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Orange Fleshed Sweet Potato Response to Filter Cake and Macadamia Husk Compost in Two Agroecologies of KwaZulu-Natal Province, South Africa

Kayode Fatokun [1,*], Nozipho M. Motsa [1] and Albert T. Modi [2]

[1] Department of Agriculture, University of Zululand, Private Bag X1001, KwaDlangezwa 3886, KwaZulu-Natal, South Africa
[2] School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, P. Bag X01, Scottsville, Pietermaritzburg 3209, KwaZulu-Natal, South Africa
* Correspondence: kayfatokun@yahoo.com

Abstract: Field experiments were carried out during the summer/autumn (first trial) and winter/spring (second trial) seasons of 2019 and 2021 in the Dlangubo, Ngwelezane, and Mtubatuba areas of KwaZulu-Natal Province of South Africa to study the drought amelioration effects and impact of two locally available organic wastes (filter cake—a residue derived from sugar cane filtration (FC) and macadamia husk compost (MHC)) on the productivity and physiological responses of four orange-fleshed sweet potato cultivars (Beauregard cv., Impilo, W-119 and 199062.1). The effects of FC and MHC were compared with that of inorganic fertilizer (IF) [2:3:2 (30)], FC + IF, MHC + IF, and the control. The soil amendments were applied in the first trials only. Climatic data such as humidity, temperature, and rainfall were taken via remote sensing. The results of the first trial indicated that filter cake and IF significantly performed better than MHC. The strength of filter cake may be attributable to its rich array of mineral nutrients such as calcium, magnesium, potassium, sodium, zinc, copper, manganese, iron, and phosphorus. The limited performance of MHC may be attributable to its ability to hold water. Furthermore, a positive correction occurred between the yield of the test orange-fleshed sweet potato (OFSP) cultivars, rainfall, and vegetation indices (normalized difference vegetation index, enhanced vegetation index, and normalized difference water index) investigated in the study. In season two, IF treatment did not have any significant effect on the growth and productivity of any of the tested sweet potato cultivars, but, FC, FC + IF, and MHC treatments largely maintained their performances. In conclusion, the use of FC is highly recommended in the production of the test OFSP cultivars. Furthermore, the study indicates that both FC and MHC may not only supply the needed plant nutrients but has the capacity to reduce the impact of drought on the growth of the test cultivars. These findings are of great value to farmers, especially the resource-poor ones.

Keywords: amendments; drought; filter cake; macadamia husk compost; sweet potato; vegetation indices

Citation: Fatokun, K.; Motsa, N.M.; Modi, A.T. Orange Fleshed Sweet Potato Response to Filter Cake and Macadamia Husk Compost in Two Agroecologies of KwaZulu-Natal Province, South Africa. *Agronomy* **2022**, *12*, 3091. https://doi.org/10.3390/agronomy12123091

Academic Editors: Zhongbing Chen, Safdar Bashir and Saqib Bashir

Received: 14 October 2022
Accepted: 24 November 2022
Published: 6 December 2022

1. Introduction

Agricultural land has continued to reduce due to urbanization, industrialization, desertification, drought, and many other alternative uses that require land [1,2]. Furthermore, as agricultural lands are cropped, soil nutrients are reduced. Soil nutrients are also lost via erosion and leaching [3]. With the ever-increasing world population, and the continually decreasing agricultural land, one of the greatest challenges of the present century is the continued production of enough food to feed the people. Hence, efforts must be made toward enhancing farmers' yield. Hence, proper crop management is very essential to increase yield and ensure that the genetic potentials of crops are fully expressed [4]. One of such management practice that ensures the supply of nutrients to crops is the use of inorganic fertilizer.

Inorganic fertilizers are synthetic and are produced in industries. While some are applied to soil to enhance its nutrient base, others are applied directly to the foliar region of the plants and are directly absorbed into the plant [5]. Nutrients contained in fertilizer include macronutrients such as nitrogen, phosphorus, and potassium and micronutrients such as zinc, copper, and manganese. Nutrients from inorganic fertilizers are readily available to plants; hence, their actions are very fast. In the same vein, the application of inorganic fertilizers is very easy. It can be applied manually by hand, especially on small-scale farms. It can also be applied with large farm machinery on large-scale farms. Inorganic fertilizer can be applied in liquid, pellets, and dry forms [5,6].

However, due to the high cost of fertilizers which is unaffordable to small-scale farmers, the use of organic wastes generated by agricultural commodities is receiving considerable attention [4]. Apart from providing soil nutrients, organic wastes from agricultural activities contribute to the conservation of natural resources in the soil. Other beneficial uses of organic wastes generated by agricultural commodities include serving as an alternative method of disposing of such wastes, which invariably addresses the rising costs and environmental concerns associated with waste disposal and management [7]. It is recognized that using organic waste, which is a low-cost material, can improve soil fertility, improve soil structure, and enhance the water-holding capacity of the soil. It has also been reported that the use of organic waste is beneficial to soil's physical attributes, such as stability and average weighted diameter of aggregates [4].

The use of organic waste is a sustainable activity, which is increasingly necessary when dealing with natural resources. Soil improvement and conservation are pertinent because drought is one of the major concerns building strong restrictions to crop productivity in many parts of the country. KwaZulu-Natal Province has recurrent and severe drought problems [1]. Adaptation strategies and investment are needed in response to drought. These adaptation strategies include developing new technologies such as improved crop varieties and building resilience to climate within agricultural communities. In doing this (combating the challenges posed to farming by drought), it is very important that locally available and inexpensive methods are proposed to farmers and extension agents to ensure ease of adaptation and use on the farms [4,5]. One of such methods of ameliorating drought is the use of organic wastes [4].

Some organic wastes are used as they were collected; such wastes include filter cake. Filter cake is a residue derived from sugar cane filtration and it is produced in large volumes; 30–40 kg t^{-1} of crushed cane [8,9]. Some other wastes need to be processed before use, e.g., macadamia husks must be processed into macadamia husk compost before use [5,10,11]. Macadamia husks are the outer coating of the nut-in-shell of macadamia. They are produced in the process of de-husking macadamia nuts [12]. It has been reported that processing organic waste could improve its agricultural value when it is used as fertilizer; such values include the bioavailability of the nutrients in the waste. Besides the chemical and physical characteristics of organic waste such as favorable electrical conductivity, and pH, high moisture content, carbon, good C:N ratio, improved soil structure, and low cost which makes organic wastes good candidates for soil fertilization [5,10,11].

The intensity of drought and other climatic factors that affect agricultural activities vary within the country South Africa and its provinces [13]. Hence, several agroecologies have been created by the interaction of climatic factors such as rainfall, humidity, and temperature. Other factors that affect the growth of crops in the different agroecologies include soil types, soil nutrients, soil water, sunlight, and wind. These agroecological factors determine the health or greenness of the vegetation in given agroecology and ultimately the biomass accumulation of the plants. Prominent among the indices used in determining the health of plants/vegetation in each agroecology are the Normalized Difference Vegetation Index (NDVI), the Enhanced Vegetation Index (EVI), and Normalized Difference Water Index (NDWI). While NDVI is a graphical indicator of the greenness of the vegetation; it is sensitive to photosynthetically active plant biomass and Nitrogen status and ecological monitoring [14]. NDWI is a measure of plant water status, in other words, it measures the interaction of solar radiation and the liquid water present in a plant [15]. Like NDVI, EVI is used to quantify the greenness of vegetation and plant water status. However, it can show the stress patterns of plants by using additional light wavelengths [16]. All the indices have been used to assess plant health and drought [15,17,18].

Sweet potato (*Ipomoea batatas* L.) is an important root crop of tropical origin that has been 'indigenized' in South Africa [19,20]. The edible parts of sweet potato are the roots and immature leaves/shoots. Very high in Vitamin A, energy, and other nutrients, the production of orange-fleshed sweet potato is currently being promoted to combat vitamin A deficiency among children and pregnant women of the KwaZulu-Natal province, promote food security, and tackle malnutrition [21]. Although sweet potato and by extension the OFSP exhibit phenotypic plasticity which makes them adapt to drought stress and continue to produce good yield when exposed to drought, however, under severe drought, the plants can only benefit a little from this inherent potential of phenotypic plasticity. Severe levels of droughts can cause irreversible damage to the leaf chlorophyll content and expose the plant to stress. All these ultimately lead to a reduction in photosynthesis and a decline in the root and shoot biomass [22,23].

Of all the climatic factors, drought and or water stress are of great concern in South Africa and of particular interest in this study. To ameliorate the impact of drought on crops at a lower cost and with little technical expertise requirements, the use of organic waste such as filter cake, and macadamia husks compost, are now being considered. Hence, this study is aimed at investigating the response of four orange-fleshed sweet potato cultivars to soil amendment with filter cake and macadamia husk compost indifferent agroecologies of Northern KwaZulu-Natal, province of South Africa.

2. Materials and Methods

2.1. Study Sites, Acquisition of Orange-Fleshed Sweet Potato, and Field Plans

The study was carried out during the summer/autumn (first trial) and winter/spring (second trial) seasons of 2019 and 2021 in Dlangubo, Ngwelezane, and Somkhele area of Mtubatuba in KwaZulu-Natal (KZN) Province of South Africa. All the sites were well drained and located in ward 24 (Dlangubo), ward 29 (Ngwelezane), and ward 14 (Somkhele) of the province. The experimental sites were located within the farms of volunteer small-scale farmers in the wards. Four orange-fleshed sweet potato cultivars were used for the study. The cultivar 199062.1 was obtained from the University of KwaZulu-Natal, Pietermaritzburg, KwaZulu-Natal. The other cultivars viz W-119, Impilo, and Beauregard were bought from Agricultural Research Council (ARC), Roodeplat, Pretoria, South Africa.

The filter cake was obtained from the Felixton mill of Tongaat Hulett Sugar South Africa Ltd., and macadamia husk was obtained from Mayo Macs Macadamias, Felixton, both in Empangeni, KZN. Both FC and macadamia husks were obtained free of charge. The inorganic fertilizer was sourced from the Teaching and Research Farm of the University of Zululand, KwaDlangezwa. While the filter cake was used as it was collected from the mill. Macadamia husk was composted using standard procedures for macadamia husk compost before use. Six treatments were derived from the inorganic fertilizer, filter cake, and macadamia husk compost amendments, viz. Filter cake (FC), macadamia husk compost (MHC), inorganic fertilizer (IF) [2:3:2 (30)], a combination of filter cake and inorganic fertilizer (FC + IF), a combination of macadamia husk compost and inorganic fertilizer (MHC+ IF) and the control (C). Filter cake and the inorganic fertilizer were applied at 10 tons ha^{-1} and 0.6 tons ha^{-1}, respectively [24]. The MHC was also applied at 10 tons/ha. The treatments were replicated three times and the experiments were rain-fed.

2.2. Field Preparation and Experimental Set-Up

The fields were cleared manually, ploughed, and harrowed with tractors sourced from commercial service providers. About a week after harrowing, the fields were ploughed a second time to create windrows. The height of each windrow was about 30 cm to 40 cm. The experiments were laid out in a split-plot design and replicated three times. The tested

OFSP cultivars were the main plot, while the treatments were the subplot. While each of the 4 main plots was 4.5 m × 10 m, each subplot/treatment plot was 5 m in length by 1.5 m in breadth. The treatment plots consisted of 5 rows which were 1 m apart. The distance between plants on each row was 0.3 m. Thus, the total number of plants in each subplot (treatment) was 25, the total number of plants per OFSP cultivar (main plot) was 150 and for the entire field (4 cultivars and 6 treatments) was 600. The sites were irrigated to field capacity a day before planting and a week after planting to ensure plant establishment. Thereafter, the experiments were rainfed.

2.3. Plant Growth Data Collection

Plant growth data collected included plant mortality, dry mass of storage root, shoot dry mass, chlorophyll content, and stomatal conductance. Plant mortalities were taken by counting the number of dead plants every two weeks. The dead plants were replaced with new vines and tagged as replacement plants. The dates of replacement were also noted on the tags. At harvesting, the plants were carefully pulled out of the soil with the aid of garden forks. Thereafter, the shoot and storage roots were separated. The storage roots were washed. Both the storage roots and shoots were oven dried at 75 °C to constant mass and weighed.

Leaf chlorophyll content was measured at 10 WAP using a SPAD chlorophyll meter (model SPAD-502; Minolta Corp., Ramsey, NJ, USA). Six plants were randomly selected per treatment plot. Although the plants were randomly selected, replacement plants were avoided. Chlorophyll contents were measured on the fourth and fifth leaves counting from the terminal bud. Hence, the reported chlorophyll content per treatment was estimated as the mean of 12 readings (n = 12 per treatment plot) and expressed as the chlorophyll content index (CCI). The rate of carbon dioxide (CO_2) uptake and transpiration as determined by the degree of stomatal opening (Stomatal conductance), was measured at 10 WAP using a Leaf Porometer Model SC-1(Meteo-Tech Ltd. Meteorological Services, Tel Aviv, Israel). The measurements were taken on the third leaf counting from the terminal bud across all treatments and replicates. Thus, the reported stomatal conductance per treatment was estimated as the mean of 6 readings (n = 6 per treatment) and expressed as mmol m^{-2} s^{-1}.

2.4. Preparation of Macadamia Husk Compost

The composting operation was done at the orchard unit of the department of agriculture, University of Zululand. The compost was made from macadamia husks only. The macadamia husks were mixed and piled into windrows which were approximately 1.5 m high. The husks were covered with polythene bags. The compost piles were turned once a week for the first month and every other week for the second month or when the temperature maintained or exceeded 55 °C for 3 days [25]. The piles were watered several times during the 8-week composting period with a sprinkler system to keep them moist.

The filter cake was used as collected from the sugar refinery without further processing

2.5. Compost, Soil Sampling, and Analyses

Filter cake and macadamia husks were analyzed at the beginning of the study to determine their chemical compositions. Furthermore, soil samples were taken from all the sites at the start of the study. All samples taken were replicated 3 times. The soil samples were prepared using the method of [26].

To determine N, 1 g of soil was digested in a 15 mL concentrated sulfuric acid block digester at a temperature of about 370 °C. Titration of the excess acid with standard sodium hydroxide solution to orange endpoint was then performed—Kjeldahl method [27]. The Bates method was used to determine the pH of the samples [28]. Automated Dumas dry combustion method (catalyst used was vanadium pentoxide) using a LECO CNS 2000 (Leco Corporation USA, St. Joseph, MI, USA) [29] was used to determine total carbon and nitrogen. Phosphorus (P), potassium (K), zinc (Zn), copper (Cu), and manganese (Mn) were extracted using Ambic-2 extracting solution (0.25 M ammonium carbonate

(NH_4CO_3) + 0.01 M disodium ethylene diamine tetra acetate (NaEDTA) + 0.01 M ammonium fluoride (NH_4F) + 0.05 g L-1 Superfloc). Potassium, Zn, Cu, and Mn were determined by atomic absorption from the extract. In determining phosphorus (P), a modification of the Murphey and Riley (1962) molybdenum blue procedure was used [30]. Calcium (Ca) and magnesium (Mg) were extracted with potassium chloride solution and were determined by atomic absorption.

2.6. Metrological Data Collection

Meteorological data namely humidity, temperature, and rainfall were obtained from the South Africa Weather Service (SAWS). With their sensors installed at different locations, the reports were sent to the central system on an hourly basis. Reported in this study were the average monthly humidity, average monthly temperature, and total monthly rainfall. The health of the vegetation of the wards where the experiments were sited was monitored bimonthly from January 2019 to November 2021. The NDVI, EVI, and NDWI were used to analyze remote sensing measurements, which were acquired using the ArcGIS space platform software using the method of [31]. The vegetation indices were calculated thus:

$NDVI = (NIR - Red)/(NIR + Red)$

$EVI = 2.5 \times (NIR - Red)/(NIR + 6 \times Red - 7.5 \times Blue + 1)$

$NDWI = (Green - NIR)/(Green + NIR)$

NIR = Near-infrared light, Red is the visible red light, Blue is the visible blue light.

2.7. Statistical Analyses

Analyses of the data generated from the soil, filter cake, and macadamia compost were done with the analysis of variance (ANOVA) using Gen Stat Release 12.1 (PC/Windows Vista) (VSN International, Hemel Hempstead, UK 2009). Plant growth data viz shoot dry mass, storage root dry mass, chlorophyll content, and stomatal conductance was subjected to split-plot repeated measures. The significant differences between means of treatments were checked at $LSD_{0.05}$. Climate data (humidity, rainfall, and temperature) were presented using excel color scales.

3. Results and Discussions

The yields of all four OFSP cultivars responded positively to soil amendments with filter cake (FC), macadamia husk compost (MHC), inorganic fertilizer (IF), a combination of filter cake and inorganic fertilizer (FC + IF), and a combined application of macadamia husk compost and inorganic fertilizer (MHC + IF) when compared to the control. However, the responses varied across the study sites, cultivars, and seasons. The variations were attributable to changes in meteorological conditions, soil and soil amendments compositions, and the inherent properties of the test OFSP cultivars.

3.1. Climate, and Meteorology of the Study Sites

Temperatures of all the sites in both seasons were greater than 12.8 °C, hence, the temperatures in all the sites were favorable to the growth of OFSP [32]. Furthermore, although temperature and humidity are known to play some roles in crop growth, however in this study, no definite role could be deduced because the values were not significantly different between the study sites. However, the role of rainfall was very clear. Apart from the second trial of 2019, both Ngwelezane and Dlangubo received more rainfall than Mtubatuba in both first (February-June) and second (July–November) seasons of 2019 and 2021 (Table 1). While Dlangubo and Ngwelezane received a total of 405.8 and 412.6 mm of rainfall, Mtubatuba received only 282.6 mm of rainfall (Table 1). In 2021, the average rainfall in the first season is higher than that of the second season in all three experimental sites. Although in the second season of 2019, total rainfall at Mtubatuba (315 mm) was higher than that of Ngwelezane (201.2 mm), the monthly rainfall distribution indicated that 184.4 mm representing 58.5% of the rain was received in November 2019; the month the sweet potato was harvested, a period when the rainfall was least needed [33]. Furthermore, there was no rainfall in July 2019 the month the OFSP cultivars were planted at Mtubatuba (Table 1), a period rainfall was critically needed for vine establishment. All the sites were well-drained and frost-free. The texture of the soil was sandy loam. Well-drained, sandy loam soil has been reported to be favorable for sweet potato growth [34].

Table 1. Average monthly temperature, rainfall, and humidity in Ngwelezane, Dlangubo and Mtubatuba for the years 2019 and 2021.

MONTH	TEMPERATURE (°C)			TOTAL RAINFALL (mm)			UZ—HUMIDITY (%)		
	UZ	RV	AP	UZ	RV	AP	UZ	RV	AP
2019									
January	24.4	24.5	24.9	103.4	70	106.6	80	79	76
February	25.3	25.3	25.6	146.4	182.6	90	81	80	79
March	25.6	25.3	25.9	58	109.6	131.4	80	81	78
April	22.7	23	23	146.6	106.6	54.2	82	84	81
May	21.4	21.7	21.8	7.6	0.2	0.2	78	80	78
June	19.1	19.8	19.4	47.2	13.6	6.8	74	77	76
July	19.1	20.1	19.1	21.6	1.2	0	66	67	68
August	20.8	22.1	20.2	56	17.8	23.4	76	77	79
September	20.8	22.3	20.1	95	26.2	32.4	74	74	76
October	22.9	24	22.3	136.8	82.2	74.8	76	75	78
November	23.9	24.4	23.3	128.4	73.8	184.4	80	79	81
December	23.8	24.3	23.4	319.4	129.6	100.8	80	78	80
2021									
January	26.1	26.4	25.6	241.2	168	198	79	77	80
February	26.1	24.9	25	131.6	283.2	253.6	82	84	84
March	25.6	24.4	24.4	59.4	88	83	78	82	81
April	23.8	22.6	22.6	103.8	55.8	39.4	79	81	82
May	20.7	19.9	19.9	120.8	34.2	9.4	79	80	80
June	18.7	17.9	18.2	89	45	14	73	81	80
July	17.4	16.9	17	50.2	12.2	13.4	65	74	75
August	18.8	18.6	18.4	38	20.8	19.6	68	79	79
September	21	20.1	20.1	103	75.4	65.6	76	78	78
October	22.6	20.3	20.3	83.6	73	91.8	77	79	78
November	24.1	22.8	22.3	95.4	32.2	15.6	77	76	78
December	26.3	24.4	24.1	87.6	119	0	78	79	81

The temperature and humidity data represent the monthly average of the daily average of temperature and humidity in the sites. The daily average indicates the average temperature/humidity for the day and is calculated as the average of the daily maximum and minimum temperatures. The rainfall data represents the total monthly rainfall at Ngwelezane (UZ), Dlangubo (RV), and Mtubatuba (AP) sites.

The vegetation at the Ngwelezane site was greener than that of Dlangubo and the least green site was Mtubatuba (Figure 1). It must also be noted that the vegetation in each of the sites in season 1 was generally greener than its corresponding season 2 (Figure 1). The patterns of variation in the NDVI values of the three sites were not very different between Dlangubo and Ngwelezane sites, but Somkhele area of Mtubatuba had much lower NDVI, EVI, and NDWI when compared to the other two sites. NDVI values ranged from 0.87 to 0.53, 0.79 to 0.46, and 0.80 to 0.38 at the Dlangubo, Ngwelezane, and Somkhele sites, respectively (Figure 2). In the same vein, EVI values ranged from 0.62 to 0.28, 0.61 to 0.19, and 0.53 to 0.14 at the Dlangubo, Ngwelezane, and Somkhele sites, respectively (Figure 3). Furthermore, the NDWI values ranged from 0.35 to −0.04, 0.30 to −0.06, and 0.24 to −0.23 at the Dlangubo, Ngwelezane, and Somkhele sites, respectively (Figure 4). In all the three indices investigated, the higher the value, the better the health of the vegetation [15–17].

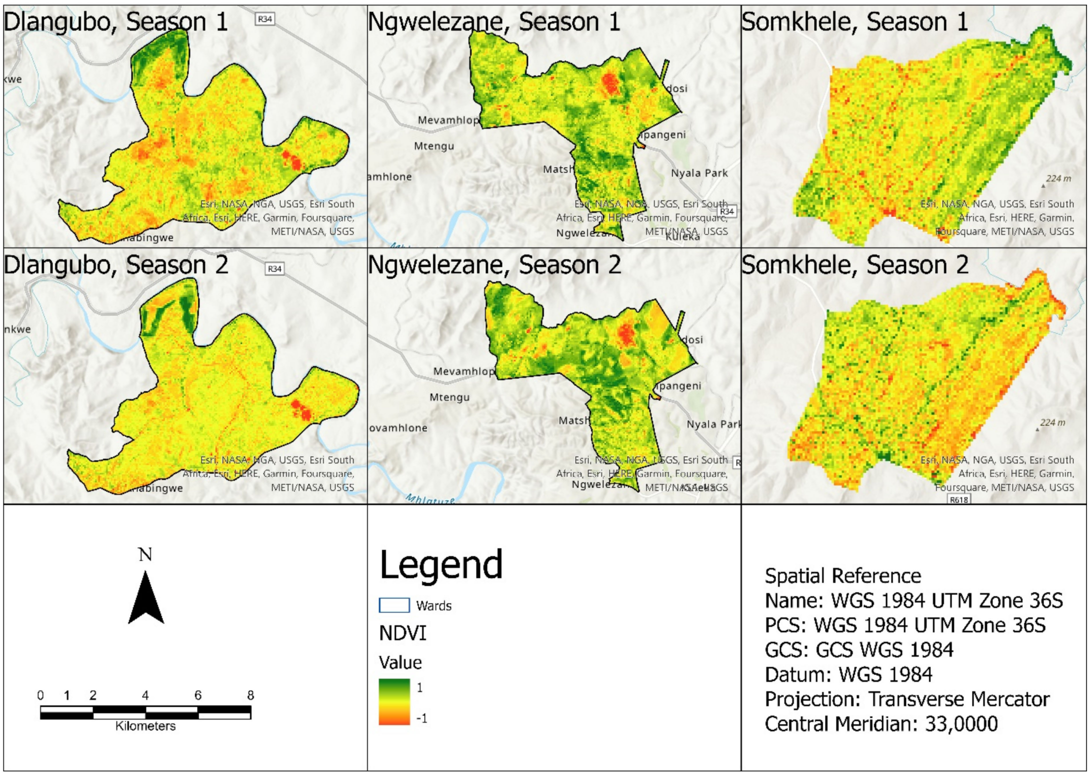

Figure 1. The NDVI of the Dlangubo, Ngwelezane, and Mtubatuba sites in season one and the season two of 2019 and 2021 as determined by satellite imagery. The variation in the greenness of the sites was an indication of the variation in the health of the vegetation in the sites. The greenness of the sites varied thus: Ngwelezane > Dlangubo > Somkhele. Generally, season two is less green than season one. The sites were in ward 24 (Dlangubo), ward 29 (Ngwelezane), and ward 14 (Somkhele) of the KwaZulu-Natal province of South Africa. Note: This figure is our original work. The use of it in part or whole is allowed, but the authors must be referenced appropriately.

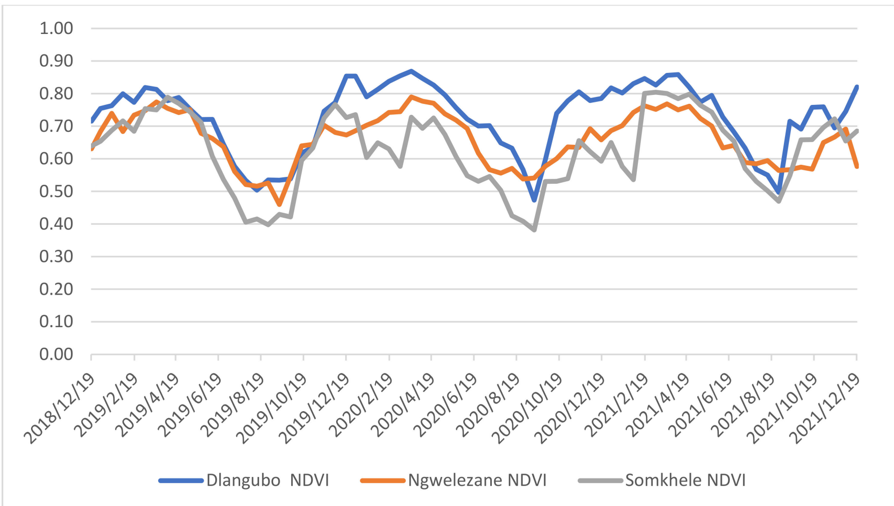

Figure 2. Time series of the Normalized Difference Vegetation Index of the Dlangubo, Ngwelezane, and Somkhele (Mtubatuba) sites from 19 December 2018 to 19 December 2021. Higher NDVI values (>0.5) were an indication of the presence of healthy green vegetation. As the value decreased, the healthiness of the vegetation declined. Values below 0.5 show very poor vegetation [35], and it only occurred at the Somkhele site and only in season two.

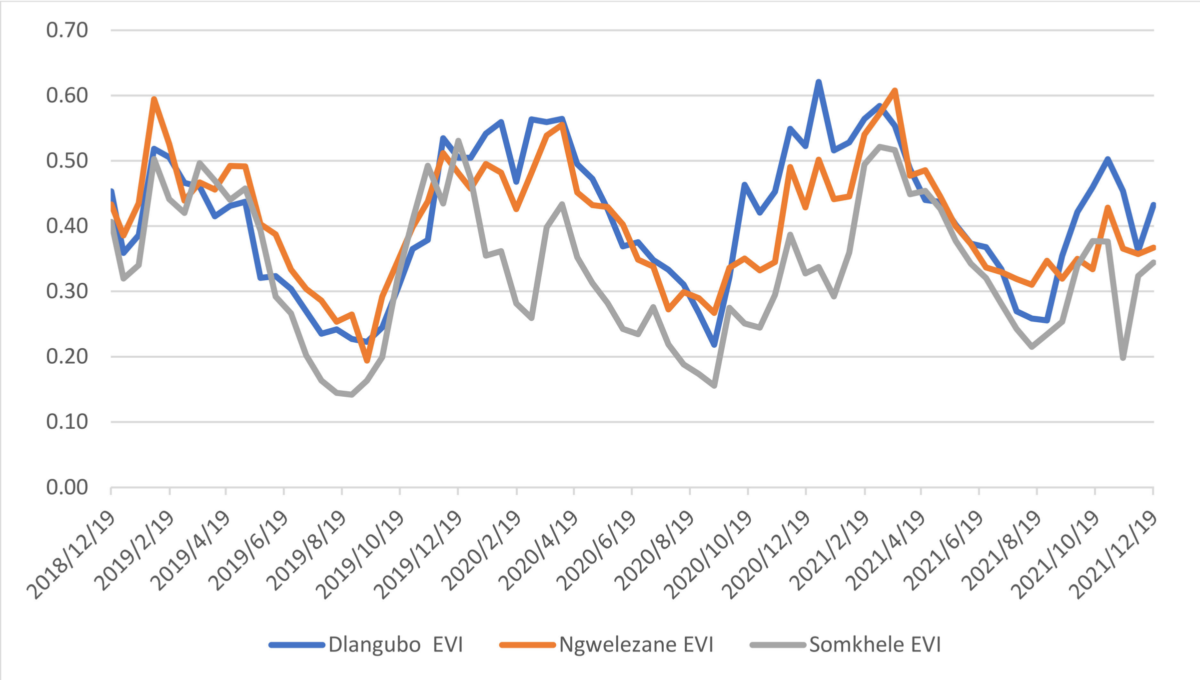

Figure 3. Time series of the Enhanced Vegetation Index in the Dlangubo, Ngwelezane, and Somkhele (Mtubatuba) sites from 19 December 2018 to 19 December 2021. As EVI declined, the greenness and water status of the vegetation declined. Values below 0.2 show very poor vegetation [35] and it only occurred at the Somkhele site and in the second season.

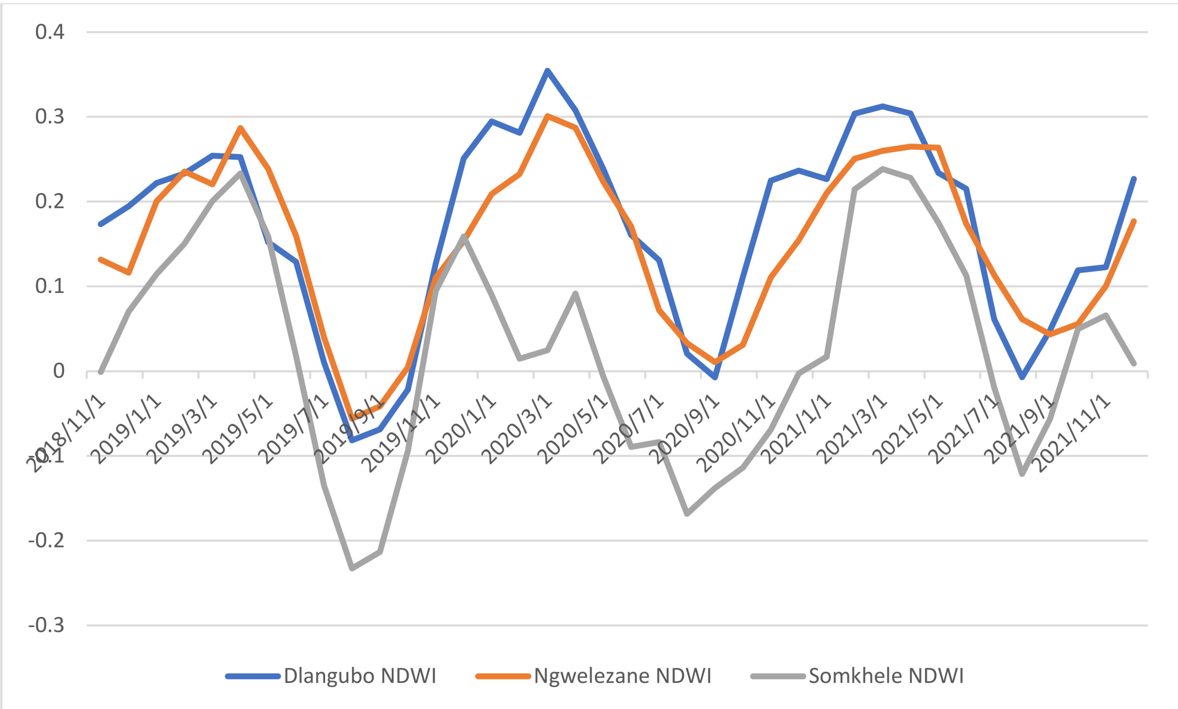

Figure 4. Time series of the Normalized Difference Water Index (NDWI) in the Dlangubo, Ngwelezane, and Somkhele (Mtubatuba) sites from 19 December 2018 to 19 December 2021. As NDWI declined, the greenness and water status of the vegetation declined. Values below 0 show very poor vegetation [35], and it principally occurred at the Somkhele site and in the second season. Jan = January, Mar = March, Jul = July, Sep = September, and Nov = November.

At NDVI, EVI, and NDWI values below 0.5, 0.2, and 0, respectively, the health of the vegetation is considered poor [35]. Within the period investigated only the NDVI in the Somkhele site fell below 0.5 for a period of over 6 months, while the NDVI at the other two sites fell below 0.5 for a period less than 1 month each. Furthermore, it was only in the Somkhele site that EVI and NDWI fell below 0.2 and 0, respectively, for extended periods. In all the 3 indices, the lowest values occurred in the second season of the study. While NDVI and EVI are measures of the greenness and Nitrogen status of the vegetation, NDWI is both a measure of the vigor and the water status of the vegetation at the site. The greener the vegetation, the higher the photosynthetic activities and consequently the higher the biomass accumulation [23]. Low NDVI values are an indication that the vegetation lacks vigor and it is moisture-stressed, and higher values indicate a higher density of green vegetation. NDWI is a measure of the water status of the plants. It measures the amount of water available in plants that interact with solar radiation during photosynthesis. The results of the NDVI, EVI, and NDWI indicated the occurrence of drought in Somkhele in the second season. All the three indices have been used to monitor drought [15–18].

3.2. Chemical Composition of the Initial Soil of the Study Sites, Filter Cake, and Macadamia Husk

The initial soil chemical properties of the three sites included the macronutrients, micronutrients, total cation, acidity, clay content, and pH value (Table 2). Sweet potato thrives well in slightly acidic soil. Hence, with soil pH ranging between 4.94 and 5.88, the pH of all the sites was within the optimal soil pH for nutrient uptake of between 4.5 and 7.0 recommended for sweet potato growth [36]. Of the three primary macronutrients (N, P, and K), potassium plays the largest role in full and healthy OFSP growth. A lack of phosphorus can result in stunted growth, and diminished yield. With N ranging from 0.12 (Dlangubo) to 0.23 (Ngwelezane), and C ranging from 1.96 at Dlangubo to 2.68 at Ngwelezane, the soil in all the sites is low in N and C [37]. Except at Mtubatuba, P appears to be adequate at Ngwelezane and Dlangubo. However, all the sites have enough K, Ca, Mg, Mn, and Cu. More K is needed by OFSP than P. Although N is a macronutrient, it is not needed as much as P and K [38].

Table 2. Initial chemical composition of the Ngwelezane, Mtubatuba, and Dlangubo sites' soil and that of filter cake and macadamia husks.

NUTRIENTS	SOIL COMPOSITION				SOIL AMENDMENTS	
	Unit	Ngwelezane	Mtubatuba	Dlangubo	FC	MHC
Nitrogen (N)	%	0.23	0.18	0.12	0.15	1.15
Phosphorus (P)	mg/Kg	313.3	10.6	60	6500	3700
Potassium (K)	mg/Kg	158.3	188	403	5800	11,100
Calcium (Ca)	mg/Kg	1573	2750	1291	24,700	25,200
Magnesium (Mg)	mg/Kg	296	619	418	4900	3200
Carbon (C)	%	2.68	2.03	1.96	6.54	51.24
Zinc (Zn)	mg/Kg	180.6	2.8	4.2	101.6	134.2
Copper (Cu)	mg/Kg	28.3	2.3	5.7	61.5	32.2
Manganese (Mn)	mg/Kg	18.7	19.6	44	1030.4	324.8
Sulphur (S)	%	*	*	*	0.07	0.04
Sodium (Na)	mg/Kg	*	*	*	798	1623
Iron (Fe)	mg/Kg	*	*	*	22,145	14,263
Aluminium	mg/Kg	*	*	*	16,919	14,671
Moisture	%	*	*	*	40.1	55.8
Clay	%	7.7	22.2	21.5	*	*
CN ratio	-	11.4	11.0	16.3	*	*
Acidity	cmol/L	0.08	0.07	0.08	*	*
Total cations	meq/100 g	10.77	19.37	10.99	*	*
pH	KCl	4.94	5.88	5.76	*	*
Density	mg/m^{-3}	1	1.07	1	*	*

* Values not investigated.

The chemical composition of macadamia husks was as follows; carbon (C), 51.24; sulfur (S), 0.04; nitrogen (N), 1.15%; calcium (Ca), 25,200; magnesium (Mg), 3200; potassium (K), 11,100, sodium (Na), 1623.61; zinc (Zn), 134.15; copper (Cu), 32.22; manganese (Mn) 324.84; iron (Fe), 14,263.41; phosphorus (P), 0.37; aluminum (Al), 14,674.17 mg/Kg, and moisture content, 55.81%; while that of filter cake were C, S, N, Ca, Mg, K, Na, Zn, Cu, Mn, Fe, P, and Al, were 6.54, 0.07, 0.15%; 24,700, 4900, 5800, 797.6, 101.6, 61.48, 1030.4, 22,146, 6500, 16,920 mg/Kg, and 40.10%, respectively (Table 2).

3.3. Effects of Soil Amendments on the Physiology of the Test OFSP Cultivars

One of the ways that inorganic fertilizer and organic soil amendments improve seedling growth is by improving chlorophyll content in the leaves of the plant [39]. The application of FC, IF, FC + IF, and MHC + IF significantly ($p < 0.05$) improved the chlorophyll contents in all the cultivars and sites. While the improvement in cultivar 199062.1′s chlorophyll content at the Dlangubo site was 19.3% in FC treatment, that of Beauregard, Impilo, and W119 improved by 60.3, 24.0, and 40.1%, respectively (Figure 5). Improvement in chlorophyll content has severally been reported to increase photochemical efficiency via an increase in photosynthetic electron transport, or possibly a greater investment in enzymes of the Calvin cycle [40] in plants, which ultimately led to increase in both shoot and storage roots productivities.

The effect of MHC treatments on the chlorophyll content was less when compared to other treatments in all the sites and all OFSP cultivars investigated in this study. Furthermore, increases in the chlorophyll content occasioned by soil treatment with FC, FC + IF, IF, and MHC + IF varied and are in most treatments more pronounced in the Dlangubo and Ngwelezane sites when compared to the Mtubatuba site. For instance, FC, FC + IF, IF, and MHC + IF at the Ngwelezane site led to significant increases of 39.9, 44.7, 40.9, and 34.9%, respectively, in cultivar WII9 at the Ngwelezane site, only an insignificant increase of 4.6% occurred in MHC treatment (Figure 5). In the second season, chlorophyll contents were generally lower in almost all the treatments and sites when compared to the first season.

Stomatal conductance is a measure of the stomatal opening, and it was influenced by the application of FC, FC + IF, IF, and MCH + IF in most cases significantly lowered stomatal conductance in all the species and in all study sites. The stomatal conductance in 199062.1 treated with FC + IF was reduced by 36.8% at the Dlangubo site (Figure 6). MHC at best had very minimal effects, which in most cases were insignificant on the stomatal conductance when compared with the control. Stomatal conductance at the Mtubatuba site was generally higher than the values at the Dlangubo and Ngwelezane sites (Figure 6). Stomatal conductance is an indicator of plant water status and has been used as an indicator of leaf water stress [20]. Although the detailed mechanism of stomatal conductance was not investigated in this study, theoretically, reductions in stomatal conductance occasioned by the soil treatments may have prevented further decreases in leaf water status via reducing transpiration; this may have increased photosynthesis, and ultimately, both shoot and storage root yield. In this study, variation in stomatal conductance was negatively correlated with chlorophyll content.

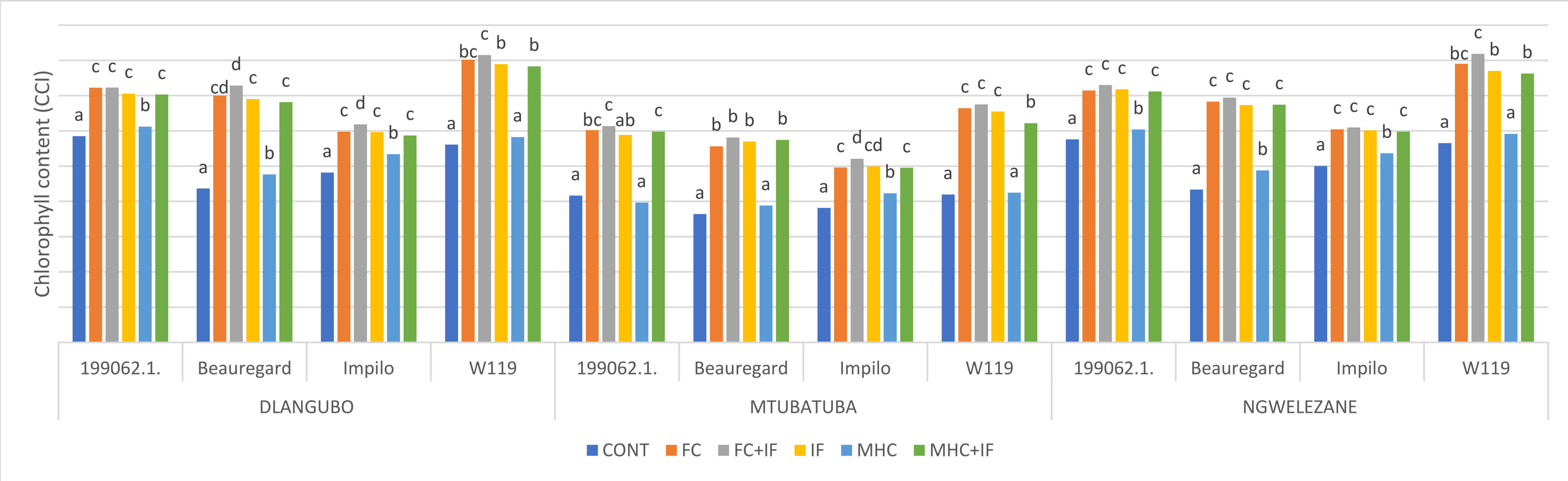

Figure 5. Chlorophyll content in the leave of orange-fleshed sweet potato grown at Dlangubo, Mtubatuba, and Ngwelezane. Each bar represents the average of data collected in season one and season two of 2021. ANOVA was performed across treatments. Means of replicates were separated at $LSD_{0.05}$. Post hoc was done using a Tukey test. The means of the treatments for each cultivar in a site with different letters were significantly different ($p < 0.05$, $n = 48$).

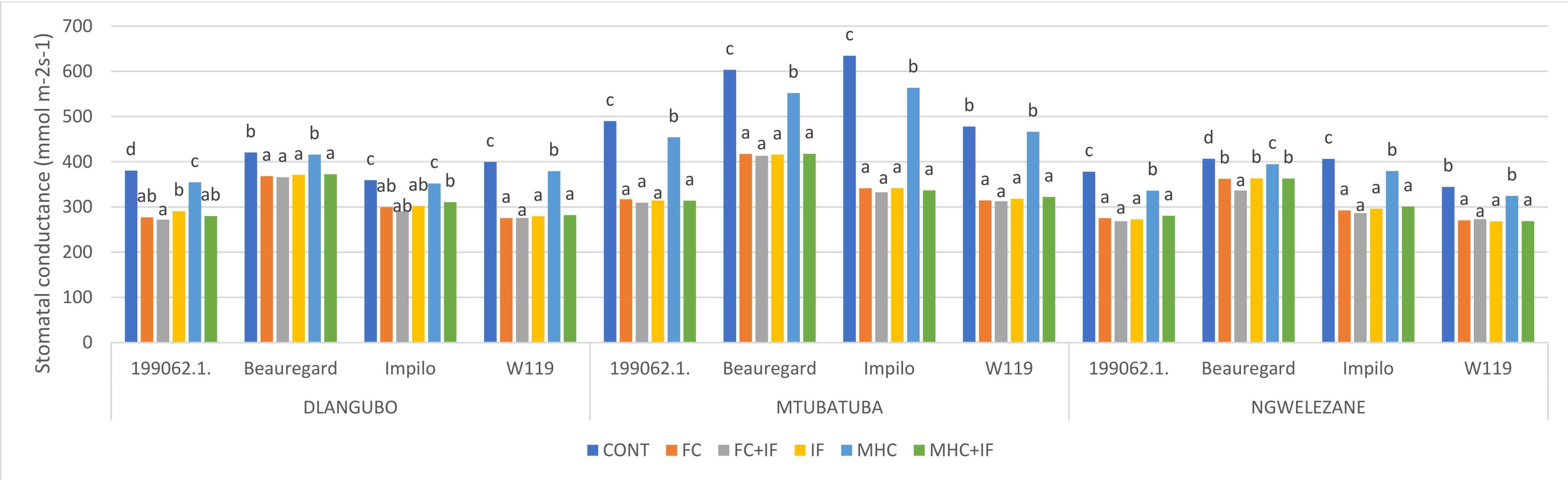

Figure 6. Leaf stomatal conductance of orange-fleshed sweet potato grown at Dlangubo, Mtubatuba, and Ngwelezane. Each bar represents the average of data collected in season one and season two of 2021. ANOVA was performed across treatments. Means of replications were separated at $LSD_{0.05}$. Post hoc was done using a Tukey test. The means of the treatments for each cultivar in a site with different letters were significantly different ($p < 0.05$, $n = 24$).

3.4. Effects of Soil Amendments on the Productivity of the Test OFSP Cultivars

In the first season, increases in storage root occurred with the application of FC, IF, FC + IF, and MHC + IF, and in most cases, the improvements were significant (Table 3). Although MHC application generally led to some increases in the root biomass, the increases were insignificant. In the second season, there were general reductions in the productivity of all the storage roots and shoot biomass in all the sites, and cultivars (Table 3). However, most of the significant reductions occurred in IF and MHC + IF treatments when compared to biomass yield in the first season.

Table 3. Effects of filter cake, a combination of filter cake and inorganic fertilizer, inorganic fertilizer, macadamia compost, a combination of macadamia husk compost, and control treatments on the storage roots of four orange-fleshed sweet potato cultivars grown at the Dlangubo, Ngwelezane, and Mtubatuba areas of KwaZulu-Natal Province of South Africa in seasons one (February-June) and two (July–November) of 2019 and 2021.

	199062.1.		Beauregard		Impilo		W-119	
	DLANGUBO							
	ROOT-1	ROOT-2	ROOT-1	ROOT-2	ROOT-1	ROOT-2	ROOT-1	ROOT-2
CONT	265.1 ^{a}	244.8 ^{a}	155.2 ^{a}	138.5 ^{a}	151.8 ^{a}	151.6 ^{a}	175.4 ^{a}	154.3 ^{a}
FC	653.8 ^{c}	587.0 ^{c}	333.7 ^{bc}	293.6 ^{bc}	338.1 ^{c}	297.5 ^{c}	367.0 ^{bc}	322.9 ^{c}
FC + IF	702.3 ^{c}	624.9 ^{c}	399.3 ^{bc}	351.4 ^{c}	311.3 ^{bc}	273.9 ^{bc}	409.9 ^{c}	360.7 ^{c}
IF	617.8 ^{c}	244.9 ^{a*}	336.6 ^{b}	272.7 ^{bc*}	284.8 ^{bc}	161.8 ^{a*}	300.0 ^{b}	229.8 ^{ab*}
MHC	347.9 ^{ab}	327.4 ^{b}	269.5 ^{b}	237.1 ^{ab}	202.8 ^{a}	184.1 ^{a}	200.7 ^{a}	176.6 ^{a}
MHC + IF	399.2 ^{b}	370.3 ^{b*}	427.5 ^{c}	376.2 ^{c*}	233.6 ^{ab}	205.5 ^{ab}	328.9 ^{bc}	289.4 ^{bc*}
$LSD_{0.05}$	72.9	51.3	73.6	73.6	54.55	49.15	59.21	52.73
	MTUBATUBA							
CONT	223.1 ^{a}	76.2 ^{a*}	154.1 ^{a}	52.7 ^{a*}	147.8 ^{a}	50.6 ^{a*}	151.8 ^{a}	51.9 ^{a*}
FC	451.2 ^{c}	154.3 ^{b*}	257.9 ^{c}	71.9 ^{bc*}	284.9 ^{b}	97.4 ^{b*}	325.7 ^{c}	111.4 ^{b*}
FC + IF	470.9 ^{c}	174.9 ^{b*}	232.2 ^{bc}	79.4 ^{bc*}	274.9 ^{b}	94.0 ^{b*}	342.1 ^{c}	117.0 ^{c*}
IF	431.5 ^{c}	82.4 ^{a*}	199.0 ^{ab}	68.1 ^{ab*}	210.2 ^{ab}	71.9 ^{ab*}	269.5 ^{b}	56.7 ^{a*}
MHC	285.9 ^{ab}	97.8 ^{a*}	173.4 ^{a}	59.3 ^{a*}	170.5 ^{a}	58.3 ^{a*}	193.4 ^{a}	66.1 ^{b*}
MHC + IF	319.9 ^{b}	82.9 ^{a*}	210.2 ^{abc}	88.2 ^{c*}	198.2 ^{a}	67.8 ^{a*}	268.3 ^{b}	91.8 ^{b*}
$LSD_{0.05}$	60.26	27.40	39.32	13.45	50.29	97.43	35.19	13.47
	NGWELEZANE							
CONT	230.6 ^{a}	210.4 ^{a}	63.8 ^{a}	58.2 ^{a}	156.2 ^{a}	142.5 ^{a}	202.4 ^{a}	184.6 ^{a}
FC	523.6 ^{b}	477.6 ^{b}	133.5 ^{bc}	121.8 ^{bc}	290.2 ^{c}	269.3 ^{b}	441.5 ^{c}	402.8 ^{c}
FC + IF	520.9 ^{b}	475.1 ^{b}	145.6 ^{c}	132.8 ^{c}	299.6 ^{c}	273.3 ^{b}	444.8 ^{c}	405.8 ^{c}
IF	434.5 ^{b}	264.2 ^{a*}	105.6 ^{b}	96.3 ^{b}	223.0 ^{b}	206.7 ^{ab*}	384.6 ^{bc}	350.9 ^{bc*}
MHC	259.3 ^{a}	227.8 ^{a}	115.9 ^{bc}	105.7 ^{bc}	177.6 ^{ab}	160.7 ^{a}	275.4 ^{ab}	251.2 ^{ab}
MHC + IF	437.8 ^{b}	266.3 ^{a}	116.6 ^{bc}	106.4 ^{bc}	206.8 ^{ab}	188.7 ^{a}	343.2 ^{bc}	313.1 ^{bc}
$LSD_{0.05}$	100.4	85.5	22.36	20.40	39.09	46.80	76.1	69.42

ROOT-1, and ROOT 2, were the yield of the storage roots or storage root dry mass (g) in season one and season two, respectively. CONT = control; FC = filter cake; FC + IF = combination of filter cake and inorganic fertilizer; IF = inorganic fertilizer; MHC = macadamia husk compost; MHC + IF = combination of macadamia compost and inorganic fertilizer; ANOVA was performed across the 6 treatments and across the two seasons. Means of replicates were separated at LSD0.05. Post hoc was done using a Tukey test. Means along the same row with different letters were significantly different ($p < 0.05$). * Mean between the two seasons are significantly different ($p < 0.05$).

In both seasons, a total of 5, 7, and 25 plants died and were replaced at the Dlangubo, Ngwelezane, and Mtubatuba sites, respectively (Table not shown). All the plant mortalities occurred within the first month of planting and in the control and IF treatments; only a few plants were from the FC and MHC-related treatments. About 80% of the mortality occurred in the second season. Plant mortality could only be linked to failure in stand establishment caused by lack of insufficient soil moisture. MHC and FC contain 55.8 and 40.1% moisture; hence, the vines planted in MHC and FC treatments would have benefited from the moisture of the two soil amendments. Besides the moisture content of FC and MHC, they have the potential to hold moisture much better than the IF and the control. Most of the mortalities may have occurred in the second season due to the droughty situation which occurred at the Mtubatuba site. In the first month of season two, there was no rainfall at the Mtubatuba site. Drought and water stress have been reported to cause failure in plant establishment [20,41].

In the first season, the shoot yield of cultivar 199062.1 treated with IF significantly ($p < 0.05$) increased 2.33-, 1.93-, and 1.88-fold at the Dlangubo, Ngwelezane, and Mtubatuba sites, respectively, when compared to the control (Table 4). The application of inorganic fertilizer at the recommended dose has severally been reported as the 'standard' method of improving soil fertility; resulting in increases in yield and yield attributes of several crops, for instance, the application of inorganic fertilizer has been reported to increase the yield of rice [42], maize [43], silage corn and soybean [39]. However, in the second season, the effect of the inorganic fertilizer had waned; no significant differences occurred in any of the three sites. The decline or lack of significant influence of IF treatments on the yield of the tested OFSP cultivars in the second season may have been due to loss of the applied IF from the soil due to leaching and or run-off water during rain [41,44]. It may also be attributed to plant removal in the first season [45], this is particularly important because sweet potato is a heavy feeder, hence, the nutrients may have become depleted through plant uptake [44,46].

In the first season, the application of FC had significant increases in both the shoot and root yield of all the test OFSP cultivars and at all the experimental sites. The improvement because of FC application was comparable to that of IF; and in some cases, FC caused significantly higher yields when compared to IF treatments (Tables 3 and 4). For instance, FC treatment at the Ngwelezane site led to 127.1, 109.2, 85.8, and 118.1% increases in the root yield of cultivars 199062.1, Beauregard, Impilo, and WII9, respectively (Table 3). The improvement in the yield may have been due to the array of nutrients such as C, S, N, Ca, Mg, K, Na, Zn, Cu, Mn, Fe, P, and Al, which were 6.54, 0.07, 0.15, 2.47, 0.49, 0.58%, 797.58, 101.59, 61.48, 1030.41, 22,145.51, 0.65, 16,919.65 mg/Kg, and 40.10%, respectively, which are contained in FC (Table 1). Of all these nutrients, S, Mg, Cu, Mn, Fe, P, and Al were higher than that of MHC. In the second season, although there were general reductions in both the shoot and root yields in all the test OFSP cultivars, the impact of FC still led to significant improvement in both the root (Table 3) and shoot (Table 4) yield of most of the test cultivars. Hence, it can be deduced that the effect of FC in the soil is persistent into the second season, despite no fresh application. FC has been reported to increase plant productivity in sugarcane [47,48], and wheat [49]. A combined application of FC and IF (FC + IF) did not significantly improve the yield of the test cultivars in most of the cultivars and at the three study sites. This may call to question the need to augment FC with the IF application.

MHC treatment had the least influence on the shoot and root yield of the test OFSP cultivars, and in most cases, the effects were insignificant when compared to the control. While FC, FC + IF, and IF, treatments led to significant 114.6, 125.4, and 77.5% increases in FC, FC + IF, and IF treatments, respectively, in the root yield of Beauregard at the Mtubatuba site (season 1) when compared to the control, MHC only led to a statistically insignificant increase of 27.4% (Tables 3 and 4). Although an analysis of MHC revealed an array of nutrients such as C, N, Ca, K, Na, and Zn which were higher than what was obtainable in FC, also MHC influenced soil structure (noticeable soil crumbs) by physical examination of the MHC and MHC + IF treatment plots. Such soil crumbs were not noticed in all other treatment plots. All of these did not translate to improvement that was as high as that of FC and IF. It can be opined that the nutrients in MHC were not fully released into the soil within the duration of the study, hence, its minimal influence on yield. This may be due to the slow rate of mineralization associated with macadamia husk; furthermore, the organic N in waste amendments must be converted to inorganic forms to be plant available [50,51]. Perhaps, the application of MHC is a source of nutrients in the future as it has been reported to decompose very slowly [12,51]. Unlike the IF treatment, only an insignificant decline in yield occurred in the MHC treatment in the second season when compared to the first season. However, augmenting MHC with IF (MHC + IF) led to higher improvement in both root and shoot yield in the first season and in most of the test OFSP cultivars and in all the sites (Tables 3 and 4). Although not fully investigated, MHC's noticeable influence on soil structure may be due to its high moisture content. MHC has been reported to improve physical and chemical properties of soil and nutrients uptake, crop yields, and yield attribute in Chinese cabbage [46,50].

Table 4. Effects of filter cake, a combination of filter cake and inorganic fertilizer, inorganic fertilizer, macadamia compost, a combination of macadamia husk compost, and control treatments on the shoots of four orange-fleshed sweet potato cultivars grown at the Dlangubo, Ngwelezane, and Mtubatuba areas of KwaZulu-Natal Province of South Africa in seasons one (February–June) and two (July–November) of 2019 and 2021.

	199062.1.		**Beauregard**		**Impilo**		**W-119**	
TREAT	DLANGUBO							
	SHOOT-1	SHOOT-2	SHOOT-1	SHOOT-2	SHOOT-1	SHOOT-2	SHOOT-1	SHOOT-2
CONT	343.3 ^{a}	302.1 ^{a}	97.3 ^{a}	85.6 ^{a}	69.8 ^{a}	64.0 ^{a}	247.1 ^{a}	217.4 ^{a}
FC	1011.2 ^{bc}	889.9 ^{c}	285.2 ^{d}	251.0 ^{c}	148.7 ^{bc}	136.8 ^{b}	622.9 ^{cd}	548.2 ^{c}
FC + IF	1098.8 ^{c}	966.9 ^{c}	277.5 ^{cd}	215.2 ^{c}	171.1 ^{bc}	152.9 ^{b}	674.2 ^{d}	593.2 ^{c}
IF	837.9 ^{b}	377.7 ^{ab*}	229.0 ^{c}	88.3 ^{a*}	175.5 ^{c}	117.1 ^{ab*}	481.2 ^{bc}	273.5 ^{a*}
MHC	465.0 ^{a}	409.2 ^{ab}	136.5 ^{ab}	120.5 ^{ab}	71.2 ^{a}	72.6 ^{a}	279.6 ^{a}	246.0 ^{a}
MHC + IF	508.3 ^{ac}	447.3 ^{b*}	175.0 ^{b}	154.0 ^{b*}	118.0 ^{ab}	71.7 ^{a*}	460.8 ^{b}	405.5 ^{b*}
$LSD_{0.05}$	145.3	92.2	32.82	27.06	36.62	40.6	103.7	86.5
	MTUBATUBA							
CONT	334.7 ^{a}	114.8 ^{a*}	108.7 ^{a}	37.3 ^{a*}	92.6 ^{ab}	31.6 ^{ab*}	256.3 ^{a}	87.9 ^{a*}
FC	639.5 ^{cd}	219.4 ^{b*}	183.3 ^{b}	103.3 ^{c*}	127.2 ^{b}	45.1 ^{b*}	538.9 ^{bc}	184.8 ^{cd*}
FC + IF	686.6 ^{d}	235.5 ^{b*}	179.3 ^{b}	61.5 ^{b*}	133.4 ^{b}	46.3 ^{b*}	556.3 ^{c}	190.8 ^{d*}
IF	564.9 ^{bc}	132.9 ^{a*}	152.8 ^{ab}	52.4 ^{ab*}	127.0 ^{b}	25.2 ^{ab*}	432.9 ^{b}	148.5 ^{bc*}
MHC	340.0 ^{a}	141.8 ^{a*}	130.7 ^{ab}	67.6 ^{b*}	52.1 ^{a}	17.9 ^{a*}	315.3 ^{a}	108.2 ^{a*}
MHC + IF	512.9 ^{b}	145.2 ^{a*}	171.4 ^{ab}	58.8 ^{ab*}	60.0 ^{a}	20.6 ^{a}	457.9 ^{bc}	124.6 ^{ab*}
$LSD_{0.05}$	65.25	28.39	44.56	15.26	32.44	14.65	77.4	26.17
	NGWELEZANE							
CONTR	400.4 ^{a}	360.4 ^{a}	94.2 ^{a}	84.7 ^{a}	58.0 ^{a}	55.7 a	230.2 ^{a}	214.6 ^{a}
FC	930.4 ^{b}	869.9 ^{b}	197.5 ^{bc}	177.7 ^{bc}	127.5 ^{bc}	111.1 ^{ab}	574.6 ^{b}	517.1 ^{b}
FC + IF	942.5 ^{b}	856.2 ^{b}	202.5 ^{bc}	182.2 ^{bc}	135.5 ^{c}	121.9 ^{b}	562.1 ^{b}	505.9 ^{b}
IF	860.1 ^{b}	366.9 ^{a*}	172.5 ^{bc}	85.6 ^{bc*}	163.0 ^{c}	146.6 ^{b*}	480.8 ^{b}	229.3 ^{b*}
MHC	387.1 ^{a}	358.4 ^{a}	147.5 ^{ab}	133.7 ^{ab}	68.0 ^{ab}	61.2 ^{a}	240.9 ^{a}	216.2 ^{a}
MHC + IF	850.8 ^{b}	376.2 ^{b*}	215.8 ^{c}	92.3 ^{bc*}	97.8 ^{abc}	90.7 ^{ab}	556.7 ^{b}	247 ^{b}
$LSD_{0.05}$	73.9	81.1	43.90	39.41	44.36	39.72	114.2	102.5

SHOOT-1 and SHOOT-2 were the shoot yield or shoot dry mass (g) in the first season and second season respectively. TREAT = soil treatments; CONT = control; FC = filter cake; FC + IF = combination of filter cake and inorganic fertilizer; IF = inorganic fertilizer; MHC = macadamia husk compost; MHC + IF = combination of macadamia compost and inorganic fertilizer; ANOVA was performed across the six treatments and across the two seasons. Means of replicates were separated at $LSD_{0.05}$. Post hoc was done using a Tukey test. Means along the same column with different letters were significantly different ($p < 0.05$). * Mean between the two seasons are significantly different ($p < 0.05$).

At the three sites and in all cultivars, both root and shoot yield in the second season was lower than that of the first season. The declines were most pronounced at the Mtubatuba site (Tables 3 and 4). For instance, in the control treatment, Root-1 and Root-2 of Impilo at the Dlangubo site were almost the same in mass; at the Ngwelezane site, an insignificant decline of 9.6% occurred. However, a significant drop of 192.1% occurred at the Mtubatuba sites. Such significantly lower yield reduction in season 2, when compared to season 1 is an indication that the changes were not due to nutrient depletion as it was in the case of IF treatments. The second season fell within a period of drought in the province which was more pronounced around Mtubatuba. Drought stress has been reported to have negative effects on photosynthetic apparatus such as chlorophyll content and stomatal conductance which ultimately reduce crop yield [52]. The general correlations between the root and shoot biomass were expected. The shoot biomass which comprised the leaves and the shoot contained the photosynthetic apparatus. This is also confirmed with the trend of chlorophyll content in this study (Figure 5). Hence, an improvement or lack of it in the shoot because of any soil amendment will have similar effect on the biomass accumulation of the storage root [23,53].

3.5. Conclusion and Recommendations

Ngwelezane and Dlangubo were largely similar both in terms of shoot and root productivity, NDVI, EVI, and NDWI. Hence, they can be regarded as similar agroecologies. Furthermore, in both seasons, changes in most of the parameters investigated were not significantly different; hence, it can be suggested that the sites enjoyed relatively stable weather conditions suitable to produce OFSP in both seasons 1 and 2; this means that OFSP could be produced at Ngwelezane and Dlangubo all year round. This is in consonance with the report of [54].

Mtubatuba and more specifically the Somkhele area of Mtubatuba, experienced a very sharp contrast between season one and season two. This sharp contrast occurred in shoot and root biomass, chlorophyll content, stomatal conductance, total rainfall, and rainfall distribution. The total rainfall and its distribution at Somkhele and the poor health of the vegetation as confirmed by NDVI, EVI, and NDWI were indications that drought may have occurred in season two at Somkhele. Therefore, the area could be classified as a different agroecology. This is agreement with an earlier report which classified Empangeni (both Ngwelezane and Dlangubo were considered as parts of Empangeni) and Somkhele areas in different agroecologies [20]. In the winter/spring season, OFSP may not be produced at the Somkhele area of Mtubatuba without the application of FC, MHC and probably some irrigation. This study affirmed the use of NDVI, EVI, and NDWI for drought monitoring, as severally reported [15–18].

Besides the high cost of purchasing IF, which is unaffordable to small-scale farmers, two clear disadvantages of IF use have been identified in this research: the inability of IF to hold water and its non-persistence in soil. Hence, the need to seek alternative means of improving soil nutrients [41]. The result of this study clearly showed that FC is a very good source of soil nutrients to produce OFSP; also, combining FC application with IF was not necessary. Another beauty of FC application was its persistence in the soil [47], as could be seen in this study, significant improvement in the productivity of OFSP occurred in the second season without new application of FC, which makes it a better choice when compared with IF.

Although MHC when analyzed contained an array of mineral nutrients, the nutrients or most of the nutrients were not readily available for plant uptake within the limit of the study duration. However, farmers can benefit from MHC via its high moisture content/water retention ability and improvement in soil structure. Hence, farmers who chose to use MHC may need to combine its application with IF. The best deal to handle both the issue of drought and soil nutrients may be a combined application of both FC and MHC which were not investigated in this study. Hence, both FC and MHC have the potential of ameliorating the effects of drought, increasing the yield of the test OFSP cultivars, and consequently improving farmers' income, improving food security, and sustainable use of agricultural land.

Author Contributions: Conceptualization, N.M.M.; Methodology, K.F., A.T.M. and N.M.M.; Supervision, A.T.M. and N.M.M.; Investigation, K.F.; Formal analysis, K.F.; Writing—original draft, K.F.; Writing—review and editing, K.F. and N.M.M.; Funding acquisition, K.F., A.T.M. and N.M.M.; Resources, N.M.M. and K.F.; Validation, N.M.M. and K.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partly funded by the University of Zululand Research office; grant to K Fatokun (Project registration number: S615-17, Ethical clearance number: UZREC 171110-030 PGD 2017/175 entitled 'Sweet Potato (*Ipomoea Batatas* L.) Response to Different Agroecologies and Soil Amendments in Northern Kwazulu-Natal'. The APC was funded by the University of KwaZulu-Natal, South Africa.

Conflicts of Interest: The authors declare that there is no conflict of interest.

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