Investigation of Leaf Water Content Using Transmission Method

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Abstract

This investigation is the water content of betel (*Piper Betel Linn*) leaves have been determined based on their mass attenuation characteristics to beta particles. The transmitted intensities and mass attenuation coefficient for particles of ^{90}Sr radioactive source with end point energy 0.546MeV is used as beta emitters. The Geiger Muller Counter is used as detector through the fresh and dry leaves of the different thickness are measured of beta attenuation for betel leaf sample. These parameters vary as the amount of water content in selected leaves gets changed. The mass attenuation coefficient is obtained as the slope of leaf thickness versus logarithm of relative transmission intensity. The transmission intensity decreases with increase of water amount in plant leaves. For leaf thickness versus logarithm of relative transmission intensity provides the attenuation coefficient. The measured value of mass attenuation coefficient agrees well with that calculated from statistical regression method. Also, the percentage water content values are determined using beta attenuation and found to be in close agreement with direct weighing.

Keywords: Beta particle transmitted intensity, linear attenuation coefficient, Mass attenuation coefficient, Water content of leaves

Introduction

Water content of the leaves and vegetation is an important variable in physiological plant activities. It maintains their vitality, photosynthetic efficiency and hence is an important production limiting factor. Water content of the leaves and plants varies with its type and the environmental conditions. When leaves dry up, they mainly lose their water content and hence it is found to be a strong indicator of vegetation stress also. It is an important production limiting factor and strong indicator of vegetation stress. It can determine whether there is water shortage that can reduce yields or if there is excessive water application that can result in water logging or leaching of nitrates below root zone. Leaf water content is an important factor to show water scarcity in farmland. Water status of plant can be indicated by the features of tissues such as root, stem and leaf or the whole canopy.

Compared with of the tissues of plant, leaf analysis is the most important tool for evaluating nutrients and water status of plant, which are used for guiding its irrigation and fertilization, Water stress not only reduces leaf area but often increases leaf thickness, thereby increasing the weight per unit area. Attenuation is the kind of absorption or scattering of radiations as they travel through the matter. The probability that beta particles will interact somewhere within matter depends on the total number of atoms ahead of it along its path. Travelling beta particles gradually lose their energy by collisions with atoms and change their direction by multiple scattering. The beta attenuation studies in matter have helped a lot in solving variety of problems in physical sciences, agricultural sciences and medical sciences. The attenuation studies in matter have helped a lot in solving variety of problems in physical sciences, bio–sciences, agricultural sciences and medical physics.

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The propagation of energy through matter or space can be defined as radiation. It can be in the form of electromagnetic waves or energetic particles, ionizing radiation has the ability to knock an electron from an atom. Examples of ionizing radiation does not have enough energy to ionize atoms in the material it interacts with. Examples of non-ionizing radiation include microwaves, visible light and radio waves. The detection and measurements of radiation is based upon the detection and measurement of its effects in medium, and the history of the emergence of radiation detectors is closely related to the radiation and its effects. Radioactive material emits ionizing radiation without having been subject to any external influence. The type of radiation emitted and its associated energy is characteristic for the kind of radioactive substance. The radiation produced during radioactivity is predominantly of three types, designated as alpha, beta, and gamma rays. These types differ in velocity, in the way in which they are affected by a magnetic field, and in their ability to penetrate or pass through the matter. Other, less common, types of radioactivity are electron capture and positron emission-both are the forms of beta decay and resulting the change of a proton to a neutron within the nucleus-an internal conversion in which and excited nucleus transfers energy directly to one of the atom's orbiting electrons and ejects it from the atom.

Plants are important in the global circulation of water, and conversely, water plays many essential roles in plant growth and function, even the hardiest desert plants need water. Water is indispensable to plants and the shortage of such critical resource leads to a decline in land productivity and yield loss, Water helps a plant by transporting important nutrients through the plant. Nutrients are drawn from the soil and used by the plant. The internal water status of a plant represents the integrated interaction of the plant with the environment, leading to the plant's growth. Without enough water in the cells, the plants droop, so water helps a plant to stand. Water carries the dissolved sugar and other nutrients through the plant. So, without the proper balance of water, the plant not only is malnourished, but it is also physically weak and cannot support its own weight.

Theory

Water is the major constituent in a plant leaf. Thus changes in water content of leaves are reflected by changes in the absorber thickness. The attenuation of beta radiation is occurred due to the effect of all the energy exchange mechanisms (Compton effect and Photoelectric attenuation) as it interacts with the atoms contained in a material, thus reducing the transmitted intensity. The transmitted intensity depends on the, thickness of the absorbing layer, density and the across-sectional properties of the material. The attenuation of beta radiation through a plant leaf depends upon mass per unit area of the leaf. The intensity of transmitted beta radiation through a plant leaf, is given as

$$I = I_0 e^{-\mu t} \tag{1}$$

Where, I_0 is the intensity of the no attenuated beta radiation, μ and t are the mass attenuation coefficient and thickness of leaf respectively (organic matter and water). From this equation mass attenuation coefficient (μ) can be calculated by knowing the other quantities. From equation (1) for a fresh leaf,

$$t_f = \frac{1}{\mu_f} \ln\left(\frac{I_0}{I_f}\right) \quad (2)$$

Where, I_f, t_f and μ_f are the intensity, mass per unit area, and mass attenuation coefficient respectively of fresh leaf.

for a dry leaf,

$$t_d = \frac{1}{\mu_d} \ln\left(\frac{I_0}{I_d}\right) \quad (3)$$

Where, I_d, t_d and μ_d are the intensity, mass per unit area, and mass attenuation coefficient respectively of dry leaf (organic matter).

Since, leaves contain water and organic matter, we can write

$$t_w = t_f - t_d \quad (4)$$

Where, t_w is the mass of water per unit leaf area.

Using equation (2), (3) and (4), we get,

$$t_w = \frac{1}{\mu_d} \ln\left[\left(\frac{I_0}{I_f}\right)^n \times \left(\frac{I_d}{I_0}\right)\right] \quad (5)$$

Where, n = μ_d/μ_f ratio of mass attenuation coefficients of completely dry leaves to those of fresh leaves. Thus, given by using the experimental values of I_d/I_0 ,μ_d and μ_f and measuring the ratio I_f/I_0 for a fresh leaf, equation (5) provides the absolute water content. The percentage water content is the following formula.

$$\frac{t_w}{t_f} \times 100 \quad (6)$$

For direct water content the following formula is used,

$$\%\text{water content} = \left[\frac{fresh\ leaf\ mass - dry\ leaf\ mass}{fresh\ leaf\ mass}\right] \times 100 \quad (7)$$

The percentage water content values derived from direct weighing and beta attenuation are compared with each other.

Experiment

Geiger Muller Counter, a radiation detector based on ionization effect of radiation to count beta rays with radioactive sources ^{90}Sr made is available in Physics Nuclear Lab of Mandalay University. We made standard connections and arrangement between G.M. Counting System, detector, absorber and source. Plant leaves were taken from the local market. The selected leaves were washed and air dried to remove excess water from tissues of leaves. A beta source is placed in the source tray at about 3 cm from the end window of the GM tube. . The source-absorber geometry is centrally aligned and is kept same throughout the experiment. The operating voltage of the GM tube was set as 960V. The absorber (leaves of Betel) was placed between end window detector and source holder containing ten absorbers of respective thickness. We took the reading for a present time of 60 sec. Without any absorber and tabulate and repeated the experiment by recording the data stores for the same present time for different thickness in the increasing order and their transmission study was done. The same steps were repeated as explained above for next absorber sets of leaves. The circular leaves are kept to dry at room temperature for 3 days. Transmission of beta particles through these dry leaf samples are measured. Corresponding calculations are done as represented in tabular forms and respective graphs are plotted.

Figure 1 Experimental set–up of GM counter

Results and Discussion

In the present work mass attenuation coefficient and percentage water content of selected betel leaves is determined by using β attenuation techniques. The data for leaf thickness, transmitted intensity and logarithm of relative transmitted intensity, for two leaf varieties at two states (fresh and dry) has been shown in Table.1 for fresh leaf and in Table. 2 for dry leaf. The column (2) in data table contains the values for thickness of leaf. This thickness (mass per unit area) includes water content and organic matter of betel leaf. The column (4) shows the logarithmic values of relative transmission through leaves with different thickness.

Table1 Fresh Betel leaf for ^{90}Sr source

Sr. No.	Thickness (mg/cm^2)	Count per sec	ln (N0/N)
1	0.0199	96.7523	0.4999
2	0.0291	69.9767	0.6389
3	0.0472	43.5978	1.1594
4	0.0711	31.1221	1.6435
5	0.1011	18.9659	2.0357
6	0.1342	13.5495	2.5432
7	0.1589	9.1735	2.9321
8	0.1733	6.4258	3.4375
9	0.1943	3.3529	3.9631
10	0.2276	1.5214	4.3756

Table 2 Dry Betel leaf for ^{90}Sr source

Sr. No.	**Thickness (mg/cm^2)**	**Count per sec**	**ln (N0/N)**
1	0.0076	119.5213	0.2342
2	0.0163	101.6835	0.3412
3	0.0257	90.1324	0.5749
4	0.0328	75.5693	0.7956
5	0.0396	64.3825	0.9462
6	0.0481	53.0248	1.1458
7	0.0527	47.5321	1.2979
8	0.0612	39.2377	1.6105
9	0.0723	30.3459	1.8276
10	0.0794	26.1454	2.0314

Table.1 is the data of fresh betel leaf, thickness **(**mg/cm^2**)** and logarithm of relative transmission intensity has been shown in Figure.2 from which linear attenuation coefficient is determined. The thickness (mg/cm^2) and counts per second of fresh betel leaf has been shown in Figure.3 from which mass attenuation coefficient is determined.

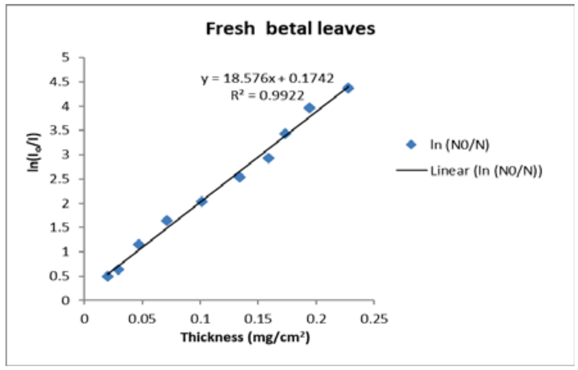

Figure 2 Thickness Vs relative transmission intensity of fresh leaf for

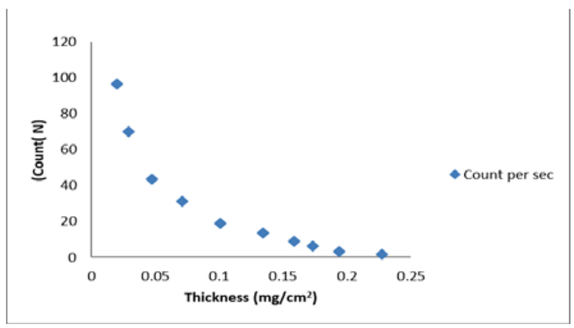

Figure 3 Thickness Vs Counts per second of fresh leaf for ^{90}Sr

Table.2 is represented the data of dry betel leaf, thickness (mg/cm^2) and logarithm of relative transmission intensity has been shown in Figure.4 from which linear attenuation coefficient is determined. The thickness (mg/cm^2) and counts per second of dry betel leaf has been shown in Figure.5 from which mass attenuation coefficient is determined.

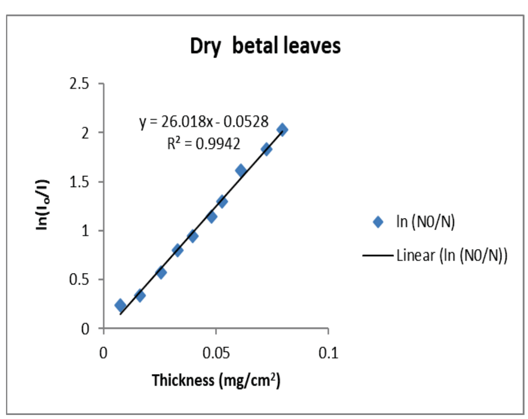

Figure 4 Thickness Vs relative transmission intensity of dry leaf for ^{90}Sr

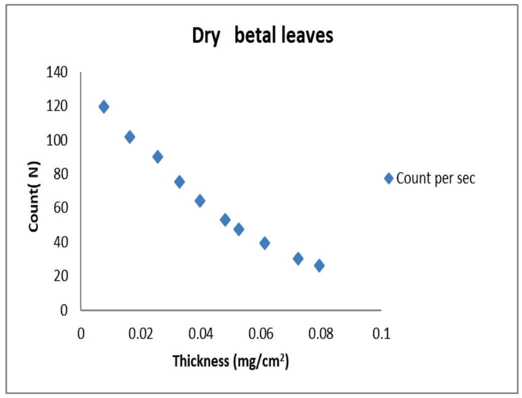

Figure 5 Thickness Vs Counts per second of dry leaf for

Data of leaf thickness, transmitted intensity and water content has been shown in Table.3 for betel of different thickness. The column1 in data table contains the values for thickness of leaves. This thickness (mass per unit area) includes water content and organic matter of betel leaf. On drying the betel leaf, its thickness decreases (as leaf has lost water content). As the thickness of the leaf increases, its absolute water content increases which in turn leads to increase in the absorption of radiations. The percentage water content of leaves by beta attenuation method and by direct weighing (calculated by equation 6 and 7) has been shown in columns 3 and 4 respectively. The percentage water content of the leaf calculated by beta attenuation method and direct weighing are also in closed agreement with each other. The plots of transmitted intensity as a function of water content and thickness of leaf are shown in Figure 6.

Table 3 Leaf thickness, transmitted Intensity and % of water content of Betel Leaf for ^{90}Sr

Mean Thickness (mg/cm^2)	Mean Intensity	%Water Content	
		Beta attenuation	Direct Weighing
0,0138	108.1368	31.39	31.01
0.0227	85.8301	28.71	28.74
0.0568	67.0552	28.16	28.34
0.052	59.5836	27.71	27.21
0.0704	41.6742	26.06	26.14
0.0895	33.2872	26.41	25.99
0.1058	28.3528	25.93	25.59
0.1173	22.8318	25.38	25.17
0.1333	16.8494	24.46	24.96
0.1535	13.8335	24.41	24.84

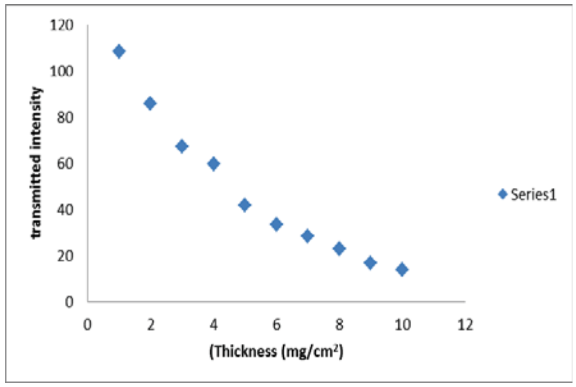

Figure 6 Thickness Vs Transmitted Intensity of Betel leaves for ^{90}Sr

The slope of fitted line is negative because increase of water content causes more absorption of beta particles and hence decreases of transmitted intensity. The best-fit straight lines serving as calibration carves provide an alternative way to measure water content. In field situations for monitoring the water content in plant leaves these types of curves can be of great use. We believe that the present experimental findings with regard to agricultural field will be quite useful to other investigators in improving their design for field instruments.

Conclusion

The mass attenuation coefficient values are useful for quantitative evaluation of interaction of radiations with betel leaves of plants. Water is an essential and important constituent of plants and trees. Thus, we studied that the mass absorption coefficients values were measured for the leaves of betel by using Sr-90 source. The mass attenuation coefficient of fresh leaves is greater than dry leaves. The water content in the leaves plays a vital role in attenuation of radiations hence the "Leaves" of various tree act as "natural absorbers". Moreover, the attenuation coefficient method is fast, non-destructive, an easy-to handle and hence can be utilized for planted leaves. Investigations based on beta transmission methods are rarely available for selected vegetable leaves that are grown in seasonal conditions of this region. It will lay an important foundation for sustainable development and modern agricultural technology. There is also a need to simulate the present experiment with some suitable.

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