural system. Therefore, the urgency of dealing with climate change induced problems provides a new impetus for paradigms of integrated research, policy and action. There is need for both local and global policy-linked research to accelerate sharing of information on agricultural practices and technologies for adaptation and mitigation. In addition, government must take necessary measures through extensive methods that will ensure safe environment and increased agricultural productivity.

Conclusions

Therefore in order to increase rural agricultural production, it is important to consider challenges such as lack of information to small-scale farmers on mitigating measures to limit and control climate change. Therefore, it was suggested that governments should give agricultural and rural development practical and idealistic goals with formulation and implementation of consistent policies on food system that will reduce the negative environmental impact on agricultural production. However, the choice of these policies will still depend on social and political realities for rural development.

Also, there is the need for identification of well targeted community based interventions necessary to meet the emerging challenges, mitigate the effects of climate change and increase crop productivity in order to meet the food and fibre need of the growing population. Lastly, strengthening national and local institutions that provides information and support should be an integral component of development strategies for climate change.

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A review: secondary metabolites of *Uvaria chamae* p. Beauv. (Annonaceae) and their biological activities

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Abstract

Uvaria chamae p. Beauv., synthesizes and accumulates a variety of secondary metabolites from its root, stem, leaf and fruit. These consist mainly of essential oils, flavonoids, alkaloids and annonaceous acetogenins. Some of these biologically active secondary metabolites validate the claim made in traditional system of medicine. The present review summarizes the information available on the secondary metabolites isolated from *U. chamae* and their biological activities.

Keywords: Secondary metabolites, Essential oils, Flavonoids, alkaloids, Annonaceous acetogenins

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Introduction

The primary metabolites are of major importance to plants, while the secondary metabolites are of medicinal value to man (Trease and Evans, 1989) and these can equally be obtained from various anatomical structures of plants (Fahn, 1974). Man has benefited from the presence of these chemicals by exploiting the plant products as sources of sustenance in a variety of ways. For example, many drugs today are of plant origin. Pharmacological history is abounding with examples such as quinine, aspirin, picrotoxin, reserpine etc., while many of the synthetic drugs are fashioned after natural plant products (Sofowora, 1982).

The Annonaceae is a large family of shrubby aromatic plants composed of 112 genera with about 2,150 species (Mabberly, 1997) and grows to about 3.6 m to 4.5 m tall. *Uvaria chamae* P. Beauv., commonly known as "finger root" is a climbing shrub and is found in the tropical wet and dry forests of west and central Africa along coastal scrubland. It is found alongside water in marsh forest with *Alchornea cordifolia*, *Thalia* (Maranthaceae), *Dracaena arborea*, *Cyrtosperma*, *Anthocleista vogeliana*, *ferns*, *Mussa endaiserteana*, *Mitragyna stipulosa*, *Cyclosaurus* (Arbonnier, 2004; Bongers et al., 2005). The fruit carpel's are in finger-like clusters, the shape giving rise to many vernacular names translated as "bush banana" or the like implying wildness where in Igala is called Ayiloko, Hausa: Kaskaifi, Yoruba: Okooja and Ghana: Akotompo. The fruits are yellow when ripe and have a sweet pulp which are edible and widely eaten (Iwu, 1993). *Uvaria chamae* is an important medicinal plant. The secondary metabolites isolated from the plant and their biological activities are reviewed.

Chemical Constituents

The search for the concerned active compounds has led to isolation of the several flavonoids, alkaloids, annonaceous acetogenins and essential oils from different plant parts of *U. chamae*. The preliminary phytochemicals detected from different parts of the plant are listed in Table 1 which shows the phytochemical groups present or absent in different plant parts. The bioactive compounds present in the essential oils and flavonoids isolated from the plant are listed in Table 2 and 3.

Scientific classification

Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Magnoliids
Order:	Magnoliales
Family:	Annonaceae
Genus:	*Uvaria*
Species:	*chamae*

Essential oils

The essential oil from the root bark and leaves of *U. chamae* showed the presence of different constituents (Table 2). The oil from the root contained a number of oxygenated benzylbenzoate derivatives and ethers. The oil from the leaf contains predominantly sesquiterpene hydrocarbons, oxygenated sesquiterpenes, monoterpene hydrocarbons as well as oxygenated ones (Ayedoun et al., 1999). Thymoquinoldimethyl ether, benzyl benzoate, chamanen, o-methoxybenzylbenzoate, o-methoxybenzyl benzyl ether, and di-o-methoxybenxyl ether are the major components of the root oil (Park and Sutherland, 1969; Lasswell and Hufford, 1977a) while the oil from the leaf was dominated by 1-nitro-2-phenylethane (63.2%), linalool (9.9%), and germacrene D (6.6%) (Moses et al., 2013) as shown in Table 2. The bioactivities of the major constituents account for the traditional uses of *U. chamae* leaves and roots to treat fevers, wounds, swellings, injuries, etc.

Flavonoids

Since 1976, flavonoids of a special type have been obtained from several *Uvaria chamae*. These are the novel

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C-benzylated flavanones and C-benzylated dihydrochalcones as shown in Table 3. Some of them have demonstrated cytotoxic, antitumor and antimicrobial properties. Although flavanones and chalcones are wide-spread in higher plants, the introduction of benzyl groups is quite rare and seems to be limited to *Uvaria chamae* (Bindu, 1998).

Annonaceous Acetogenins

Annonaceous Acetogenins are a unique class of C-35 or C37 secondary metabolites derived from long chain (C-32 or C34) fatty acids in the polyketide pathway. They are usually characterized by a combination of fatty acids with a 2-propanol unit at C-2 that forms a methyl-substituted α,β-unsaturated γ-lactone (Alali et al., 1999). Since the discovery of uvaricin from *Uvaria accuminata* in 1982, more than 500 acetogenins have been identified from different parts of the plants in the Annonaceae family (Tempesta et al., 1982; McLaughlin, 2008) and over 400 members of this family of compounds have been isolated from 51 different species of plants (Bermejo et al., 2005). Due to the special structures and extensive biological activities, Acetogenins have attracted significant scientific interest in recent years.

Various biological activities have been reported for Acetogenins, including antimalarial, antiparasitic and pesticidal activities (Zafra-Polo et al., 1998; Alali et al., 1999). However, the biological activities of AGEs are primarily characterized with toxicity against cancer cells and inhibitory effects against the mitochondrial complex I (mitochondrial NADH: ubiquinone oxido-reductase) (Zafra-Polo et al., 1996; Chih et al., 2001). However, new adjacent bis –tetrahydrofuran annonaceous acetogenin, joolanin, along with eight known acetogenins, squamocin, desacetyluvaricin, chamuvarinin, tripoxyrollin, dieporeticanin-1, dieporeticanin-2 and dieporeticenin were isolated from the seeds of *Uvaria chamae*. Joolanin has been shown to exhibit cytotoxicity effect towards the KB 3-1 cell line (IC_{50}) =0.4 nM (Fall et al., 2004). Also, cis-bullatencin, bullatencin, annotemoyin-1, solamin, uvariamicin-I, -II, -III, cis-reticulatacin and cis-uvariamicin-I (Fall, 2002) and chamuvarinin (Fall et al., 2004) was also isolated from the root of *U. chamae*.

Alkaloids

Philipov and co-workers in 2000 carried out a study on the phytochemical evaluation of leaves of *Uvaria chamae* which resulted in the isolation for the first time for the genus of *Uvaria* of benzylisoquinoline alkaloids (+)-armepavine and racem O, O-dimethyl coclaurine. The aporphines nornantenine, nantenine and corydine are new for the species.

Ethnopharmacology

All parts of *Uvaria chamae* are fragrant. The root-bark yields an oleo-resin and is taken internally for catarrhal inflammation of mucous membranes, bronchitis and gonorrhoea in Nigeria (AkéAssi et al., 1985), while at one time a fluid extract entered into the composition of a stock hospital prescription in Ghana for dysentery (Marshall et al., 2000). The properties are mainly astringent and styptic, and it is used in native medicine as a specific for piles, useful also for menorrhagia (for which it is taken mixed with Guinea grains and added to food), epistaxis, haematuria, hematemesis and haemoptysis. In Sierra Leone, the root is credited with having purgative and febrifugal properties (Ayedoun et al., 1999; Burkill, 2000; Igoli et al., 2005). In Sierra Leone the root or the root-bark is boiled with spices and the decoction drunk for fevers classed locally as 'yellow-fever', including almost any indisposition accompanied by jaundice (Ayedoun et al., 1999; Burkill, 2000), and in the Ivory Coast it enters into a treatment for a form of jaundice (Arbonnier, 2000). In the Casamance of Senegal, leaves and roots are macerated for internal use as a cough mixture (Burkill, 2004), and mixed with those of *Annona senegalensis*, dried and pulverized are considered strong medicine for renal and costal pain (Madubunyi et al., 1996). The roots are used in the Casamance for healing sores, and a concoction called n'taba in the Bayot dialect is reputed to cure infantile rickets. In Nigeria a root-decoction is also held to be stomachic and vermifugal, and is used as a lotion; sap from the root and stem is applied to wounds; used for the treatment of nose bleeding, heart diseases (bronchi, lungs etc.), and blood in urine, pile and fever (Adams and Moss, 1999; Etukudo, 2003). The root is made into a drink and a body-wash for oedematous conditions (Ayedoun et al., 1999). Its root-decoction is given for the pains of childbirth in Togo (Oguntimein et al., 1989; Nwosu, 2000).

Table 1. The preliminary phytochemicals present in different parts of *Uvaria chamae*

		Plant parts			
S/No.	**Chemical classes**	**Root**	**Stem Bark**	**Leaves**	**Fruit/seeds**
1.0	Alkaloids	+	-	+	NPD
2.0	Glycosides	-	+	NPD+	NPD
3.0	Saponins	-	+	+	,,
4.0	Tannins	+	+	+	,,
5.0	Flavonoids	+	+	+	+
6.0	Reducing sugar	+	+	-	NPD
7.0	Quinonic derivatives	+	NPD	NPD	,,
8.0	Leucoanthocyanes	+	NPD	,,	,,
9.0	Terpenes/Terpenoids	+	,,	+	,,
10	Essentials oils	+	,,	+	,,
References		Thierry et al., 2012; Emordi et al., 2015	Ebia et al., 1999; Oluremi et al., 2010	Borokini and Omotayo, 2012; Moukimou et al., 2014	Basil, 2017

+: Present, -: Absent, NPD: No published data

Table 2. Chemical Composition of *Uvaria chamae* Leaf and Root Essential Oil

S/No.	Compounds	%	S/No.	Compounds	%
1.0	α-Pinene	0.3	38	Thymoquinoldimethyl ether	-
2.0	β-Pinene	0.2	39	Alloaromadendrene	0.1
3.0	Camphene	Trace	40	*cis*-Cadina-1(6),4-diene	Trace
4.0	Benzaldehyde	Trace	41	*trans*-Cadina-1(6),4-diene	0.1
5.0	Myrcene	0.2	42	γ-Muurolene	0.2
6.0	α-Phellandrene	Trace	43	Germacrene D	6.6
7.0	δ-3-Carene	Trace	44	β-Selinene	1.0
8.0	a-Terpinene	Trace	45	*trans*-Muurola-4(14),5-diene	0.3
9.0	*p*-Cymene	0.4	46	*epi*-Cubebol	0.7
10	Limonene	0.1	47	Bicyclogermacrene	0.3
11	1,8-Cineole	0.6	48	α-Muurolene	0.3
12	(*Z*)-b-Ocimene	0.1	49	Germacrene A	0.2
13	(*E*)-b-Ocimene	1.9	50	(*E,E*)-α-Farnesene	0.1
14	γ-Terpinene	0.2	51	Cubebol	0.8
15	Linalool	9.9	52	δ-Cadinene	2.1
16	Benzeneacetonitrile	0.1	53	*trans*-Cadina-1,4-diene	0.1
17	(*E*)-Epoxyocimene	Trace	54	α-Cadinene	Trace
18	Borneol	0.1	55	Elemol	0.1
19	Terpinen-4-ol	Trace	56	Germacrene B	Trace
20	α-Terpineol	0.1	57	(*E*)-Nerolidol	1.4
21	(3*Z*)-Hexenyl 2-methylbutanoate	Trace	58	(3*Z*)-Hexenyl benzoate	0.2
22	Bornyl acetate	Trace	59	Spathulenol	0.2
23	1-Nitro-2-phenylethane 63.2	63.2	60	Caryophyllene oxide	0.3
24	(3*Z*)-Hexenyltiglate	0.1	61	Gleenol	Trace
25	α-Cubebene	0.2	62	Humulene epoxide II	0.1
26	α-Copaene	0.4	63	1-*epi*-Cubenol	0.4
27	β-Bourbonene	0.2	64	τ-Cadinol	Trace
28	β-Cubebene	0.2	65	τ-Muurolol	0.7
29	β-Elemene	0.2	66	α-Muurolol (= Torreyol)	0.2
30	(*E*)-Caryophyllene	1.7	67	α-Cadinol	0.5
31	β-Copaene	0.1	68	Pentadecanal	0.1
32	α-*trans*-Bergamotene	0.1	69	Benzyl benzoate	0.9
33	6,9-Guaiadiene	Trace	70	Palmitic acid	0.2
34	*cis*-Muurola-3,5-diene	0.1	71	(*E*)-Phytol	0.1
35	α-Humulene	0.6	72	o-methoxybenzylbenzoate	-
36	(*E*)-β-Farnesene	0.2	73	o-methoxybenzyl benzyl ether	-
37	chamanen	-	74	di-o-methoxybenzyl ether	-

Table 3. Chemical Composition of *Uvaria chamae* Stem and Root bark C-benzylated Flavonoids

S/No.	Compounds	Plant part	References
1.0	Pinocembrin	Stem, Root	Hufford and Lasswell, 1976
2.0	Pinostrobin	Stem, Root	Hufford and Oguntimein, 1980
3.0	Chamanetin	Root	Hufford and Lasswell, 1976; Lasswell and Hufford, 1977, Hufford et al., 1980; Hufford and Oguntimein, 1980
4.0	Chamanetin 5-methylether	Root	Hufford and Lasswell, 1976, El-Soly et al., 1979
5.0	Isochamanetin	Root	Hufford and Lasswell, 1976
6.0	Uvaretin	Stem, Root	Okorie, 1977; Nkunya et al., 1985
7.0	Isouvaretin	Stem, Root	Hufford et al., 1980; Nkunya et al., 1985
8.0	Dichamanetin	Root	Hufford and Lasswell, 1976; Lasswell and Hufford, 1977
9.0	Dichamanetin-5-methylether	Root	Hufford and Lasswell, 1976; Lasswell and Hufford, 1977
10	Diuvaretin	Stem, Root	Okorie, 1977; Nkunya et al., 1993
11	Chamuvaritin	Root	Hufford et al., 1979; Derbre´ et al., 2004; Fall et al., 2004; Laurens et al., 2004
12	Uvarinol	Stem, Root	Hufford et al., 1979

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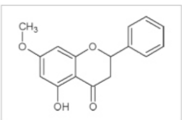
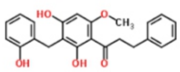
Table 4. Biological activities for extracts of *Uvaria chamae*

S/No.	Extract	Plant part	Country	IC_{50}/ED_{50} conc. used	Species	Ref.
1.0	Antidiabetic & hypolipidemic activity 93.3% aqueous ethanol ext.	Root	Nigeria	100 mg/kg 250 mg/kg 400 mg/kg	Rat	Emordi et al. 2016
2.0	Hypoglycaemic activity 93.3% aqueous ethanol ext.	Root	Nigeria	250 mg/kg 500 mg/kg	Rat	Emordi et al. 2015
3.0	Anti-inflammatory activity ethanol ext.	Root	Nigeria	25 mg/kg 150 mg/kg	Mouse Rat	Okwu et al., 2009.
4.0	Oxytocic activity ethanol ext.	Root	Nigeria	15 mg/100 mL	Guinea pig	Okwu et al., 2009.
5.0	Antioxidant activity 1. Ethanol, acetone (AcE), 2. aqueous (AqE) extracts	1. Leaves 2. Seed	Nigeria „	1. 2-50 µg/mL 2. 1 mL	1,1-diphenyl-2-picrylhydrazyl (DPPH)	Moukimou et al., 2014; Basil, 2017.
6.0	Anti-malarial activity 1. Ethanol ext. 2. aqueous extracts	Leaf, stem bark, and root	Nigeria	100 mg/kg	*Plasmodium berghei* NK 65	Ene et al., 2016
7.0	Antibacterial activity 1. 70% ethanol ext., aqueous ext. 2. Methanol ext.	1. Root 2. Root, stem & leaf	1. Côte d'Ivoire 2. Nigeria	1. 3.125 to 100 mg/ml. 2. 50, 100, 150, 200 & 250 mg/ml	1. *E. c.*s, *E.c.*E., *S.f.*E and *S.*sp 2. MRSA, S.a, E.c, *K.*spp, *P.* spp, strains of *E.c*, *S.a*, *P.a*	Kone et al., 2015; Oluremiet al., 2010
8.0	Hepatoprotective activity Methanol extract	Root bark	Nigeria	60 mg/kg	Rats	Madubunyi, 2012
9.0	Antihaemolytic activity Water extract	Root bark	Nigeria	5 mg/mL	Red blood cells	Thierry et al., 2012
10	Genotoxic activity Methanol extract	Leaf	Nigeria	125, 250, 750 mg/kg	Mouse	Awodiran et al., 2017

*E.c.s: Escherichia coli*soluble; *E.c.*E: *Escherichia coli* ESBL; *S.f.*E: *Shigella. Flexneri* ESBL; *S*: *Shigella*:; MRSA: Methicillin-Resistant *Staphylococcus aureus*; *S.a*: *Staphylococcus aureus*; *K*: *Klebsiella*; *P*: *Proteus*; *P.a*: *Pseudomonas aeruginosa*


Pinostrobin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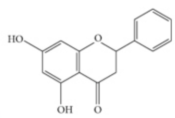
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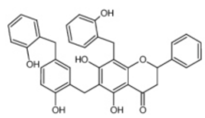
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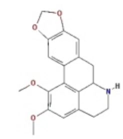
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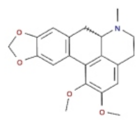
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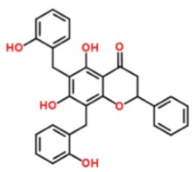
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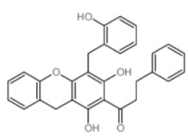
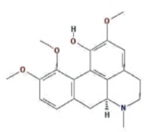

Chamuvaritin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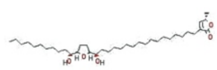
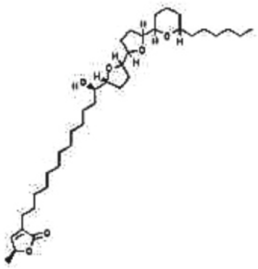
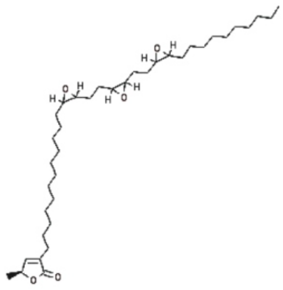

Uvariamicin



Chamuvarinin



Tripoxyrollin

Biological Activities

Antidiabetic activity

Emordi et al. 2016 evaluated the antidiabetic effect of *Uvaria chamae* extract in rat. The effects of the extract on weight, plasma glucose and other biochemical parameters were evaluated using standard procedures. The diabetic rats treated with the extract showed significant reductions ($p < 0.05$) in weight, plasma glucose levels, low density lipoprotein and cholesterol compared with the control. The extract showed maximum glucose reduction of 85.16, 81.50 and 86.02% respectively. Histologically the pancreas of the diabetic rats treated with the extract, showed clusters of variably sized regenerated islet of Langerhans within sheets of normal exocrine pancreas, while the pancreas of diabetic rats treated with insulin showed no islet of Langerhans. These activities of the extract may be accounted for by the presence of several bioactive compounds like flavonoids, tannins and alkaloids. Suba et al., 2004 reported that tannin has antidiabetic activity. Research has shown that many plants containing flavonoids have been used for the treatment of diabetes (Meiselman et al., 1976; Choi et al., 1991; Hassig et al., 1999). Tannins induce phosphorylation of the insulin receptors as well as translocation of glucose transporters 4 (GLUT-4) , the protein factor involved in the signaling pathway of insulin-mediated glucose transport and the inhibition of the expression of key gene for adipogenesis thereby helping to reduce blood glucose level without increasing adiposity (Liu et al., 2005).

Antimicrobial activity

Studies have shown that Pinocembrin can significantly inhibit the activity of *Penicillium italicum* (Sala et al., 2003), *Candida albicans* (Metzner and Schneidewind, 1978; Katerere et al., 2012), *Staphylococcus aureus* (Soromou et al., 2013), *E. coli* (Katerere et al., 2012), *Bacillus subtilis*, *Trichophyton mentagrophytes*, *Streptococcus mutans* (Uzel et al., 2005) and *Neisseria gonorrhoeae* (Ruddock et al., 2011). More so, the antimicrobial activities of a number of cytotoxic C-benzylatedflavanones (Flavonoids) namely chamanetin, isochamanetin and dichamanetin from *Uvaria chamae* root bark ethanol extracts were also determined. The minimum inhibitory concentration values of these compounds and certain of their derivatives against *Streptococcus aureus*, *Bacillus subtilis* and *Mycobacterium smegmatis* compare favorably with those of streptomycin sulphate (Anam et al., 1993; Achenbach et al., 1997). Alkaloids are also significantly recognized for their antimicrobial properties (Manikandan et al., 2006; Mariita et al., 2011), and they might play a role in disease resistance (Salisbury and Ross, 1992). In addition, linalool has shown antimicrobial activities (Peana et al., 2003), which is present in the leaf extract of *U. chamae*.

Anti-inflammatory and oxytocic activity

The anti-inflammatory and oxytocic properties of *U. chamae* root ethanol extract were assessed. The extracts and aspirin were found to inhibit carrageenan-induced paw oedema on albino rats and mice with a strong activity in aspirin having (80.43 %) inhibition while *U. chamae* had 69.57% inhibition respectively. In the oxytoxic property assessment, uterus from young virgin guinea pig was used. The plant extract exhibited more uterine contraction in the guinea pig which was comparable to that of oxytocin (Okwu et al., 2009). 1-Nitro-2-phenylethane and linalool had shown anti-inflammatory effect (Peana et al., 2002; De Lima, 2008). Flavonoids possessed the highest phytochemical content in this study which may be responsible for the above activities. However, Pinocembrin has been shown in *in vitro* studies to inhibit proinflammatory cytokines in the murine macrophage and endotoxin-induced acute lung injury model, partly by decreasing the levels of MAPK and NF-kB activation. More so, *in vivo* studies also showed that pretreatment with pinocembrin (intraperitoneal, 50 mg/kg) attenuated inflammation and reduced lung injury in a murine model of lipopolysaccharide (LPS)-induced inflammation (Soromou et al., 2012).

Furthermore, the anti-inflammatory effect of *Uvaria chamae* methanol extract on acetic acid- induced acute colitis in rats identified from a previous ethnobotanical study was evaluated. Acetic acid was diluted in normal saline to be 4% and infused into the colon of rats through a rubber cannula at the dose of 4 mL/kg. 50 – 400 mg/kg and 2 mg/kg of prednisolone (standard drug) was orally administered 48, 24 and 1 hour prior to the induction of colitis and continued for 1 week. The extract doses (50-400mg/kg) significantly reduced the macroscopic inflammation scores and morphological alterations associated with an increase in the mucus secretion ($p<0.05$) with no significant difference among the treatment groups which indicated its effectiveness at all levels of doses in the treatment of ulcerative colitis (Abu et al., 2018).

Cytotoxicity Activity

The MTT (3-(4, 5-dimethyl thiazole-2-yl)-2, 5-diphenyl-tetrazolium bromide) colorimetric assay was used to determine the cytotoxic concentration of extracts/ fractions at 50% (CC_{50}) with ten-fold serial dilution (100 to 0.001 µg/mL) of each extract treatment. The methanol crude extract of *Uvaria chamae* root bark was most toxic with CC50 of 15.90 µg/mL, while *Uvaria chamae* stem bark was least toxic with CC50 of 38.92 µg/mL. The methanol fraction from *Uvaria chamae* stem bark was more toxic than its other fractions with CC50value of 23.01 µg/mL, while hexane, dichloromethane, and ethylacetate fractions and the crude extract have similar cytotoxic activity pattern with CC50 values of 39.10 µg/mL, 38.95µg/mL, 38.15 µg/mL and 38.92 µg/mL respectively (Oluremi and Adeniji, 2015). Recently, Awodiran et al., 2017, assessed the cytotoxicity properties of methanol *U. chamae* leaves extract by using mitotic index determinant and found to exhibit dose-dependent cytotoxicity at doses of 125, 250, and 750 mg/kg/day comparable to the standard, Cyclophosphamide (50 mg/kg, single dose).More so, ethanol extract of the stem bark of *U. chamae* was found to show activity *in vivo* against P-388 leukemia in the mouse and *in vitro* against cells derived from human carcinoma of the nasopharynx (KB). Fractionation of the ethanol extract was guided by assay against carcinoma of the nasopharynx (KB). The activity was concentrated in the ethyl acetate soluble fraction of an ethylacetate-water partition. Chromatography of the ethyl acetate fraction over salicylic acid gave uvaretin and isouvaretin (Hufford and Lasswell, 1976). In addition, the isolation and characterization of three novel C-benzylated flavanones, chamanetin, isochamanetin, and dichamanetin and three C-benzylated dihydro-chalcones, uvaretin, isouvaretin and diuvaretin from ethanol extracts of the root bark of *U. chamae* also showed to be responsible for its cytotoxic effect (Hufford and Lasswell, 1976; Lasswell and Hufford, 1977). Chamuvarinin has also showed significant cytotoxicity toward KB 3-1 cervix cancer cell lines (IC_{50}) 0.8 nM) (Derbre´ et al., 2004; Fall et al., 2004).

The aforementioned alkaloids were found to express cytotoxic activity against L929 transformed cells. The highest activity was shown by (+)-armepavine and nornantenine (Philipov et al., 2000).

Antioxidant activity

The antioxidant activity of seed extracts of *Uvaria chamae* was investigated by measuring its DPPH (1, 1-diphenyl-2-picrylhydrazyl), ABTS (2, 2-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) scavenging activities and its metal chelating and ferric reducing potentials. In addition, total phenolic and flavonoid content of the seed extracts was evaluated. The seed extracts exhibited potent antioxidant activity in the DPPH and ABTS assay, with the ethanol seed extract of *Uvaria chamae* being more effective (IC_{50} = 34.3 and 29.6 µg/mL respectively). However, the aqueous seed extract of *Uvaria chamae* exhibited the highest metal chelating activity (IC_{50}= 23.5 µg/mL), while its ethanol extract showed higher reducing power than the standard. In addition, high content of phenolics and flavonoids was found in the organic seed extracts (Basil, 2017). Flavonoids are a group of phytochemicals that have been shown to exert potent anti-oxidant activity against the superoxide radical (Hertog et al., 1993). Hence, Pinocembrin, a natural flavonoid compound which has also been extracted from other source, e.g. honey, propolis etc., has shown the ability to reduce reactive oxygen species (Liu et al., 2008).

Hepatoprotective activity

The hepatoprotective activity of *U. chamae* methanol root bark extract was tested *in vivo* and *in vitro*. An oral administration of the methanol extract (60 mg/kg) significantly reduced ($p < 0.05$) pentobarbitone-induced sleep in rats poisoned with acetaminophen. In this model, a protection of 92% against cytotoxicity of acetaminophen is obtained by pretreatment with the methanol extract as compared to a protection of 89.6% when the animals were pretreated with silibinin. Intraperitoneal injection of the methanol extract into rats showed no significant effect on pentobarbitone-induced hypnosis. The elevation of serum glutamate oxaloacetate transaminase, glutamate pyruvate transaminase, alkaline phosphatase, and urea induced by paracetamol intoxication in rats was also significantly attenuated ($p < 0.05$) by the methanol extract. The methanol extract did not influence the concentration of microsomal proteins in the serum. This *in vivo* efficacy was substantiated by significant hepatoprotection on acetaminophen (AA)-induced hepatotoxicity in isolated rat hepatocytes. The methanol extract, at a dose of 1 mg/ml, remarkably ($p < 0.05$) reduced the leakage of lactate dehydrogenase in primary cultured rat hepatocytes and showed a significant effect on lipid peroxidation. The AA-induced elevation of the lipid peroxidation in rats was significantly ($p < 0.05$) decreased in the presence of *U. chamae* root bark methanol extract. A protection of 56% against the tert-butyl hydroperoxide-induced lipid peroxidation in rats was obtained by pretreatment with the methanol extract (Madubunyi, 2012). Liver-protective medicinal plants contain a variety of chemical compounds, such as phenols, coumarins, lignans, essential oils, monoterpenes, glycosides, alkaloids, carotenoids, flavonoids, organic acids and xanthines (Bhauna and Kumar, 2009) which is evident in the study above.

Antivenom activity

The venom neutralizing properties against *Naja nigricollis* venom in rats using methanol leaf extract of *U. chamae* was evaluated. To study the antivenom properties, albino rats were orally administered with a dose of 400 mg/kg body weight and 1 h later, the venom was administered intraperitoneally at a dose of 0.08 mg/kg body weight of rats. Blood clothing time, bleeding time, antipyretic activity, haemoglobin, RBC, WBC, creatine kinase, AST, ALP and ALT activities total protein antioxidant activity and some blood electrolytes, plasma urea and uric acid were measured. Results showed that *Uvaria chamae* methanol extract neutralized some biological effects of *Naja nigricollis* venom. The venom increased the rectal temperature, enzyme activities, bleeding time and other blood parameters. The plant extract was able to reduce these parameters in the extract treated groups (Omale et al., 2013). However, several chemical constituents like alkaloids, flavonoids, glucoside, and tannins have also been previously reported for anti-snake venom activity (Moreno et al., 1993; Grau and Ortiz, 1998). All these classes of chemical compounds are capable of interacting with macromolecular targets with enzymes or receptors and it can effectively inhibit the toxic effect of snake venoms *in vitro* than *in vivo* (Borges et al., 2005).

Insecticidal activity

The insecticidal effects of the powdered stem bark extract of *Uvaria chamae* and its ethanol extract was evaluated on three most devastating stored products pests (Coleopterous) in Nigeria, namely: *Callosobruchus* *maculatus* F. (Bruchidae), *Rhizopertha dominica* F. (Bostrichidae) and *Sitophilus zeamais* Motschulsky (Curculionidae). It was shown that *U. chamae* powdered and ethanol stem bark extracts have potentials for use during storage of grains, ensuring food security, profit maximization and availability of seeds for the next planting season without being damaged by these test insect species which may be the responsibility of the presence of high concentration of steroids and terpenes (Negbenebor et al., 2018).

Antimalarial activity

Methanol extracts of the dried leaves and fresh fruits administered at 100 – 800 mg/kg on *Plasmodium berghei*-infected mice were evaluated using the four-day (chemosuppressive) and curative (Rane's) antimalarial test models; distilled water and amodiaquine (10 mg/kg) were negative and positive controls, respectively. At 800 mg/kg, leaf and fruit extracts gave chemosuppression of 42 and 28% (four-day test) and parasite clearance of 36.3 and 49.5% on day 5 (curative test), respectively while the positive control-treated groups were 72.8% and 98%. The leaf and fruit extracts showed better chemosuppressive and curative antimalarial activity, respectively thus justifying their folkloric uses and secondary metabolites present (Adepiti et al., 2013).

Conclusion

Uvaria chamae secondary metabolism appears to be a resource of many biologically active compounds. However, because the majority of the previous studies were focused on the biological activities of the plant extract, further investigations on the biochemical and physiological functions of active compounds and the detailed mechanisms underlying these activities are completely pivotal for the development of pharmaceutical products. More so, clinical trials concerning the rich pharmaceutical potential of *U. chamae* have been markedly neglected in previous studies. This review is hoped to be a source of enlightenment and motivation for researchers to further perform *in vitro*, *in vivo* and clinical investigations on the biological activities of *U. chamae* to gain insight into developing new potential pharmaceutical agents of commercial importance.

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