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NET PRIMARY PRODUCTIVITY OF WHEAT AND BARLEY FIELDS IN PESHAWAR, PAKISTAN.

S.M. CHAGHTAI

Islamia College, University of Peshawar

AND

QAISAR ALI

Department of Botany, University of Peshawar.

Abstract

The net primary productivity of the fields of wheat and barley was determined. The standing crop of live shoot material was found to be higher in wheat than in barley. The standing crop of dead shoot material and total mortality of shoot material was also found to be higher in wheat than in barley. No significant difference was noticed in the increase of standing crop of roots of the two species. A faster rate of disappearance of dead organic material was observed in wheat. The net primary productivity of the inflorescence of barley was found to be two times greater than that of wheat; but the net primary productivity of aboveground shoot (excluding inflorescence) of the latter was twice that of the former.

Introduction

The study of energy cycle in the biosphere and the fixation of solar energy by vegetation is regarded as one of the most thrilling topics of the biological sciences. The energy can be regarded as the currency of ecology (Odum, 1971). It is fundamental to the functioning of ecosystems and its rate of flow through the systems is an index of community metabolism (Ashby, 1969). A large proportion of the solar energy that impinges on the earth is transformed into heat energy and only a small fraction of it is fixed by green plants as potential chemical energy in the process of photosynthesis; all the life on this planet depends upon this stored chemical energy.

Net primary productivity (NPP) of an ecosystem is the rate at which solar energy is fixed by the vegetation less that is lost in respiration. Its measurement accounts for all the energy exchange that occurs in a community

The measurement of NPP of various crops and fodders, occupying a large area of the surface of earth and used by man and his domestic animals, is gaining striking importance. The estimation of the rate of energy fixation by crops manifests a fundamental view of the energy flow through the principal food chains in an ecosystem. The NPP of the grasses and cultivated crops is calculated from the yield (the amount of new biomass produced in a growing season during a specific time) taken from a unit area of land. Harvest method is generally used for the measurement of yield. Some doubts have been expressed about the accuracy of this method (Odum, 1960; Wiegert & Evans, 1964), however, an effort has been made in this study to avoid the shortcomings of the previous workers. The productivity of roots, which is substantially difficult to measure because of various complications, has also been included. This study provides a sufficiently accurate measurement of NPP of wheat and barley fields because special care was taken to prevent grazing, mortality of the shoot material was taken into account and the productivity of the roots was also included.

Materials and Methods

The method employed for the measurement of NPP is that of Wiegert & Evans (1964) with some modifications. Clipping 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 study period and the rate of disappearance of dead organic material. For each species, three plots each 0.2 X 0.2 m, having similar plant density and composition, were selected. The plots were placed randomly and marked permanently with stakes.

Treatment of plots

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 was collected from the ground surface and was stored in another bag.

Plot No. 2 :

The living shoot material was clipped at the gound level and was removed at the start of the experiment. The dead shoot material was left on the ground and the plot was covered by wooden frame with chicken gauze on top to prevent the loss of material by wind and water. Four weeks later, the dead shoot material which escaped decomposition was collected and bagged.

Plot No. 3 :

The living shoot material was clipped at the end of the study period and stored in a bag. The dead shoot material was also collected from the ground surface.

Each treatment had ten replicates. The plant material collected from these plots was dried at 100 ^{o}C for 48 hours in an electric oven and then weighed on a mettler balance.

Disappearance of dead shoot material

The instantaneous rate of disappearance of dead shoot material (r) was calculated by the formula:

$$r \text{ (g/g/day)} = \frac{\text{Log}_e (W_o / W_1)}{t}$$

W_o and W_1 are the weights of dead shoot material from plot 1 and plot 2 respectively; and t is length of production period in days.

An estimate of the quantity of dead material (x) disappearing from the undisturbed plot 3 during the production period was made as under :

$$x \text{ (g/plot)} = \frac{(a_o + a_1)\ rt}{2}$$

a_o is the weight of dead shoot material at the start of the experiment from plot 1; and a_1 is the weight of dead shoot material from plot 3 at the end of the study period.

Mortality of live shoot material

The mortality of live shoot material (d) during production period was estimated from the equation :

$$d \text{ (g/plot)} = x + (a_1 - a_o)$$

Yield or shoot biomass

The yield (y) of the shoot material or the shoot biomass was calculated from the change in the standing crop of live shoot material during the production period and the estimate of shoot mortality by the formula :

$$y \text{ (g/plot)} = (b_1 - b_o) + d$$

b_o and b_1 are the weights of live shoot material from plots 1 and 3 respectively.

Root biomass

The yield or the root biomass of the crop under study was also measured to estimate NPP. After removing the live and the dead shoot material from plot 1, the soil was then watered and excavated to a depth of 30 cm. In majority of grasses, the roots hardly exceed beyond 22 cm (Spedding, 1971). The chunk of the soil was washed with water on a sieve. The roots were removed with excessive care and labour by method of floating and screening (Pavlychenko, 1937; and Milner & Hughes, 1968). At the end of the study period, plot 3 was treated in the same way. After oven-drying, increase in root biomass during the production period was calculated by the formula :

$$R \ (g/plot) = R_3 - R_1.$$

R equals yield of root material during production period: and R_1 and R_3 are weights of root material from plots 1 and 3 respectively.

TABLE 1. Climatic data of the study period. (average of 4 weeks) (Courtesy Pakistan Forest Institute, Peshawar).

Soil Temperature (°C) at 9 A. M.		Air Temperature (°C)		Sunshine Duration		Relative Humidity	Precipitation mm
At surface	5 cm below surface	Max	Min	hrs	min	%	
21.2	17.2	26.6	15.5	6	50	60	94.2

Determination of caloric values

The dried material was ground in a hand-operated grinding machine, reduced to powder, formed into pellets and stored for several days in a desicator over a drying agent. The caloric content was measured with adiabatic oxygen bomb calorimeter, model Parr 1200 (Parr Instrument Co., 1960). The caloric values were calculated by the following formula :

$$Hg = \frac{t(W) - L - V}{M} \times \frac{1}{1000}$$

Hg is the gross heat of combustion in kilocalories/ g; W is energy or water equivalent of calorimeter in calories/°F; t is rise in temperature in °F; M equals to weight of sample in grams; L is fuse wire corrections and equals to the length of fuse wire in cm x 2.3 calories; and V is acid correction and equals to mls of standard alkali (0.1450 N) used.

Determination of NPP

The NPP was calculated by multiplying yield with its corresponding caloric value.

Climatic data of the study period have also been recorded (Table 1). The study was conducted in Malakandare Farm of the Faculty of Agriculture, University of

Peshawar. The soil of the research area have already been studied by Khattak *et al.* (1973). The period of study stretches over last three weeks of March and the first week of April, 1975. Mexi-Pak variety of wheat (*Triticum aestivum* L.) and local pink-stemmed variety of barley (*Hordeum vulgare* L.) were used in this study.

Results and Discussion

Disappearance rate of dead organic material

The dead organic material of crop undergoes decomposition and mineralization in the soil and plays an important role in the ecosystem. A considerable recycling of minerals in the ecosystem occurs in the life time of the crop. The faster rate of disappearance of dead organic material of wheat suggests that the nutrients locked up in this plant are returned to the ecosystem much earlier than those in barley (Table 2). In barley they remain tied up for a longer period of time and thus their availability to the growing plants is delayed. The rate of decay of organic material not only depends on its chemical nature but also on the number and types of microorganisms present in the soil. In each gram of dry weight of dead organic material, the microorganisms are one hundred times more than the corresponding weight of soil with no organic material (Russell & Russell, 1961; Sukhachev & Dylis, 1964). The characteristics of dead organic material vary constantly during the growth period because of microbiological processes and the periodic addition of fresh organic material to the successive stages of its decomposition (Sukhachev & Dylis, 1964). Similarly, the number and the species composition of microorganisms in the soil fluctuate considerably during the growth period which results in an uneven rhythm of decay of dead organic material. Thus, the rate of liberation of mineral elements follows an irregular pattern (Stepanov, 1929, 1940; Shumakov, 1941; Boswell, 1956).

TABLE 2. Rate of disappearance of dead organic material

	(r). g/g/ day.
Wheat	0.08390
Barley	0.07277

Significant at 5 % level based on paired t test.

Yield (shoot biomass) during study period

Simple measurement of green standing crop at the beginning and at the end of the study period is not sufficient for estimating the yield (Wiegert & Evans, 1964). The process of growth and mortality go on simultaneously. Leaves die and remain attached to the parent plant for sometime and finally they are lost to the soil. The total increase in the biomass of the standing crop, thesefore, will be equal to the sum of the increase in live material, dead leaves still attached to the plants and the dead leaves lost to the soil during the production period. In spite of the fact that the total losses due to mortality are higher in wheat than in barley, the change in the standing crop of live material during the study period is higher in the former than the latter (Table 3.). Total yield of the aboveground shoot in wheat is higher than barley but the yield of the inflorescence of barley is greater than that of wheat. The rate of increase of biomass in wheat is 8 times and in barley it is 6 times higher than that of swale studied by Wiegert & Evans (1964). This discrepancy is mainly because of the difference of the two areas in terms of growth form and vegetation components; yet another reason may be the length of the study period over which the calculations are based. Wiegert & Evans (1964) calculated the total increase of shoot biomass on yearly basis; whereas in this study it is determined on the basis of a study period stretched over 30 days during which the rate of growth had been at its maximum.

TABLE 3. Calculation of yield.

Crop	$b_1 - b_o$	a_o a_1	x	d	y	z
Wheat	18.6932	0.7940	3.8535	4.6475	29.5650	6.2243
Barley	12.3369	0.1373	0.4421	0.5794	20.7932	7.8769

(All calculations are at g/plot/study period basis)

Standing crop of live shoot material, $b_1 - b_o$; standing crop of dead shoot material, $a_o - a_1$; decomposed dead material during the production period, x; total mortality of shoot material, d; yield of aboveground shoots (inflorescence included), y; and yield of inflorescence only, z.

Standing crop of root

It is common practice that root biomass is not included in the estimation of NPP because of the difficulty in excavating the roots. But there seems no justification of doing so. In this study extra care has been taken to excavate the roots and root biomass has also been taken into account while calculating NPP of wheat and barley. The mortality of roots during the study period was presumed to be negligible. At present, there is no way of determining the mortality in roots analogous to that for shoots (Wiegert & Evans, 1964). Moreover the life span of roots for grasses varies from 61 days to 2 years (Spedding, 1971): and since the study period was kept at 30 days, it was believed that the results would not be much affected if the mortality of the roots was not taken into account.

The increase in the root biomass of wheat and barley is almost the same probably because of the similar growth habits of these two species (Table 4).

TABLE 4. Increase in standing crop of root (R) during the production period.

Crop	g/plot/30 days	g/ m^2/30 days
Wheat	0.7690	19.2250
Barley	0.7160	17.9000

Significant at 5 % level based on paired t test.

The valuse of root biomass reported in this work are very low in comparison with those calculated by Wiegert & Evans (1964) for the swales. The difference may be attributed to a number of factors of which the most important one seems to be related to the short study period.

TABLE 5. Caloric values (kcal/g) plant parts.

Crop	Above ground shoot		inflorescence alone	Root
	with inflorescence	without inflorescence		
Wheat	3.4028*	4.1824*	2.6232*	3.9310 N.S.
Barley	4.0906*	3.8778*	4.3035*	3.9350 N.S.

* Significant at 5 % level based on paired t test.

N.S. = Not significant.

Caloric values

The caloric value for aboveground shoot in barley was found to be higher than that of the similar part in wheat and it is largely because of higher caloric value for inflorescence in barley than in wheat (Table 5). No marked difference in the caloric values for roots was noticed in these crops. Wiegert & Evans (1964) determined the caloric values for the aboveground shoots in grasses and forbs separately and that for the roots combined. These values were found to be slightly higher than those reported in this work. The chief cause of this discrepancy is that Wiegert & Evans (1964) were dealing with the mixed type of vegetation in which the plant material contributed by different species yielded different caloric values; whereas, in this investigation pure stands of wheat and barley were analysed.

TABLE 6. Net primary productivity (NPP).
(kcal /m^2/day)

Crop	Aboveground shoot without inflorescence	Aboveground shoot with inflorescence	Inflorescence only	Root	Whole plant
Wheat	81.35	94.95	13.60	2.52	97.47
Barley	41.74	69.99	28.25	2.35	72.33

Significant at 5 % level based on t test.

Net primary productivity (NPP)

NPP of the roots of these crops was found to be very low in comparision with shoots (Table 6). It is highly advantageous because the roots of wheat and barley are neither used by man nor by his domestic animals. No marked difference was noticed between the yields of the inflorescence of barley and wheat (Table 3); but NPP of the former is twice that of the latter (Table 6). This difference is primarily because of the higher caloric value of the grain of barley (Lange, 1956). However, NPP of the aboveground shoot of wheat (excluding inflorescence) is almost two times greater than that of barley in the same condition. Although it is not conventional, yet it is suggested that whenever the desired product is grain, the cultivation of barley should be preferred to that of wheat; whereas for fodder, the cultivation of wheat should be encouraged and the crop should be harvested before the appearance of inflorescence. On the whole, NPP of wheat is significantly higher than that of barley (TAble 6).

References

Ashby, M. 1969. An Introduction to Plant Ecology. 2nd ed., Macmillan St. Martin's Press, New York.

Boswell, I.G. 1956. Decay of plant litter. Nature, 178.

Khattak, J.K., S.A. Babar and A. Rashid. 1973. Effect of nitrogen and phosphorus on protein and oil content of two sunflower varieties. Pak. J. Sci. Land. Res., 16: 123-125.

Lange, N.A. 1956. Handbook of chemistry. 9th ed., Handbook Publishers Inc., Sandusky, Ohio.

Milner, C. and E.R. Hughes. 1968. Methods for the measurement of the primary production of grassland. IBP Handbook No. 6; Blackwell Scientific publications, Oxford & Edinburgh.

Odum, E. P. 1960. Organic production and turnover in old field succession. Ecology, 41: 34-49.

Odum, H.T. 1971. Environment, power and society. John Wiley & Sons Inc., New York.

Parr Instrument Company. 1960. Oxygen bomb calorimeter and combustion methods. Technical Manual No. 130; Moline, Illinois.

Pavlychenko, T.K. 1937. Quantitative study of entire root system of weed and crop plants under field conditions. Ecology. 18 : 62.

Russell, E.W. and F.J. Russell. 1961. Soil conditions and plant growth. Longmans. Green & Co. Ltd., London.

Shumakov, V.S. 1941. Dynamics of decomposition of plant remains and interaction of their decomposition products with forest soil. Trudy uses. nauchno-issled. Inst. les. Khoz; 24.

Spedding. C.R.W. 1971. Grassland ecology. Clarendon Press, Oxford.

Stepanov, N.N. 1929. Chemical properties of forest litter as a basic factor in natural regeneration. Trudy les. Opyt. Delu.

Stepanov, N.N. 1940. Process of mineralization of shed leaves and needles of trees and shrubs. Pochvovedenie.

Sukhachev. V. and N. Dylis. 1964. Fundamentals of forest biogeocoenology (Transl. from Russian). R. Cunningham & Sons Ltd.. Edinburgh & London.

Wiegert, R.G. and F.C. Evans. 1964. Primary production and the disappearance of dead vegetation on an old field in southeastern Michigan. Ecology, 45: 49-63.