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Effect of Quarry Activities on Some Morphological Parameters of Two Maize Varieties (SWAN 1 and SAMMAZ 52)

Bridget Odiyi, Olubukola Maku, Foluso Akinbode Ologundudu*, Sylvanus Efetobor Abiya
Department of Biology, School of Life Sciences, Federal University of Technology, Akure, Nigeria.

Corresponding author*
akinbodefoluso@gmail.com

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Abstract

The effect of quarry activities on some morphological parameters of two maize varieties (swan 1 and sammaz 52) was investigated with the aim of determining the impact of quarry activities on some growth parameters of the maize varieties under study. The seeds were collected from the Seed Bank Department of the Ondo State Ministry of Agriculture, Akure, Ondo State. They were authenticated at the Herbarium unit of the Federal University of Technology, Akure, and the voucher was deposited. Soil samples were collected at 50m, 100m, 150m, 200m, and 250m from the quarry site and transferred to the laboratory for analysis. A screen house experiment was set up to house the pots. Seeds of SWAN 1 and SAMMAZ 52 were sown into perforated plastic pots (30 cm diameter and 33 cm depth) filled with 10 kg of quarry soil. The following morphological parameters were determined; shoot height, leaf area, plant dry weight, shoot dry weight, root dry weight, root-shoot ratio, leaf area, and determination of photosynthetic parameters especially chlorophylls a and b. The result revealed that at 50 meters from the quarry site, SAMMAZ 52, one of the maize varieties grown in soil taken from the site, had the highest shoot height (94 cm). which showed that plants growing in higher concentrations of dust pollution respond to nutrient stress by devoting more of their available carbon to shoot growth, resulting in elongated stems, were consistent with the observed higher shoot height in SAMMAZ 52, daily variations in photosynthetic activity and the rate of nitrogen uptake are to blame for these alterations in plant behavior. The efficiency with which plants use the available nutrients determines whether they will survive in an area where there is quarry dust. The observed higher biomass (3.84g) under SAMMAZ 52's management regime can be attributed to the best possible rates of photosynthesis and nutrient assimilation, as well as to the presence of more chlorophyll and larger leaf surfaces.

Keywords: dust pollution; quarry, maize; morphological.

INTRODUCTION

Despite its importance as a major food in many parts of the world, corn is inferior to other cereals in nutritional value. Its protein is of poor quality, and it is deficient in niacin. Diets in which it predominates often result in pellagra (niacin-deficiency disease). Corn is high in dietary fiber and rich in antioxidants. Corn oil can be converted into margarine by hydrogenation, a process in which the oil is combined with hydrogen at high temperature and pressure in the presence of a catalyst. Corn is also used to produce ethanol (ethyl alcohol), a first-generation liquid biofuel (Upadhay et al., 2015). The response of the plant to dust accumulation may vary according to different species, as dust deposition fluctuates with plant species due to leaf orientation, leaf surface canopy, phyllotaxy, epidermal and cuticular features, leaf pubescence, height and canopy of roadside plants (Wang et. al.,2019; Yun et. al., 2017) With the accumulation of dust, the roadside plant may exhibit adaptive response by changing morphological and physiological attributes. Air pollution stress leads to stomatal closure, which reduces CO2 availability in leaves and inhibits carbon fixation. The net photosynthetic rate is a commonly used indicator of the impact of increased air pollutants on tree growth (Cao et al., 2015). Plants that are constantly exposed to environmental pollutants absorb, accumulate and integrate these pollutants into their systems. The relationship between traffic density and photosynthetic activity, stomatal conductance, total chlorophyll content, and leaf senescence has been reported (Silva et al., 2016). One of the most common impacts of air pollution is the gradual disappearance of chlorophyll and concomitant yellowing of leaves, which may be associated with a consequent decrease in the capacity for photosynthesis (Gupta et al., 2015).

METHODS

Seed collection/authentication Seeds of two maize varieties

SWAN 1 and SAMMAZ 52 were utilized in the experiment. The seeds were collected from the Seed

Bank Department of the Ondo State Ministry of Agriculture, Akure, Ondo State. They were authenticated at the Herbarium unit of the Federal University of Technology, Akure, and the voucher was deposited.

Study site
The study was conducted in a screen house behind the Department of Biology, Federal University of Technology, Akure.

Soil sample collection
Soil samples were collected at 50m, 100m, 150m, 200m, and 250m from the quarry site. The soil samples were taken at a plowing depth of 0 - 10 cm using a calibrated soil auger. The samples from each site were bucked together to obtain a composite sample and the replicate samples were packed in polyethylene bags, labeled appropriately, and transported to the laboratory for analysis. The topsoil taken from the garden served as the control. A completely randomized design (CRD) was set up which comprises two maize varieties, six plowing depths, and 3 replicates.

Experimental setup
A screen house experiment was set up to house the pots. This was necessary to protect the plants from rainfall contaminations and to avoid being destroyed by rodents as the plants develop.

Soil analysis
Soil analysis was carried out at the Department of Crop, Soil and Pest Management, School of Agriculture and Agricultural Technology, Federal University of Technology, Akure. The following physicochemical properties of the quarry soil were determined; dissolved oxygen, conductivity, nitrogen, phosphorus, copper, iron, organic matter, and organic carbon.

Planting procedure
Seeds of SWAN 1 and SAMMAZ 52 were sown into perforated plastic pots (30 cm diameter and 33 cm depth) filled with 10 kg of quarry soil. The seedlings were allowed to establish for 14 days before data were taken.

Weight Analysis
On the zero-day i.e. the day when feeding with appropriate nutrient solution commenced and at intervals of seven days, weight analysis was carried out on five seedlings harvested at random. The plants were carefully uprooted, blotted dry, weighed fresh, and then placed inside a labeled envelope and kept in a Gallenkamp drying oven set at 80oC to dry to constant weight.

Measurement of growth parameters
A meter rule was used to measure the following; leaf length, leaf width, and shoot height from soil level to the terminal end, and the number of leaves per plant were noted. The fresh weight was taken after which the plants were dried at 80oC in a Gallenkamp oven until a constant weight was achieved. After cooling, the dry weight was determined. The dried samples were separated 19 into leaves, shoots, and roots and their different dry weights were determined. These were kept for further analysis.

Growth parameters: The following plant growth parameters were determined from the data obtained from the physical parameters:
Leaf Area (LA) = The unit of LA is cm2 L and W are leaf length and width respectively while 2.75 is the correction factor for maize respectively. LA = L x W x 2.75 (maize) Anderson et al (2005) 3.4.5.2. Root Shoot Ratio (RSR) RSR = W3/W2 Root shoot ratio defines the method of assimilate partitioning, W2, and W3 are shoot and root dry weights respectively, the unit is g-1 3.5.

Photosynthetic Pigment Analysis
Chlorophyll Extraction: 5g each of the leaves of the seedlings were grounded in 20 ml of 80% (%) acetone using a mortar and pestle. The brew was filtered through a Whatman's No 1 filter paper. The pigment quantities in the acetone extract were determined on a CE 373 (visible) linear readout spectrophotometer at a wavelength of 664nm and 647nm, chlorophyll "a" and "b" and the total chlorophyll quantities were determined using the formula.
Chlorophyll 'a' (µM) = 13.19A664 – 2.37A647 Chlorophyll 'b' (µM) = 22.10A647 – 5.26A664 Total Chlorophyll (µM) = 7.93A664 + 19.53A67 20 A664 is the absorbance at 664nm A647 is the absorbance at 647nm (Coombs et al; 1993).

RESULT AND DISCUSSION

Particulate emissions from a wide range of industrial operations may hinder plant growth and development. At 50 meters from the quarry site, SAMMAZ 52, one of the maize varieties grown in soil taken from the site, had the highest shoot height (94 cm). Given that stem extension and apical dominance were more pronounced in the plants than in SWAN 1, it can be said that they devoted more of their nutrients to these processes. The ability to measure changes in the general growth habit of soybeans caused by the environment using apical dominance has been found to be valuable (Thomas and Raper, 2013). The results of Bouma et al. (2010) and Bonifas et al. (2015), show that plants growing in higher concentrations of dust pollution respond to nutrient stress by devoting more of their available carbon to shoot growth, resulting in elongated stems, were consistent with the observed higher shoot height in SAMMAZ 52. According to Reynolds et al. (2016), daily variations in photosynthetic activity and the rate of nitrogen uptake are to blame for these alterations in plant behavior. The efficiency with which plants use the available nutrients determines whether they will survive in an area where there is quarry dust (Ralphs et al; 2013). The observed higher biomass (3.84g) under SAMMAZ 52's management regime can be attributed to the best possible rates of photosynthesis and nutrient assimilation, as well as to the presence of more chlorophyll and larger leaf surfaces. The findings of Peace and Grubb (2018) and Tischer et al (2010) that higher dry weight was due to ideal leaf expansion rates were supported by an increase in the generation of dry matter under optimal conditions. Plants SWAN 1 and SAMMAZ 52 accumulated less biomass, as nutritional effects on photosynthetic rate per unit leaf area (Greenwood, 2016). The low shoot biomass (0.04g) under SWAN 1 was because more carbon was diverted for greater root growth than in SAMMAZ 52 plants and this carbon may be from the stem tissues (Peace and Grubb, 2018). When the nutrient supply was high, in the control regime (normal soil), SAMMAZ 52 plants had more stem components than SWAN 1 plants because the soil had an adequate nutrient supply. The lowering of the shoot biomass under a low nutrient supply may not be unconnected with the reduction in the production of photosynthates as more carbon was diverted to root growth from both stem and leaf tissues (Morgan and Smith, 2011). Plants reduce root growth relative to leaf area as an adaptation to dust pollution (Chung et al; 2013). The reduced root and shoot biomasses in SWAN 1 at 250 m and 200 m from the Quarry site, respectively, were explained by the aforementioned. According to Thompson et al. (2008), low carbon content caused root growth to be reduced at low nutrient delivery levels. Richer soil encourages better shoot development with roots that are less compact and branches out less (Oke, 1985). Nutrient-stressed plants expanded their roots quickly in search of nutrition.

There was an increase in vegetative growth with maximum leaf production in SAMMAZ 52 at the control regime compared to SWAN 1. Lindquist *et al* (2016) reported that in Velvetleaf, a reduction in nitrogen content increased leaf number but decreased leaf area. In *Phaseolus vulgaris*, Bridges (2012) found leaf number to increase with increased nitrogen application. The production of more leaves under the control regime may be a mechanism evolved by maize plants to increase the total surface area for photosynthesis due to reduced leaf area (Morgan *et al*, 2018). In SWAN 1, at 200m from the quarry site, there was an increase in leaf abscission and a reduction in the number of leaves produced due to the fact that the extra carbon needed for greater root growth as a result of low nutrient supply was taken from their non-assimilatory tissue as well as leaf tissue (Peace and Grubb, 2012).

Roots are very important not only for absorbing water and nutrient but also for optimizing plant growth (Renalto *et al*; 2017). The ability of a plant to compete for soil nitrogen is dependent upon root morphological characteristics such as root radius, root length, and root surface area (Hilbert, 2010). Previous research has shown that excessive dust pollution can inhibit root growth in corn (Wang *et al*, 2018). The above is in agreement with the low root biomass accumulation recorded in SWAN 1 at 250m. Plants respond to limiting soil nutrients by increasing the amount of biomass allocated to roots (Bonifas *et al*; 2015). This substantiates the observation recorded in SWAN 1 plants. Plants may modify their root morphology to further aid their capacity to take in nutrients (Clemens, 2018). The relationship between nitrogen uptake and root growth was demonstrated in the result observed in the root-shoot biomass ratio. According to Bonifas *et al* (2000), velvetleaf had greater nitrate uptake efficiency than corn, suggesting that velvetleaf may have more roots with a smaller radius and/or greater specific root length which would increase the surface area available for uptake. In ~~the~~ SWAN 1, there was a reduction in leaf length, leaf width, and consequently leaf area. This can be attributed to the transfer of photosynthates (assimilates) for stem elongation and the production of new leaves. According to Cracker, 2013, one of the most important factors affecting leaf development is a nutrient. According to Junk *et al*; 2012, the size of the leaf is determined by nutrient and carbon supply. Since SWAN 1 plants had a lower assimilation rate, they were expected to have lower leaf areas. According to Cardwell *et al*; 2016, nitrogen-stressed plants adapt by producing leaves with longer internodes and an increase in leaf surface area at the expense of food allocation to the roots. Leaf area may be decreased by nitrogen deficiency depending on the severity (Bonifas *et al*; 2005). Nutrient stress reduces crop photosynthesis by reducing leaf area development and leaf photosynthesis rate and by accelerating leaf senescence (Pandy *et al*; 2000). The trend in root shoot ratio showed that the SAMMAZ 52 higher leaf area ratio than the SWAN 1 plants as a consequence of nutrient addition; more leaves led to a higher surface area for photosynthesis and so a proportionate high dry matter in plant tissues. The lower leaf area ratio observed in the SWAN 1 plants may be due to reduced carbon allocation to the leaf tissues for leaf development (Morgan and Smith, 2018). There was more or less a direct correlation between the root shoot ratio (RSR) and shoot dry weight.

In the study conducted, the proportionate decrease in the root shoot ratio noticed in SWAN 1 plants compared to the SAMMAZ 52 plants could be attributed to lower biomass partitioned to the root than to the shoot. Hong *et al* (2000) while working with cucumber plants found dust particles to affect root shoot ratio. According to Summerfield *et al* (2016), the root shoot ratio declines with an increase in nutrient application in cowpea because there is a decline in the symbionts and therefore a reduced carbon allocation to the roots.

The relationship between photosynthetic capacity and dust pollution had been documented by Evans and Seemann, 2009. Also, Alt *et al*; 2010, reported a correlation between photosynthetic capacity dust emissions from industries in *Vernonia herbacea*. Nitrogen deficiency leads to disruption of the fine structure of chlorophyll and instability of the pigment-protein complex (Reddy *et al*; 2017). Reddy *et al* (2017) also reported a positive correlation between leaf nitrogen, net photosynthetic rate, stomata conductance, and ion transport in cotton. Hence, this was in agreement with the result obtained under SWAN 1 (10.54µm) at 250m from the Quarry site plants which showed a lower accumulation of chlorophylls a and b. About 75% of leaf nitrogen is allocated to chloroplasts (Hak, 2013), most of which is being used for the synthesis of components of photosynthetic apparatus, in particular, "Rubisco", the most representative leaf protein, playing a key role in carbon assimilation (Evans and Terashima, 2017). The above accounted for the chlorosis, necrosis, abscission, and senescence of older leaves noticed in the latter part of the experiment in SWAN 1 plants. The chlorosis spreads from older to younger leaves because of the mobility of nitrogen from older to younger leaves. (Mengel *et al*; 2017).

The accumulation of chlorophylls "a" and "b" showed consistent patterns. This was in agreement with the findings of Ashraf and Rehman (2019) that with adequate nutrients, chlorophylls "a" and "b" are increased, hence these substantiated the highest chlorophylls accumulation ("a" and "b") recorded in SAMMAZ 52 plants compared to SWAN 1. The lowest values of photosynthetic apparatus in SWAN 1 plants could be a result of low stomata conductance and protein contents, affecting Rubisco activity and electron transport (Evans, 2013).

The higher accumulation of calcium in SAMMAZ 52 plants at 100m from the Quarry site substantiates the earlier findings of Ashraf *et al* (2019) while working on sorghum. A comparison of calcium ion and magnesium ion concentrations in both regimes reveals that the two ions show antagonism in uptake (Ashraf *et al*; 2000). The calcium and magnesium contents in the two varieties followed inconsistent patterns. This confirms the result of the experiment indicating the highest magnesium accumulation in SWAN 1 plants while calcium accumulation was observed to be relatively low. There is a correlation between nitrogen and magnesium accumulation as magnesium ion plays a vital role in chlorophyll biosynthesis (Walker *et al*; 2011), protein synthesis, and photosynthesis (Marschner *et al;* 2017). Analysis of potassium ions showed different patterns of accumulation in SAMMAZ 52 and SWAN 1. The percentage of potassium content which decreases in the latter part of the distance from the Quarry site can be explained in view of the argument that a high amount of potassium is needed to maintain nitrogen metabolism when large amounts of nitrogen are supplied in the external medium (Leigh *et al,* 2014). However, these results were at variance with the observation of Ashraf *et al, (*2000) who found a lower accumulation of potassium in nutrient-stressed plants grown under normal conditions.

Magnesium limitation resulted in a reduction in shoot growth and photosynthetic capacity in maize (Foyer *et al;* 2010). Supraoptimal levels of magnesium have been reported to increase in corn (Diao *et al*; 2018, Tsialtas *et al*; 2018). This can therefore be interpreted to mean greater metabolic activities, utilization and uptake noticeable in both SAMMAZ 52 and SWAN 1 plants. However, this was at variance with the observation of Tischer *et al* (2000) that an increase in magnesium supply not only delays senescence and stimulates growth but also changes plant morphology in a typical manner, particularly if the magnesium availability is high in the rooting medium during the early growth, shoot elongation is enhanced and root elongation inhibited, a shift which is unfavorable for nutrient acquisition and water uptake in later stages. The efficient translocation of photosynthate from source to sink organs is the key factor driving plant growth and increased crop yield (Dakora, 2003; Cornu, 2007). Photosynthesis was reported to be affected by sink strength as an increased photosynthate supply is required to meet the increasing demand for photoassimilates during early vegetative growth and seed development in *Zea mays* (Richards, 2000). Strong positive correlations have been found between the photosynthetic capacity of leaves and their magnesium content, most of which is used for the synthesis of components of the photosynthetic apparatus (Gastal *et al*, 2012).

CONCLUSION

The efficiency with which plants use the available nutrients determines whether they will survive in an area where there is quarry dust. The observed higher biomass (3.84g) under SAMMAZ 52's management regime was attributed to the best possible rates of photosynthesis and nutrient assimilation, as well as to the presence of more chlorophyll and larger leaf surfaces. This can be attributed to the transfer of photosynthates (assimilates) for stem elongation and the production of new leaves. There were correlations between nitrogen and magnesium accumulation as magnesium ion plays a vital role in chlorophyll biosynthesis, protein synthesis, and photosynthesis. There were clear inconsistent patterns in the accumulation of the chlorophylls a and b.

Abbreviations: Not applicable.

Ethics approval and consent to participate**:** Not applicable.

Consent for publication**:** All authors are aware of the publication of this manuscript.

Availability of data and material: The datasets used and/or analyzed during the current study are available from the corresponding author on request.

Competing interest**:** The authors declare that they have no competing interest.

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Authors' contributions: Prof Mrs B. O. Odiyi designed the experiment, Maku Olubukola carried out the laboratory works. Dr. F. A. Ologundudu carried out the statistical analysis and interpretation of the results. The author(s) read and approved the final manuscript.

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Table S1. Shoot height of *Zea mays* at different distances from the Quarry site.

Varieties	Days	Distance (m)					
		Control	50	100	150	200	250
VAR 1	28	43.67±1.86a	**39.33±1.33a**	37.33±1.33a	36.00±5.29a	39.00±4.58a	**33.00±5.19a**
	35	51.33±1.76b	**45.33±1.76b**	43.33±2.40ab	38.67±4.81a	44.00±3.06ab	37.33±4.67a
	42	58.00±1.16c	**56.00±1.16c**	48.67±2.33ab	42.67±5.18a	49.33±0.67ab	46.00±2.31a
	49	61.33±0.67b	58.67±0.67b	50.33±2.03a	45.67±5.67a	50.67±1.59a	49.33±0.67a
	56	63.67±0.88b	62.00±1.16b	52.33±1.45a	46.67±5.69a	54.00±1.16a	51.33±0.67a
	63	70.67±0.67b	67.67±1.45b	57.67±1.45a	52.67±4.67a	59.33±0.67a	57.00±0.58a
	70	77.67±2.19c	**72.33±1.45bc**	63.67±0.88a	57.33±5.46a	64.67±0.67ab	63.67±0.33a
VAR 2	28	49.67±3.28b	**48.00±1.16b**	38.33±2.03a	**33.33±1.76a**	38.67±1.20a	39.33±2.96a
	35	57.00±1.53c	**56.00±1.16c**	46.33±0.88b	37.33v0.67a	44.33±2.33b	45.00±2.52b
	42	66.00±1.00c	**67.33±1.76d**	54.00±1.16b	40.67±0.67a	51.00±2.08b	49.00±2.08b
	49	72.67±1.76d	**73.67±2.03e**	60.00±0.00c	46.67±0.67a	55.33±1.76bc	53.33±1.76b
	56	80.00±1.16d	**80.00±1.16e**	64.00±1.16c	52.33±1.45a	58.00±1.16b	57.00±1.53b
	63	86.00±1.16d	**86.33±0.88f**	69.33±0.67c	58.67±0.67a	63.33±2.40b	61.67±1.67ab
	70	92.67±1.76c	**94.00±2.08g**	76.00±0.58b	65.00±0.00a	68.67±2.40a	68.00±2.31a

Mean follow by the same alphabet in a row are not significantly different (P>0.05) from one another, using Duncan New Multiple Range Test, VAR 1 = SWAN 1, VAR 2 = SAMMAZ 52

Shoot height of Zea mays at different distances from the Quarry site ranged between 33cm and 94cm respectively relative to the control. The highest shoot height (94cm) was observed in SAMMAZ 52 in the 7th at 50m from the quarry site. The lowest shoot height was however noticeable in SWAN 1 at 250m. There is a significant difference in the shoot height of SWAN 1 at 50m from the quarry site between the first and the third week. Also, significant differences were also observed in SAMMAZ 52 at 50m from the quarry site and from the beginning till the end of the experimental period.

Table S2. Plant dry weight (PDW) of maize at different distances from the quarry site.

Varieties	Distance	Dry weight (g)/days after planting (DAP)						
		28	35	42	49	56	63	70
SWAN 1	0	0.06±0.02a	0.36±0.00ab	0.16±0.00a	0.80±0.00b	0.65±0.00a	0.48±0.00abc	0.52±0.07bc
	50	**0.04±0.01a**	0.40±0.04a	0.21±0.04a	1.01±0.11abc	0.62±0.12a	0.40±0.04ab	0.55±0.04c
	100	0.05±0.02a	0.48±0.02c	0.21±0.02a	1.19±0.14abcd	0.69±0.42a	0.32±0.07a	0.54±0.06bc
	150	0.04±0.01a	0.46±0.05bc	0.28±0.02ab	1.21±0.10abcd	0.70±0.29a	0.31±0.11a	0.31±0.04a
	200	0.09±0.03a	0.51±0.02c	0.16±0.04a	1.51±0.08bcd	1.11±0.30a	0.48±0.10abc	0.32±0.07a
	250	0.04±0.00a	0.42±0.04abc	0.23±0.04a	2.06±0.43cd	1.40±0.49a	0.71±0.27abc	0.38±0.06ab
SAMMAZ 52	0	0.07±0.01a	0.45±0.02abc	0.18±0.04a	**3.84±0.23e**	3.29±0.54b	0.98±0.31c	0.47±0.07abc
	50	0.07±0.01a	0.34±0.04a	0.21±0.03a	3.35±0.23e	2.84±0.61b	0.89±0.34bc	0.46±0.03abc
	100	0.12±0.11a	0.46±0.06bc	0.28±0.14ab	2.19±0.98d	1.57±0.72a	0.22±0.05a	0.54±0.03bc
	150	0.28±0.07b	0.47±0.02bc	0.29±0.08ab	0.26±0.05a	0.38±0.09a	0.28±0.04a	0.52±0.03bc
	200	0.28±0.04b	0.51±0.03c	0.28±0.03ab	0.27±0.03a	0.36±0.15a	0.33±0.07a	0.56±0.04c
	250	0.33±0.07b	0.52±0.04c	0.45±0.05b	0.26±0.04a	0.33±0.09a	0.38±0.05ab	0.46±0.04abc

Mean follow by the same alphabet in row are not significantly different (P>0.05) from one another, using Duncan New Multiple Range Test

Biomass accumulation in the two maize varieties ranged between 0.04g and 3.84g. The highest biomass was recorded in SAMMAZ 52(3.84g) in the 4th week while the least was recorded in SWAN 1(0.04g) at the beginning of the experimental period. There was no significant difference in the PDW of the varieties relative to the control.

Table S3. Root dry weight (RDW) of the varieties at different distances from the quarry site.

Varieties	Days	Distance (m)					
		Control	50	100	150	200	250
V1	28	0.033±0.003c	**0.027±0.003bc**	0.023±0.003b	0.010±0.000a	0.063±0.003d	**0.030±0.000bc**
	35	0.117±0.072a	**0.193±0.013ab**	0.270±0.034b	0.273±0.013b	0.307±0.024b	0.227±0.052ab
	42	0.217±0.087a	0.467±0.012b	0.480±0.047b	0.483±0.063b	0.500±0.020b	0.500±0.030b
	49	0.050±0.012a	0.063±0.012a	0.037±0.003a	0.050±0.027a	0.050±0.012a	0.067±0.003a
	56	0.391±0.015a	0.391±0.028a	0.452±0.054a	0.421±0.022a	0.437±0.032a	0.456±0.019a
	63	0.113±0.002a	0.111±0.002a	0.134±0.021a	0.119±0.008a	0.116±0.008a	0.123±0.006a
	70	0.550±0.072bc	0.580±0.042c	0.560±0.050bc	0.317±0.047a	0.377±0.068ab	0.407±0.056abc
V2	28	0.073±0.003d	**0.040±0.000c**	0.017±0.003a	0.010±0.000a	0.033±0.003bc	0.027±0.003b
	35	0.217±0.038a	**0.277±0.012a**	0.240±0.055a	0.553±0.209b	0.560±0.021b	0.563±0.013b
	42	0.510±0.25b	0.289±0.008a	0.277±0.004a	0.351±0.038a	0.305±0.015a	0.312±0.023a
	49	0.317±0.020a	0.347±0.026ab	0.447±0.015c	0.380±0.017ab	0.373±0.013ab	0.387±0.022b
	56	0.193±0.003a	0.233±0.039a	0.230±0.015a	0.290±0.023a	0.223±0.038a	0.257±0.044a
	63	0.112±0.002a	0.144±0.025ab	0.164±0.015b	0.141±0.001ab	0.146±0.008ab	0.132±0.002ab
	70	0.540±0.070a	0.500±0.025a	0.550±0.032a	0.523±0.034a	**0.593±0.043a**	0.490±0.035a

Mean follow by the same alphabet in a row are not significantly different (P>0.05) from one another, using Duncan New Multiple Range Test. VAR 1 = SWAN 1, VAR 2 = SAMMAZ 52

Root dry weight of the varieties at different distances from the quarry site ranged from 0.030g at 250m (SWAN 1) from the quarry site and 0.593g at 200m (SAMMAZ 52) from the quarry site. There were significant differences in RDW at 50m in SWAN 1 and SAMMAZ 52 respectively between the first and the second week. However, there were no significant differences between the varieties at 100-250m from the quarry site.

Table S4. Shoot dry weight (SDW) of the maize varieties at different distances from the quarry site.

Varieties	Days	Distance (m)					
		Control	50	100	150	200	250
V1	28	0.030±0.006c	**0.025±0.000b**	0.015±0.001a	**0.008±0.000a**	**0.037±0.001c**	0.029±0.001b
	35	0.173±0.001a	**0.170±0.015a**	0.187±0.009a	0.190±0.025a	**0.197±0.013a**	0.170±0.006a
	42	0.064±0.005d	**0.051±0.001c**	0.038±0.004b	0.016±0.001a	**0.099±0.003e**	0.059±0.002cd
	49	0.079±0.003ab	0.073±0.003a	0.082±0.003ab	0.089±0.006b	**0.08±0.003b**	0.082±0.004ab
	56	0.088±0.003d	0.080±0.002bc	0.069±0.000a	0.074±0.003ab	**0.09±0.005d**	0.092±0.004d
	63	0.080±0.003b	0.073±0.002a	0.082±0.004b	0.092±0.002c	0.115±0.005d	0.067±0.004a
	70	0.750±0.067d	0.559±0.034c	0.399±0.009b	0.178±0.018a	**0.71±0.014d**	0.602±0.018c
V2	28	**0.066±0.003c**	**0.049±0.005b**	0.035±0.002a	0.028±0.004a	0.046±0.002b	0.035±0.001a
	35	**0.023±0.005a**	**0.026±0.003a**	0.033±0.003a	0.033±0.004a	0.029±0.002a	0.032±0.002a
	42	**0.138±0.004e**	**0.088±0.006d**	0.050±0.003b	0.037±0.003a	0.079±0.017d	0.062±0.004c
	49	0.061±0.011a	0.081±0.010a	0.108±0.07b	0.078±0.005a	0.076±0.001a	0.068±0.005a
	56	0.065±0.009a	0.087±0.005b	0.125±0.002c	0.930±0.003b	0.095±0.003b	0.084±0.003b
	63	0.056±0.008a	0.086±0.009bc	0.099±0.004bc	0.079±0.005b	0.103±0.004c	0.095±0.006bc
	70	0.095±0.009d	0.783±0.034c	0.512±0.016b	0.258±0.013a	**0.733±0.048c**	0.588±0.057b

Mean follow by the same alphabet in the columns are not significantly different (P>0.05) from one another, using Duncan New Multiple Range Test. VAR 1 = SWAN 1, VAR 2 = SAMMAZ 52

There were significant differences in the shoot biomass of SWAN 1 at 50m and at 200m between the first and the 5th week relative to the control. Similarly, significant differences were also observed in SAMMAZ 52 between the 28th and the 42nd day at 50m relative to the control. The highest shoot dry weight (0.71g) was observed in SWAN 1 at 200m while the least SDW was noticeable at 150m.

Table S5. Mineral nutrient composition of maize varieties at different distances from the quarry site.

Varieties	Distance	Nutrients			
		Na	K	Mg	Ca
SWAN 1	0	0.31±0.05b	**0.57±0.03b**	0.23±0.05ab	0.23±0.05ab
	50	0.33±0.04bc	0.47±0.25b	0.26±0.03abc	0.26±0.03ab
	100	0.21±0.02a	0.48±0.02b	0.34±0.04bc	0.33±0.03b
	150	**0.18±0.01a**	0.56±0.04b	0.36±0.04c	0.33±0.04b
	200	0.33±0.01bc	0.59±0.06b	0.55±0.03d	0.29±0.02ab
	250	0.42±0.05cd	0.50±0.06b	0.17±0.02a	0.32±0.02b
SAMMAZ 52	0	0.38±0.01bc	0.27±0.09a	0.28±0.01abc	0.34±0.05b
	50	0.36±0.02bc	0.51±0.07b	0.34±0.04bc	0.29±0.03ab
	100	0.50±0.03d	0.75±0.04c	0.25±0.04ab	0.33±0.04b
	150	0.43±0.04cd	0.50±0.06b	0.29±0.02bc	0.27±0.02ab
	200	0.40±0.03bc	0.55±0.03b	0.48±0.01d	0.21±0.02a
	250	0.40±0.02bc	0.44±0.03b	0.51±0.06d	0.24±0.04ab

Table S6. Leaf area (cm^2) of maize varieties at different distances from the quarry site

	Leaf Area (cm^2)	
Distance (m)	**SWAN 1**	**SAMMAZ 52**
50	32.50±0.07d	33.06±0.03d
100	18.50±0.01b	22.18±0.04b
150	29.00±0.07c	28.37±0.02c
200	17.50±0.04b	19.32±0.01a
250	12.45±0.12a	15. 24±0.07a
Control	35.50±0.08d	35.24±0.06d

The leaf area of both varieties increased gradually for a greater part of the experimental period. Similar growth patterns were recorded throughout the experimental period. Gradual increases were observed at 200m and at 250m from the quarry site. The highest leaf area was recorded in the control regime followed by 50m while 250m was observed to be the least. Results of the ANOVA showed that there were significant differences ($p<0.05$) in the varieties grown on the soils from the quarry site.

Chlorophyll ''a'' accumulation of maize varieties at various distances from the quarry site

There were gradual decreases in a linear fashion in chlorophyll 'a' accumulation for a greater part of the experimental period in the two maize varieties. Both maize varieties had approximately equal chlorophyll accumulation at 150m from soil collected from the quarry site. These were followed by a gradual increase between 50 and 100m from the quarry site. The highest chlorophyll 'a' accumulation was recorded in control, while 250m was observed to be the lowest (SWAN 1). Results of the ANOVA showed that there were significant differences ($p<0.05$) at 50 and 250m respectively relative to the control.

Table S7. Chlorophyll ''a'' accumulation of maize varieties at various distances from the quarry site.

	Chlorophyll a (µm)	
Distances (m)	**SWAN 1**	**SAMMAZ 52**
50	8.57±0.07a	24.55±0.02d
100	10.27±0.05b	12.50±0.04a
150	10.78±0.01b	10.45±0.03a
200	8.23±0.02a	16.99±0.02c
250	**7.52**±0.02**a**	17.72±0.01c
Control	24.52±0.04c	**35.76**±0.02**d**

Mean follow by the same alphabet in the columns are not significantly different (P>0.05) from one another, using Duncan New Multiple Range Test

Table S8. Chlorophyll ''b'' accumulation of maize varieties at various distances from the quarry site.

	Chlorophyll b (µm)	
Distance(m)	**SWAN 1**	**SAMMAZ 52**
50	11.64±0.02a	25.43±0.01c
100	16.24±0.02b	23.23±0.02c
150	14.58±0.01b	18.76±0.06b
200	12.58±0.01a	15.57±0.05a
250	10.54±0.03a	12.78±0.05a
Control	18.76±0.04c	38.56±0.08d

Mean follow by the same alphabet in the columns are not significantly different (P>0.05) from one another, using Duncan New Multiple Range Test

In the same pattern like chlorophyll 'a' contents, the chlorophyll 'b' contents in maize followed similar pattern except that initial contents of chlorophyll 'a' were lower than those of chlorophyll 'b' Also, both varieties decreased gradually between 100 and 200m in the soil collected from the quarry site. SAMMAZ 52 had the highest accumulation under the control regime while the least was observed in SWAN 1 at 250m. Results of the ANOVA showed that there was no significant difference (p>0.05) in the two maize varieties.

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