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ACCUMULATION OF SOLAR ENERGY BY SUGAR BEET FIELDS OF PESHAWAR, N.W.F.P., PAKISTAN

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Abstract

An estimate of net primary productivity of sugar beet fields has been made by measuring yield as determined by the harvest method. Mortality of shoot tissue had also been taken into account. Paired-plots method was used for determination of dead organic material of shoots. Net primary productivity of various plant-parts was calculated by the product of their calorific values and yield. Addition of these values gave total net primary productivity for the crop. It was found that the net primary productivity of sugar beet fields during its growing period (15 October 1978 to May 1979) was 4672.14 Kcals/m^2. The relative Efficiency based on total solar radiations was 0.8 per cent and Absolute Efficiency based on photosynthetically efficient solar radiations was 1.7 per cent.

Introduction

An attempt has been made to estimate the net primary productivity of sugar beet (*Beta vulgaris* CV. KWS.AA) fields of Peshawar Net primary productivity (NPP) of an ecosystem is the rate at which solar energy is fixed by the vegetation less that respired. Energy cycle of vegetation is a contemporary topic and ecologists are doing much work in this regard. Transeau (1926) estimated the rate of energy fixed by plants. In the past few years Eugene Odum and his school at the University of Georgia, U.S.A., have conducted considerable research on energy field problems. Wiegert & Evans (1964) estimated NPP in an old field. Chew & Chew (1965) determined the primary productivity of a desert shrub (*Larrea tridentata*) community. Slatyer (1968) proposed methods for measurement of NPP of arid zone plant community. Monteith (1965) measured the distribution of light in field crops and compared solar radiation with net production. Recently Chaghtai & Ali (1978) determined NPP of cultivated fields of wheat and barley.

Measurement of NPP of various crops and fodders, occupying a large area of the earth surface and used by man and his domestic animals, is gaining striking importance, because it is directly equivalent to the energy supplied to man and his animals. It is also important because we can estimate energy requirements for a population. The calculations of rate of energy fixation by crops manifests a fundamental view of the energy flow through principal food chains in an ecosystem. For grasses and cultivated crops NPP is calculated from the yield (the amount of new biomass produced in a growing season) taken from a unit area of land. The present research provides a sufficiently accurate measurement of NPP, by preventing grazing and determining the amount of mortality by measuring disappearance rate of dead organic material of the crop.

In this study efficiency of the crop has also been calculated. Efficiency of a community is defined as the calories of energy per unit area, stored in the harvested vegetation in any period, divided by the calories of solar energy available during that period. It is the percentage of energy which has been stored out of total available radiant energy. An attempt has been made to avoid errors by selecting the study area adjacent to meteorological station, having similar topographic exposure, as the radiant energy available to the ecosystem under investigation is not the same quantity as that measured many miles away from it.

The study has been conducted in the Malakandare Farm of the Faculty of Agriculture, University of Peshawar. The district of Peshawar lies between latitudes $30^{o}.40'$ and $34^{o}.35'$North and longitudes $71^{o}.25'$and $72^{o}.15'$East at an altitude of 370m. The research site is located at the foot of Khyber Hills.

Materials and Methods

The method employed for the measurement of NPP is that of Wiegert & Evans (1964) with some modifications. Clipping and digging techniques used are those of Milner & Hughes (1968). Paired plot method was used in this study for estimating the amount of shoot biomass (yield) produced during the growing period. The estimate of yield was finally corrected by taking into account the loss of shoot material due to death and decomposition. Sowing was done on 15 October, 1978. Three plots, each 0.4 x 0.4m which were almost similar in plant density and composition were selected on 12 January, 1979. Each plot had 10 replicates. Scattered plots were permanently marked with stakes and in turn were treated as under:

Plot No. 1:

At the beginning of the study period shoot material was clipped at the ground level and was bagged. The dead shoot material, after clipping green shoots in the plot, was collected from the ground level and was stored in another bag. The soil was excavated to a depth of 30cm and roots were removed and stored.

Plot No. 2:

The living shoot material was clipped at the ground level and was removed at the start of the experiment. The dead material was left on the ground to estimate its loss by decomposition. Plot was covered with wooden frame with chicken guaze at the top to prevent loss of material by wind and water. At the end of study period, the dead shoot material which escaped decomposition, was collected from this protected plot.

Plot No. 3:

The living shoot material was clipped at the end of the study period and stored. The dead shoot material was also collected from the ground surface. Roots were removed and stored.

Plant material collected from these plots was dried at 100°C for 48 hours in an oven and then weighed. Oven dry weights for 10 replicates was taken (Table 1). Analysis of variance was done and variations were found to be non-significant. The rate of disappearance of dead shoot material (Table 2) was calculated as under:

W_o = Weight of dead shoot material from plot 1,
W_1 = Weight of dead shoot material from plot 2,
r = rate of disappearance of dead shoot material,
t = Length of production period, in days, and

$$r \quad \text{(grams/gram/day)} = \frac{\ln(W_o/W_1)}{1} \quad \ldots\ldots\ldots\ldots \text{(i)}$$

Estimate of shoot growth during the production period was calculated in grams dry weight per plot by the following formula:

X = An estimate of the quantity of dead material disappeared from the undisturbed plot 2 during the production period.
a_o = Weight of dead shoot material at the start from plot 1,
a_1 = Weight of the dead shoot material at the end from plot 3,
r = Rate of disappearance of dead shoot material in grams per gram per day.

$$X \quad \text{(in grams/plot)} = \frac{a_o + a_1}{2}\, rt \quad \ldots\ldots\ldots\ldots \text{(ii)}$$

d = Mortality of live shoot material during production period.
d (in grams/plot) = $X + (a_1 - a_o)$ . . . . (iii)
y = Net production (yield) of shoot material during study period.
b_o = Weight of live shoot material from plot 1.
b_1 = Weight of live shoot material from plot 3.
y (in grams/plot) = $b_1 + d$ . . . . (iv)

Increase in root biomass was calculated during the production period (Table 1) by the following formula:

Yield of root material during production period = R
Weight of root material from plot 1 = R_1
Weight of root material from plot 3 = R_3

$$R = R_3$$

Table 1. Oven dry weights in grams (average of 10 replicates) for standing crop of shoot, total root material and dead shoot material from sample plots at the beginning and at the end of the study period.

	Standing crop of shoot	Total root material	Dead shoot material
Plot No. 1.	8.205	1.516	0.6783
Plot No. 2.	—	—	0.1062
Plot No. 3.	35.758	135.464	6.256

The Calorific values of the material were determined by an adiabatic Oxygen bomb calorimeter, model Parr 1200 (Parr Instrument Company, 1960). Techniques for determination of calorific values of plant material were given by Chaghtai & Ali (1978). NPP was calculated by multiplying yield with its corresponding calorific value. Total

Table 2. Calculations of yield in grams of dry weight of biomass.

Rate of disappearance of dead shoot material (grams/gram/day) = r=0.014;

Decomposition of dead material during the production period (g/plot) = X=6.456;

Weight of live shoot material from plot 3 (grams) = b_1 =35.758;

Change in standing crop of dead material (g/plot) = $a_1 - a_0$ 5.577;

Mortality of live shoot material (g/plot) = d=12.033;

Shoot growth during the production period (yield=g/plot) = y=47.791;

Weight of root biomass during the production period (g/plot) =R=135.464.

radiant energy for the study period was calculated from the daily amount of radiant energy recorded by Pyrheliograph at the observatory of Pakistan Forest Institute, Peshawar. The total radiant energy received during the study period of 220 days (15 October, 1978 to 25 May 1979) was 584362 KCals/m^2.

Results and Discussion

Yield (Shoot biomass)

The determination of NPP, accomplished by measuring biomass of the plant community at the start and at the end of the study period is a common practice. Total increase in the biomass, by growth, in the standing crop of shoot per unit area will be equal to the sum of the increase in live shoot material plus mortality of the detached leaves during that time.

Data of shoot and root biomass increased during the production period of under study crop is given in Table 2. Rate of disappearance of dead organic material of wheat and barley is 0.0839 and 0.06208 grams per gram per day respectively (Chaghtai & Ali, 1978). Rate of disappearance of dead material of sugar beet shoots is lower as compared with wheat and barley (Table 2). The nutrients of the sugar beet crop remain tied up for a longer period of time and thus relative avaiability to the growing plants is delayed.

Net Primary Productivity (NPP)

NPP of various parts of the crop has been obtained by multiplying yield by its corresponding calorific values (Table 3). NPP of the whole plant (shoots and roots) has been obtained by adding NPP of the shoots and roots in the study plots. In case of wheat

Table 3. Net primary productivity (NPP) per study period (15 October 1978 to 25 May 1979).

Treatment	Yield g/plot	Calorific value KCal/g	NNP KCal/plot
Above ground shoot	47.791	3.17	151.50
Root	135.464	4.4	596.04
Whole plant including shoot and root	–	-	747.54

and barley, energy content of the roots is too low as compared with shoots (Chaghtai & Ali, 1978). In this work the energy stored in the roots is very high as compared with shoots (Table 3). The NPP of the sugar beet roots under present investigations was 16.933 $KCal/m^2/day$. The NPP of sugar beet roots in Netherland is 40.6 $KCal/m^2/day$ (Odum, 1971). The score of the present crop in this regard is discouraging. High temperature may be considered as one of the factors responsible for low NPP of sugar beet under these conditions. Under high temperature conditions, the rate of respiration is enhanced consuming a major portion of gross NPP energy (Odum, 1971). This view is also supported by Best (1962) that yield of rice is low in equatorial regions as compared with temperate ones.

Efficiency

The efficiency of the crop under study has been calculated by taking the ratio of NPP in KCals per m^2 per period (Table 4) to the radiant energy in the identical units and expressed in per cent (Table 5). The total solar radiation received during the study period was 584362 $KCals/m^2$. Efficiency of the crop under study has been calculated both on

Table 4. Net primary productivity of the crop during production period (15. October 1976 to 25.5 May 1979) in $KCal/m^2$.

Plant part	Per day	Per growing period
Shoot	4.304	946.88
Root	16.933	3725.26
Whole plant including shoots and roots	21.237	4672.14

Table 5. Per cent Efficiency of the whole plant (including shoots and roots) during the production period (15 October 1978 to 25 May 1979).

Relative Efficiency	Absolute Efficiency
0.8%	1.7%

the basis of total as well as photosynthetically efficient solar radiations (0.4 micron to 0.7 micron). Photosynthetically active solar radiations has been calculated to be 47% of the response of Pyrheliograph (Yocum et al., 1964). The value for the former was called Relative Efficiency and those for the latter Absoltue Efficiency (Chaghtai et al., 1978).

Efficiency for the various parts of a crop cannot be exactly measured, as the exact amount of solar radiation available to these parts cannot be calculated. Botkin & Malone (1968) have reported that efficiency of one year old field on New Jersy piedment was 3.8 per cent for the upper vegetational layer and 10 per cent for the lower. However, the influence of interception in this study can be assumed to have been practically eliminated becasue of the pure stand of sugar beet crop with small plants of almost uniform size. It is true that on the same plant the upper leaves receive more radiant energy than the lower leaves, but the radiant energy generally never becomes a limiting factor even for the lower leaves in the case of species selected for this study. Bray (1961) has mentioned that higher values of efficiency will be obtained if losses due to reflection, absorbtion by the ground and non-photosynthetic tissues are taken into account.

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