ABSTRACT

Oil solarization is increasingly used to control soil-borne pathogens because it is environment-friendly. However, performance varied geographically, necessitating experimental trials before its introduction. This study assessed the effects of solarization on soil-borne bacteria and fungi, growth, and proximate composition of *Amaranthus viridis* (African spinach) in Lagos, Nigeria. Two raised beds were solarized for six weeks with a transparent and black polyethylene sheet, and a non-solarized (control) bed was equally made. The vegetable seeds were planted and their growths were recorded for four weeks. Soil samples at 15-20 cm deep and leaves were obtained for microbiological and proximate analysis, respectively. The mean temperature of transparent polyethylene’s soil was 45.33 °C, black polyethylene (35 °C), and non-solarized (33.50 °C). The mean height and width of transparent polyethylene’s *A. viridis* were 24 and 3 cm, black polyethylene (19 and 2.2 cm), and non-solarized (17 and 1.6 cm). The transparent polyethylene’s soil had 3100 and 250 cfu/g bacterial and fungal colonies, black polyethylene (3200 and 1900 cfu/g), and non-solarized (37000 and 1900 cfu/g), respectively. The proximate contents of the transparent polyethylene’s *A. viridis* were (70 moisture, 10 ash, 4.24 protein, 1.45 fat and 9.94 % fibre), black polyethylene (73.35 moisture, 8.36 ash, 3.1% protein, 1.23 fat, and 6.77 % fibre), and non-solarized (76.09 moisture, 5.91 protein, 3.15 ash, 1.31 fat and 6.75 % fibre). Overall, statistical differences (p ≤ 0.05) existed between the solarized and non-solarized and between transparent and black polyethylene (transparent > black > non-solarized). Thus, solarization could be an effective strategy for controlling soil-borne bacteria and fungi of *A. viridis* in the area studied.

**Keywords:** *Amaranthus viridis, Environment, Pathogens, Polyethylene, Soil*
INTRODUCTION

Amaranthus species is a popular group of vegetables that has about 70 members (Alegbejo, 2013). They are grown in the temperate and tropical climates of the world and are eaten as grains or vegetables (Alegbejo, 2013). The vegetable is highly nutritious and contains several phytochemicals, vitamins, and minerals (Peters and Gandhi, 2017). Amaranthus is anti-diabetic, anti-pyretic, anti-snake venom, anti-leprotic, anti-gonorrheal, anti-androgenic, anti-helmintic, anti-inflammatory, and has immunomodulatory properties (Alegbejo, 2013). In Nigeria and other sub-Saharan Africa, Amaranthus is considered the most consumed and traded green vegetable. It is a major source of nutrition in the region and provides income to farmers and market women. According to Ali et al. (2002), horticulture, which includes vegetable production, provides more employment per hectare of production than grain crop production. However, soil-borne pathogens constitute a great challenge to farmers in the region, reducing the nutritional content and market value of the vegetable. Some diseases of the vegetable include Alternaria rot (caused by A. solani and A. tenuis) and Phytophthora rot (caused by P. infestans and P. nicotianae) (Salau et al., 2012). Bacterial leaf spot (caused by B. andyopogonis) and leaf blight disease (caused by R. solani) are also frequently reported (Uppala et al., 2009). These pathogens are difficult to control because they can remain active for a long time in the host (Panth et al., 2020).

Common methods for managing soil-borne pathogens include the use of sanitation, resistant cultivars/varieties and grafting, cropping systems, soil solarization, bio-fumigation, and soil improvements (Panth et al., 2020). Others are anaerobic soil disinfestation, soil steam sterilization, soil fertility improvement, as well as chemical and biological control (Panth et al., 2020). In Nigeria and some other parts of the world, chemical control is the commonest. The chemical method is easy, fast, and effective, but harms human health and the environment and reduces plant pollinators and beneficial microorganisms (Christopher et al., 2010; Panth et al., 2020). An alternative strategy becomes imperative. Fortunately, in places with high sunlight and temperatures like Nigeria, solarization may be a suitable alternative.

Soil solarization, otherwise known as plasticulture, is an environment-friendly, pre-planting method that uses solar energy to control soil-borne pathogens, insects, and weed seeds (Mihajlović et al., 2017). It is very effective for less extensive farming, such as irrigating vegetables and orchards. Soil solarization can be done by placing plastic sheets, most often transparent materials, over the seed bed after irrigation (Panth et al., 2020). Soil solarization can kill and alter microbial populations by heating the soil (Panth et al., 2020). In an experiment by Emoghene and Futughe (2011), A. viridis plants grown on solarized seed-beds grew higher and did not develop shoot disease compared with non-solarized. However, aside from sunlight and temperature mentioned earlier, some other factors also influence the performance of solarization. These factors include soil moisture, soil types, soil colour, soil structure and texture, and soil organic matter content (Katan, 1987; Panth et al., 2020). Other factors include the length of the day, the sensitivity of pathogens and pest species in the area to heat, cropping history, and other components of soil ecology (Katan, 1987; Panth et al., 2020). Thus, it is necessary to test the performance of soil solarization before its introduction in any area. Literature searches showed that such a study has not been conducted in Ikorodu, Lagos, Nigeria, and environs. Therefore, this study investigated the effects of soil solarization on fungal and bacterial populations associated with Amaranthis viridis L. (African spinach) in Lagos, Nigeria. The findings of the study will provide primary data for soil solarization application in the study area.
MATERIALS AND METHODS

DESCRIPTION OF THE STUDY AREA
This study was conducted in the Owode Ibese area of Ikorodu, Lagos State, Nigeria (Figure 1). Lagos State is in the Southwest of the country on latitudes 6°36'–38'N and longitudes 3°40'–3°42'30'E (Salami et al., 2012). Lagos State borders Ogun State in the north and east, as well as the Republic of Benin in the west and the Atlantic Ocean in the south (Yahaya et al., 2020). The vegetation of the state is tropic with a short dry season between December and February and a long rainy season between March and November (Yahaya et al., 2020). The weather is very humid year-round, with monthly average maximum temperatures ranging from 28.6°C in July/August to 33.7°C in February/March (Ojeh et al., 2016). Ikorodu is on the outskirts of the state, characterized by extensive farmlands which are being rapidly lost to increasing urbanization. The soil of the study areas is composed of organic top soil, followed by loamy soil and lateritic sandy clay.

![Figure 1: Location of Owode Ibese, Ikorodu, Lagos (ArcGIS 10.3 software)](image)

COLLECTION OF A. VIRIDIS
Seeds of *A. viridis* were collected from a local farmer at Ikorodu in June 2020.

EXPERIMENTATION
The solarization was done as described by Elmore *et al.* (1997). A piece of land devoid of any debris was tilled, leveled, and moistened thoroughly for proper heat conductivity. Three raised planting beds (4 feet wide, 9 feet long, and 10 feet high) were made (Nair, 2016), of which one was covered with a black polyethylene sheet, transparent polyethylene sheet, and an uncovered planting bed served as the control. The polyethylene sheets were buried deep
around the bed to prevent them from flapping and tearing in the wind, which may have caused heat and moisture loss. The experiment was monitored daily and ensured that the beds were covered tightly with no holes in the polyethylene, which helped generate heat deep into the soil. After 6 weeks of solarization, the polyethylene sheets were removed and the A. viridis seeds were planted with a spacing of about 5 inches between seeds on all sides (Nair, 2016). The plant height and width of 20 samples of A. viridis from each bed were recorded weekly for four weeks. At the end of the experiment, 20 samples of the leaves of the A. viridis and 20 soil samples (at 15-20cm deep) from each bed were collected in sterile foil papers and taken to the laboratory for microbiological and proximate analysis, respectively.

**PLANT HEIGHT AND WIDTH MEASUREMENT**
The height and width of the A. viridis were measured as described by Moore (2018). The height was measured by placing a ruler on the ground next to the stem and measured to the height of the tallest stem. The width (diameter) was measured with a pair of calipers (Mitutoyo 500-196-20 Digital Vernier Caliper 150mm/6-inch Model).

**SOIL TEMPERATURE MEASUREMENT**
The soil temperature was measured between 1 and 2 pm daily, using a glass bulb thermometer as described by Sabri et al. (2018). A screwdriver was used to make a pilot hole in the soil to aid the insertion of the thermometer and avoid breakage. The thermometer was inserted 15cm deep into the soil (Elmore et al., 1997) and allowed to stay for about 5 minutes for the temperature to register.

**MICROBIOLOGICAL ANALYSIS**
The pour plate method described by Sanders (2012) was used to estimate the bacterial and fungal loads of the soil samples. Serial dilution was prepared by taking 1g of the soil in 9ml of distilled water (diluent) in a sterilized test tube and shaken for several minutes to obtain a stock solution. One (1) ml was taken from the stock solution into 9ml of distilled water in a test tube, which constituted a 10⁻¹ dilution. In the same manner, the second (10⁻²), third (10⁻³), fourth (10⁻⁴), and fifth (10⁻⁵) dilutions were prepared. One (1 ml) of each of 10⁻³, 10⁻⁴, and 10⁻⁵ dilution factors was placed in the centre of the Petri dishes using a sterile pipette, molten cooled nutrient agar and potato dextrose agar were then poured separately on the inoculum in the Petri dishes and the content mixed well. After solidification of the agar, the plates were incubated at 33°C (the average soil temperature) for 24 hours (nutrient agar) and 72 hours (potato dextrose agar). The potato dextrose agar was used to isolate fungi, while nutrient agar was used for bacteria isolates. The bacterial and fungal colonies grown in each media were then counted.

**PROXIMATE ANALYSIS OF THE A. VIRIDIS**

**MOISTURE CONTENT**
The moisture content of the vegetables was determined as described by AOAC (2000). Fresh leaves of the vegetables were weighed and oven-dried at 101°C for about 10 hours until a constant weight was obtained, after which it was cooled and re-weighed. The moisture content was obtained from the difference between the fresh and dry weight.

**ASH CONTENT**
The oven-dried samples obtained above were heated further in a muffle furnace at 550°C for about 3 hours. The ash content was obtained by subtracting the final weight from the initial weight.
CRUDE FIBRE CONTENT
The crude fibre content of the samples was obtained from the weight difference between the ash content and the sample analyzed (Ilodibia et al., 2014).

CRUDE FAT CONTENT
Five (5)g of each sample wrapped in filter paper was extracted in a Soxhlet apparatus using petroleum ether. The solvent was allowed to evaporate, after which the extracted material left was weighed and the fat content calculated.

CRUDE PROTEIN CONTENT
Crude protein was analyzed as described by the Kjeldahl method (AOAC, 2000). The samples were digested, distilled, and titrated. Using a conversion factor of 6.25 (Krul, 2019), the total nitrogen obtained was converted to crude protein. The percentage of protein in the samples was calculated thereafter.

DATA ANALYSIS
The Statistical Package for Social Science (SPSS) version 20 for Windows was used for all the analyses. Comparison of data among the test groups and control was done using ANOVA. Statistical significance was defined as p ≤ 0.05.

RESULTS AND DISCUSSION
MICROBIAL COUNTS OF SOLARIZED AND NON-SOLARIZED SOILS
The bacterial and fungal counts of the solarized and non-solarized soil are presented in Table 1. Compared with non-solarized, the solarized soils had lower bacterial and fungal counts (p ≤ 0.05). This result is consistent with Emoghene and Futughe (2011), who investigated the effects of solarization on A. viridis shoot disease and observed that only 5% of the plants in a solarized bed developed the shoot disease compared to 50% of the plants in non-solarized bed. Similarly, Zaid et al. (1991), showed that in a soil solarized for 45 days, fungal and bacterial populations were reduced by 76.6 and 71.1%, respectively. The reduction in the microbial populations of the solarized soils in this study, particularly soil solarized with the transparent sheet, could have been induced by the increased soil temperature following solarization (Table 1). According to Pokharel (2011), high temperatures raise soil volatile compounds to toxic levels and weaken soil microorganisms. Most organisms in the soil are negatively affected by temperatures greater than 39°C (Stapleton and DeVay, 1995), which was achieved by the soil solarized with transparent sheets in this study, but not in the other two soils (Table 1). This could explain why the soil solarized with transparent polyethylene had significantly (p ≤ 0.05) lower bacterial and fungal counts than the soil solarized with black polyethylene. It further showed that, aside from trapping more heat, transparent polyethylene transmits heat in the soils more efficiently, leading to more microbial death. Transparent materials allow radiation to pass through and heat the underlying soil, while black materials absorb some solar energy and radiate it back (Krueger and McSorley, 2018). In 10-week soil solarization that compared the effectiveness of transparent and black polyethylene, the transparent material was slightly more effective (Abu-Gharbieh et al., 1991). Barakat (1987) also showed that a black material reduced soil temperatures by several degrees compared to a transparent material. However, Hasing et al. (2004) observed similar soil temperatures by transparent and black polyethylene following solarization.
Table 1: Total Viable Bacterial and Fungal Counts of Solarized and Non-solarized Soils in Ikorodu, Lagos Nigeria

| Plot                      | Maximum Soil Temperature (°C) | Ambient Temperature (°C) | Bacteria count (cfu/g) | Fungal count (cfu/g) |
|---------------------------|------------------------------|--------------------------|------------------------|----------------------|
| Transparent Polyethylene Sheet | 45.33±1.20*^a               | 32.60±2.20               | 3150.00±28.9*^a        | 258.33±4.14*^a      |
| Black Polyethylene Sheet  | 35.00±0.56                   | 32.60±2.20               | 3250.00±27.9*          | 1883.30±44.1*       |
| Control                   | 33.50±0.50                   | 32.60±2.20               | 37200.00±53            | 7817.00±58          |

Note: Values were expressed as means ± SD (n = 20); the values with an asterik (*) in the column are statistically different from the control at p ≤ 0.05 (ANOVA); the values with a letter ‘a’ in the column are statistically different from black polyethylene sheet at p ≤ 0.05 (ANOVA).

GROWTH PERFORMANCES OF SOLARIZED AND NON-SOLARIZED A. VIRIDIS

Table 2 contrasts the growth characteristics of A. viridis grown on solarized soils with those grown on non-solarized soils. Compared with the non-solarized, the A. viridis grown on the solarized soils significantly (p ≤ 0.05) grew taller. This result is consistent with that of Sabatino et al. (2019), who reported higher plant growth on solarized soil compared with non-solarized. Some other studies also reported that black plastic materials resulted in higher early yields, but reduced total crop yield compared to transparent film (Schonbeck and Evanylo, 1998). As noted in Table 1, solarization increases soil temperatures, which, according to Farias-Larios et al. (1998), promotes nutrient availability and uptake by roots, resulting in increased growth. High temperatures also increase the activity of beneficial microorganisms, which speed up plant growth (Farias-Larios et al., 1998). Furthermore, solarization stabilizes temperatures up to 30cm deep in the soil, which favors root development and plant growth (Kasirajan and Ngouajio, 2012). However, the growth performance of plants under solarization depends on the capacity of light penetration or transparency, as evident in Table 2, in which plants grew significantly (p ≤ 0.05) higher under transparent polyethylene than under black polyethylene. Helaly et al. (2017), monitored the effects of polyethylene types on the growth of husk tomato plants, and reported higher plant height, stem diameter, and leaf area by transparent polyethylene than black polyethylene. In another experiment that compared the effects of soil solarization among transparent, black, and white polyethylene sheets on lettuce yields, transparent polyethylene performed best (Mahmood et al., 2015). Solarization kills soil pathogens and pests. However, many beneficial soil organisms such as mycorrhizal fungi and Bacillus species can either survive solarization or recolonize the soil quickly afterward, improving soil nutrients, which aids plant growth (Stapleton et al., 2019).
Table 2: Growth Performances (Stem Length and Width) of A. viridis in Solarized and Non-solarized Soils in Ikorodu, Lagos Nigeria

| Plot                      | Week 1 (cm)   | Week 2 (cm)   | Week 3 (cm)   | Week 4 (cm)   |
|---------------------------|---------------|---------------|---------------|---------------|
| Transparent Polyethylene Sheet | H= 2.87±0.18* | H= 9.63±0.09**a | H=14.57±0.43**a | H=24.83±0.15**a |
|                           | W= 0.60±0.06  | W=1.50±0.15   | W= 2.37±0.09**a | W= 3.63±0.15**a |
| Black Polyethylene Sheet  | H= 3.03±0.19* | H= 6.83±0.04  | H=10.73±1.23  | H=17.63±1.11  |
|                           | W= 0.70±0.12  | W=1.00±0.06   | W= 1.53±0.15  | W= 2.27±0.12* |
| Control                   | H = 2.35±0.05 | H = 5.87±0.26 | H = 9.67±0.24 | H = 16.40±0.61|
|                           | W= 0.65±0.05  | W= 0.83±0.03  | W= 1.30±0.06  | W= 1.90±0.12  |

Note: Values were expressed as mean ± SD (n = 20); H = height; W = width; the values with an asterisk (*) in the column are statistically different from the control at p ≤ 0.05 (ANOVA), the values with a letter ‘a’ in the column are statistically different from black polyethylene sheet at p ≤ 0.05 (ANOVA).

PROXIMATE COMPOSITION OF THE SOLARIZED AND NON-SOLARIZED A. VIRIDIS

The moisture, ash, crude protein, fat, and the crude fibre content of the A. viridis solarized with transparent and black polyethylene sheets as well as non-solarized are presented in Table 3. The A. viridis grown on soil solarized with the transparent polyethylene sheet had the highest levels (p ≤ 0.05) of ash, crude protein, fat, and crude fibre, while moisture content was highest in the control. Generally, there was no significant difference (p ≥ 0.05) between the A. viridis solarized with the black polyethylene sheet and the non-solarized in the levels of the mentioned nutrients. These results follow similar trends with the phytonutrient properties of some solarized plants compared with the non-solarized. Notably, Grünzweig et al. (1999) reported increased concentrations of nitrogen and copper in solarized tomato plants compared with the non-solarized tomatoes of the same species. In another study, solarization with calcium cyanamide significantly increased the ascorbic acid and phenolic content of tomato fruits compared with the non-solarized (Sabatino et al., 2019).

The high proximate compositions of the A. viridis solarized with a transparent polyethylene sheet showed that solarizing with the material promotes plant nutrient accumulation. According to Saloum and Almahasneh (2015), soil solarization improves soil physical, chemical, and biological properties, resulting in improved overall plant quality, including nutritional contents. Soil solarization boosts the bioavailability of phytochemicals and phytonutrient-enhancing soil nutrients such as nitrogen, calcium, and magnesium as well as extractable phosphorus and potassium (Pokharel, 2011).
Table 3: Proximate Composition of Solarized and Non-solarized A. viridis Grown in Ikorodu, Lagos Nigeria

| Plot                     | Moisture Content (%) | Ash Content (%) | Crude Protein (%) | Fat Content (%) | Crude Fibre (%) |
|--------------------------|----------------------|----------------|-------------------|-----------------|-----------------|
| Transparent Polyethylene Sheet | 70.98±4.24*         | 10±2.0*        | 4.24±0.00*        | 1.45±0.57       | 9.94±0.00*      |
| Black Polyethylene Sheet  | 73.35±0.27*          | 8.36±1.9       | 3.16±0.28         | 1.23±0.06       | 6.77±1.1        |
| Control                  | 76.09±0.01           | 8.31±0.11      | 3.35±0.15         | 1.31±0.45       | 6.75±0.11       |

Note: Values were expressed as means ± SD (n = 20); the values with an asterik (*) in the column are statistically different from the control at p ≤ 0.05 (ANOVA); the values with a letter ‘a’ in the column are statistically different from black polyethylene sheet at p ≤ 0.05 (ANOVA).

LIMITATIONS OF THE STUDY
Due to financial constraints, the study could not investigate the effects of solarization on many microorganisms associated with A. viridis. For the same reason mentioned, the study could not also assess the performance of seed bed covers other than transparent and black polyethylene.

CONCLUSION
The results showed that the solarized soils had lower bacterial and fungal counts than the non-solarized, which suggests that solarization had killed some soil microorganisms. The transparent polyethylene sheet reduced the microbial counts more than the black polyethylene because the transparent material trapped and transmitted solar energy more efficiently. Moreover, the A. viridis planted in the solarized soils grew more in height and width than in the non-solarized soil. The positive effects of soil solarization on the A. viridis are evident in their proximate compositions, in which the A. viridis in the transparent and black polyethylene (in that order) had higher fat, crude fibre, protein, and ash content. Overall, findings from this study imply that solarization may be an effective strategy for controlling soil-borne pathogens of A. viridis in the studied area. We recommend similar studies on other plants grown in the area and other regions in Nigeria.

CONFLICT OF INTEREST
The authors have no conflict of interest.
REFERENCES
Abu-Gharbieh, W.I., Saleh, H. and Abu-Blan, H. (1991). Use of black plastic for soil solarization and post-plant mulching. FAO plant production and protection paper 109 food and agriculture organization of the united nations rome. http://www.fao.org/3/T0455E0j.htm. (Accessed May 8, 2020).

Alegbejo, J.O. (2013). Nutritional Value and Utilization of Amaranthus (Amaranthus spp.) – A Review. Bayero Journal of Pure and Applied Sciences, 6 (1): 136-143. http://dx.doi.org/10.4314/bajopas.v6i1.27.

Ali M, Farooq, U. and Shih, Y.Y. (2002). Vegetable research and development in the ASEAN region: a guideline for setting priorities. In: C.G. Kuo (ed). Perspectives of ASEAN cooperation in vegetable research and development. Shanhua, Taiwan: Asian Vegetable Research and Development Center, pp: 20-64.

Association of official analytical chemists (AOAC) (2000). Official Methods of Analysis of the Association of the Official Analytical Chemists, AOAC International, Washington, DC, USA, 17th edition, pp: 13.

Barakat, R.M. (1987). Comparative effect of different colors of polyethylene tarping on soil borne pathogens. University of Jordan, Amman. (M.Sc. thesis).

Barakat, R.M. and AL-Masri, M.L. (2012). Enhanced Soil Solarization against Fusarium oxysporum f. sp. lycopersici in the Uplands. International Journal of Agronomy, 2012: Article ID 368654. https://doi.org/10.1155/2012/368654.

Christopher, D.J., Raj, T.S., Rani, S.U. and Udhayakumar, R. (2010). Role of defense enzyme activity in tomato as induced by Trichoderma virens against Fusarium wilt caused by Fusarium oxysporum f.sp. lycopersici. Journal of Biopesticides, 3:158–162.

Elmore, C.L., Stapleton, J.J., Bell, E.C. and Devay, E.J. (1997). Soil Solarization A Non pesticidal Method for Controlling Diseases, Nematodes, and Weeds. University of California Vegetable Research and Information Center. https://vric.ucdavis.edu/pdf/soil_solarization.pdf. (Accessed May 8, 2020).

Emoghene, A.O. and Futughe, E.A. (2011). Effect of Soil Solarization on Amaranthus viridis Shoot Disease caused by Choanephora cucurbitarum. Nigerian Annals of Natural Sciences, 11 (1): 33-40.

Farias-Larios, J., Orozco-Santos, M. and Perez, J. (1998). Effect of plastic mulch, floating row covers and microtunnels on insect population and yield of muskmelon. Proceedings of National Agricultural Plastics Congress, 27:76–83.

Federal Ministry of Health (2013). Nigeria master plan for neglected tropical diseases (NTDs) 2013–2017, Abuja: Federal Ministry of Health, pp: 142.

Grünzweig, J.M., Katan, J. and Ben-Tal, Y. (1999). The role of mineral nutrients in the increased growth response of tomato plants in solarized soil. Plant and Soil, 206:21-27. https://doi.org/10.1023/A:100432118896.
Hasing, J.E., Motsenbocker, C.E. and Monlezun, C.J. (2004). Agroeconomic effect of soil solarization on fall-planted lettuce (*Lactuca sativa*). *Scientia Horticulturae, 101* (3): 223- 233.

Helaly, A.A., Goda, Y. and El-Rehim, A.A. (2017). Effect of polyethylene mulching type on the growth, yield and fruits quality of physalis pubescens. *Advances in Plants and Agricultural Research, 6* (5):154–160. DOI: 10.15406/apar.2017.06.0029.

Ilodibia, C.V., Ugwu, R.U., Okeke, C.U., Ezeabara, C.A., Okeke, N.F., Akachukwu, E.E. and Aziagba, B.O. (2014). Determination of Proximate Composition of Various Parts of Two Dracaena Specie. *International Journal of Botany, 10*: 37-41.DOI: 10.3923/ijb.2014.37.41.

Kasirajan, S. and Ngouajio, M. (2017). Polyethylene and biodegradable mulches for agricultural applications: a review. *Agronomy for Sustainable Development, 32*:501-529. https://doi.org/10.1007/s13593-011-0068-3.

Katan, J. (1987). Soil solarization: In Innovative approaches to plant disease management, I. Chet, ed., John Wiley and Sons, New York, pp. 77-105.

Krul, E.S. (2019). Calculation of Nitrogen-to-Protein Conversion Factors: A Review with a Focus on Soy Protein. *Journal of the American Oil Chemist’s Society, 96* (4): 339-364. https://doi.org/10.1002/aocs.12196.

Krueger, R. and McSorley, R. (2018). Solarization for Pest Management in Florida. IFAS Extension Foundation, University of Florida. https://edis.ifas.ufl.edu/pdffiles/IN/IN82400.pdf. (Accessed May 10, 2020).

Mahmood, S., Al-Solimani, S.G., El-Nakhlawy, F.S. and Namatallah, A.A. (2015). Effect of Soil Solarization with Polyethylene Colored Sheets and Organic Manures on Lettuce Yield, Weed Growth, Soil Nutrients and Fungi. *International Journal of Engineering Research and Technology, 4* (11): 383-387.

Mihajlovi´c, M., Rekanovi´c, E., Hrusti´c, J. and Tanovi´c, B. (2017). Methods for management of soilborne plant pathogens. *Pesticidi Fitomedicina, 32*:9–24.

Nair, A. (2016). Raised beds for Vegetable Production. Iowa State University Extension and Outreach. https://www.extension.iastate.edu/smallfarms/raised-beds-vegetable-production. (Accessed March 15, 2021).

Ojeh, V.N., Balogun, A.A. and Okhimamhe, A.A. (2016). Urban-Rural Temperature Differences in Lagos. *Climate, 4*:29. https://doi.org/10.3390/cli4020029.

Moore, A. (2018). Measuring the Diameter and Height of Plants. New York State Science, Technology, Engineering and Mathematics Summer Institute. https://teachclimatescience.files.wordpress.com/2018/08/nyc-stem-st03-toolkit-2-measuring-plants.pdf. (Accessed March 15, 2021).

Panth, M., Hassler, S.C. and Baysal-Gurel, F. (2020). Methods for Management of Soilborne Diseases in Crop Production. *Agriculture, 10* (16): 1-7. http://dx.doi.org/10.3390/agriculture10010016.
Peters, K. and Gandhi, P. (2017). Rediscovering the therapeutic potential of Amaranthus species: A review. *Egyptian Journal of Basic and Applied Sciences*, 4 (3): 196-295. https://doi.org/10.1016/j.ejbas.2017.05.001.

Pokharel, R. (2011). Colorado State University Extension. https://extension.colostate.edu/topic-areas/agriculture/soil-solarization-an-alternative-to-soil-fumigants-0-505/. (Accessed May 11, 2020.

Sabatino, L., D’Anna, F., Prinzivalli, C. and Iapichino, G. (2019). Soil Solarization and Calcium Cyanamide Affect Plant Vigor, Yield, Nutritional Traits, and Nutraceutical Compounds of Strawberry Grown in a Protected Cultivation System. *Agronomy*, 9 (9):513-526. https://doi.org/10.3390/agronomy9090513.

Sabri, N., Zakaria, Z., Mohamad, S.E., Jaafar, A.B., and Har, H. (2018). Importance of Soil Temperature for the Growth of Temperate Crops under a Tropical Climate and Functional Role of Soil Microbial Diversity. *Microbes and environments*, 33(2):144–150. https://doi.org/10.1264/jsme2.ME17181.

Salami, B.M., Falebita, D.E., Fatoba, J.O. and Ajala, M.O. (2012). Integrated Geophysical and Geotechnical Investigation of a Bridge Site - A Case Study of a Swamp/Creek Environment in South East Lagos, Nigeria. *Ife Journal of Science*, 14 (1): 75-82.

Salau, I.A., Kasarawa, A.B. and Tambuwal, N.I. (2012). Fungi associated with vegetable plant diseases in the Fadama land areas of Sokoto Metropolis. Proceeding of Agricultural Society of Nigeria (ASN) 46th Annual Conference (“Kano 2012”), pp: 779-782.

Saloum, A. and Almahasneh, H. (2015). Effect of Soil Solarization and Organic Fertilization on Yield of Maize (Zea mays L.) Genotypes and Soil Chemical Properties. *Asian Journal of Agricultural Research*, 9: 173-179. DOI: 10.3923/ajar.2015.173.179.

Sanders, E.R. (2012). Aseptic laboratory techniques: plating methods. *Journal of Visualized Experiments*, 63: e3064. https://doi.org/10.3791/3064.

Schonbeck, M.W. and Evalylo, G.E. (1998). Effects of mulches on soil properties and tomato production. I. Soil temperature, soil moisture, and marketable yield. *Journal of Sustainable Agriculture*, 13: 55–8. http://dx.doi.org/10.1300/J064v13n01_06.

Stapleton, J.J., Wilen, C.A. and Molinar, R.H. (2019). UCIPM Pest Notes: Soil Solarization for Gardens and Landscapes. UCANR Publication 74145. Oakland, CA. (Accessed May 11, 2020.

Uppala, L.S., Beena, S., Chapala, M., Bowen, K.L., Reddy, M.S., Desai, S., Sayyed, R.Z., Rao, V.K., Sarma, Y.R., Reddy, B.C., Reddy, K.R.K., Podile, A.R. and Kloeper, J.W. (2009). Bioefficacy of endophytes in the management of leaf blight disease of amaranth. ages 524-530. In: Plant Growth Promotion by Rhizobacteria for Sustainable Agriculture.(eds.). Scientific Publishers, India. DOI: 10.13140/RG.2.1.2767.0564.
Yahaya, T., Esther, O., Itunuoluwa, F., Abdulmalik, A. and Yusuf, Y. (2020). The Concentration and Health Risk Evaluation of Heavy Metals and Microorganisms in Groundwater in Lagos, Southwest Nigeria. *Journal of Advances in Environmental Health Research*, 8 (3):234-242.10.22102/jaehr.2020.245629.1183.

Zaid, A.M., Ismail, W., Khader, A. and Mayof, M. (1991). Control of soilborne pathogens with soil solarization in the southern region of Libyan Jamahiriya. FAO Plant Production and Protection Paper 109 Food and Agriculture Organization of the United Nations Rome. http://www.fao.org/3/T0455E00.htm#Contents. (Accessed May 10, 2020).