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Infrared Remote Sensing of Solar-induced Physiological Parameters of *Manihot esculenta* Canopy

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***Abstract**: This communication reports the direct measurement of Solar-induced canopy reflectance, fluorescence intensity, fluorescence, Chlorophyll luminescence, canopy Moisture and Canopy Temperature of Manihot esculenta using a multispectral radiometer. The stakes chosen from old Manihot esculenta (8-12 months old) was planted, using standard procedures, on well-drained fertile sandy soil, vertically by pushing lower part of the stakes of about 5cm depth into the ridges. The physiological parameters were measured from germination stage to foliage stage. The result showed that there was low absorption of radiation by chlorophyll pigment, low photosynthesis activity, and carbon dioxide uptake at the germination stage as indicated by relatively high canopy spectral responses of the parameters. Photosynthesis activity was more intense at the foliage stage.*
***Keywords:** Direct measurement, Physiological properties, Multispectral Radiometer, Manihot esculenta*

I. Introduction

Cassava, *Manihot esculenta* is the world's third most important crop and an essential source of food and income throughout the tropics (IFAD, 2008). It was introduced into Central Africa, from South America in the sixteenth century by the early Portuguese explorers (Jones, 1959). It is the basic staple food of millions of people in the tropical and subtropical regions, as well as being a major source of raw material such as flour and starch for numerous industrial applications and animal food with worldwide acreage of more than 18 million hectare and annual root yield of more than 233 Mt (Anderson et al, 2000; 2011).

Cassava is also an important cash crop, especially in the state of Tamil Nadu where about 61% of total cultivation is located; it is the raw material used for the industrial production of starch and sago and caters to the needs of 1300 starch and sago factories, providing employment to 0.4-0.5 million people (Bijou et al, 2010;CTCRI, 2012). Knowledge and monitoring of the growth pattern and means of detecting early warning signs of stress of *Manihot esculenta* will therefore be quite beneficial to those in agric business, growers and related agro allied industries. Remote sensing technique has been used for real-time plant monitoring and even for an early production assessment in many parts of the world (Benedetti et al, 1993). Early detection of cassava crop damage by remote sensing could be a useful tool for initiating remedial measures to reduce further damage i.e. cassava mosaic disease, a prominent virus infection that cause considerable crop damage, stress, yield reduction, detection of Chlorophyll fluorescence, can easily be detected at early stage. The infrared remote sensing technique has great potential for monitoring the health of crops as *Manihot esculenta* with multispectral radiometric system (Taylor, 2005). The role of physiological research in crop improvement and cropping systems management has recently been reviewed. As a branch of basic science, plant physiological research has a fundamental role in advancing the frontier of knowledge that is essential for the better understanding of plants and their interactions with surrounding biophysical environments (El-Sharkawy, 2005, 2006).

Canopy reflectance is required for assessing the spatial variability of crop conditions in fields. Many factors complicate the transition from leaf reflectance to canopy reflectance. As leaf area per unit ground area or LAI increases, the contribution of the background (i.e., soil or crop residue) to the overall scene reflectance decreases and the total amount of radiation scattered by plant cells increases (Norman et al, 1985). Multiple scattering is particularly important in the near-infrared (700–1300 nm) where plant pigments do not absorb radiation (Knipling 1970; Chappelle et al, 1992; Gitelson et al, 1996). Basic plant research has shown that specific light wavelengths such as the blue light are important in plant processes such as germination and stem growth, biomass accumulation and transition to flowering ((Kim et al, 2004;Valverde et al, 2004). Red light is important in stem/shoot elongation, phytochrome responses, and changes in plant anatomy (Schuerger et al, 1997). The red light also contributes to plant photosynthesis by allowing the opening of stomata at appropriate times for the plant to take up enough Carbon dioxide and hence metabolic influence of the red light cannot be ignored (Okamoto et al, 1996). On the other hand, blue light is important in chlorophyll biosynthesis and chloroplast maturation, stomata opening, enzyme synthesis and the whole process of photosynthesis (Samuoliene et al, 2010). Plants are exposed to the same amount of light, but the amount of reflected light intensity off the plant leaf surface may depend on a number of factors including the leaf surface properties (Barnes and Cardosa-Vilhena, 1996). The normal temperature range for the growth of cassava which is between

19 to 32°C although; the variations in this case had a significant effect on the thermal and solar characteristics of the cassava leaves (Alves et al, 2000). The effectiveness of remote sensing of canopy temperature lies in the fact that the presence of water stress corresponds with a closure of stomata and a decrease in the transpiration rate, which is the main process responsible for cooling the plants, with a resulting increase in canopy temperature (Idso et al, 1981). The canopy water content provides a measure of the amount of water contained in the foliage canopy. Water content is an important quantity of vegetation because higher water content indicates healthier vegetation that is likely to grow faster and be more fire-resistant. Canopy water content use reflectance measurements in the near-infrared and shortwave infrared regions to take advantage of known absorption features of water and the penetration depth of light in the near-infrared region to make integrated measurements of total column water content (Hunt and Rock, 1989).

Chlorophyll pigments 'fluoresces' as it re-emit unused light in the photosynthesis process as radiation of longer wavelengths in a reaction time of microseconds. This process is called Chlorophyll Fluorescence and it is a biochemical reaction in the cytoplasm of the plant leaves and can be used to quantify the photosynthesis process. Fluorescence detection is dependent on the sensitivity of the instrument and is therefore measured in arbitrary units (Welch et al, 1995). While leaf reflectance is important for assessing individual plants, canopy reflectance is required for assessing the spatial variability of crop conditions in fields. Many factors complicate the transition from leaf reflectance to canopy reflectance. As leaf area per unit ground area or LAI increases, the contribution of the background (i.e., soil or crop residue) to the overall scene reflectance decreases and the total amount of radiation scattered by plant cells increases (Norman et al, 1985). Multiple scattering is particularly important in the near-infrared (700–1300 nm) where plant pigments do not absorb radiation (Knipling, 1970; Chappelle et al, 1992; Gitelson et al, 1996). The influence of leaf water on reflectance includes both direct effects, those caused by the absorption properties of water itself, and indirect effects, those associated with other leaf properties that change with hydration and water stress. As with water absorption in the atmosphere, the direct effects of liquid water in foliage include distinct features at 1450 and 1950 nm, with weaker features at 980 and 1150 nm (Jacquemoud et al, 2000). This work reports the use of a new Instrument (Taiwo Adekolawole and Timothy Oke, 2016) to study solar-induce physiological parameters as Reflectance, Fluorescence,, Fluorescence Intensity, Chlorophyll luminescence, Canopy moisture and Temperature of *Manihot esculenta*.

II. Materials And Method

Cassava was planted using stem cutting called "stakes". The stakes were chosen from old cassava (when the mother plant was 8-12 months old). An accessible well-drained fertile sandy soil was chosen. Stakes of 15- 20cm were planted vertically in beds by pushing lower part of the stakes of about 5cm depth into the soil (ridges). The stakes (stem cutting) were planted at the spacing of 1.0 by 1.0m or at wider row (up to 2m between rows). Planting was done in the month of June, 2016, within the mid tropical rainfall period, in Ede, semi urban South Western Nigeria. Measurements were made on field grown cassava canopy at different growth stages and readings were noted.

Figure 1: Taking radiometric readings from *Manihot esculenta* Canopy

The Solar-induced Reflectance, at panchromatic wavelengths, of the cassava canopy was measured using a multispectral radiometer built for the purpose (Taiwo Adekolawole and Timothy Oke, 2016). Measurements were taken in the morning, afternoon and evening for a period of 5 days, six hourly intervals and the readings were noted.

III. Results And Discussion

The radiometric data obtained from the measurements were analyzed using the Microsoft Excel line charts and were as shown on the accompanying Figures.

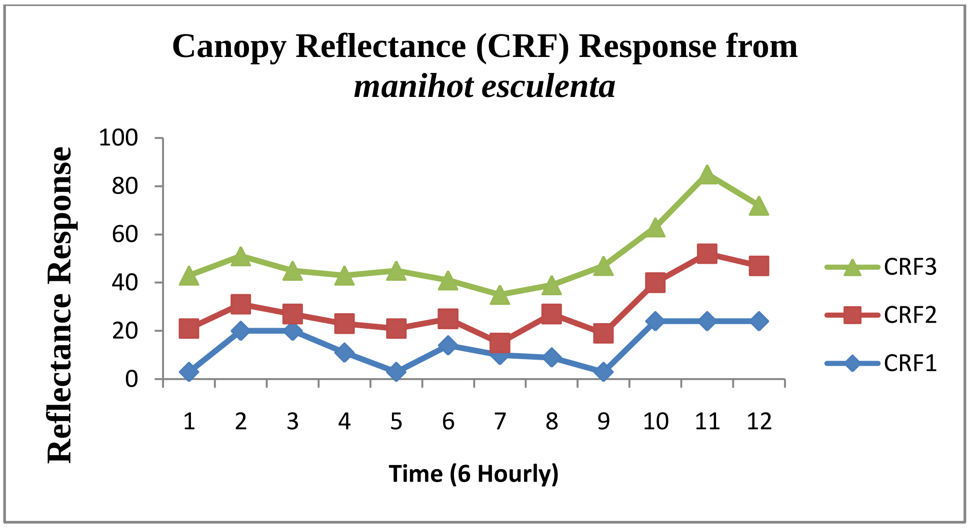

Figure 2: Reflectance response vs Time (6 hourly) at Germination, Day 1

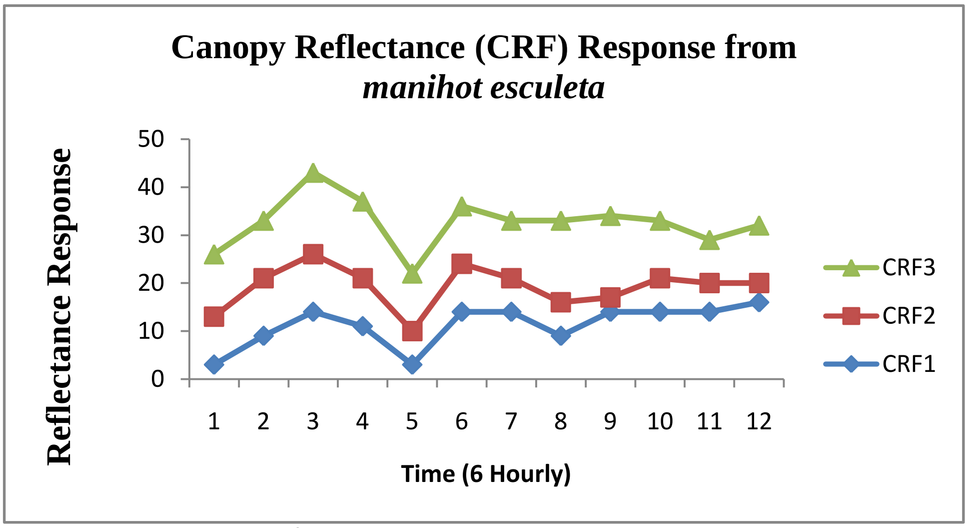

Figure 3: Reflectance response vs Time (6 Hourly) at Germination, Day 2

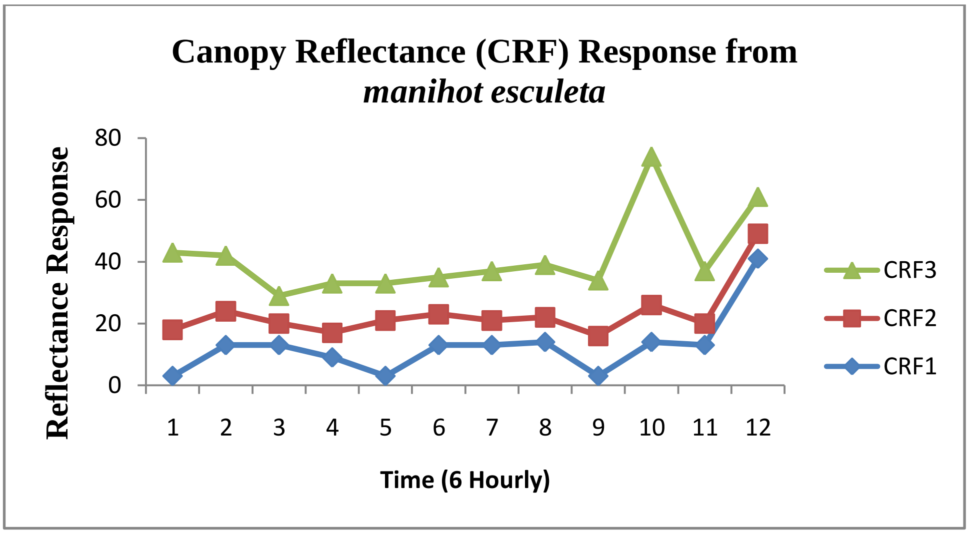

Figure 4: Reflectance response vs Time (6 Hourly) at Germination, Day 3

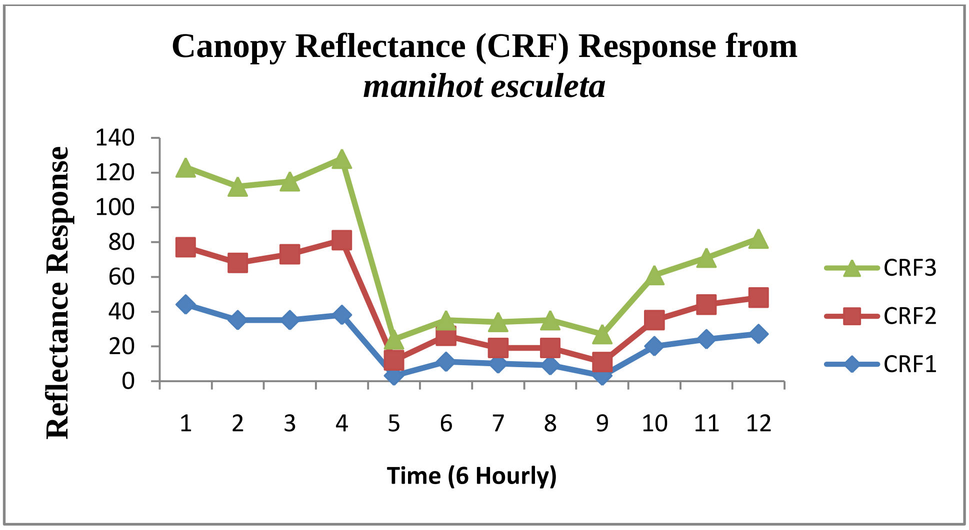

Figure 5: Reflectance response vs Time (6 Hourly) at Germination, Day 4

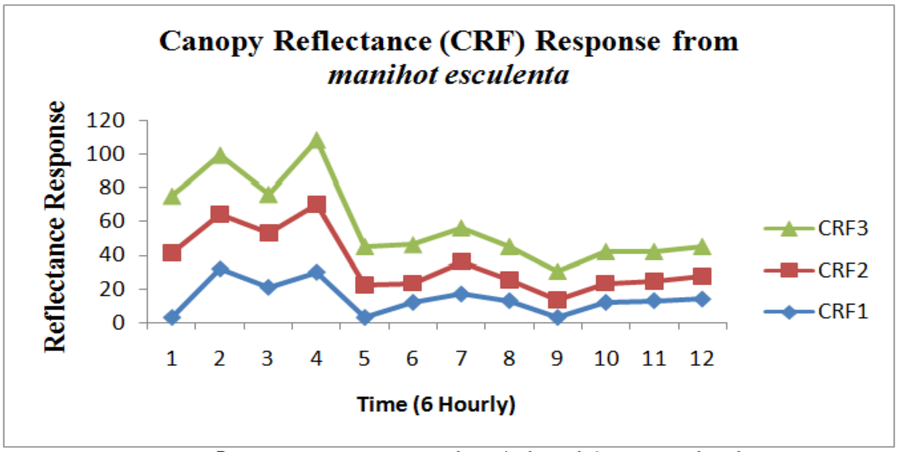

Figure 6: Reflectance response vs Time (6 hourly) at Germination, Day 5

Figures 2 to 6, Germination stage

Canopy Reflectance at the green wavelength CRF3 was more intense as expected since all green plants appear green by selective absorption. It also recorded low absorption in the red and blue wavelengths, needed for photosynthesis activity. This is also seen in the notable reflection in the red and blue wavelengths. The implication of low absorbance in the red and blue radiation means low photosynthesis activity and low carbon dioxide uptake at the germination stage when the shoots were just coming up. Of course at that stage, canopy was yet to form, and low leaf area index. The Dip on Figure 3 could be due to cloud overcast as solar-induced reflectance varied with time and cloud covers amongst others. There were enough Sunshine hours in the morning hours and the afternoon was cloudy but clearer sky at sun set as shown on Figure 5. Figure 6 had appreciable sun shine but cloudy afternoon and evening; Low reflectance but more photosynthesis activity.

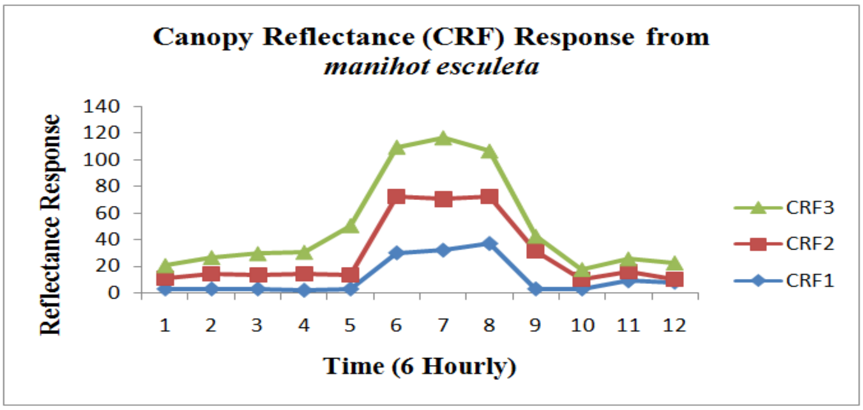

Figure 7: Reflectance response vs Time (6 Hourly) at Foliage

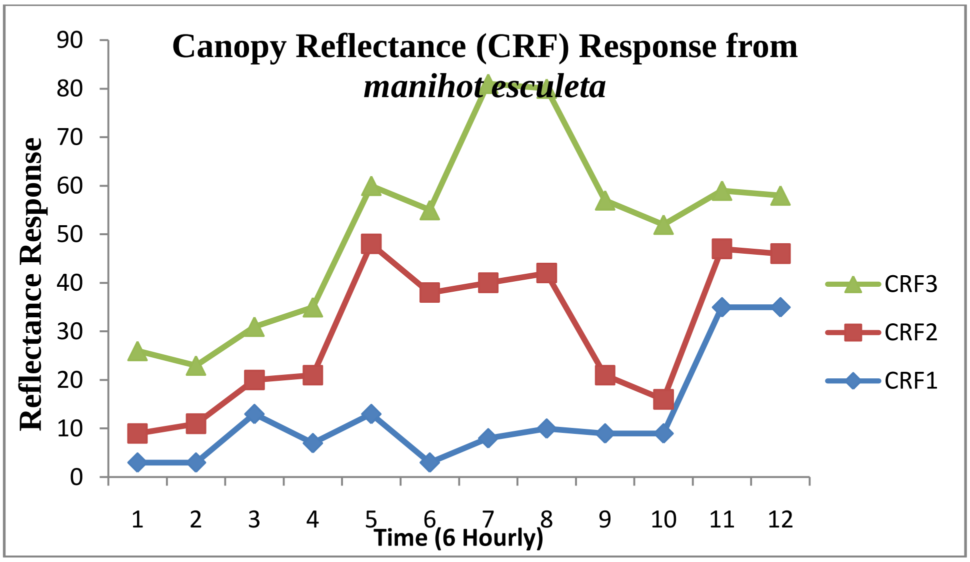

Figure 8: Reflectance response vs Time (6 hourly) at Foliage

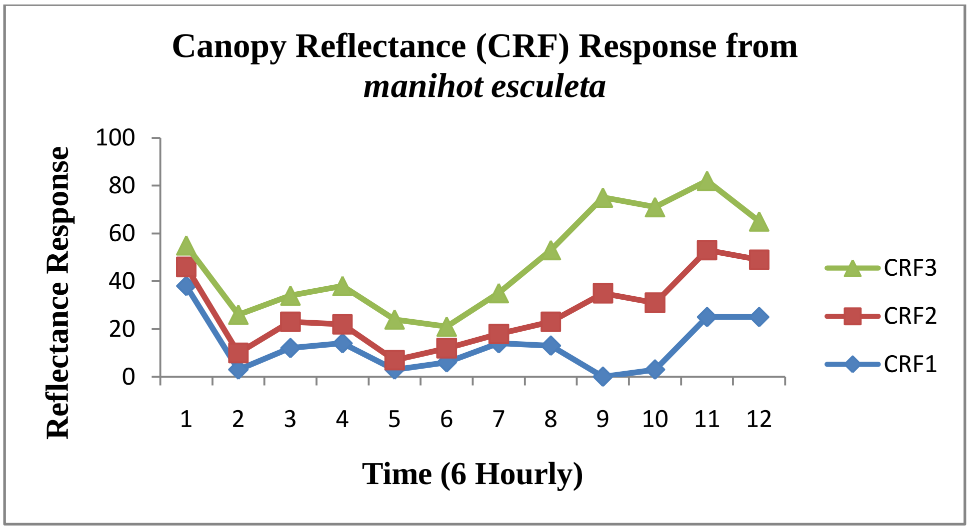

Figure 9: Reflectance response vs Time (6 Hourly) Foliage

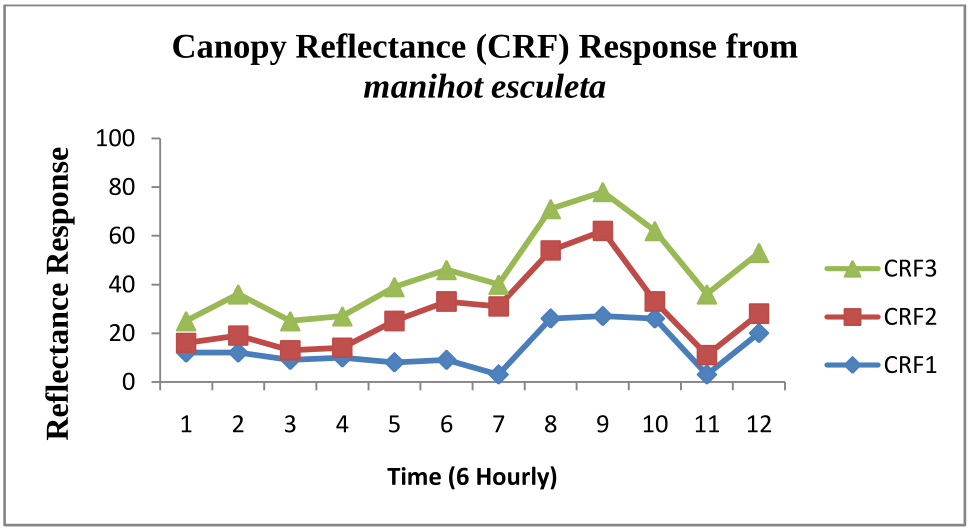

Figure 10: Reflectance response vs Time (6 Hourly) Foliage/ Flowering

Figures 7 to 10 Foliage stage
Measurements were taken on the onset of the first canopy for five days, six hourly.
It was generally observed that the solar-induced canopy reflectance was generally low at this stage due to high absorbance of the red and blue wavelengths and consequently more photosynthesis activity. However, Reflectance was slightly more intense and more pronounced at the green wavelengths in the afternoon hours of Figure 7 and 8 and evening hours on Figure 9 and 10. This may be due to variation in cloud covers and sunshine hours. As stated in the literature, high absorbance of the red light favours more opening of the stomata to take in carbon dioxide and thus more photosynthesis activity. Highlighting the Canopy Reflectance spectral response was done to clearly explain the interplay at the panchromatic wavelengths. The salient features observed could be obscured on the graph showing other physiological parameters as illustrated on the accompanying Figures.

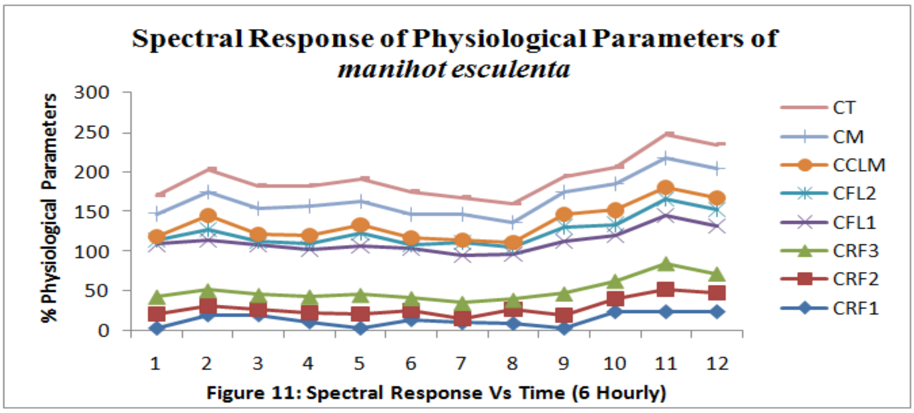

Figure 11: Physiological Parameter's response vs Time (6 Hourly)

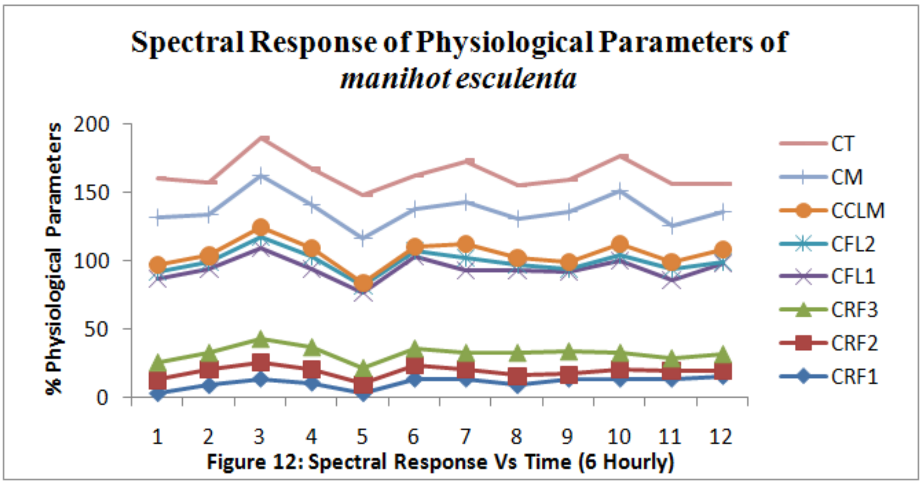

Figure 12: Physiological Parameter's response vs Time (6 Hourly)

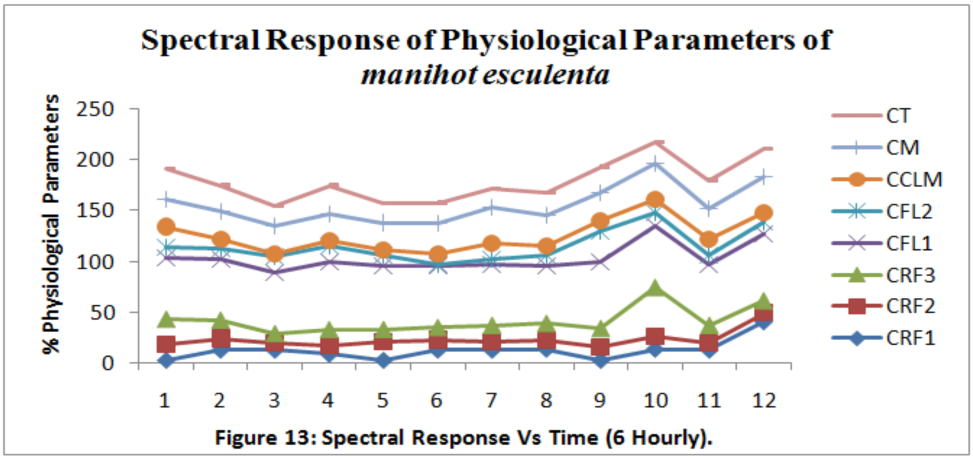

Figure 13: Physiological Parameter's response vs Time (6 Hourly)

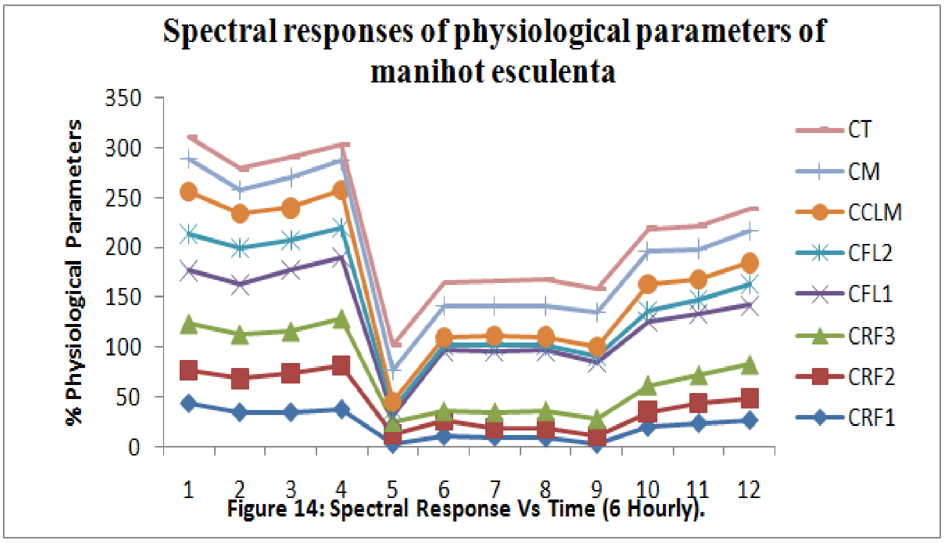

Figure 14: Physiological Parameter's response vs Time (6 Hourly)

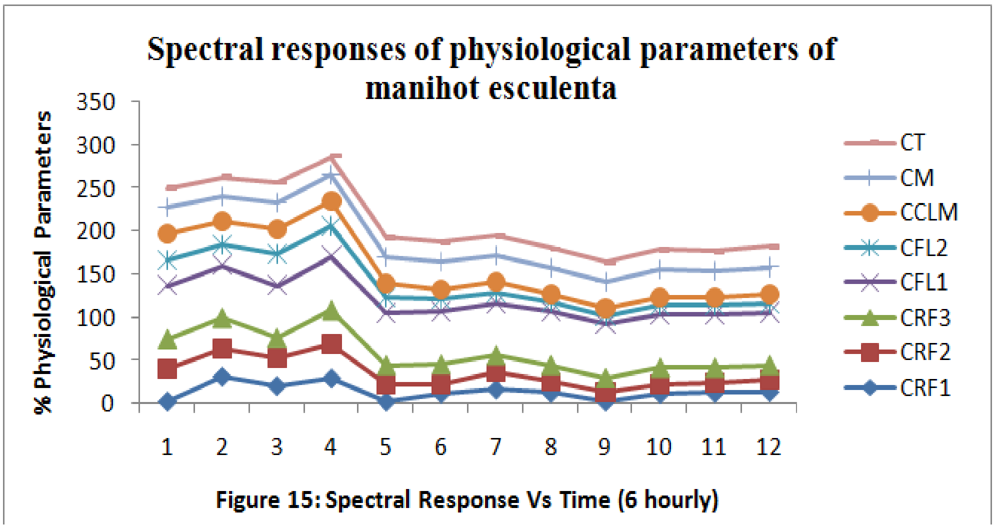

Figure 15: Physiological Parameter's response vs Time (6 Hourly)

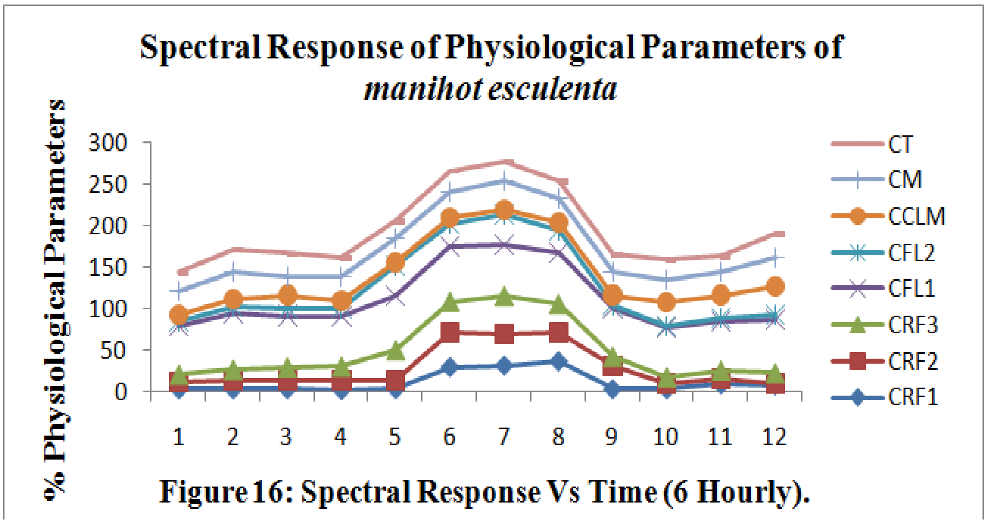

Figure 16: Physiological Parameter's response vs Time (6 Hourly)

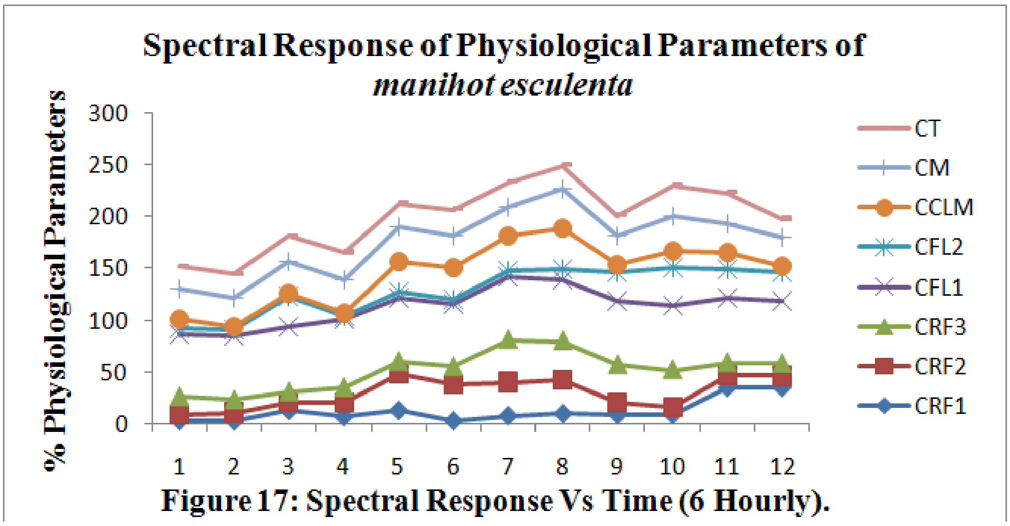

Figure 17: Physiological Parameter's response vs Time (6 Hourly)

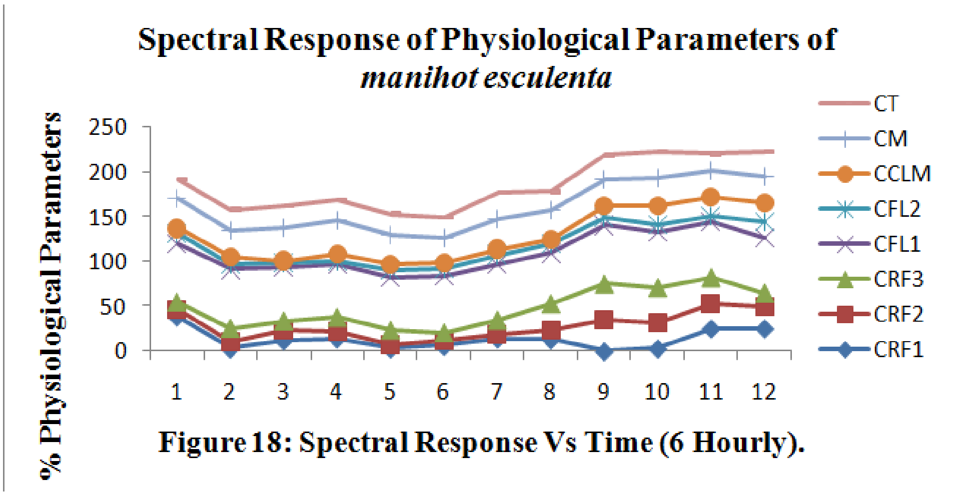

Figure 18: Physiological Parameter's response vs Time (6 Hourly)

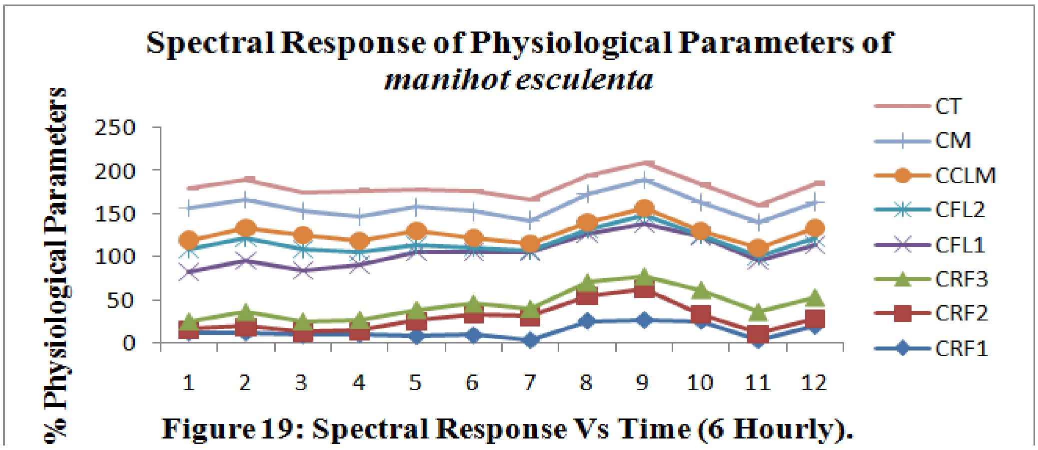

Figure 19: Physiological Parameter's response vs Time (6 Hourly)

Figures 11 to 19

These Figures showed generally low reflectance at the panchromatic wavelengths within the periods of measurement compared to other parameters as Fluorescence, Luminescence amongst others. Looking at Figure 11, Canopy Reflectance at Blue and red wavelengths was very low indicating high absorbance at these wavelengths which is favourable to photosynthesis activity and thus carbon dioxide uptake by the plants. Again, this is good news to mitigation of Global Warming via reduction of the green house gases as carbon dioxide.

Notwithstanding other indicators, low reflectance connotes healthy plant or the absence of stress. Canopy Chlorophyll luminescence was quite intense indicating that the absorbed radiant energy was not fully utilized in the manufacture of starch as the unutilized part is emitted as Fluorescence which when delayed emerged as Luminescence. The Dips on the graphs of Fluorescence Luminescence indicated portions of high utilization of absorbed energy in the photosynthesis process and carbon dioxide uptake or removal from the atmosphere. Canopy moisture and temperature exhibited similar pattern indicating regular evapotranspiration process which again illustrated sound plant health. Figures 12 - 19 showed that the solar-induced physiological parameters under consideration vary with time, Sun shine hours and cloud movements. The sharp dip on Figure 14 showed effect of sudden relief cloud overcast (showers) but more utilization of absorbed radiant energy indicating more starch production. The sharp dip on Figure 14 showed effect of sudden relief cloud overcast (showers) but more utilization of absorbed radiant energy indicating more starch production.

Figure 15 showed low canopy reflectance, fluorescence and Luminescence indicating period of intense photosynthesis Activity. Figure 16 indicated low photosynthesis activity in the afternoon hours. Figure 17 showed notable increased in physiological parameters especially Fluorescence Intensity CFL2 approaching Luminescence due to cloud covers and sun shine hours favouring more absorbance of the red lights towards sun set by scattering effects. Same but less intense was shown on Figure 18.

IV. Conclusion

Solar-induced canopy reflectance, fluorescence intensity, fluorescence, Chlorophyll luminescence, canopy Moisture and Canopy Temperature of *Manihot esculenta* has been measured directly using a multispectral radiometer. The stakes chosen from old *Manihot esculenta* (8-12 months old) was planted, using standard procedures, on well-drained fertile sandy soil, vertically by pushing lower part of the stakes of about 5cm depth into the ridges. The physiological parameters were measured from germination stage to foliage stage. The result showed that there was low absorption of radiation by chlorophyll pigment, low photosynthesis activity, and carbon dioxide uptake at the germination stage as indicated by relatively high canopy spectral responses of the parameters. Photosynthesis activity was more intense at the foliage stage.

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APPENDIX

Reflectance and Fluorescence Response from *Manihot esculenta* on each day Germination Stage

Day 1

CRF1	CRF2	CRF3	CFL	CFLI
3	18	22	66	5
20	11	20	63	13
20	7	18	63	5
11	12	20	60	6
3	18	24	62	16
14	11	16	63	4
10	5	20	60	16
9	18	12	57	9
3	16	28	66	18
24	16	23	57	14
24	28	33	60	21
24	23	25	60	21

Day 2

CRF13	CRF2	CRF3	CFL	CFLI
	10	13	61	5
9	12	12	61	5
14	12	17	66	9
11	10	16	57	10
3	7	12	55	5
14	10	12	67	5
14	7	12	60	10
9	7	17	60	4
14	3	17	58	2
14	7	12	67	5
14	6	9	57	8
16	4	12	66	1

Day 3

CRF1	CRF2	CRF3	CFL	CFLI
3	15	25	60	11
13	11	18	60	11
13	7	9	60	16
9	8	16	66	16
3	18	12	63	10
13	10	12	60	2
13	8	16	60	5
14	8	17	57	10
3	13	18	66	30
14	12	48	61	13
13	7	17	60	9
41	8	12	66	12

Day 4

CRF1	CRF2	CRF3	CFL	CFLI
44	33	46	53	38
35	33	44	50	37
35	38	42	62	31
38	43	47	61	31
3	9	12	6	7
11	15	9	61	6
10	9	15	61	6
9	10	16	61	6
3	8	16	57	6

20	15	26	64	12
24	20	27	62	15
27	21	34	59	22

Day 5

CRF1	CRF2	CRF3	CFL	CFLI
3	38	34	62	29
32	32	35	61	25
21	32	23	61	36
30	40	38	63	35
3	19	23	60	18
12	11	23	61	14
17	19	20	61	12
13	12	20	62	10
3	10	17	63	8
12	11	19	61	10
12	11	18	62	9
14	13	18	61	9

Foliage Stage Data

Day 1

CRF1	CRF2	CRF3	CFL	CFLI
3	8	9	60	5
3	11	12	70	6
3	10	16	63	9
2	12	16	61	10
3	10	37	66	36
30	42	37	67	26
32	38	46	61	37
37	35	34	62	26
3	28	11	59	4
3	7	7	61	1
9	7	9	60	4
8	2	12	66	4

Day 2

CRF1	CRF2	CRF3	CFL	CFLI
3	6	17	60	6
3	8	12	62	5
13	7	11	63	29
7	14	14	66	2
13	35	12	61	6
3	35	17	61	4
8	32	41	61	6
10	32	38	59	10
9	12	36	61	29
9	7	36	66	37
35	12	12	62	29
35	11	12	60	29

Day 3

CRF1	CRF2	CRF3	CFL	CFLI
38	8	9	66	10
3	7	16	66	6
12	11	11	60	5
14	8	16	60	2
3	4	17	59	8
6	6	9	63	9
14	4	17	63	10
13	10	30	57	10
0	35	40	66	9
3	28	40	63	8
25	28	29	63	6
25	24	16	62	17

Day 4

CRF1	CRF2	CRF3	CFL	CFLI
12	4	9	57	28
12	7	17	59	28
9	4	12	59	26
10	4	13	63	16
8	17	14	66	9
9	24	13	60	5
3	28	9	66	2
26	28	17	57	4
27	35	16	61	10
26	7	29	62	2
3	8	25	60	5
20	8	25	61	8