EFFECT OF LEAF EXTRACT OF SOME MULTIPURPOSE TREES AND ITS CONCENTRATIONS ON GROWTH AND PRODUCTION OF MAIZE †

[EFECTO DEL EXTRACTO DE HOJA DE ALGUNOS ÁRBOLES MULTIUSOS Y SUS CONCENTRACIONES EN EL CRECIMIENTO Y PRODUCCIÓN DE MAÍZ]

A. Azene[1], R. Chauhan[2*], A. Tesfaye[2] and D. Misgana[2]

[1]*Department of Biodiversity Research and Conservation Center, College of Natural Science, Arba Minch University,Ethiopia*
[2]*Department of Forestry, College of Agriculture, Arba Minch University, Ethiopia*
**Corresponding Author*

SUMMARY

Background. There is a need to understand multipurpose trees promotory or inhibitory allelopathic effects prior to selection of any crop to be cultivated in their vicinity. **Objective.** Present study was carried out during 2019 on Arba Minch University Research Farm with the specific objectives of to investigate the effect of leaf extract of some multipurpose trees and its concentrations on growth and production of Maize. **Methodology.** Leaf extracts of 3 species namely *Moringa stenopetala*, *Croton macrostachyus* and *Terminalia brownii* were tested at 5 concentration levels (0%, 25%, 50%, 75% and 100%). The experiment was laid out with Randomized Complete Block Design with three replications. The leaf extract was applied at biweekly interval right from its emergence. **Results.** The growth components which were significantly affected by the application of leaf extracts include leaf length, leaf area, stem thickness and days to tasseling of maize while effect of leaf extract on plant height, number of leaves plants^{-1}, days to silking and days to maturity was found non significant. On the other hand with the exception of number of cobs plant^{-1} all yield and yield components, like number of grains row^{-1}, number of grains column^{-1}, number of grains cobs^{-1}, 1000-seed weight of cob, length of cob, diameter of cob, fresh and dry yield of maize were significantly varied with leaf extracts of the selected MPTs and their concentration levels. The application of leaf extract resulted in increase in yield from 6.95 T ha^{-1} (control) to 8.95 T ha^{-1}, 7.58 T ha^{-1} and 7.40 T ha^{-1} for *Croton macrostachyus*, *Moringa stenopetala* and *Terminalia brownii* respectively. **Implications.** The results of the present study contribute in knowing the positive or negative effect of leaf extract of three MPTs on Maize production. **Conclusions.** It can be concluded that introduction of these multipurpose trees in farmland under agroforestry system is safe and without any inhibitory allelopathy. Thus leaf extract application of these species are recommended for further improvement of maize yield.

Keywords*:* Agroforestry*;* Leaf extracts, Allelopathy*;* Concentrations*;* Maize*;* Multi-purpose trees

RESUMEN

Antecedentes. Es necesario conocer los efectos alelopáticos promotores o inhibidores de los árboles de usos múltiples necesitan antes de la selección de cualquier cultivo que se cultivará en su vecindad. **Objetivo.** El presente estudio se llevó a cabo durante 2019 en la Granja de Investigación de la Universidad de Arba Minch con los objetivos específicos de investigar el efecto del extracto de hoja de algunos árboles multipropósito y sus concentraciones sobre el crecimiento y producción de maíz. **Metodología**. Se probaron extractos de hojas de 3 especies, a saber, *Moringa stenopetala, Croton macrostachyus y Terminalia brownii* con 5 niveles de concentración (0%, 25%, 50%, 75% y 100%). El experimento se diseñó con diseño de bloques completos aleatorios con tres repeticiones. El extracto de hoja se aplicó quincenalmente desde su aparición. **Resultados:** Los componentes de crecimiento que se vieron significativamente afectados por la aplicación de extractos de hojas incluyen la longitud de la hoja, el área de la hoja, el grosor del tallo y los días para la formación de espigas de maíz, mientras que el efecto del extracto de hoja sobre la altura de la planta, el número de hojas de plantas^{-1}, los días para la formación de espigas y días hasta la madurez no fue significativo. Por otro lado, con la excepción del número de mazorcas planta^{-1}, todos los componentes de rendimiento y rendimiento, como número de granos fila^{-1}, número de granos columna^{-1}, número de granos mazorcas^{-1}, peso de 1000 semillas de mazorca, longitud de mazorca, diámetro de mazorca, rendimiento fresco y seco de maíz varió significativamente con los extractos de hojas de los MPT seleccionados y sus niveles de concentración. La aplicación de extracto de hoja resultó en un aumento en el rendimiento de 6.95 T ha^{-1} (control) a 8.95 T ha^{-1}, 7.58 T ha^{-1} y 7.40 T ha^{-1} para *Croton macrostachyus, Moringa stenopetala* y *Terminalia brownii* respectivamente. **Implicaciones.** Los resultados del presente estudio contribuyen a conocer el efecto positivo

† *Submitted November 10, 2020 – Accepted January 28, 2021.*
ISSN: 1870-0462.

o negativo del extracto de hoja de tres MPT sobre la producción de maíz. **Conclusiones.** Se puede concluir que la introducción de estos árboles multipropósito en tierras agrícolas bajo un sistema agroforestal es segura y sin alelopatía inhibitoria. Por lo tanto, se recomienda la aplicación de extracto de hoja de estas especies para mejorar aún más el rendimiento del maíz.
Palabras clave: Agroforestería; Extractos de hojas, alelopatía; Concentraciones; Maíz; Árboles polivalentes

INTRODUCTION

Farmers are practicing agroforestry to sustain the productivity of farm's land in humid tropic farming system including Ethiopia (Nair, 1993). Agroforestry can be defined as the deliberate growing of woody perennials on the same unit of land as agricultural crops and/or animals, either in some form of spatial mixture or sequence.The retention and cultivation of multipurpose trees are usually economical (Burley and wood, 1991), most distinctive component of agroforestry and needs to exploit its potential for making agroforestry as a viable land use option (Lantican and Taylor, 1991). Its a source of security for rural community in many African countries by providing food, energy (Koffi *et. al*, 2016) and source of income for the people (Garrity *et. al*, 2010). These woody species having the capacity to sustain productivity of farmlands basically through enhancing soil fertility and reducing the erosion hazards. Food, medicine, firewood, windbreaks are some other benefits that it provides to the farmers.

The integration of trees and shrubs with crops in garden is a means of poverty alleviation for community (Pokwana *et. al*, 2021). These home gardens has been recognized as an imperative social and economic unit of rural family unit (Azeez *et. al*, 2007; Li *et. al*, 2020) and ensure availability of variety of crops, trees, herbs, shrubs and livestock which are managed to provide food, shade, fuel, income, medicines, construction materials, and socio-cultural purposes (Sahoo, 2009). Moreover, home gardening and agroforestry are identified as a means to reduce pressure from natural forest caused by increased population (Dewi *et. al*, 2013). However, farmers are keep on growing multipurpose trees (MPTs) on their farm for diversified products and services without knowing its shortcomings, such as allelopathic effect on crop growth and production. These MPTs are either inter-cropped or cultivated as shelter belts with economically important crops (Chaudhry, 2003) which improves physical and chemical property of soil periodically and contributes to its organic matter contents by littering (Singh and Sharma, 2007). However, litter fall from these trees upon decomposition may pose allelopathic stress upon crops growing in their vicinity.

Thus its necessary to check the compatibility and interaction of tree or shrub species with companion crops prior to its introduction in any type of agroforestry system as it is not easy to replace them once they have been planted. Its necessary to understand the promotory or inhibitory allelopathic effects of multipurpose trees prior to selection of any crop to be cultivated in their vicinity. Its nature, concentration of allelochemicals (secondary metabolites) and the soil biota that decides either it will results in growth promotion, inhibition/suppression of the receiving plant (Saraf *et al.*, 2014; Cheng and Cheng, 2015; Fernandez *et al.*, 2016; Majeed *et al.*, 2017a). The planted MPTs have allelopathic potential, hence, they may inhibit or promote the growth of agricultural crops, through release of secondary metabolites or allelochemicals (Bansal *et al.*, 1992; Mallik, 2008). These allelochemicals are present in many plants and in many organs, including leaves, flowers, fruits and buds. Often, allelo-chemicals of decomposing litters affect the seed germination, growth and development of adjoining crops in agroforestry systems.

The positive effect of Moringa leaf extract on some of growth and yield parameters of maize crop have earlier been reported by Biswas *et al. (*2016) & Phiri (2010). Similarly, Dechasa (1997) reported increased yield of finger millet by 15% under the canopy of *Croton macrostachyus* than 15 m away from the tree canopy. Maize (*Zea mays* L.) is one of the dominant crop that are grown in the study area. The trend of introducing MPTs to their fields is increasing as it improves their socio-economic status significantly through reduction in soil erosion hazards, production of fuel wood, timber, construction wood, providing fodder for animals and others multiple uses. Farmers in the study area are growing maize under different trees such as *Azadirachta indica*, *Anacardium occidentale*, *Croton macrostachyus*, *Moringa stenopetala*, *Mangifera indica*, *Ensete ventricosum*, *Terminalia brownii*, and *Khaya senegalenses* etc. However, farmers are unaware about their allellopathic effects or compatibility of these MPTs with maize. So, it was felt to assess the effect of extracts of some selected MPTs on maize.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted during 2019 at Arba Minch University research Demo field, located at an altitude of 1218 m.a.s.l with 37°20' 36"- 37° 40' 0"E longitude and 6°0' 0"N - 6°10' 0"N) latitude (Figure 1). The average annual rainfall of the area is around 500-1100 mm and its mean annual temperature ranged between 17°C and 39°C. The soil texture is characterized by silty clay having bulk density of 1.29 gcm-3 with 8.96% sand, 46.72% silt, and 44.32% of clay and soil temperature at different depths ranges between 22°C to 35°C.

Methodology

The present experiment was carried out at Arba Minch University research farm field during 2019 to evaluate the effects of leaf extract and its concentrations on growth and yield of maize. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Total number of treatment combinations were 15 (3 tree species x 5 leaf extracts concentrations) and were replicated thrice. Thus 45 plots with size of 3mx2m were laid down and Maize Variety BH140 was sown with uniform spacing in all plots. The tree species that were examined under this experiment include *Moringa stenopetala*, *Terminalia brownii* and *Croton macrostachyus*. Leaves collected from these species were air dried under shade and grounded by electrical grinder to make fine powder. The grounded powder was weighed and mixed with distilled water at a ratio of 1:10 (w/v) followed by shaking of mixture before being placed at room temperature for 24 hrs. Thereafter mixture was filtrated through Whatman paper No. 1 and this filter-ate served as the stock solutions (100%). The desired concentrations were prepared from the stock solution by diluting with distilled water. 5 concentrations of these leaf extracts used include [C_0 - Control (100 % water); C_1 - (25% leaf extract + 75 % Water); C_2 - (50 % leaf extract + 50 % Water); C_3 - (75 % leaf extract + 25 % Water); C_4 - (100 % leaf extract + 0% Water)]. The leaf extract was applied at biweekly interval right from the emergence of the seedling.

Data collection and analysis

Ten maize plants were randomly selected for recording different growth components such as plant height, leaf length, stem thickness, leaf area, number of leaves plant^{-1}, days to tasseling, days to silking and days to maturity. Similarly yield and yield components recorded include number of cobs plant^{-1}, number of grains row^{-1}, number of grains column^{-1}, number of grains cobs^{-1}, length of cobs, diameter of cobs, grain weight of 1000-seeds, fresh yield plant^{-1}, dry yield plant^{-1} and yield ha^{-1}. The collected data were subjected to two ways ANOVA. The Statistical Analysis System (SAS version 2001) was used and LSD (Tukey's student zed Range) test was computed for mean separation at 5 % (P <0.05) level of significance.

RESULTS

Effect of Leaf Extracts on Growth Components of Maize

All growth components except plant height and number of leaves plant^{-1} varied significantly (P<0.05) with extracts of different species (*Croton macrostchyus*, *Moringa stenopetala* and *Terminalia brownii)* as well as its concentrations besides their interactions. However, growth performance at 75% and 100 % concentrations were at par to each other for most of the growth parameter studied.

Maximum plant height (231.67 cm) and leaf length (97.55 cm) was recorded for *Moringa stenopetala* whereas, maximum leaf area (913.9 cm^2), stem thickness (104 mm) and number of leaves plant^{-1} (9.20) was recorded for *Croton macrostachyus* while *Terminalia brownii* extract except height

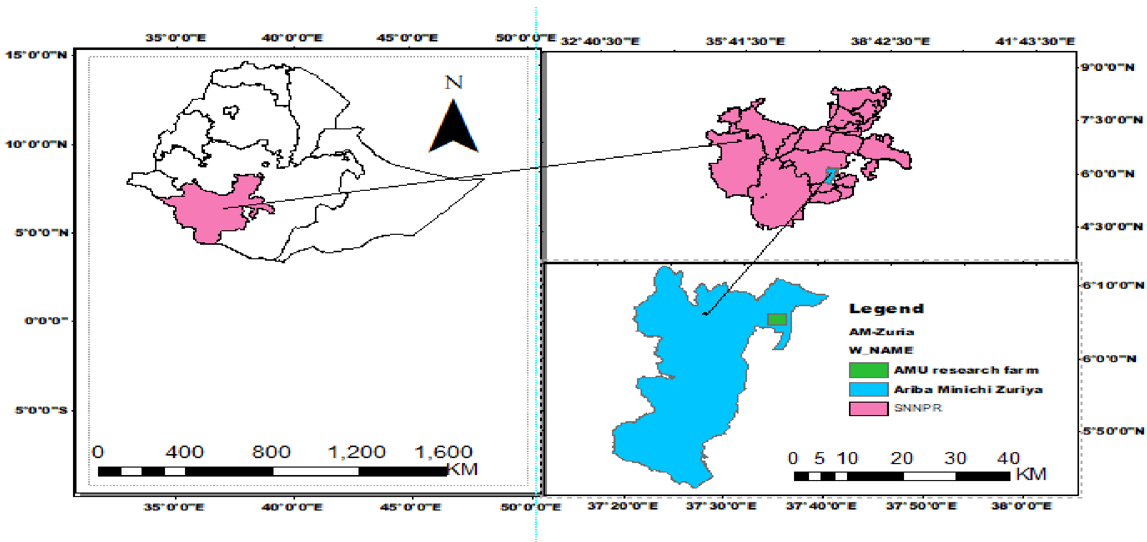

Figure 1. Map of the study area (location at national and regional level).

Table 1. **Effects of leaf extracts and its concentrations on growth parameters.**

Tr.	Plant ht. (cm)	Leaf length (cm)	Leaf area (cm^2)	Stem thickness (mm)	Leaves plant^{-1} (No.)
A_1	231.67	97.53^{a}	888.7^{b}	96.73^{b}	8.99
A_2	229.67	97.00^{ab}	913.9^{a}	104.00^{a}	9.20
A_3	230.00	93.00^{c}	884.6^{b}	94.80^{b}	8.93
Sig.	P=0.78; NS	P<0.0068; LSD=2.90	P=0.0139; LSD =20.64	P<0.0001; LSD =3.26	P=0.61; NS
C_0	227.89^{c}	90.89^{c}	858.7^{d}	88.7^{d}	8.73
C_1	228.56^{bc}	92.44^{c}	879.4^{dc}	96.8^{c}	8.93
C_2	230.11^{ba}	96.44^{b}	900.9^{bc}	100.8^{bc}	9.12
C_3	230.89^{a}	97.22^{b}	909.7^{ba}	101.1^{ba}	9.14
C_4	230.44^{a}	102.22^{a}	930.0^{a}	105.2^{a}	9.19
Sig.	P=0.01; LSD=1.89	P<.0001; LSD= 3.75	P=0.0001; LSD= 26.64	P<0.0001; LSD =4.21	P=0.63; NS
Interactions					
AXC	P=0.43 NS	P<0.0001	P <0.0001	P <0.0001	P=0.9532 NS

Note: Tr = Treatment; Sig. = significance; A_1= *Moringa stenopetala;* A_2= *Croton macrostachyus;* A_3 = *Terminalia brownie*; C_0 - Control (100 % water); C_1 - 25% leaf extract + 75 % Water; C_2 - 50 % leaf extract + 50 % Water; C_3 - 75 % leaf extract + 25 % Water; C_4 - 100 % leaf extract + 0% Water. The words a, b & c in superscript represents the grouping and numbers with same words represents falling in same group. The words a, b, c, d, ba, bc & dc in superscript represents the grouping and numbers with same words represents falling in same group.

performed least out of these treatments. Similarly, the performance of concentrations was in the order of C4>C3>C2>C1>C0 for most of these growth parameters where maximum leaf length (102.22 cm), leaf area (930 cm) and stem thickness (105.2 mm) was recorded for C_4 but at par with C_3 except for leaf area (Table 1). Similarly, the highest plant height (230.89 cm) was recorded for C_3 but at par with C_4. However, neither extracts of different tree species nor their concentrations showed significant (P<0.05) variation for number of leaves plant^{-1} of maize.

Effect of Leaf Extracts on Phenological Parameters of Maize

Neither species nor their concentrations showed significant (P<0.05) variation among themselves for phenological components like days to silking and days to maturity of the plant. The interaction effect was also found non- significant. However, the number of days for Tasseling showed significant difference among extracts of tree species and their concentrations. However, maximum (65.37) and minimum (64.02) days was required for Tasseling for *Croton macrostachyus and Moringa stenopetala* respectively. Maximum and minimum numbers of days for Tasseling were recorded at 75 % and 25 % respectively (Table 2).

Effects of Leaf Extracts and its Concentrations on Yield Components of Maize

The different yield components that were evaluated in the present study include number of cobs plant^{-1}, number of grains column^{-1}, number of grains cob^{-1}, number of grains row^{-1}, number of grains column^{-1}, number of grains cob^{-1}, length of cob, diameter of cob, 1000-seeds weight etc. It was observed that both the extract of species and its concentration significantly (P<0.05) affected all these yield components except number of cobs plant^{-1}.

The extract of *Croton macrostachyus* shows superiority over other two extracts for most of the yield components studied. The extract results in maximum cob length (22cm), grains row^{-1} (43.74), grains column^{-1} (16.63), Number of grains cob^{-1} (708.73) and 1000-seed weight (282.2 g). However, maximum number of cobs plant^{-1} (1.13) and maximum cob diameter (6.36 cm) but non-significant and at par with *Croton macrostachyus* was recorded for *Moringa stenopetala* (Table 3). Least performance of all these yield components were recorded for *Terminalia brownii*. Similarly it was observed that yield performance also get increased with increase in the concentration of the extract where most of the yield components was recorded with maximum value i.e. cobs length (21.46 cm), cob diameter (6.36 cm), no. of grains row^{-1} (45.78), no. of grains column^{-1} (16.61) was recorded for C_4 (100 % conc.) but at par with C_3 (75 % conc.) while number of cobs plants^{-1} and number of grains cob^{-1} and 1000-seed weight was recorded maximum for C_3 but at par with C_4 . Control (C_0) represents lowest values of all parameters studied (Table 3).

Table 2. **Effects of leaf extracts and its concentrations on phenological parameters.**

Tr.	Days to Silking (No.)	Days to Tasseling (No.)	Days to Maturity (No.)
A_1	58.73	64.02^b	86.30^b
A_2	58.60	65.37^a	87.48^a
A_3	58.53	65.22^a	87.02^b
Sig.	P=0.91; NS	P=0.0004; LSD = 0.65	P=0.273; NS
Concentrations			
C_0	58.56	64.19^c	87.14^{ba}
C_1	58.44	64.19^c	87.08^{ba}
C_2	58.67	64.78^{bc}	87.72^b
C_3	58.44	65.67^a	85.72^{bc}
C_4	59.00	65.47^{ba}	87.00^{ba}
Sig.	P=0.884; NS	P = 0.002; LSD = 0.84	P= 0.12; NS
Interactions			
AXC	P=0.145 NS	P=0.0034; LSD = 0.98	P=0.146 NS

Note: Tr = Treatment; Sig. = significance; A_1= *Moringa stenopetala;* A_2= *Croton macrostachyus;* A_3 = *Terminalia brownie*; C_0 - Control (100 % water); C_1 - 25% leaf extract + 75 % Water; C_2 - 50 % leaf extract + 50 % Water; C_3 - 75 % leaf extract + 25 % Water; C_4 - 100 % leaf extract + 0% Water. The words a, b, c, ba & bc in superscript represents the grouping and numbers with same words represents falling in same group.

Table 3. **Effects of leaf extracts and its concentrations on yield components.**

Tr.	Cobs plant^{-1} (No.)	Cob length (cm)	Cob diameter (cm)	Grains row^{-1} (No.)	Grains column^{-1}	Grains cob^{-1} (No.)	1000-grain weight
A_1	1.13	20.20^b	6.36^a	42.54^b	15.80^{ba}	675.60^b	269.8^b
A_2	1.07	22.00^a	6.29^a	43.74^a	16.63^a	708.73^a	282.2^a
A_3	1.07	19.80^b	5.20^b	42.27^b	15.20^b	660.13^b	270.37^a
Sig.	P=0.33; NS	P<0.0001 LSD= 0.90	P<0.0001; LSD= 0.41	P=<0.04; LSD =1.26	P=0.04; LSD =0.94	P=0.048; LSD=30.23	P<0.0001; LSD=3.51
C_0	1.00	19.41^b	4.85^c	38.33^d	14.33^b	605.8^b	265.63^d
C_1	1.17	20.83^a	5.91^b	41.9^{cd}	16.22^a	637.7^b	270.51^c
C_2	1.04	20.56^{ba}	6.29^a	44.0^{bc}	16.00^a	704.8^a	275.07^b
C_3	1.08	21.08^a	6.36^a	44.22^{ba}	16.22^a	733.3^a	279.86^a
C_4	1.12	21.46^a	6.36^a	45.78^a	16.61^a	721.9^a	279.56^{ba}
Sig.	P=0.054; NS	P=0.014; LSD= 1.16	P<0.0001; LSD= 0.53	P<0.0001; LSD= 2.02	P=0.002; LSD= 1.22	P=0.0007; LSD=64.85	P<0.0001; LSD=4.53
Interactions							
AXC	P=0.78 NS	P<0.0001	P<0.0001	P=0.7834	P=0.0454	P=0.0011	P<0.0001

Note: Tr = Treatment; Sig. = significance; A_1= *Moringa stenopetala;* A_2= *Croton macrostachyus;* A_3 = *Terminalia brownie*; C_0 - Control (100 % water); C_1 - 25% leaf extract + 75 % Water; C_2 - 50 % leaf extract + 50 % Water; C_3 - 75 % leaf extract + 25 % Water; C_4 - 100 % leaf extract + 0% Water. The words a, b, c, d, ba, bc & cd in superscript represents the grouping and numbers with same words represents falling in same group.

Effects of Leaf Extracts and its Concentrations on Yield of maize

Different yield parameters i.e. grain yield plant^{-1} (fresh and dry) and grain yield ha^{-1} were estimated. There was significant difference between type of extracts as well as its concentrations for grain yield of maize. The performance of *Croton macrostachyus* was superior than rest of two species in terms of yield production where maximum fresh yield plant^{-1} (319 g), dry yield plant^{-1} (191.7 g) and dry yield ha^{-1} (8.95 g) recorded for the extract of *Croton macrostachyus*. The yield performance of other two species were at par to each other (Table 4). Similarly maximum fresh grain yield plant^{-1} (305.78 g) was recorded for C_3 but at par with C_2 and C_4 , maximum dry yield plant^{-1} (211.11 g) was recorded for C_4 and maximum yield ha^{-1} (10.13 T) was recorded for C_4. Control showed minimum value of 267.22 g, 144.45 g and 6.92 T ha^{-1} for grain yield plant^{-1} (fresh), grain yield plant^{-1} (dry) and grain yield ha^{-1} respectively. (Table 4).

DISCUSSION

Application of all the three leaf extracts had significant effects on most of the growth parameters study and may be ranked in the order of *Croton macrostachyus>Moringa stenopetala>Terminalia brownii.* However, statistically insignificant but positive effect of these leaves extracts were observed for plant height, no. of leaves plants^{-1}, days to silking and days to maturity. The results are contrary to the earlier researchers (Ali *et al.,* 2011; Abbas *et al.,* 2013; Biswas *et al.,* 2016; Chattha *et al.,* 2015) where they reported increase in plant height and number of leaves plant^{-1} on application of Moringa leaf extract. Better growth performance of extract of *Croton macrostachyus* over other two species may be due to presence of number of essential mineral elements in its extracts. However, apart from *Moringa stenopetala*, literature on study of effectiveness of other two species are scanty. Amhare (2015) reported that *C. macrostachyus* contains sufficient amounts of major and trace metals in its leaves. Ca and Mg were the most abundant nutrients among the analyzed metals followed by, Fe, Mn and Zn. Similarly, Ebisa (2014) reported that high quality litter of *C. macrostachyus* make it most important tree for coffee production in comparison to *Cordia africana*; *Albizea gummifera* and *Acacia abyssinica*. *Croton macrostachyus* have higher amount of iron, phosphorus, zink. This could be attribute to higher rate of decomposition and nutrients release to soil (Odhiambo *et al.*, 2019).

On the other side *Moringa stenopetala* extract also performed equally well for some parameters as has been reported by number of researcher that *Moringa* leaf extract being rich in K, Ca, Fe, ammino acids, ascorbates, and growth regulating hormones such as zeatin, proved been to be an ideal plant growth enhancer (Makkar and Becker, 1996; Basra *et al.*, 2009a, 2009b). The performance of *Moringa stenopetala* is mostly dependent on Zeatin a purine adenine derivative of cytokinin which serve as growth enhancer, enhances the antioxidant properties of many enzymes and protects the cells from aging effects of reactive oxygen species (Biswas *et al.*, 2016). As cytokinins regulate leaf senescence, stimulates cell division in growing tissues, it is assumed that *Moringa stenopetala* leaf extract because of Zeatin presence can delay leaf senescence and thus maintains the photosynthesis process for longer period (Awad and Reffat, 2017).

The current study revealed the effect of leaf extracts were more pronounced with increases in its concentration. This is probably due to increasing concentrations of inorganic elements and growth hormones along with increased leaf extract concentrations. Similar results were reported earlier by Awad and Reffat (2017) while working on effect of leaf extract of *Moringa stenopetala* on *Sorghum bicolor, Penisetum typhoideum* and *Sorghum Sudanese*. Several researchers have found positive impact of higher concentration of *Moringa* extract on different crops such as onion, kidney beans, tomato (Awad and Reffat, 2017).

Table 4. **Effects of leaf extracts and its concentrations on maize yield.**

Tr.	Fresh yield plant $^{-1}$ (g)	Dry yield plant $^{-1}$ (g)	Dry yield ha^{-1} (T)
A_1	274.99^{b}	186.7^{b}	7.57^{b}
A_2	319.00^{a}	191.7^{a}	8.95^{a}
A_3	265.00^{b}	157.7^{a}	7.40^{b}
Sig.	P=0.0001; LSD =23.48	P<0.0001;LSD=11.14	P=0.0001;LSD =1.11
C_0	267.22^{c}	144.45^{d}	6.92
C_1	265.00^{c}	163.33^{c}	7.84
C_2	297.56^{a}	180.56^{bc}	8.67
C_3	305.78^{a}	193.89^{b}	9.31
C_4	296.11^{ba}	211.11^{a}	10.13
Sig.	P=0.03; LSD =30.32	P<0.0001;LSD 14.39	P=0.03; LSD =1.44
AXC	P=1.58 NS	P=4.24 NS	P=2.21 NS

Note: Tr = Treatment; Sig. = significance; A_1= *Moringa stenopetala;* A_2= *Croton macrostachyus;* A_3 = *Terminalia brownii*; C_0 - Control (100 % water); C_1 - 25% leaf extract + 75 % Water; C_2 - 50 % leaf extract + 50 % Water; C_3 - 75 % leaf extract + 25 % Water; C_4 - 100 % leaf extract + 0% Water. The words a, b, c, d, ba & bc in superscript represents the grouping and numbers with same words represents falling in same group.

Current study did not report any negative allelopathy effect for all the three extracts used on maize. However, Akhtar *et al.* (2010) while working on extracts of *Dalbergia sissoo*, reported that it suppressed the germination and early seedling growth of rice, pearlmillet and maize. The maize proved most resistant species to *D. sissoo* allelopathy. However, the foliar application of *D. sissoo* extract either did not affect or promoted the growth of crops (Akhtar *et al.,* 2010). In another study Majeed *et al.* (2017b) reported stimulatory effect of *Populus deltoides* but negative allelopathic effect of *Melia azedarach* and *Morus alba* extract on wheat germination.

Similarly leaf extracts of the tree species and their concentrations significantly influenced yield and yield components of maize. With the exception of cob number plant^{-1}, all the remaining parameters, including number of grains row^{-1}, number of grains column^{-1}, number of grains cob^{-1}, 1000-seed weight, length of cob, diameter of cob and fresh and dry grain yield of maize were significantly affected by type of leaf extracts and its concentrations. Previously, Biswas *et al.* (2016) also reported significant effect of Moringa leaf extract on yield parameters such as grains cob^{-1}, 100-grain weight and grain weight plant^{-1} but observed that length and diameter of cob remain unaffected, which are in contrary to the results of the present study. Similarly positive effect of Moringa extract was also reported by Foidle (2001) on black-gram (*Vigna munga* L.) and Phiri (2010) on three agricultural crops i.e. beans (*Phaseolus vulgaris* L.), groundnut (*Arachis hypogea* L.) and cowpea (*Vigna unguiculata* (L.)Walp.). The present study revealed that the number of cobs plant^{-1} was not significantly affected by different leaf extracts and their concentrations. The reason for this response could be mainly that it is genetically controlled trait and is less influenced by environmental than genetic factors of maize. This results corroborates with the results of some other researchers (Ashgar *et al.,* 2010; Maqsood *et al.,* 2001; Sharar *et al.,* 2003).

The present study showed significant increase in number of grains cob^{-1} and 1000-seed weight with application of leaf extracts. The results are in line with earlier researchers (Biswas *et al.,* 2016; Chatta *et al.,* 2015; Mehboob, 2011; Yasmeen *et al.,* 2011; Anyaegbu *et al.,* 2013) who reported increase in grain cob^{-1}, grain weight plant^{-1}and 100-grain weight with the application of Moringa leaf extract. A significant effect of Moringa leaf extract on both growth and yield parameters of maize have also been reported by Williams *et al.* (2018). The potential of *Moringa stenopetala* as a high nutrients carrier and especially because of availability of growth hormone, can therefore, be harnessed and applied either as mulch, improved fallow or foliar spray to improve soil fertility status and to increase maize production.

Inspite of rich in mineral nutrients, the foliar application of extracts of *Croton macrostachyus* is not so far being tested or reported on agricultural crops. The current results necessitate to conduct some more trial on this species to test its efficacy. The results of current study not only endorse the utility of *Moringa stenopetala* as a useful multipurpose agroforestry tree but also recommend *Croton macrostachyus* even a better substitute for it which the farmer can plant on their farm for better productivity of agricultural crops.

CONCLUSIONS

The leaf extract of all the three species under present study effect growth and yield performance of Maize positively in descending order of *Croton mcrostachyus>Moringa stenopetala>Terminalia brownii*. The effect was more pronounced with increase in its concentrations. The application of leaf extract can enhance the grain yield upto 8.95 T ha^{-1}, 7.58 T ha^{-1} & 7.40 T ha^{-1} for *Croton macrostachyus*, *Moringa stenopetala* and *Terminalia brownii* respectively. Thus it can be concluded that introduction of these multipurpose trees in farmland under agroforestry system is helpful to increase the yield of crop as these tree species have considerable nutrient concentrations that are very essential for plant growth and development. The leaf extract application is also recommended for further improvement in the yield. Thus introduction of these species under agroforestry practices will be helpful in maintaining soil fertility.

REFERENCES

Abbas, R.N., Tanveer, A., Khaliq, A., Iqbal, A., Ghaffari, A.R., Matloob, A., and Maqsood, Q. 2013. Maize (*Zea mays* L.) germination, growth and yield response to foliar application of *Moringa oleifera* Lam. leaf extracts. Crop Environment 4(1): 39- 45.

Akhtar, H., Kausar, A., Akram, M., Cheema, Z.A., Ali, I., and Mushtaq, M.N. 2010. Effects of *Dalbergia sissoo* Roxb. leaf extract on some associated crop species of agroforestry. Allelopathy Journal 25 (1): 221-226.

Ali, Z., Basra, S.M.A., Munir, H., Mahmood, A., and Yousaf, A. 2011. Mitigation of drought stress in maize by natural and synthetic growth promoters. Journal of Agriculture and Social Sciences 7(2): 56-62.

Anyaegbu, P.O., Iwuanyanwu, U.P., and Omaliko, C.P.E. 2013. Comparative evaluation of effects of *Moringa oleifera* extracts and different fertilizers on the performance of *Telfaria occidentalis*. International

Journal of Applied Research and Technology 2(11): 127-134.

Ashgar, A., Ali, A., Syed, W.H., Asif, M., Khaliq, T., and Abid, A.A. 2010. Growth and yield of maize cultivars affected by NPK application in different proportion. Pakistan Journal of Science 62(4): 211-216.

Awad, O.A., and Refaat, A.A. 2017. Effect of *Moringa olifera* on growth and productivity of three cereal forages. Journal of Agricultural Science 9(7): 236-243. DOI: https://doi.org/10.5539/jas.v9n7p236

Azeez, I.O., Jimoh, S.O., and Amusa, T.O. 2007. Factors affecting adoption behaviour of Agroforestry production in Atisbo, local government area of Oyo state, Nigeria. Journal of Environment Extension 6(1): 5-9. DOI: https://doi.org/10.4314/jext.v6i1.2754

Bansal, G.L, Nayyer, H., and Bedi, Y.S. 1992. Allelopathic effect of *Eucalyptus macorrhyncha* and *E. yoymanii* on seedling growth of wheat (*Triticum aestivum*) and radish (*Raphanus sativus*). Indian Journal of Agricultural Science 62: 771-772.

Basra, S.M.A., and Farrooq, M. 2009a. Evaluating the response of sorghum and moringa leaf water extracts on seedling growth in hybrid maize. In: *Proceedings of the International Conference on Sustainable Food Grain Production: Challenges and opportunities*. University of Agriculture, Faisalabad, Pakinstan. 5(1): 104-108.

Basra, S.M.A., and Zahoor, R. 2009b. Response of root applied brassica and moringa leaf water extracts on seedling growth in sunflower. In: Proceedings of the International Conference of Sustainable Food Grain Production: Challenges and Opportunities. University of Agriculture Faisalabad, Pakistan. Biochemical Society Transactions 33: 1502–1506.

Biswas, A.K, Hoque, T.S., and Abedin, M.A. 2016. Effects of Moringa leaf extract on growth and yield of maize. Progressive Agriculture 27(2): 136-143.

Burley, J., and Wood, P. 1991. A tree for all reasons. The introduction of MPTs for agroforestry, ICRAF, Kenya. Published by the International Center for research in Agroforestry, 167.

Chattha, M.U., Sana, M.A, Munir, H., Ashraf, U., Haq, I. and Zamir, S. 2015. Exogenous application of plant growth promoting substances enhances the growth, yield and quality of maize (*Zea mays* L.). Plant Knowledge Journal 4(1): 1- 6.

Chaudhry, A.K., Khan, G.S., Siddiqui, M.T, Akhtar, M., and Aslam, Z. 2003. Effect of arable crops on the growth of poplar (*Populus deltoides*) tree in agroforestry system. Pakistan Journal of Agriculture Science 40(1-2):82-86.

Cheng, F., and Cheng, Z. 2015. Research Progress on the use of Plant Allelopathy in Agriculture and the Physiological and Ecological Mechanisms of Allelopathy. Frontiers in Plant Science 6: 1020. DOI: https://doi.org/10.3389/fpls.2015.01020

Dechasa, J. 1997. Integrated sustenance for feed, wood and food from traditional agroforestry tree intercrop, pp 111-118. In Sebil Vol 8: Proc. of the 8th annual Conference of the Crop Science Society of Ethiopia, 26-27 Feb, 1997. Addis Ababa, Ethiopia.

Dewi, S., Noordwijka, M.V., Ekadinataa, A., and Pfund, J.L. 2013. Protected areas within multifunctional landscapes: squeezing out intermediate land use intensities in the tropics. Land Use Policy 1 (30): 38–56. DOI: https://doi.org/10.1016/j.landusepol.2012.02.006.

Ebisa, L. 2014. Effect of Dominant Shade Trees on Coffee Production in Manasibu District, West Oromia, Ethiopia. Science Techcnology and Arts Research Journal 3(3): 18-22. DOI: https://doi.org/10.4314/STAR.V313.3

Fernandez, C., Monnier, Y., Santonja, M., Gallet, C., Weston, L.A., Prévosto, B., and Bousquet-Mélou, A. 2016. The impact of competition and allelopathy on the trade-off between plant defense and growth in two contrasting tree species. Frontiers in Plant Science 7: 594. DOI: https://doi.org/10.3389/fpls.2000.00594

Foidle, N., Makkar, H.P.S., and Becker, K. 2001. The potential of *Moringa oleifera* for agricultural and industrial uses. What development potential for Moringa products? October 20th–November 2nd. Dares Salaam.

Garrity, D.P. , Akinnifesi, F.K., Ajayi, O.C., Weldesemayai, S.G., Mowo, T.G., Kalinganire, A., Larwanou, M, and Bayala, J. 2010. Evergreen agriculture a robust approach to sustainable food security in Africa. Food security 2(3):197-214. DOI: https://doi.org/10.1007/s12571-010-0070-7

Koffi, C.K., Houria, D.H., and Denis, G.D. 2016. Landscape diversity and associated cropping strategies during food shortage periods: evidence from the Sudano Sahelian Region of Burkina Faso. Regional Environmental Change 17, 1369-1380. DOI: https://doi.org/10.1007/s10113-016-0945-z

Lantican, C.B., and Taylor, D.A. 1991. Compendium of national research on multipurpose tree species 1976-1990/Lantican, C.B Taylor, DA.

Li, R. Zheng, H., Zhang, C, Keeler, B., Samberg, I.H., Li, C. Polasky, S., Ni, Y., and Ouyang, Z. 2020. Rural household livelihood and tree plantation dependence in the central muntaineous region of Hainan island, China: Implications for poverty alleviation. Forests 11(2): 248. DOI: https://doi.org/10.3390/f11020248

Majeed, A., Muhammad, Z., Hussain, M., and Ahmad, H. 2017a. In vitro allelopathic effect of aqueous extracts of sugarcane on germination parameters of wheat. Acta Agriculturae Slovenica 9(2): 339-356

Majeed, A., Muhammad, Z., and Ahmad, H. 2017b. Allelopathic effects of leaf extracts of three agroforestry trees on germination and early seedling growth of wheat (*Triticum aestivum* L.). Azarian Journal of Agriculture 4(3): 69-73.

Makkar, H.P.S., and Becker, K. 1996. Nutritional value and anti-nutritional components of whole and ethanol extracted *Moringa oleifera* leaves. Anim. Feed Science and Technology 63 (1/4): 211–228. DOI: https://doi.org/10.1016/S0377-8401(96)01023-1.

Mallik, A.U. 2008. Allelopathy in forested ecosystems. In: Allelopathy in Sustainable Agriculture and Forestry, (Eds., R.S. Zeng, A.U. Mallik and S.M. Luo). Springer, New York, USA. Pp. 363-377. DOI: https://doi.org/10.1007/978-0-387-77337-7_19.

Maqsood, M., Abid, A.M, Iqbal, A., and Hsain, M.I. 2001. Effect of variable rate of nitrogen and phosphorus on growth and yield of maize (golden). Online Journal of Biological Sciences. 1(1): 19-20. DOI: https://doi.org/10.3923/jbs.2001.19.20.

Mehboob, W. 2011. Physiological evaluation of prime maize seed under late sown conditions. M.Sc. Thesis, Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan.

Naire, P.K. 1993. An Introduction to Agroforestry. Book published by Springer, Pp 499.

Odhiambo, K., Murungi, J., Wanjau, R., and Naumih, N. 2019. The effect of *Croton macrostachyus*, *Plectranthus barbatus* Leaf aqueous Extracts and inorganic fertilizers on growth and nutrient concentration of *Brassica olerasia* L. in green house at Nairobi. Asian Journal of Agriculture Extension, Economics and Sociology 29(3):1-10. DOI: https://doi.org/10.9734/AJEES/2019/46347

Phiri, C. 2010. Influence of *Moringa Oleifera* Leaf extracts on germination and early seedling development of major cereals. Agriculture and Biology Journal of North America 1(5):774-777. DOI: https://doi.org/10.5251/abjna.2010.1.5.774.777.

Pokwana, S., Tshidzumba, R.P., and Chirwa, P.W. 2021. Evaluating potential of introducing multipurpose tree species in the rural landscapes of Weza, Ugu District municipality, Kwazulu-Natal, South Africa. Tree, Forests and People 3(2021):100055. DOI: https://doi.org/10.1016/j.tfp.2020.100055.

Sahoo, U.K. 2009. Traditional home gardens and livelihood security in North-East India. Journal of Food Agriculture and Environment 7 (2): 665–670.

Saraf, M., Pandya, U., and Thakkar, A. 2014. Role of allelochemicals in plant growth promoting rhizobacteria for biocontrol of phytopathogens. Microbiological Research 169(1): 18-29. DOI: https://doi.org/10.1016/j.micres.2013.08.009

Sharar, M.S., Ayub, M., Nadeem, M.A., and Ahmad, N. 2003. Effect of different rates of nitrogen and phosphorus on growth and grain yield of maize. Asian Journal of Plant Sciences. 2(3): 347-349. DOI: https://doi.org/10.3923/ajps.2003.347.349

Singh, B., and Sharma, K.N. 2007. Tree growth and nutrient status of soil in a poplar (*Populus deltoides* artr.)-based agroforestry system in Punjab, India. Agroforestry Systems 70(2):125-134. DOI: https://doi.org/10.1007/s10457-007-9048-7

Williums, O.A, Ogunwande, O.A., and Amano, O. 2018. Potentials of *Moringa oleifera* leaf extracts in increasing maize (*Zea mays* L.) production in Nigeria. DOI: https://doi.org/10.29322/JSRP.8.12.2018.p8438.

Yasmeen, A., Basra, S.M.A., and Wahid, A. 2011. Performance of late sowed wheat in response to foliar application of *Moringa oleifera* Lam. leaf extract. Chilean Journal of Agriculture Research 72(1):92-97. DOI: http://dx.doi.org/10.4067/S0718-58392012000100015.