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SEASONAL IMPACT OF QUARRY MINING EFFLUENT DISCHARGE IMPACTED SOILS ON GROWTH PARAMETERS AND PHYTOCHEMICAL CONSTITUENTS OF EDIBLE VEGETABLES

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Abstract

This study was designed to assess the impact quarry mining effluent discharge impacted soil on growth parameters and phytochemical constituents of edible vegetables. Three quarry mining sites were used for the study that covered wet and dry seasons. Plant growth such as plant height, leaf area, internodes and plant collar diameter were measured while plant phytochemical composition was analysed using Gas chromatography flame ionization detector (GC-FID). Results indicated decrease in plant growth and plant chlorophyll content in dry season compared to wet season (P<0.05). This values were however significantly lower than the control. Phytochemical constituents of vegetables as observed from this study increased in dry season in response to trace metal stress. The results imply that mining activities impacted negatively on the growth of these edible vegetables. This is indicative of potential health risk that may be associated with prolonged consumption of edible vegetables grown in these soils. Hence farmers should be discouraged from planting edible plants around these quarry sites as this may have detrimental effect on health of consumers.

Key Words: *Quarry mining, Phytochemicals, Edible vegetables, Plant growth, Effluent discharge*

Introduction

Plants are always under threat due to various biotic and abiotic stresses. Dust from quarry mining activities have been noted to not only cause air pollution in terms of deposition on surfaces and possible health effect but can also have physical effect on the surrounding plants by blocking and damaging their internal structure, abrasion of leaves and cuticles which may affect long term survival of plants (Lameed and Ayodele, 2010). Iqbal and Shafig, (2001) reported that dust from quarry mining sites are known to cause vegetation injury, crop yield loss, reduction in plant cover, height and number of leaves. Plants are affected when these tailings settle on leaves surface, it impedes respiration and photosynthesis and thus become a threat to the survival of plants in mining areas (Wang, 2007). In Ishiagu, Southeastern Nigeria, quarry; lead and zinc mining have been going on for over fifty years

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and in recent times their exploration have been intensified with attendant problems un-addressed (Obiekezie *et al.*,2006; Nwaugo *et al.,* 2007b; Ogbonna *et al.,* 2013; Akubugwo *et al.,* 2015). These quarry mining industries discharge dust and effluent which settles not only on land, plants and trees but also on surface waters used for drinking and other domestic chores by the rural dwellers (Osha, 2006). In view of this, there is need to determine the impact of these mining effluents discharge on plant growth and phytoconstituents as the inhabitants are mainly farmers producing farm products not only for local consumption but for food supply to other parts of the country.

Study Area

Ishiagu the study area is a community where lead/zinc mine and quarry mining is the major industrial activities. The major economic activity in the study area is mainly mining and agriculture where farm products like cassava, vegetables, yam, cocoa yam and rice are produced. These crops and vegetables are produced not only for local consumption but for food supplies to other parts of Nigeria. Three different quarry mining effluent discharge soils were used for the study. The vegetables were planted *in situ* in dry and wet season.

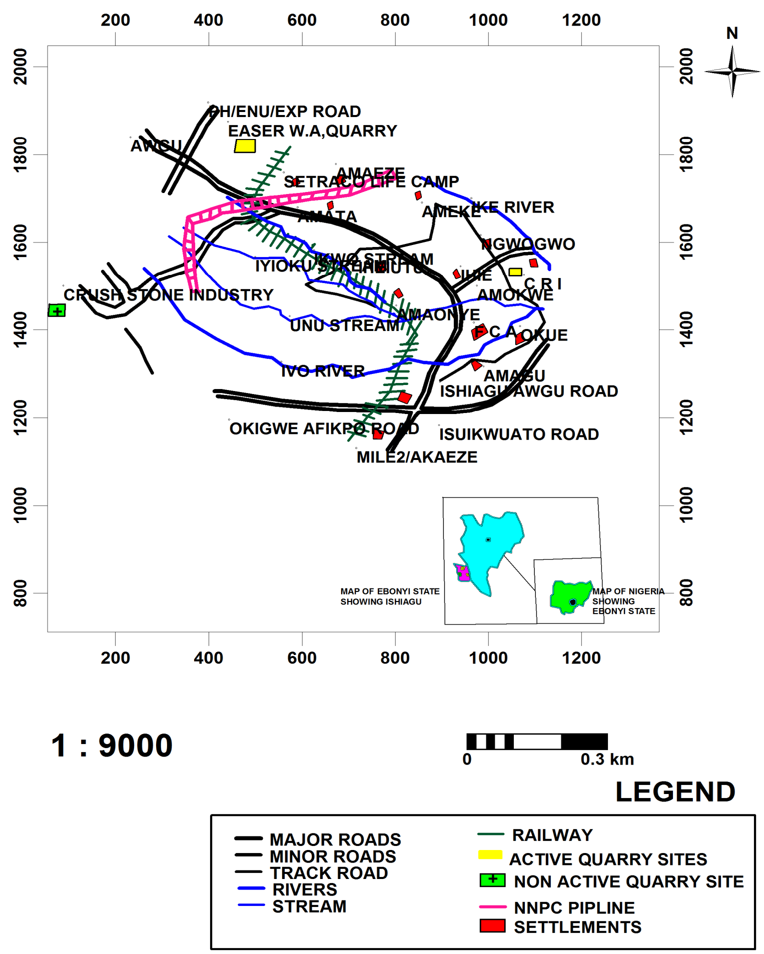

Figure 1: Map of Ishiagu Quarry Sites Showing Sampling Locations

Measurement of Plant Growth Parameters and Phytochemical Constituents

Plant growth parameters were measured according to the method described by Akonye and Nwauzoma (2003) while phytochemical composition such as flavonoid, carotenoid, Phenolic compounds and Lignin were determined using GC-Fid as described by AOAC (2009).

Data Analysis

Data collected were subjected to statistical analysis using One Way Analysis of Variance (ANOVA) and t-test statistic. Values are mean of triplicate determination ± standard deviation. The mean of the samples were compared to control using ANOVA while mean of the two seasons were compared using student t-test. The individual mean differences were ascertained using Least Significant Difference (LSD) as described by Onuh and Igwemma, (2000). The student package for social sciences (SPSS) version 20 computer software was used for the analysis.

Results and Discussion

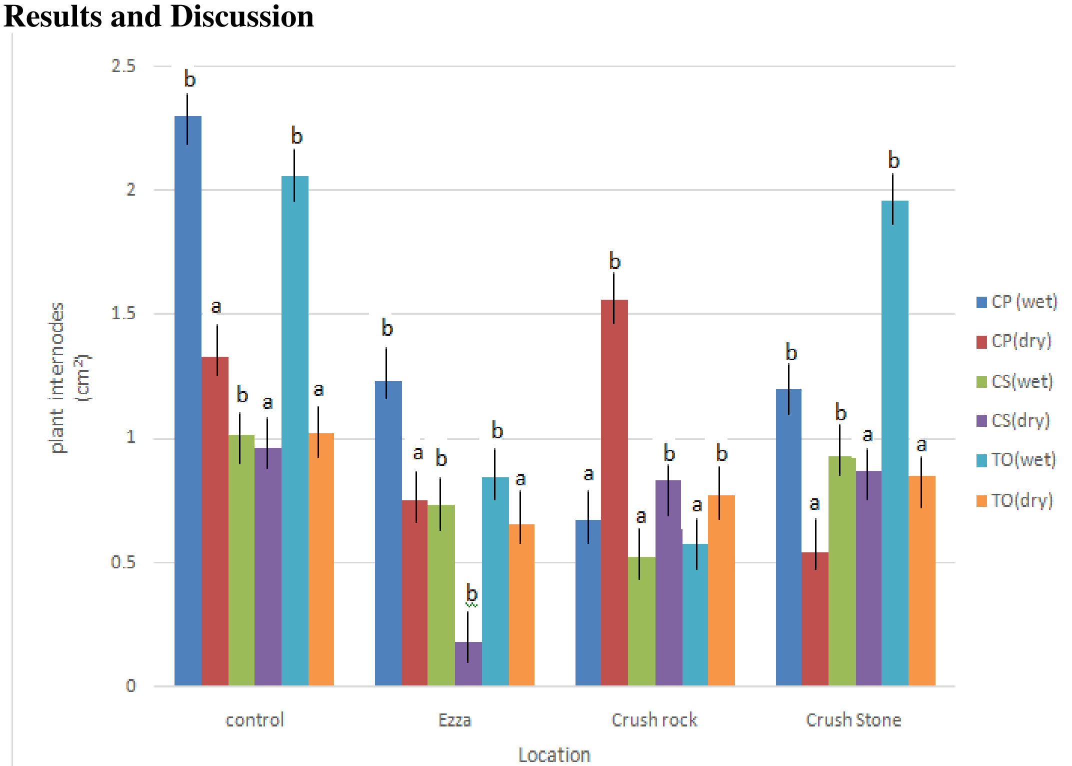

Figure 2: Comparative assessment of plant internodes performance (cm^2) of vegetables grown in quarry mining effluent discharge soild in wet and dry season. CP = *Cucurbita pepo,* CS = *Cucumis sativus,* TO = *Telferia occidentalis*

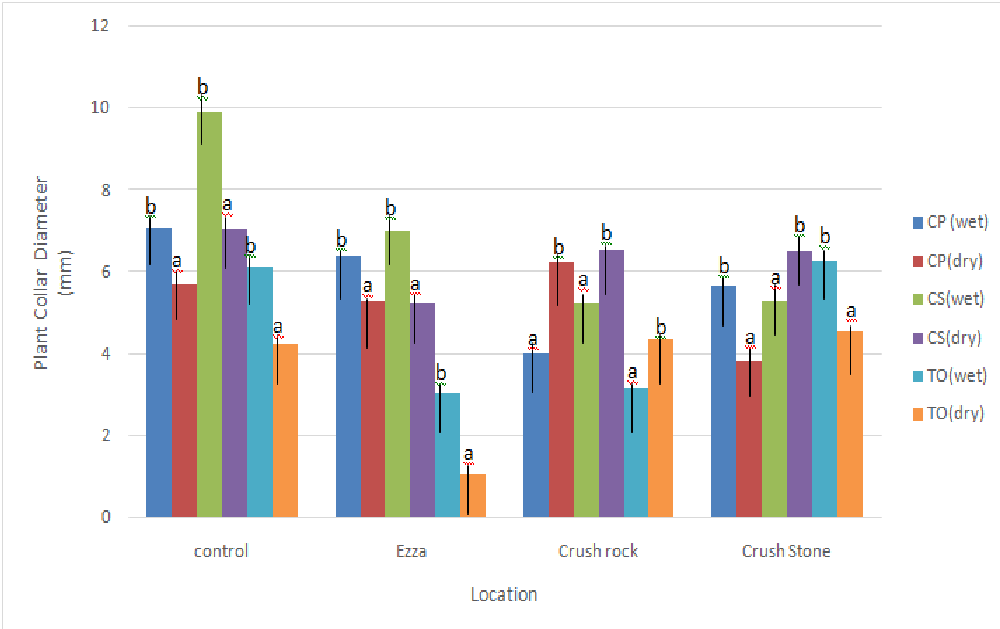

Figure 3: Comparative assessment of plant collar diameter performance (mm) of vegetables grown in quarry mining discharge soils in wet and dry seasons. CP = *Cucurbita pepo,* CS = *Cucumis sativus,* TO = *Telferia occidentalis*

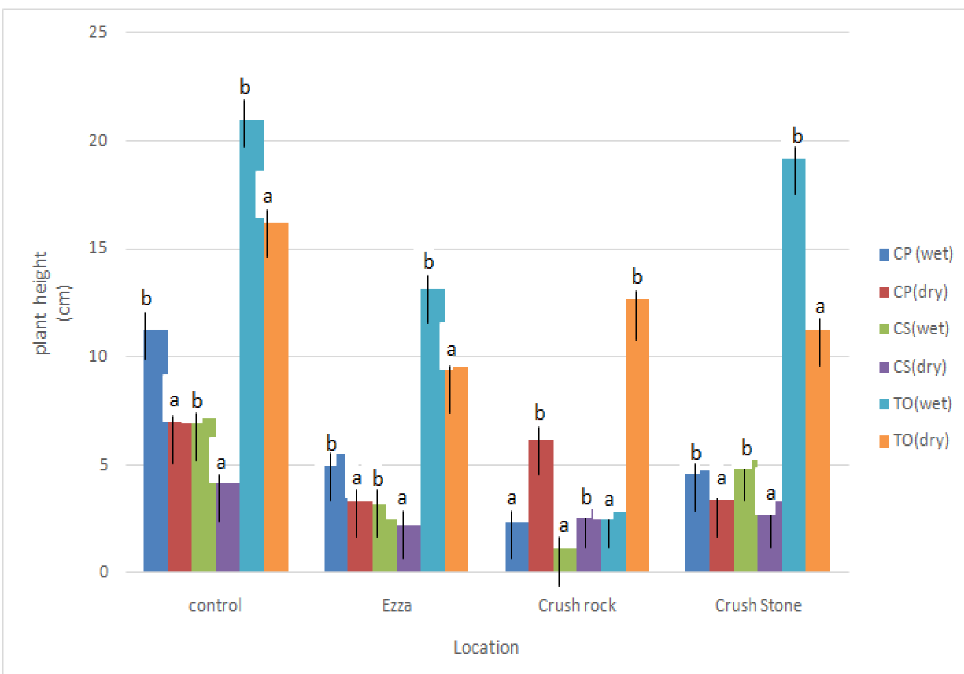

Figure 4: Comparative assessment of plant height performance of vegetables grown in quarry mining effluent discharge soils (cm) CP = *Cucurbita pepo,* CS = *Cucumis sativus,* TO = *Telferia occidentalis*

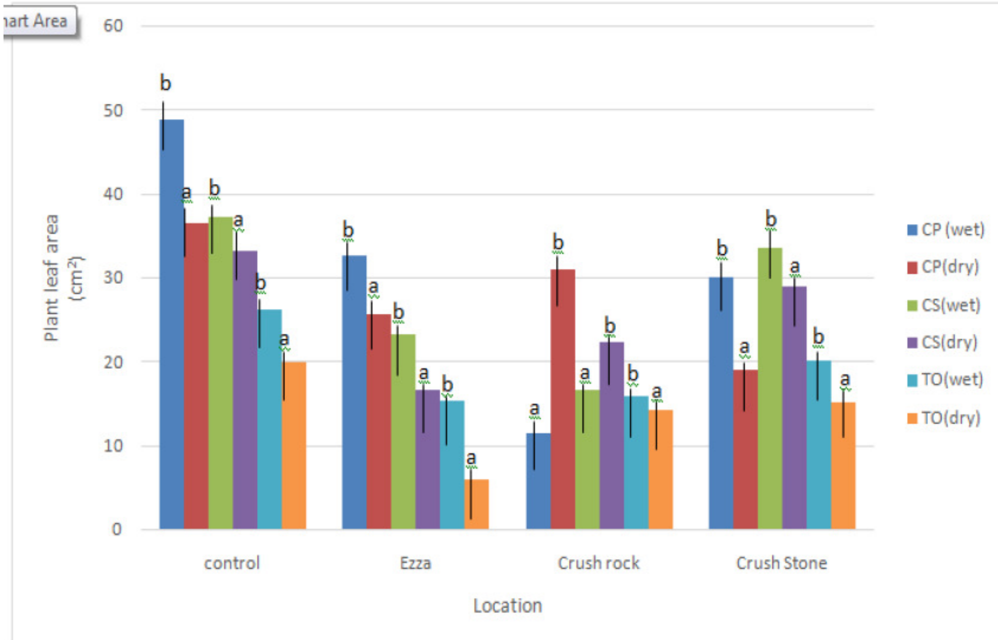

Figure 5: Comparative assessment of plant leaf area performance (cm^2) of vegetables grown in quarry mining effluent discharge soils in wet and dry seasons. CP = *Cucurbita pepo,* CS = *Cucumis sativus,* TO = *Telferia occidentalis*

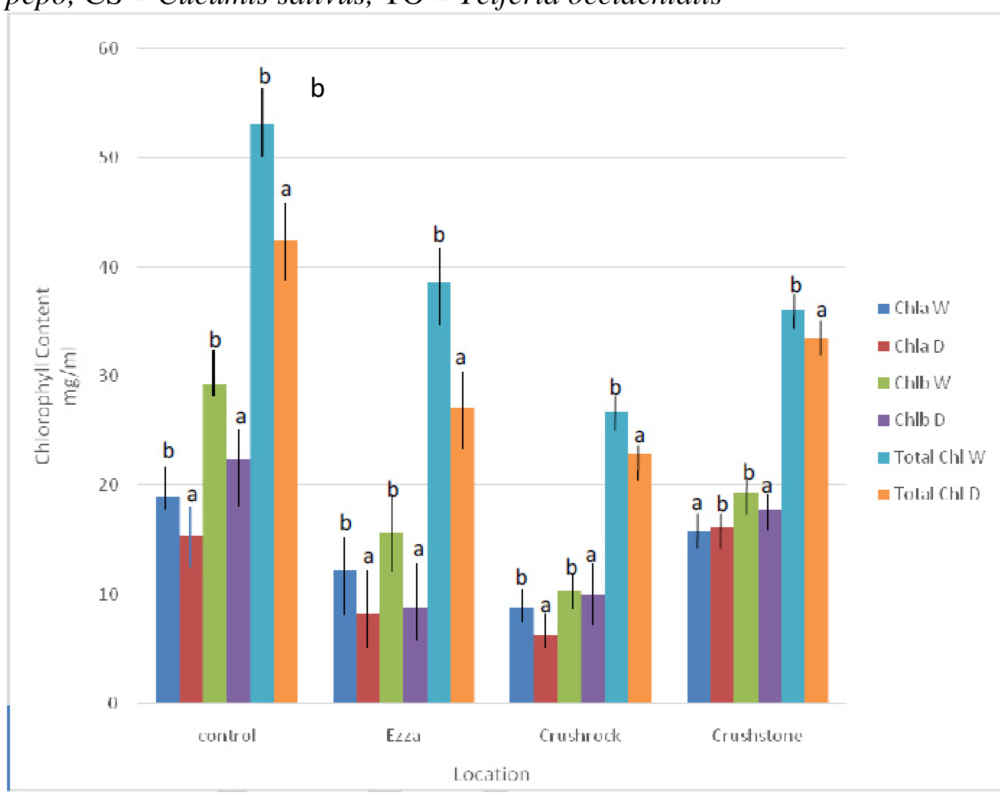

Figure 6: Comparative assessment of chlorophyll content of *Cucurbita pepo* vegetable in wet and dry season (mg/ml). W= wet seon, D= dry season

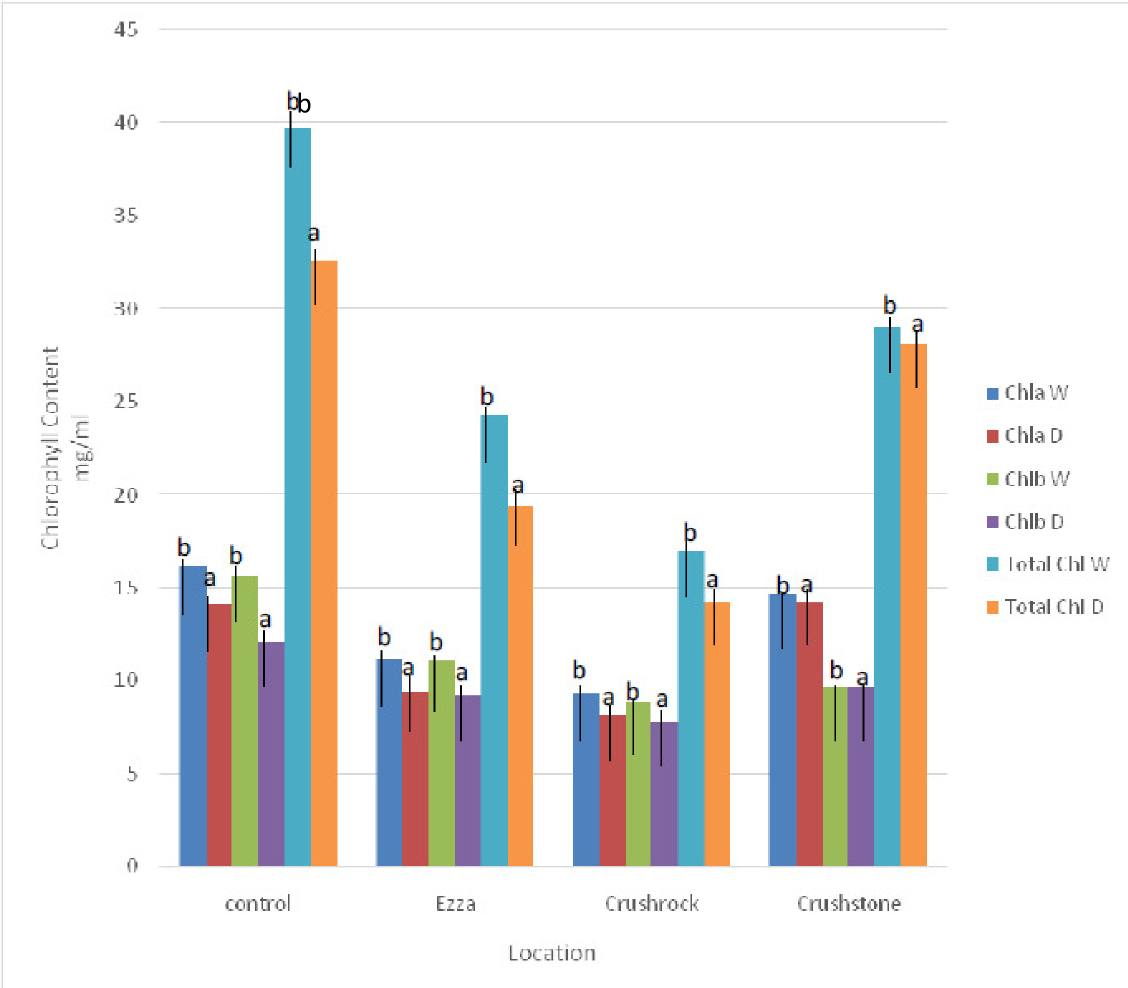

Figure 7: Comparative assessment of chlorophyll content of *Cucumis sativus* in wet and dry seasons (mg/ml). W= wet season, D= dry season

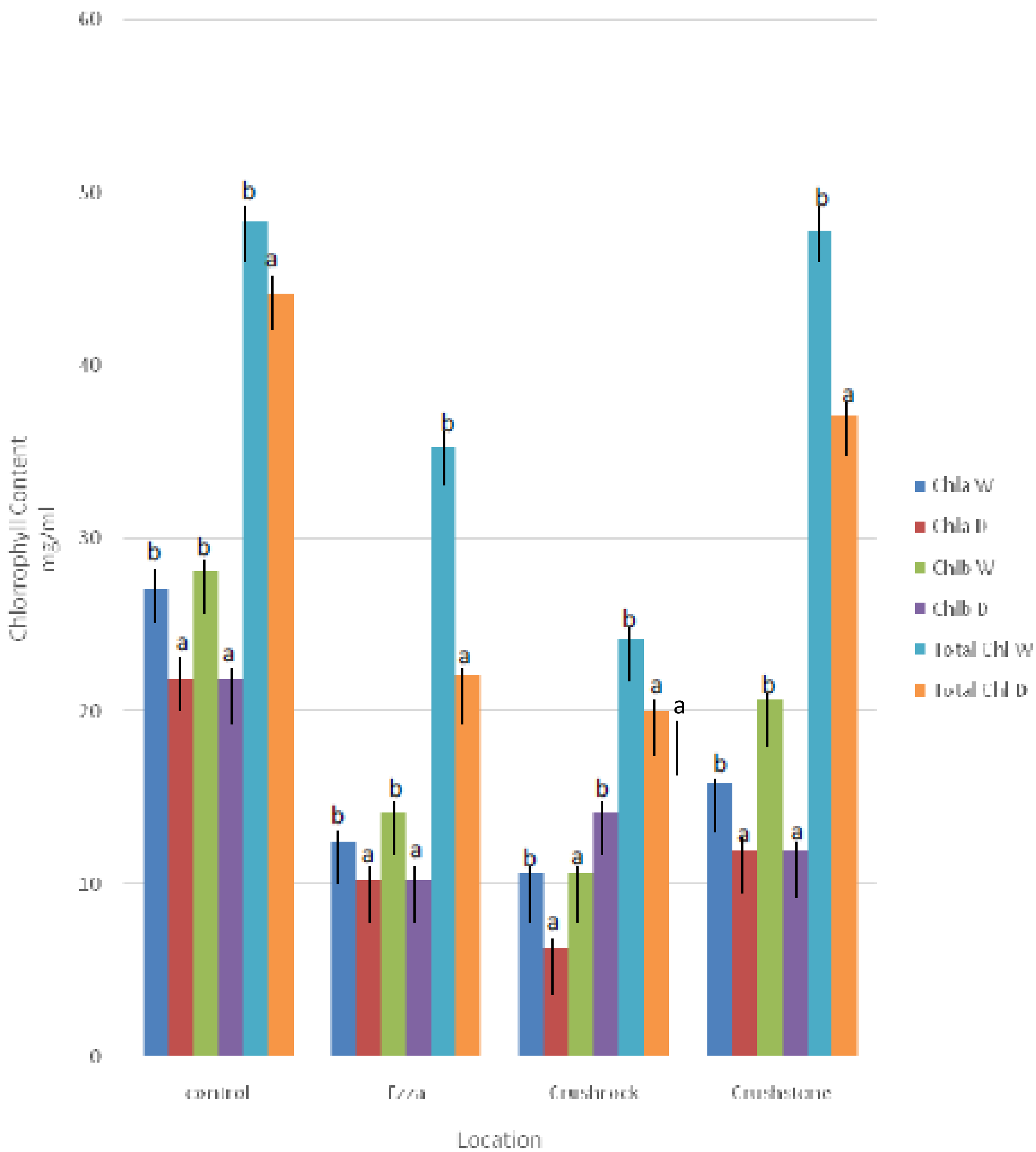

Figure 8: Comparative assessment of chlorophyll content of *Taliferia occidentalis* (mg/ml) in wet and dry season. W= wet season, D= dry season.

Table 1: Carotenoid content of *Cucurbita pepo* vegetable grown in quarry mining effluent discharge soils (mg/100g)

Name of compound	Control Wet season	Sample Wet season	Control Dry season	Sample Dry season
Malvidin	0.0857	0.1125	0.5786	0.9044
Carotene	0.0325	0.0657	0.723	1.0526
Lycopene	0.09492	0.12172	0.56958	0.89518
Beta-crytoxanthin	0.3328	0.3596	0.3315	0.6573
Lutein	0.2544	0.2812	0.4101	0.7357
Anther-xanthin	0.0871	0.1139	0.5774	0.903
Asta-xanthin	0.0125	0.0457	0.707	1.0326
Viola-xanthin	0.4874	0.5142	0.1773	0.5027
Neo-xanthin	0.6624	0.6892	0.0021	0.3277
Xanthophylls	0.1584	0.1852	0.5062	0.831

Table 2: Carotenoid content of *Cucumis sativus* grown in quarry mining effluent discharge soils (mg/100g)

Name of compound	Control Wet season	Control Dry season	Sample Wet season	Sample Dry season
Malvidin	0.0033	0.1022	0.0331	0.1277
Carotene	0.115	0.046	0.1651	0.205
Lycopene	0.00592	0.11142	0.04232	0.13692
Beta-crytoxanthin	0.2438	0.3493	0.2802	0.3748
Lutein	0.1654	0.2709	0.2018	0.2964
Anther-xanthin	0.0019	0.1036	0.0345	0.1291
Asta-xanthin	0.0315	0.026	0.1951	0.0605
Viola-xanthin	0.3984	0.5039	0.4348	0.5294
Neo-xanthin	0.5734	0.6789	0.6098	0.7044
Xanthophylls	0.0694	0.1749	0.1058	0.2004

Table 3: Carotenoid content of *Taliferia occidentalis* grown in quarry mining effluent discharge soils (mg/100g)

Name of compound	Control Wet season	Control Dry season	Sample Wet season	Sample Dry season
Malvidin	0.0481	0.2079	0.0582	0.2784
Carotene	0.1963	0.0597	0.2064	0.4266
Lycopene	0.0389	0.21712	0.04898	0.26918
Beta-crytoxanthin	0.189	0.0313	0.1989	0.455
Lutein	0.1106	0.1097	0.1205	0.3766
Anther-xanthin	0.0467	0.2093	0.0568	0.277
Asta-xanthin	0.1763	0.0797	0.1864	0.4066
Viola-xanthin	0.3516	0.1096	0.4435	0.6233
Neo-xanthin	0.5286	0.2846	0.585	0.7983
Xanthophylls	0.0246	0.2016	0.017	0.2857

Table 4: Phenolic content of *Cucurbita pepo* vegetable grown in quarry mining effluent discharge soils (mg/100g)

Name of compound	Control Wet season	Sample Wet season	Control Dry season	Sample Dry season
4-hydroxy benzaldehyde	0.0167	0.1920	0.0599	0.6760
4-hydroxybenzoic acid	0.0693	0.3340	0.0125	0.1500
4-hydroxybenzoic acid methyl ester	0.0920	0.4510	0.0340	0.9350
Vanillic acid	0.0237	0.5960	0.0195	1.0800
Gallic acid	0.1420	0.2170	0.0574	0.7010
Ferulic acid	0.0431	0.7900	0.0010	1.2740
Capsaicin	0.0400	0.3990	0.3920	0.8830
Rosmarinic acid	0.0927	0.5680	0.0359	0.4840
Tannic acid	0.044	0.0900	0.0881	0.3940

Table 5: Phenolic content of *Cucumis sativus* grown in quarry mining effluent discharge soils (mg/100g).

Name of compound	Control Wet season	Control Dry season	Sample Wet season	Sample Dry season
4-hydroxy benzaldehyde	0.133	0.450	0.155	0.510
4-hydroxybenzoic acid	0.065	0.076	0.371	0.016
4-hydroxybenzoic acid methyl ester	0.126	0.709	0.414	0.769
Vanillic acid	0.271	0.854	0.559	0.914
Gallic acid	0.010	0.475	0.128	0.535
Ferulic acid	0.465	1.048	0.753	1.108
Capsaicin	0.074	0.657	0.362	0.717
Rosmarinic acid	0.089	1.310	0.605	1.250
Tannic acid	0.150	0.168	0.172	0.228

Table 6: Phenolic content of *Taliferia occidentalis* vegetable grown in quarry mining effluent discharge soils (mg/100g)

Name of compound	Control Wet season	Control Dry season	Sample Wet season	Sample Dry season
4-hydroxy benzaldehyde	0.3420	0.7210	0.3770	0.8560
4-hydroxybenzoic acid	0.1840	0.2470	0.9030	0.3820
4-hydroxybenzoic acid methyl ester	0.0601	0.4620	0.1180	0.5970
Vanillic acid	0.0746	0.3170	0.2700	0.4520
Gallic acid	0.0367	0.6960	0.3520	0.8310
Ferulic acid	0.0940	0.1230	0.2210	0.2580
Capsaicin	0.0549	0.5140	0.1700	0.6490
Rosmarinic acid	0.0418	0.0481	0.1370	0.6160
Tannic acid	0.0600	0.0030	0.6590	0.1380

Table 7: Flavonoid content of *Cucurbita pepo* grown in quarry mining effluent discharge soils (mg/100g)

Name of compound	Control Wet season	Control Dry season	Sample Wet season	Sample Dry season
Catechi	0.4611	0.6005	0.5801	0.6066
Resveratrol	0.2119	0.3513	0.3309	0.3574
Genistein	0.0072	0.1322	0.1118	0.1383
Daidzein	0.0348	0.1742	0.1538	0.1803
Apigein	0.027	0.1124	0.092	0.1185
Butein	0.3698	0.5092	0.4888	0.5153
Naringenin	0.0002	0.1392	0.1188	0.1453
Biochanin	0.1182	0.0212	0.0008	0.0273
Luteolin	0.0178	0.1572	0.1368	0.1633
Kaemferol	0.2828	0.4111	0.4018	0.4217
(-) Epicatechin	0.0808	0.2200	0.1998	0.2274
(-)Epigalocatechin	0.0038	0.1490	0.1228	0.1496
Quercetin	0.6508	0.7902	0.7698	0.7968
Gallocatechin	0.1484	0.009	0.0294	0.0029
(-) Epicatechin -3-gallate	0.167	0.0215	0.048	0.0276
(-)Epigallocatechin-3-gallate	0.1212	0.0182	0.0022	0.0243
Isorhamnetin	0.1258	0.2652	0.2448	0.2713
Robinetin	0.2868	0.4262	0.4058	0.4323
Ellagic acid	0.0932	0.0462	0.0258	0.0523
Myricetin	0.2848	0.4242	0.4038	0.4303
Baicalein	0.0522	0.0872	0.0668	0.0933
Nobicalein	0.3618	0.5012	0.4808	0.5073
Kaempferol -3,7,4,-trimethyl ether	0.0008	0.1402	0.1198	0.1463
Quercetin-3,7,4’–trimethyl ether	0.2128	0.3522	0.3318	0.3583
Baicalin	0.1221	0.0173	0.0031	0.0234
Tangeretin	0.1269	0.0125	0.0079	0.0186
Quercetin-3,7,3’,4’-tetramethyl ether	0.1385	0.0009	0.0195	0.007
Artemetin	0.1952	0.0498	0.0762	0.0556
Hyperoside	0.0908	0.2302	0.2098	0.2363
Silymarin	0.1968	0.3362	0.3158	0.3423
Kaempferol-3-Arabinoside	0.1468	0.2862	0.2658	0.2923
Quercitrin	0.0672	0.2066	0.1862	0.2127
Naringin	0.1299	0.0095	0.0109	0.0156
Isoquercetin	0.128	0.0114	0.009	0.0175
Oriebtin	0.7613	0.9007	0.8803	0.9068
Rutin	0.2895	0.4289	0.4085	0.435
Isoorientin	0.90931	1.04871	1.02831	1.05481
Hesperidin	0.4611	0.6005	0.5801	0.8000

Table 8: Flavonoid content of *Cucumis sativus* grown in quarry mining effluent discharge soils (mg/100g)

Name of compound	Control Wet season	Control Dry season	Sample Wet season	Sample Dry season
Catechi	0.6147	0.653	0.6329	0.662
Resveratrol	0.3655	0.4038	0.3837	0.4128
Genistein	0.1464	0.1847	0.1646	0.1937
Daidzein	0.1884	0.2267	0.2066	0.2357
Apigein	0.1266	0.1649	0.1448	0.1739
Butein	0.5234	0.5617	0.5416	0.5707
Naringenin	0.1534	0.1917	0.1716	0.2007
Biochanin	0.0354	0.0737	0.0536	0.0827
Luteolin	0.1714	0.2097	0.1896	0.2187
Kaemferol	0.4364	0.4747	0.4546	0.4837
(-) Epicatechin	0.2344	0.2727	0.2526	0.2817
(-)Epigalocatechin	0.1574	0.1957	0.1756	0.2047
Quercetin	0.8044	0.8427	0.8226	0.8517
Gallocatechin	0.0052	0.0435	0.0234	0.0525
(-) Epicatechin -3-gallate	0.0134	0.0249	0.0048	0.0339
(-)Epigallocatechin-3-gallate	0.0324	0.0707	0.0506	0.0797
Isorhamnetin	0.2794	0.3177	0.2976	0.3267
Robinetin	0.4404	0.4787	0.4586	0.4877
Ellagic acid	0.0604	0.0987	0.0786	0.1077
Myricetin	0.4384	0.4767	0.4566	0.4857
Baicalein	0.1014	0.1397	0.1196	0.1487
Nobicalein	0.5154	0.5537	0.5336	0.5627
Kaempferol -3,7,4,-trimethyl ether	0.1544	0.1927	0.1726	0.2017
Quercetin-3,7,4’–trimethyl ether	0.3664	0.4047	0.3846	0.4137
Baicalin	0.0315	0.0698	0.0497	0.0788
Tangeretin	0.0267	0.065	0.0449	0.074
Quercetin-3,7,3’,4’-tetramethyl ether	0.0151	0.0534	0.0333	0.0624
Artemetin	0.0416	0.0033	0.0234	0.0057
Hyperoside	0.2444	0.2827	0.2626	0.2917
Silymarin	0.3504	0.3887	0.3686	0.3977
Kaempferol-3-Arabinoside	0.3004	0.3387	0.3186	0.3477
Quercitrin	0.2208	0.2591	0.239	0.2681
Naringin	0.0237	0.062	0.0419	0.071
Isoquercetin	0.0256	0.0639	0.0438	0.0729
Oriebtin	0.9149	0.9532	0.9331	0.9622
Rutin	0.4431	0.4814	0.4613	0.4904
Isoorientin	1.06291	1.10121	1.08111	1.11021
Hesperidin	0.0012	0.00451	0.0054	0.0073

Table 9: Flavonoid content of *Taliferia occidentalis* grown in quarry mining effluent discharge soils (mg/100g)

Name of compound	Control Wet season	Control Dry season	Sample Wet season	Sample Dry season
Catechi	0.587	0.6382	0.6203	0.6438
Resveratrol	0.3378	0.389	0.3711	0.3946
Genistein	0.1187	0.1699	0.152	0.1755
Daidzein	0.1607	0.2119	0.194	0.2175
Apigein	0.0989	0.1501	0.1322	0.1557
Butein	0.4957	0.5469	0.529	0.5525
Naringenin	0.1257	0.1769	0.159	0.1825
Biochanin	0.0077	0.0589	0.041	0.0645
Luteolin	0.1437	0.1949	0.177	0.2005
Kaemferol	0.4087	0.4599	0.442	0.4655
(-) Epicatechin	0.2067	0.2579	0.24	0.2635
(-)Epigalocatechin	0.1297	0.1809	0.163	0.1865
Quercetin	0.7767	0.8279	0.812	0.8335
Gallocatechin	0.0225	0.0287	0.108	0.0343
(-) Epicatechin -3-gallate	0.0411	0.0101	0.078	0.0157
(-)Epigallocatechin-3-gallate	0.0047	0.0559	0.038	0.0615
Isorhamnetin	0.2517	0.3029	0.285	0.3085
Robinetin	0.4127	0.4639	0.446	0.4695
Ellagic acid	0.0327	0.0839	0.066	0.0895
Myricetin	0.4107	0.4619	0.444	0.4675
Baicalein	0.0737	0.1249	0.107	0.1305
Nobicalein	0.4877	0.5389	0.521	0.5445
Kaempferol -3,7,4,-trimethyl ether	0.1267	0.1779	0.16	0.1835
Quercetin-3,7,4'–trimethyl ether	0.3387	0.3899	0.372	0.3955
Baicalin	0.0038	0.055	0.0371	0.0606
Tangeretin	0.001	0.0502	0.0323	0.0558
Quercetin-3,7,3',4'-tetramethyl ether	0.0126	0.0386	0.0207	0.0442
Artemetin	0.0693	0.0181	0.036	0.0125
Hyperoside	0.2167	0.2679	0.25	0.2735
Silymarin	0.3227	0.3739	0.356	0.3795
Kaempferol-3-Arabinoside	0.2727	0.3239	0.306	0.3295
Quercitrin	0.1931	0.2443	0.2264	0.2499
Naringin	0.004	0.0472	0.0293	0.0528
Isoquercetin	0.0021	0.0491	0.0312	0.0547
Oriebtin	0.8872	0.9384	0.9205	0.944
Rutin	0.4154	0.4666	0.4487	0.4722
Isoorientin	1.03521	1.08641	1.06851	1.09201
Hesperidin	0.0000	0.6382	0.0000	0.6438

Table 10: Lignin content of *Cucurbita pepo* vegetable grown in quarry mining effluent discharge soils (mg/100g)

Name of compound	Control Wet season	Control Dry season	Sample Wet season	Sample Dry season
2-ally1-5ethoxy-4-methoxyphenol	0.003	0.262	0.014	0.343
(9E, 12E, 15E)-9, 12, 15-Octadecatrien-1-01	0.205	0.054	0.194	0.551
Apigenin-4,7-methyl ether	0.226	0.315	0.237	0.92
Dehydroabietic acid	0.034	0.207	0.045	0.812
Retusin	0.013	0.254	0.002	0.859
Galgravin	0.112	0.329	0.123	0.934
Epieudesmin	0.13	0.389	0.141	0.216
Sakuranin	0.221	0.48	0.232	0.125

Table 11: Lignin content of *Cucumis satiuvs* grown in quarry mining effluent discharge soils (mg/100g)

Name of compound	Control W	Control D	Smaple W	Sample D
2-ally1-5ethoxy-4-methoxyphenol	0.142	0.637	0.181	0.668
(9E, 12E, 15E)-9, 12, 15-Octadecatrien-1-01	0.35	0.429	0.027	0.46
Apigenin-4,7-methyl ether	0.081	0.86	0.404	0.891
Dehydroabietic acid	0.111	0.668	0.212	0.699
Retusin	0.158	0.621	0.165	0.652
Galgravin	0.033	0.746	0.29	0.777
Epieudesmin	0.015	0.764	0.308	0.795
Sakuranin	0.076	0.855	0.399	0.886

Table 12: Lignin content of *Taliferia occidentalis* vegetable grown in quarry mining effluent discharge soils (mg/100g)

Name of compound	Control Wet season	Control Dry season	Sample Wet season	Sample Dry season
2-ally1-5ethoxy-4-methoxyphenol	0.024	0.393	0.07	0.483
(9E, 12E, 15E)-9, 12, 15-Octadecatrien-1-01	0.184	0.185	0.138	0.275
Apigenin-4,7-methyl ether	0.247	0.616	0.293	0.706
Dehydroabietic acid	0.055	0.424	0.101	0.514
Retusin	0.008	0.377	0.054	0.467
Galgravin	0.133	0.502	0.179	0.592
Epieudesmin	0.151	0.52	0.197	0.61
Sakuranin	0.242	0.611	0.288	0.701

Plant growth and development are affected by the conditions of the growing environment. Accumulation of toxic metals in plant cell results in various deficiencies such as reduction in cell activities and inhibition of plant growth (Osuocha *et al.,* 2015). They also result in chlorosis, reduced water and nutrient intake and damage root tips (Irum *et al.,* 2013). Findings from the study (Figures

2-4) showed a significant decrease in plant growth parameters such as plant internodes, leaf area, collar diameter and plant height of vegetables grown in quarry mining effluent discharge soils compared to control (P<0.05). This reduction in plant growth could be due to the effect of high trace metals content in soil reported by (Osuocha *et al.,* 2016), nutrient uptake and distribution within the plant cell or could be attributed to unavailability of nutrients due to increased level of trace metals in the mining sites thus inducing stress. Similar decrease in plant growth in metal contaminated sites has been reported on *Cucumis sativus* (Abu-Muriefah, 2008), on Lemna polyrrhiza (John *et al.,* 2008), on *Glycyrrhiza uralensis* (Zheng *et al.,* 2010) and on *Veronica anagallis* (Fazal *et al*., 2014). Non essential trace metals such as cadmium, chromium and lead have been reported to cause significant decrease in plant growth parameters (Raifa and Hanan, 2013; Abdussalam *et al.,* 2015). According to Sandalio *et al.,* (2005) reduction in plant growth by trace metals induced toxicity could be the direct consequence of decreased uptake of nutrient elements, inhibition of various enzyme activities, and induction of oxidative stress including alterations in enzymes of the antioxidant defense system. Pritesh *et al*. (2013) reported that decreases in plant growth are due to irregular cell division. Similar findings have been reported by Osuocha *et al.* (2016) that elevated concentration of both essential and non essential trace metals in plants can lead to toxicity symptoms and plant growth inhibition. Osuocha *et al.* (2016) also noted that plants growing on soils with high metal concentration exhibit characteristics of unhealthy growth. Findings from the study showed a significant increase in plant growth parameters in wet season compared to dry season (P<0.05). This could be attributed to reduced level of trace metals in soil as reported by Osuocha *et al.* (2016). Significant decrease in plant growth parameters were recorded in crush rock quarry mining site in wet season compared to dry season (P<0.05). This could be attributed to influence of water flooding in the area which can cause a decline in plant growth. Wegner, (2010) noted that the first constraint for plant growth under flooding is the immediate lack of oxygen necessary to sustain aerobic respiration of submerged tissues. The decline in growth parameters of plants grown in quarry mining effluent discharge soil is an indication of oxidative stress caused by elevated amount of trace metals.

Chlorophyll is an essential component of photosynthesis present in chloroplast with porphyrin nucleus with a chelated magnesium atom at the centre. Chlorophyll is often measured in order to assess the impact of environmental stress since changes in the pigment are linked to visual symptoms of growth disorder and photosynthetic productivity. Results of the study showed a significant reduction in chlorophyll content of vegetables grown in quarry mining effluent discharge soils compared to control vegetables (P<0.05). Similar results have been reported in Radish, mung bean and lettuce (Baszynski *et al.,* 1980), wheat (Mysliwa-Kurdziel and Strzalka, 2004). The results also agreed with the report of Monni *et al*. (2001) that chlorophyll content in leaves of *Empetrum nigrum* (crowberry) growing close to copper and nickel smelter decreased significantly. Odjegba and Fasidi (2006) also reported reduction in chlorophyll content of *Eichhornia crassipes*. The results indicates significant decrease in chlorophyll content of plants grown in crushrock quarry sites in wet season compared to other sites. This could be attributed to the water logged nature of the area under study as this can decrease Leaf chlorophyll content in plants due to reduced soil conditions

Results of the present study showed significant reduction in chlorophyll content of plants in dry season compared to wet season ($P<0.05$). This reduction in chlorophyll content of vegetables in dry season (Fig 6 – 8) could be as a result of elevated level of trace metals in soil and dust deposition on plant leaves. Decreased chlorophyll content associated with increased trace metals may be due to inhibition of enzymes responsible for chlorophyll biosynthesis such as α-aminolevulinic acid dehydratase and protochlorophyllide reductase (Pritesh *et al.,* 2013), replacement of magnesium with heavy metal in chlorophyll structure(Kupper *et al.,* 1998), decrease in the source of essential metals that are involved in chlorophyll synthesis such as Fe^{2+} and Zn^{2+}(Kupper *et al.,*1996), destruction of chloroplast membrane by lipid perioxidation due to increase in peroxidase activities and lack of antioxidant such as caroteniod (Prasad *et al*., 1999). Dust deposition on leaf surfaces of these vegetables in dry season may also reduce the synthesis of chlorophyll due to shading effect. Dusts effects on vegetation may be connected with decrease in light available for photosynthesis, increase in leaf temperature due to changed surface optical properties, and interference with the diffusion of gases in and out of leaves.

Phytochemicals form part of the natural plant defense system against infection, microbial invasions and free radical generation and is one of the initial responses of plants to stress. Findings from this study showed an increase in the amount of phytochemicals in vegetables grown in quarry effluent discharge soils in relation to control (Table 1-11). Findings from the present study also showed an increase in the amount of phytochemicals in dry season in relation to wet season. This increase especially in phenolic compounds could be due to protective function of these compounds against increase in trace metal stress by metal chelation and ROS scavenging. This is in agreement with the findings of Pritesh *et al*. (2013); Abdussalam *et al.* (2015) who reported significant increase in phenolic compounds in vegetables treated with heavy metals. Many authors have reported induction of phenolic metabolism as a response of plants to metal stress (Hegazy *et al.,* 2013). Phenolic compounds are known to have strong antioxidant activity in plants growing under heavy metal stress. It has been suggested that their antioxidant act resides chiefly in their chemical structure. Theunissen *et al*. (2010) reported that phenolic compounds are known to be synthesized in response to various environmental stress such as nutritional stress, pest and diseases and temperature. Similarly, the induction of phenolic compound biosynthesis has been reported in wheat in response to nickel toxicity (Diaz *et al.,* 2001) and in maize in response to aluminum (Winkel-Shirley, 2002). Flavoniod are important secondary plant metabolites that possess strong antioxidant activity due to their ability to scavenge reactive oxygen species and inhibit oxidative stress. The results showed an increase in flavonoid concentration of vegetables in dry season compared to wet season. These results were however higher than the controls. This could be due to increased heavy metal stress that triggers the biosynthesis of the flavonoids as flavonoids have been reported as efficient metal chelators (Brunetti *et al.,* 2013). Carotenoid content of the vegetables grown in quarry mining effluent discharge soils increased in dry season in relation to wet season. This increase could be due to increased metal stress as carotenoid has been reported to play important role in detoxification of ROS (Chandra *et al.,* 2009). Carotenoid increase in dry season could be due to its antioxidant role in protection of chlorophyll reduction under trace metal stress. Similar findings in carotenoid increase in plants under metal stress has also been reported by Hegazy *et al.* (2013). This accumulation of carotenoid in these edible vegetables may be regarded as a mechanism to counter stress in plants.

Pritesh *et al*. (2013) reported that at extreme high level of trace metals carotenoid content is degraded. Lignin content of the vegetables grown in the mining effluent discharge soils showed an increase in relation to control. This could also be due to increased metal stress in the sites which elicit lignin biosynthesis. Buchanan *et al.* (2000) reported that phenolics are the precursor of lignin hence increased phenolic content due to heavy metal stress is directly related to lignin biosynthesis. In view of these findings quarry mining effluent discharge impacted negatively on the growth of these edible vegetables. The increase in phytochemical constituents may have resulted in response to unfavourable environmental conditions. Hence there is need to carry out proper remediation of these sites so as to improve its quality and functionality for agricultural purposes.

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