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INHIBITORY EFFECT OF EMPTY PALM FRUIT BUNCHES' BIO-OILS AGAINST SEED GERMINATION AND SEEDLING GROWTH OF THREE SELECTED SEEDS

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Abstract: In a search for effective methods for controlling seed germination and growth, bio-oils were produced from pyrolysis of bunches of empty palm fruit at different temperatures. Physicochemical chemical characteristics of the bio-oils were evaluated using standard analytical procedures. Allelopathic activities of the bio-oils were evaluated against three selected seeds (tomatoes, okra and Amaranthus). The percentage germination inhibition was calculated for each seed after 72 h of germination. The yields of the bio-oils are 22.07%, 35.13% and 37.47% at 400 °C, 500 °C, and 600 °C, respectively. The bio-oils are acidic and contain compounds such as phenols, phenol derivatives, alkanes, and organic acids. The results revealed that the empty palm fruit bunches' bio-oils have inhibitory effects on the three selected seeds. The percentage seed germination decreased with increasing concentration of the bio-oils while the inhibitory effect of the bio-oils on seedling growth increased significantly with increasing concentration of the empty palm fruit bunches' bio-oils. The bio-oils obtained at different pyrolytic temperatures showed appreciable allelopathic activities.

1 Introduction

The hazardous environmental issues arising from the use of synthetic herbicides, which started in 1960 after the enormous labour and time consuming associated with traditional ways of controlling weeds, have become unbearable [1,2]. Consequently, the search for alternative ways of controlling weeds, with less detrimental effects, are needed. Among the numerous alternative ways of controlling weed include the usage of allelochemicals [3]. Unlike synthetic herbicides, plant extracts and essential oil are environmentally friendly [4].

Bio-oil is a dark-brown condensable liquid of pyrolysis. Bio-oils are characterized with unpleasant smoky odour, high viscosity and varying quantities of water, depending on the types of biomass. Chemically, bio-oils are complex oxygenated organic compounds that are reformed through catalytic cracking into bio-fuels, which serve as substitutes for liquid fossil fuels in some applications [5]. Bio-oils can be used to produce flavours for food industries and herbicides for agricultural purposes. Other researches have shown the potential application of bio-oils as renewable resins [6].

Allelopathy is a process that involves secondary metabolites from microorganisms or plants to produce inhibitory effects on other plants, insects or microorganisms by influencing their growth and development. It is regarded as the chemical inhibition of one plant (or other organisms) by another plant due to the release of substances, which can act as germination or growth inhibitors, into the environment [7,8]. Allelopathic potential of some plants has been reported to inhibit Medicago polymorphism [9].

Allelochemicals contribute to weed management by releasing toxic chemicals into the soil which suppressed the germination of weed's seed [10,11]. The formation of secondary metabolites depends on the plant family as well as the climatic conditions [12]. The inhibitory effects of allelochemicals depend on their concentration and usage [13]. Oracz et al. [14] and Bogatek et al. [15] reported that the allelopathic extracts from sunflower influenced the

antioxidant system in targeted plants, thereby damaged plant cellular and allowed the cell membrane to be swollen and inhibited the germination of targeted plant which led to loss of seed's vigour. Allelopathic properties are not limited to crude extracts of plants, therefore, research must be extended to other forms of plants' extracts such as plant's oil or biomass oil. Jamil et al. [16] and Farooq et al. [17] reported the importance of allelopathic water extract potential of crop plants in controlling weeds. Oracz et al. [14] reported positive allelopathic potential of polyunsaturated fatty acids against plant cell membrane. In view of this, the present study was carried out to evaluate the inhibitory effect of the bio-oils obtained from slow pyrolysis of the bunches of empty palm fruits against germination and seedling growth of three selected vegetable seeds.

2 Methodology

2.1 Plant sample

Empty palm fruit bunches (*Elaeis guineensis* J.) were obtained from the Teaching and Research Farm of The Federal University of Technology, Akure, Nigeria. The samples were reduced or cut into smaller chips that could be fed into the reactor canister. The biomass was sun-dried for approximately 8 weeks before it was brought to the laboratory and oven-dried at 105 °C for 12 h. The samples were then stored in sample bags prior to pyrolysis.

2.2 Pyrolysis of empty palm fruit bunches

The pyrolysis of the dried biomass feedstock for bio-oil production was carried out using a fixed bed slow pyrolysis at three different temperatures (400, 500 and 600 ℃) as earlier reported [18,19].

A 1.0 kg of empty palm fruit bunches biomass was packed into the pyrolysis canister and placed in the muffle furnace (pyrolyser) for heating. The temperatures of the outer chamber of the furnace were separately set at 450 °C, 550 °C, and 650 °C (furnace temperature) and those of the inner chamber were correspondingly set at 400 °C, 500 °C, and 600 °C (canister temperature). The volatiles escaped from the canister through the hole in the lid when the furnace temperature reached 250 °C, and as the temperature of the furnace was increased, the volatiles escaped continuously and were condensed as pyrolyzed liquid condensates (bio-oil and bio-tar) into reagent bottle immersed in water bath as a receiver in the condensing unit. The non-condensable syngas was allowed to escape into the atmosphere after passing through a water washer. The pyrolytic temperature was maintained until the required experimental temperature was reached, and the reaction time was recorded. The biochar and liquid condensates produced were allowed to cool overnight, removed, weighed and stored in airtight containers while the bio-oil was stored in a clean bottle for further analysis and experiment. The same procedures were used for all the pyrolytic temperatures. All the pyrolytic reactions were carried out in triplicate.

2.3 Characterization of bio-oils

The Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC) and American Society for Testing Materials–Miscellaneous Materials (ASTM D-2866) methods were used to investigate the physicochemical analyses of the empty palm fruit bunches' bio-oils. The bio-oils were also characterized using Fourier Transform Infrared (FTIR) spectroscopy and Gas Chromatography-Mass Spectroscopy (GC-MS).

2.3.1 Treatment

From the bio-oils, three treatments at different concentrations of 1.0%, 2.5%, and 5.0% (w/v) were prepared for each of the temperature, controls were also prepared with distilled water for each bio-oil concentration.

2.3.2 Tested seeds treatment

The seeds were germ screened according to a method described by El-Darier [20]. Okra, Tomatoes and Amaranthus seeds were thoroughly washed, first with tap water and subsequently with distilled water. They were surface-sterilized by soaking for 90 – 300 seconds in a solution of 0.5% sodium hypochlorite, and thereafter rinsed separately 3 – 5 times with distilled water [21].

2.4 In vitro biotest

2.4.1 Seed germination test

The seed germination tests were carried out according to the method reported by Sikolia and Ayuma [22] and Suwal et al. [23] with a little modification. Viable seeds were obtained from Agricultural Development Project (ADP), Akure, Nigeria. Ten (10) uniform seeds of Okra, Tomatoes and Amaranthus were placed in separate Petri dishes lined with a double layer of 9 cm Whatman filter paper, 10 mL of each of the various prepared concentrations (5.0, 2.5 and 1.0% w/v) were added to each of the Petri dish containing filter paper to make it moistened. Ten seeds were counted and placed in each plate and covered. The Petri dishes were then placed inside a dark cupboard. Controls were similarly prepared with distilled water. Triplicates Petri dishes were prepared differently for each concentration as well as each bio-oil produced at different temperatures for the three selected seeds. The percentage germination (%G) of each of the seeds were calculated by dividing the total number of seeds that germinated after 72 h, in each treatment, by the number of seeds sowed multiplied by 100. The percentage germination inhibitions were calculated by comparing with control using Equation 1.

$$\%\, inhibition = \frac{Y-X}{Y} \times 100 \qquad (1)$$

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where *Y* is the number of seeds germination in control, and *X* is the number of seeds germination in treatment.

2.5 Seedling growth test

The tests on seedling growth were performed according to methods reported by Casimiro et al. [24] and Suwal et al. [23], with slight modifications. Healthy seeds were collected from Agricultural Development Project (ADP) in Akure, Nigeria. Different concentrations of 1.0, 2.5, and 5% w/v of the bio-oils were used to treat 9 cm Whatman filter paper placed in a separate Petri dish (10 cm). Ten seeds per treatment were placed in each Petri dish and were covered, and then placed inside a dark cupboard. Controls were similarly prepared with distilled water. The tests were carried out with three replicates per treatment and all the Petri dishes were kept in a dark cupboard at room temperature and relative humidity. The experiments were carried out for 7 days and 14 days after the introduction of the seed. The percentages of seedling growth inhibition were calculated by difference between controls and treated samples using Equation 2.

$$\%\ inhibition = \frac{A-B}{A} \times 100 \qquad (2)$$

where A is the average length of shoot and root in control, and B is the average length of the shoot/root in the tested treatments.

The results of the experiments were expressed as the mean ± standard deviation (SD). The statistical analysis to test the significance differences were conducted using ANOVA and Duncan test, with a $p < 0.05$, which indicates significance. Statistical Package for Social Science (SPSS) version 26 was used for statistical treatment of the data.

3 Results and discussion

3.1 Physicochemical characteristics

Bio-oils were successfully prepared from empty palm fruit bunches at different pyrolytic temperatures. The percentage yields of the bio-oils are 22.07 ± 0.21, 35.13 ± 1.89 and 37.47 ± 1.82 at 400 °C, 500° C, and 600 °C, respectively. The results obtained for the proximate, specific gravity and density of the bio-oil are presented in Table 1. The results showed that the bio-oils had pH values in the range of 2.29 and 2.57. This phenomenon indicates that the three bio-oils are acidic and the high acidity of the bio-oils means that they are corrosive. A number of acidic compounds, such as oleic acid, benzoic acid, and carbamic acid, are present in bio-oils [5]. The moisture contents of the bio-oils are in range of 10.56 and 16.32% wt. These values are higher than those of petroleum diesel and heavy fuel oils, which have low moisture contents of about 0.1% wt. This observation could be due to the high water content of the feedstock, as a result of this, a large amount of water was released into the bio-oils during pyrolysis (lignocellulosic) [25]. The densities of the bio-oils range between 1.0 and 0.92 g/cm3, an indication that the bio-oils are denser than light petroleum oil (diesel oil) with densities of 0.85 g/cm3. The density of heavy oil (0.96) is closer to those of the bio-oils. The specific gravities (0.92 – 1.0) are closer to the values (1.1 – 1.2) reported in literature [26].

The FTIR data and the peak assignments of the empty palm fruit bunches bio-oils at 400 °C and 600 °C are presented in Table 2. The major functional groups present in the bio-oils are O–H, C≡C, C=O, C–O, C–O–C and C–X (X = halide). The results presented in Table 2 are similar to what had been previously reported [27]. According to Keiluweit et al. [28], the C–C stretching vibration at 1595 cm^{-1} could be related to the presence of aliphatic carbon groups or deformation of aromatic groups C=C.

The GC-MS analyses of the bio-oils at 400 °C and 600 °C, with heating rate of 15 °C/min, are presented in Tables 3 and 4, respectively. The standard NIST MS (The National Institute of Standard and Technology Mass Spectral) Library of the bio-oils were used to identified compounds in the tables. The percentage peak areas of the identified compounds were recorded in relation to the yield of the products. There are similarities in the chemical composition of the bio-oils. Most of the common compounds are phenols and phenol derivatives, alkanes, and acids. Mullen et al. [29] reported similar chemical compounds for bio-oils.

Table 1 Physicochemical analysis of the empty palm fruit bunches bio-oils

Temperature (°C)	pH	Specific gravity	Density (g/cm^3)	Moisture content (% wt)	Ash content (% wt)
400	$2.29^{b} \pm 0.01$	$0.93^{a} \pm 0.04$	$1.00^{a} \pm 0.10$	$10.56^{c} \pm 0.51$	$0.31^{a} \pm 0.01$
500	$2.36^{b} \pm 0.02$	$1.10^{a} \pm 0.10$	$0.98^{a} \pm 0.01$	$14.23^{b} \pm 0.21$	$0.42^{a} \pm 0.02$
600	$2.57^{ab} \pm 0.02$	$1.02^{a} \pm 0.01$	$0.92^{a} \pm 0.02$	$16.32^{a} \pm 0.45$	$0.52^{a} \pm 0.01$

3.2 Percentage seed germination

The results obtained for percentage seed germination are presented in Table 5. The results obtained showed that different concentrations of empty palm fruit bunches bio-oils significantly reduced the germination of Tomatoes, Okra and Amaranthus seeds. For 5.0% (w/v) concentration of empty palm fruit bunches bio-oil, Amaranthus had the highest percentage seed germination of 26.67%, tomatoes and okra had no percentage seed germination for bio-oil at 400 °C. Percentage seed germination for Okra and

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Amaranthus was 10.00% each, while Tomatoes had no percentage germination for the bio-oil at 500 °C. Okra had the highest percentage germination (13.33%), followed by Amaranthus (10.00%) for bio-oil at 600 °C. For 2.5% (w/v) concentration empty palm fruit bunches bio-oils at different temperatures, the percentage seed germinations followed this order: Amaranthus (50.00%), Okra (40.00%) and Tomatoes (3.33%); Okra (30.00%), Amaranthus (20.00%) and Tomatoes 0.00%; and Amaranthus (26.67%), Okra (23.33%) and Tomatoes (3.33%) for empty palm fruit bunch bio-oil at 400 °C, 500 °C and 600 °C, respectively. For 1.0% (w/v) concentration of empty palm fruit bunches bio-oils at different temperatures, the percentage seed germinations are in the order: Amaranthus (56.67%), Okra (43.33%) and Tomatoes (6.67%); Amaranthus (60.00%), Okra (50.00%) and Tomatoes (10.00%); and Amaranthus (40.00%), Okra (53.33%) and Tomatoes (10.00%) for empty palm fruit bunches bio-oil at 400 °C, 500 °C and 600 °C, respectively. It can be deduced from the study that the percentage of the seed germination decreases as the concentration of the bio-oil increases.

Table 2 FTIR analysis of the empty palm fruit bunches bio-oils

Temperature (°C)	Wavenumber (cm^{-1})	Peak Assignment
400	3331.95	O–H stretching (phenol, alcohol, water, Keiluwiet *et al.* [28])
600	3329.16	
400	2923.84	C–H stretching
600	2925.25	
400	2093.82	C≡C stretching
600	2153.58	
400	1704.19	C=O stretching
600	1698.01	
400	1595.00	C–C stretching
600	1595.00	
400	1463.19	CH_3 deformation
600	1462.16	
400	1373.42	O–H bending of phenolic (Keiluwiet *et al.* [28])
600	1374.93	
400	1227.01	C–O–C stretching aryl-alkyl ether linkage
600	1232.47	
400	1110.56	Symmetric C–O stretching (Keiluwiet *et al.* [28])
600	1109.13	
400	752.76	C–X, Alkyl halide
600	752.67	

Table 3 Compounds in empty palm fruit bunches bio-oil at 400 °C

S/NO	Identified Compound	Retention Time (min)	Peak Area (%)	Molecular Formula
1	**Pyridine**	4.34	0.12	$C_7H_6N_2$
2	**2-Furanmethanol**	7.94	0.13	$C_5H_6O_2$
3	**Mequinol**	17.05	4.47	$C_7H_8O_2$
4	***p*-Cresol**	17.91	2.18	$CH_3C_6H_4OH$
5	**Phenol**	28.83	10.95	C_6H_5OH
6	**Vanillin**	30.57	0.29	$C_8H_8O_3$
7	**3,5-Dimethoxy-4-hydroxytoluene**	32.14	1.37	$C_9H_{12}O_3$
8	**Butyrovanillone**	37.55	0.17	$C_{11}H_{14}O_3$
9	**2,6-dimethoxy-4-(2-propenyl)-Phenol**	37.91	0.18	$C_{11}H_{14}O_3$
10	**Benzaldehyde**		0.22	C_7H_6O
11	**Ethanone**	40.24	0.38	C_2H_3O
12	***n*-Hexadecanoic acid**	42.81	0.48	$CH_3(CH_2)_{14}COOH$
13	**9-Octadecenoic acid**	50.63	0.11	$C_{18}H_{34}O_2$
14	**Oleic acid**	54.17	0.13	$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$

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Table 4 Compounds in empty palm fruit bunches bio-oil at 600 °C

S/NO	Identified Compound	Retention Time (min)	Peak Area (%)	Molecular Formula
1	**Phenol**	16.79	7.33	C_6H_5OH
2	***p*-Cresol**	17.67	3.25	$CH_3C_6H_4OH$
3	**2,6-dimethoxy-phenol**	28.60	7.71	$C_8H_{10}O_3$
4	**Benzoic acid**	28.90	0.30	$C_7H_6O_2$
5	**Vanillin**	30.53	0.44	$C_8H_8O_3$
6	**3,5-Dimethoxy-4-hydroxytoluene**	32.12	1.37	$C_9H_{12}O_3$
7	**Butyrovanillone**	37.63	0.44	$C_{11}H_{14}O_3$
8	**Heptacosane**	63.35	0.28	$C_{27}H_{56}$
9	**1,1'-Biphenyl**	67.47	0.02	$C_6H_5C_6H_5$

These results agreed with those obtained by Sikolia and Ayuma [22] and Anwar et al. [30]. In the report of Sikolia and Ayuma, the germination percentage of cowpea seeds decreased with an increase in the concentration of shoot aqueous extract of Eucalyptus saligna. Similar results were reported by Ilori et al. [31] and Malik [32]; these authors reported that the solvent extract reduced germination percentages and germination rates. Similarly, Zribi et al. [33] reported that the percentage seed germination of Lactuca sativa in the presence of aqueous extract at different concentrations of Tunisian and Indian varieties of Nigella sativa seeds decreased with an increase in concentration of the extract. However, there were no significant differences ($p < 0.05$) in germination percentages among the bio-oils (individual temperatures) for Tomatoes seed, but there were significant differences among bio-oils (individual temperatures) for Amaranthus and Okra seeds as shown in Table 5.

Table 5 Percentage seed germination of empty palm fruit bunches bio-oil on three selected seeds

Temperature (°C)	Concentration (%)	Crops		
		Tomatoes	Okra	Amaranthus
400	1.0	6.67 ± 5.77^{b}	43.33 ± 20.82^{b}	56.67 ± 15.28^{ab}
	2.5	3.33 ± 5.77^{b}	40.00 ± 20.82^{b}	50.00 ± 20.00^{bc}
	5.0	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}	26.67 ± 15.28^{c}
	Control	90.00 ± 10.00^{a}	96.67 ± 5.77^{a}	96.33 ± 5.77^{a}
500	1.0	10.00 ± 10.00^{b}	50.00 ± 26.46^{b}	60.00 ± 17.32^{a}
	2.5	0.00 ± 0.00^{b}	30.00 ± 10.00^{bc}	20.00 ± 10.00^{b}
	5.0	0.00 ± 0.00^{b}	10.00 ± 10.00^{c}	10.00 ± 10.00^{b}
	Control	95.00 ± 10.00^{a}	93.33 ± 5.77^{a}	98.33 ± 15.28^{a}
600	1.0	10.00 ± 10.00^{b}	53.33 ± 5.77^{b}	40.00 ± 20.00^{b}
	2.5	3.33 ± 5.77^{b}	23.33 ± 5.77^{c}	26.67 ± 5.77^{c}
	5.0	0.00 ± 0.00^{c}	13.33 ± 5.77^{c}	10.00 ± 10.00^{c}
	Control	89.00 ± 10.00^{a}	94.33 ± 5.77^{a}	100.33 ± 5.77^{a}

Values are means of triplicate ± standard deviation. Means of the column followed by the same superscript letters are not significantly different at $p < 0.05$.

3.3 Seedling growth bioassay

The results of the percentage inhibition of the seedling growth are presented in Table 7. From the results obtained, it was observed that the percentage inhibitions of seedling growth of shoot and root length of Tomatoes, Okra and Amaranthus significantly increased as the concentration of empty palm fruit bunches bio-oils increased. For 5.0% (w/v) concentration of the bio-oil, the inhibition activities were high for shoot length and root length at 7th and 14th days for Tomatoes, Okra and Amaranthus seeds at all temperatures. For 2.5% (w/v) concentration of the bio-oil, the inhibition activities were also high for shoot length at 7th and 14th days for Tomatoes, Okra, and Amaranthus at all temperatures. For 1.0% (w/v) concentration of the bio-oil, the inhibition activities were substantially good for root length at 7th day for tomatoes (all temperatures); bio-oil at 400 °C for Okra, bio-oils at 400 °C and 500 °C for Amaranthus, bio-oils at 500 °C and 600 °C for Okra. At 600 °C. Amaranthus has highest value for shoot length at 7th day. Similarly, the inhibition activities were high for shoot length at 14th day for okra at all temperatures for Tomatoes at 500 °C, but high for root length at day 14th for Amaranthus and bio-oils at 400 °C, 600 °C for Tomatoes. The result in Table 7A-C showed that the seedling growth on percentage inhibition of shoot and root length increased as the bio-oil concentration was increased. The result from the present study is in agreement with the reports of Cheema and Khaliq [38], Rafiqul-Hoque et al. [39], and Adetayo et al. [40]. These authors emphasized

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that the inhibitory effects were proportional to the concentration of the extracts, that is, the higher concentration of inhibiting species, the stronger the inhibition. In some cases, low concentrations of inhibiting substance showed stimulatory effect. Sarmin [41] observed 14% and 8% reduction in seed germination of cowpeas and soya bean treated with the water extract of C. odorata leaves and stems, respectively. For the shoot and root lengths of Tomatoes, Okra, and Amaranthus seedlings treated with empty palm fruit bunches bio-oils at different temperatures were observed to be significantly different compared to the control.

Table 7A Percentage inhibition of empty palm fruit bunches bio-oil against Tomatoes

Temperature (°C)	Concentration (%)	Tomatoes			
		7 days		14 days	
		Shoot	Root	Shoot	Root
400	1.0	42.11±21.54^{b}	53.33±10.10^{b}	57.14±14.29^{b}	69.70±8.02^{b}
	2.5	83.33±8.49^{a}	73.24±22.57^{b}	91.23±0.00^{a}	86.27±5.89^{a}
	5.0	97.67±2.33^{a}	97.50±2.50^{a}	98.33±1.44^{a}	97.14±2.85^{a}
	Control	16.67±5.77^{c}	16.67±5.77^{c}	10.00±5.77^{c}	8.23±5.77^{c}
500	1.0	52.63±20.89^{b}	53.33±15.07^{c}	77.14±12.45^{b}	76.34±8.12^{b}
	2.5	90.12±1.07^{a}	72.98±4.68^{b}	94.92±2.93^{a}	91.16±5.14^{a}
	5.0	99.22±1.35^{a}	98.33±2.89^{a}	99.26±1.28^{a}	98.10±3.30^{a}
	Control	6.67±4.45^{c}	6.67±4.45^{d}	8.92±2.14^{c}	3.98±1.56^{c}
600	1.0	42.10±30.35^{b}	54.17±21.55^{b}	61.76±5.89^{b}	65.52±9.12^{b}
	2.5	83.95±7.48^{a}	72.97±16.88^{b}	91.23±5.27^{a}	91.51±2.99^{a}
	5.0	99.22±1.35^{a}	98.33±2.89^{a}	99.19±1.41^{a}	98.99±1.75^{a}
	Control	10.76±3.77^{b}	9.34±4.19^{c}	11.01±1.34^{c}	8.17±3.78^{c}

Values are means of triplicates ± standard deviation. Means of the column followed by the same superscript letters are not significantly different at $p < 0.05$

Table 7B Percentage inhibition of the bio-oils against Okra

Temperature (°C)	Concentration (%)	Okra			
		7 days		14 days	
		Shoot	Root	Shoot	Root
400	1.0	24.24±29.23^{b}	37.63±6.71^{c}	55.21±15.42^{b}	52.78±13.39^{b}
	2.5	69.93±12.76^{a}	65.79±11.47^{b}	83.33±7.22^{a}	77.09±6.51^{a}
	5.0	90.38±8.38^{a}	84.85±4.73^{a}	86.21±12.43^{a}	83.33±13.89^{a}
	Control	6.67±5.77^{b}	6.67±5.77^{d}	16.67±5.77^{c}	10.54±5.77^{c}
500	1.0	62.57±9.01^{b}	46.67±24.02^{b}	42.71±13.01^{b}	38.89±30.71^{b}
	2.5	79.10±4.26^{b}	67.36±8.42^{b}	85.00±10.00^{a}	79.17±10.05^{a}
	5.0	98.75±2.17^{a}	96.79±5.55^{a}	96.88±5.41^{a}	90.91±15.74^{a}
	Control	3.33±3.32^{d}	6.67±5.77^{c}	5.11±1.02^{c}	2.56±2.51^{c}
600	1.0	63.33±8.12^{b}	58.33±10.10^{b}	58.34±12.63^{b}	47.22±26.78^{b}
	2.5	78.70±17.86^{a}	62.96±16.14^{b}	88.33±8.78^{a}	83.34±11.83^{a}
	5.0	95.11±5.05^{a}	93.83±4.28^{a}	94.25±9.95^{a}	93.94±10.50^{a}
	Control	10.00±0.00^{c}	10.00±0.00^{c}	7.34±0.61^{c}	5.83±1.23^{c}

Values are means of triplicates ± standard deviation. Means of the column followed by the same superscript letters are not significantly different at $p < 0.05$

Table 7C Percentage inhibition of the bio-oils against Amaranthus

Temperature (°C)	Concentration (%)	Amaranthus			
		7 days		14 days	
		Shoot	Root	Shoot	Root
400	1.0	38.64±17.75^{c}	48.89±18.36^{b}	63.96±3.12^{c}	64.51±5.59^{b}
	2.5	50.00±11.47^{b}	40.69±15.45^{bc}	78.84±3.33^{b}	71.67±2.89^{b}
	5.0	98.41±2.75^{a}	97.92±3.61^{a}	97.78±1.92^{a}	96.58±2.89^{a}
	Control	8.56±6.00^{d}	5.78±3.87^{d}	13.33±5.77^{d}	13.33±5.77^{c}
500	1.0	34.96±18.63^{c}	41.88±22.11^{b}	51.43±11.15^{c}	55.24±13.31^{b}
	2.5	61.77±5.09^{b}	29.63±19.51^{b}	74.79±11.26^{b}	76.85±3.21^{a}
	5.0	89.52±3.30^{a}	78.67±14.05^{a}	97.85±0.94^{a}	91.43±4.95^{a}

600	Control	3.83±8.30^{d}	6.12±10.00^{d}	9.19±0.12^{d}	8.87±2.11^{c}
	1.0	46.34±15.99^{b}	33.33±14.43^{c}	50.00±19.24^{b}	55.56±15.39^{b}
	2.5	79.41±20.38^{a}	68.52±11.56^{b}	95.43±1.13^{a}	88.57±4.95^{a}
	5.0	95.50±3.12^{a}	91.67±0.00^{a}	98.41±0.00^{a}	97.06±0.00^{a}
	Control	10.00±5.77^{c}	4.87±2.81^{d}	6.23±5.77^{c}	5.29±2.91^{c}

Values are means of triplicates ± standard deviation. Means of the column followed by the same superscript letters are not significantly different at $p < 0.05$.

4 Conclusions

Bio-oils were successfully obtained from bunches of empty palm fruit. Inhibitory effects of the bio-oils against seed germination and seedling growth of Tomatoes, Okra and Amaranthus were investigated. Bio-oils obtained from empty palm fruit bunches at pyrolytic temperatures of 400 °C, 500 °C and 600 °C exhibited allelopathic properties on the selected seeds. The bio-oils reduced the percentage seed germination and seedling growth. The inhibitory activities of the bio-oils on shoot and root of the plants were dependent on the concentration of the bio-oils. The bio-oils obtained from the lignocellulosic waste (bunches of empty palm fruit) could be used agrochemicals.

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