1973

The Role of Algae in Crust Formation and Nitrogen Cycling in Desert Soils

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1972 PROGRESS REPORT

THE ROLE OF ALGAE IN CRUST FORMATION AND NITROGEN CYCLING IN DESERT SOILS

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Utah State University

Research Memorandum, RM 73-40

MAY 1973

Report Volume 3

Page 2.3.4.6.

ABSTRACT

Algal-lichen crusts are shown to constitute a significant biomass component of the Curlew Valley region of northern Utah. Such crusts, even during minimum periods of productivity, represent up to 239 kg/ha biomass and cover approximately 70% of the desert soil surface. These crusts seem to contribute significantly to the total carbon fixation of the area and are capable of very rapid initiation of growth and carbon fixation when provided with moisture, even following an extended period of desiccation. Lag time for resumption of measurable photosynthetic activity is shown to be less than 30 minutes and may be as low as five minutes. Growth of the algal component of these descicated soil crusts, following rewetting, is so rapid as to produce a doubling of biomass within a 24 hr period under conditions of continuous illumination and optimum temperature.

Revegetation of areas whose soil crust flora has been killed appears to be very rapid even during relatively dry periods of the year. Monitoring of manipulated and control areas *in situ* indicated a rapid response to moisture in regard to growth and carbon fixation of algal crusts.

In areas disturbed by cultivation the reestablishment of the algal-lichen crust is slow although the algal component, in free-living condition, rapidly establishes itself preceding the appearance of any recognizable lichen component.

The distribution and quantity of algal crust appears to be totally independent of vascular plant distribution.

INTRODUCTION

Soil crusts are prominent features in many desert areas, especially those where distribution of higher plants is sparse. In the majority of cases, soil crusts are composed of a tightly-packed community of microorganisms which are physically held together by the proliferating trichomes of blue-green algae and fungal hyphae. Algae are present wherever moisture is available during a part of their life cycle. Light, temperature, nutrients, pH, and other physical, physiochemical, and biotic factors are generally suitable for growth throughout the year if adequate moisture is present.

Soil algae may form extensive photosynthesizing areas in hot, cold and polar desert areas or in other extreme environments with respect to salinity or pH where no other chlorophyllous plants are evident. In arid and semi-arid areas, their importance has been noted in soil stabilization as well as protection against erosion, restriction of water penetration,evaporation, reclamation of salty land, and as primary colonizers of denuded, eroded or barren ground. Their resistance to desiccation and prolonged drought, and to extreme soil temperatures including diurnal freeze-thaw cycles, plays an important role. They are noteworthy forerunners to subsequent soil-surface establishment of mosses and seed-plants (Booth, 1941; Lynn and Brock, 1969).

A recent review has indicated that desert soil crusts and associated diaphanous materials provide ecological niches where environmental factors are much less restrictive than in the surrounding soil, and the algal abundance is increased (Cameron and Blank, 1966). The abundance and diversity of populations built up in these microniches and their algal components are an important source of organic matter (e.g., Fletcher and Martin, 1948; Lund, 1962; Shields and Durrell, 1964). It has been found that some soil crusts and some of the algal isolates from arid regions have the ability to fix atmospheric nitrogen (Cameron and Fuller, 1960; Mayland et al., 1966).

Since the investigation is primarily concerned with the algae of the area and since algae constitute a significant portion of the biomass of the lichen association, both free-living algae and lichen masses were recorded as cryptogamic crusts. This was required due to the virtual impossibility of effectively, quantitatively separating the free-living algal material from the lichen association and higher plant debris. In addition, the technique of estimating algal biomass is dependent on chlorophyll per unit surface area and does not distinguish between chlorophyll of algal-fungal associations and free-living algae.

OBJECTIVES

Objectives for the 1972 study are those appearing in the 1972 interim report of the Coordinator for Microbial Process Studies, Dr. Eugene Staffeldt. Those objectives specifically assigned to the current study are indicated below:

1. Determination of biomass of algal crusts.
2. Evaluation of the contribution of algal crusts to the nitrogen content of desert soils.
3. Determination of the percent of soil coverage by algae and algal crusts in relation to types of higher vegetation present.

Objectives 1 and 3 have either been fully accomplished or are currently in a state of on-going research. Objective 2 is currently being pursued but fulfillment has been hampered by technical difficulties. These are currently being overcome and data will be forthcoming during the next investigative period. Samples to determine the variation of soil-nitrogen content in response to algal activity have been collected but are currently pending laboratory analysis. Work will continue in all above areas to ascertain relative seasonal activities of the algal crusts with regard to the listed objectives as suggested by the project Coordinator.

Other objectives being pursued, and to some extent accomplished, during the 1972 research period include the following:

4. Establishment of recovery rates of algal crusts when surface organisms are killed *in situ*.
5. Establishment of the effect of soil moisture on the growth and decomposition of algal crusts.
6. Establishment of the time period required between rainfall events and resumption of photosynthetic (carbon fixing) activity by the algae of desert soils.
7. Establishment of the time period required between a rainfall event and resumption of growth by algal crusts.
8. Establishment of the relationship between soil moisture and algal productivity, carbon fixation and nitrogen fixation.
9. Determination of the contribution by the algal crusts to the carbon and nitrogen content of desert soils via leaching of these crusts during high moisture periods.
10. Determination of the parameters (pH, temperature, salinity, and nutrient availability) governing growth, carbon fixation and nitrogen fixation of the algal crusts.

Data are presented in the following report indicating progress in the above-mentioned categories. Objectives four through eight have yielded significant data at the time of report submission, while work dealing with objectives nine and ten has only recently been initiated.

METHODS

Sampling procedures

Samples were removed from the investigative sites for subsequent laboratory experimentation or evaluation. Such samples were taken from the interspace areas between vascular vegetation. When experimentation or evaluation was in regard to quantification of values on an area basis, samples were harvested by means of a stainless steel cork borer of known diameter and the surface area of the sample calculated. All data gathered were from samples of the upper 1 cm of soil surface unless otherwise indicated.

Selection of investigative sites

These sites were selected to emphasize those areas exhibiting the most common dominant vascular vegetation of the region. One exception to this was the selection of a site characterized by crested wheatgrass, a commonly introduced forage plant of cold desert winter ranges. The locations of the intensive study sites are illustrated in Figure 1. Four investigative sites were established in southern Curlew Valley on the basis of vascular vegetation types present (two sagebrush, one grease wood and one crested wheatgrass site).

Determination of biomass

Samples of known algal surface area were homogenized in 90% acetone and extracted in the dark for 24 hr. Following extraction, the supernatant was cleared of debris by centrifugation or by filtration through glass-fiber filters. The supernatant was then decanted to a spectrophotometer tube and read at 665 mμ before and after acidifying with one drop of conc. HCl. The 750 mμ readings were subtracted from the 665 mμ readings in both pre- and post-acidified solutions to account for turbidity. In every case in which samples were filtered the 750 mμ readings were found to be stable before and after acidification. This portion of the technique will be omitted in the future. The corrected 665 mμ readings were used to calculate the concentration of chlorophyll in the sample according to the following equation:

$$C = \frac{26.73\ (665_b - 750_b)\ X\ (665_a - 750_a)\ x\ V}{A}$$

Where 665_a and 665_b and 750_a and 750_b = O.D. of the acetone extract at the indicated wave lengths before and after acidification; V = volume in liters of extracting solution; and A = the area in m^2 represented by the sample. C = chlorophyll *a* in mg/m^2.

The above method is discussed in more detail in the 1971 progress report (Lynn, 1972). The method itself is a modification of that presented in Standard Methods for the Examination of Water and Wastewater, 13th edition, 1971. All such extractions were performed in the laboratory whether on laboratory-grown or field-harvested crusts.

Previous work, also described in the 1971 progress report, indicated that the relationship between algal biomass and chlorophyll *a* content is expressed by the following equation:

$$B = \frac{84.2\ X\ (665_b - 665_a)\ \cdot\ V}{A}$$

Where B = algal biomass in kg/ha. The O.D., V and A were previously described.

Seasonal changes of algal crust biomass were monitored on a weekly or near-weekly basis along with rainfall and soil moisture. Samples to provide data regarding carbon and nitrogen variation were collected concurrently and a number of the carbon samples have been analyzed at this time. Other samples are awaiting analysis.

Since rates of productivity and decomposition were assumed to be of approximately equal magnitude in undisturbed cold desert communities, it was deemed necessary to manipulate selected study areas in such a manner as to provide an opportunity to observe these phenomena in other than a steady state system.

Experimental plots were selected for manipulation which were approximately 9 m^2 in area. Once selected, these plots were gassed with methyl bromide (Dowfume MC-2) to kill all vascular vegetation and to radically reduce the numbers of viable algae, bacteria and fungi in the upper 5 cm of soil. The gassing procedure involved trenching the plot perimeter, covering with plastic sheeting and subsequent application of the gas from aerosol cans. The plastic coverings were left in place for 8 to 10 hr to insure penetration of the gas to subsurface levels (Figure 2). Prior to application of the gas, samples for microbial analysis were removed, and a second set sampled following the gassing process. These samples served as controls to determine numbers of microorganisms present immediately prior to and immediately following the gas application. An additional set of samples from an area in the immediate vicinity of the experimental plots was taken to insure that the experimental plots themselves were truly representative of the microbial populations of the selected sites. Samples from the untreated areas were designated as controls and appear in Table 2. Such samples were used to provide a base-line value to determine recovery rate and establishment of normal standing crop levels of both bacterial and algal populations.

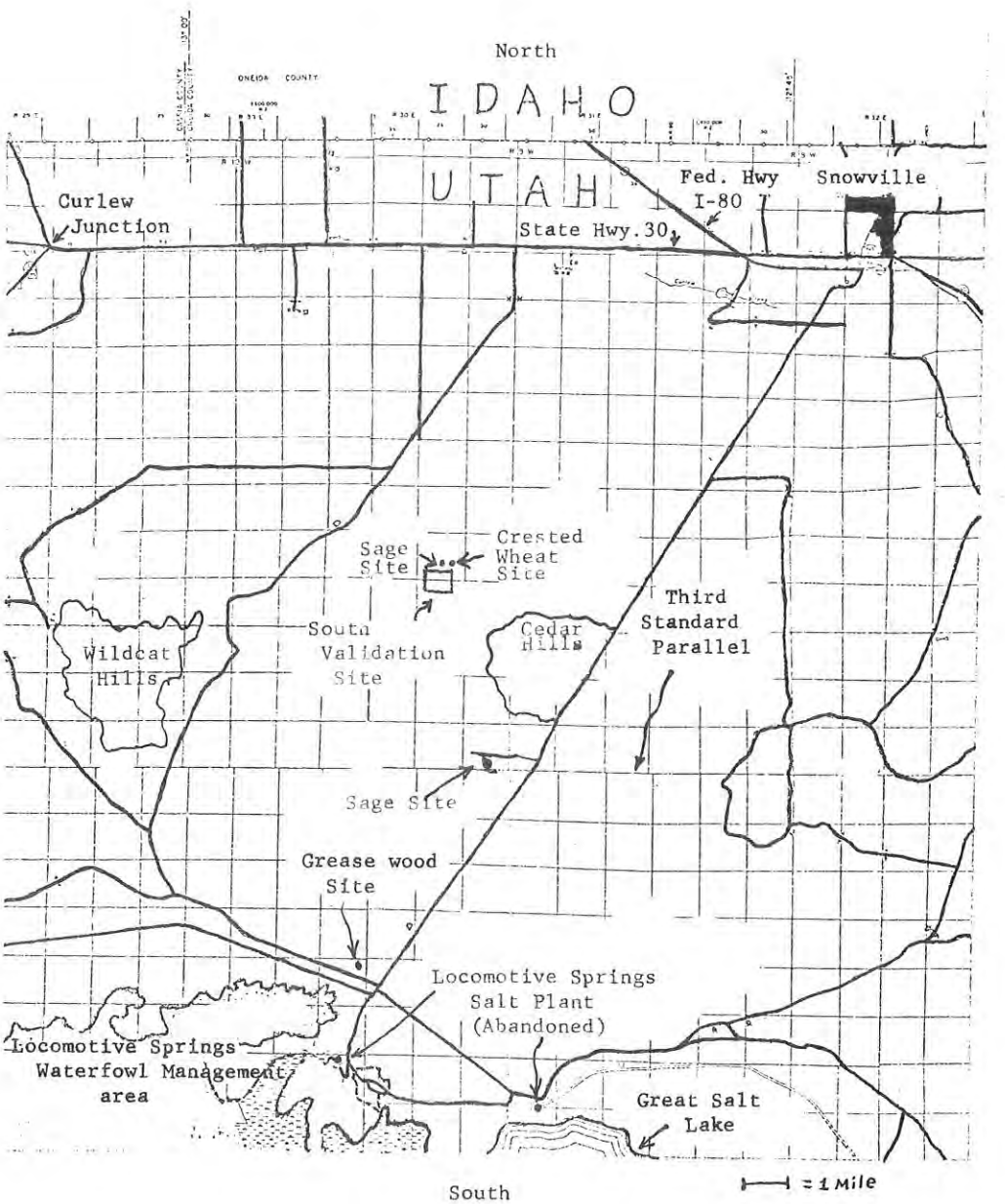

Figure 1. Approximate locations of intensive study sites of the southern Curlew Valley area.

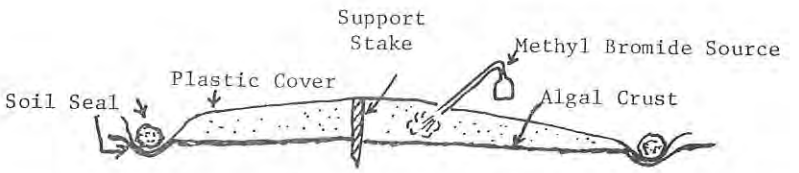

Figure 2. Illustration of methyl bromide gassing procedure.

Samples were analyzed for bacterial and fungal populations by plating on appropriate media. Algal numbers were established using dilution tubes prepared by addition of known weights of pre- and post-treatment soils. All determinations of algal numbers were made using a soil extract medium prepared by extracting one part soil from the investigative site with five parts glass-distilled water at 5 C for 48 hr and subsequently clearing of any microorganisms and particulate matter by filtration through a type HA 0.45 μ Millipore membrane filter. Dilutions were carried out on a ten-fold basis and the greatest dilution which yielded algal material was used to establish the number of algae present in the soil sample. All samples were taken from the upper 1 cm of surface crust.

Fixation of labeled carbon dioxide by algal crusts

Algal crusts were incubated in a vessel containing labeled carbon dioxide for selected time intervals. The reaction was halted by killing the algal material. Algal material and attendant soil were then dried and homogenized and subsamples of the homogenate suspended in counting cocktail and counted on a liquid scintillation counter. Results are reported in terms of counts/min/mg of chlorophyll. Determination of chlorophyll content is as previously described. A detailed presentation of the experimental procedure is provided in conjunction with the experimental design. All such experiments were conducted in the laboratory.

Determination of carbon content of soil-algal crusts

Algal crust samples collected as previously described were homogenized and assayed for carbon content by the Sawyer and McCarty modification of the method of Walkley (Sawyer and McCarty, 1967; Walkley, 1935).

Determination of surface cover by algal crusts

Line transects of 100 m were used to determine surface cover. Samples and/or observations were taken in the field as well as in the laboratory. Observation and sample intervals along the transect were at 1 m intervals.

Soil moisture determinations

Determination of soil moisture was conducted in the field at each of the sampling sites on a weekly basis during the summer months and at somewhat greater intervals during the late fall period. Determination was by means of a self-contained unit measuring the pressure of gas generated by the interaction of moisture in soil samples of known weight and a known weight of calcium carbide. Pressure readings were directly converted to wt % moisture readings by the unit at the time of sampling.

Precipitation

Precipitation data were supplied by Drs. Porcella and Fletcher, whose investigative sites were located within a few meters of those of the author.

Identification of algal genera

Identification of algal material was by microscopic examination of samples at the Utah State University Phycology Laboratory.

Resumption of growth by dry algal crusts

Resumption of growth of algal crusts was determined by placing crust material, which had been air-dried in the laboratory at 28 ± 5 C for a period of one year, in petri dishes lined with filter paper and rewetting with glass-distilled water (Figure 3).

Samples were removed at selected time intervals on an area basis by means of a stainless steel corkborer. Biomass was determined as previously described.

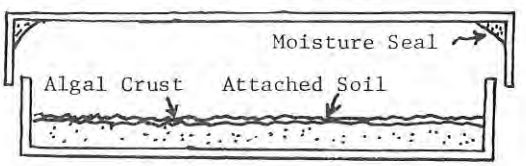

Figure 3. Incubation system used to measure resumption of growth of algal crusts following rewetting.

Resumption of photosynthetic activity of rewet algal crusts

Algal crust material was placed in a small (5 cm diameter), open, plastic petri dish which was in turn housed in a larger glass petri dish containing 0.1N HCl. The larger dish was covered with a suitable lid which had been ringed with silicone sealing compound to provide a gas-tight seal. Just prior to sealing of the larger dish the experiment was initiated by moistening the crust with glass-distilled water and the addition of 1 ml of (2 mc/ml) $NaH^{14}CO_3$ to the external acid solution to generate $^{14}CO_2$ (Figure 4). Lag time between addition of label and sealing of the vessel was less than two seconds.

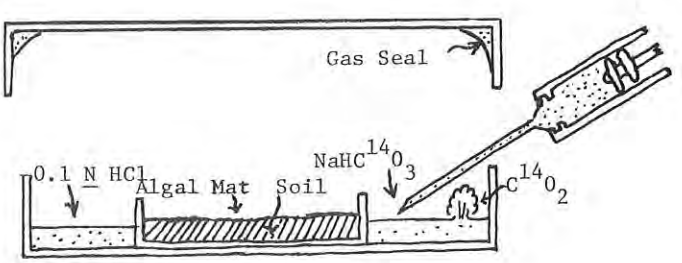

Figure 4. Incubation system used to measure photosynthetic activity of algal crusts following rewetting.

At the end of each incubation period the samples were killed by addition of 40% formalin to stop isotope incorporation and allowed to air-dry at 37 C to constant weight, usually about 24 hr. The material was then homogenized using a mortar and pestle. One g of the soil-algal homogenate was assayed for chlorophyll and duplicate 1 g sub-samples suspended in counting cocktail (15 ml Aquasol: 5 ml H_2O) and counted on a liquid scintillation counter for 10,000 counts or 10 min.

RESULTS

Estimation of algal cover and biomass *in situ*

One of the major objectives of the 1972 project was to establish the extent to which the surface soil of the Curlew Valley area is covered by algal soil crusts, and to determine the standing crop of these organisms in terms of kg/ha.

The most extensive of the surveys was conducted at the southern validation site. Using vascular vegetation maps prepared by Karl E. Holte of Idaho State University (Holte and Adamson, 1972) as a guide, the sites were surveyed by means of multiple 100 m line transects. Observations were made and samples removed at 1 m intervals along each transect. Presence or absence of visible algal crust was recorded in the field and samples were returned to the laboratory for microscopic examination and determination of biomass.

Figures 5 and 6 illustrate the location of the transects within the validation site and Table 1 presents the information collected.

Analysis of the data indicates that no correlation exists between the type of vascular vegetation present and the extent or character of the cryptogamic crust. However, the cultivated crested wheatgrass areas surveyed yielded a more homogeneous cover with regard to algal flora than did the sagebrush area which was rich in both algal and lichen cryptogams. Algal biomass in the crested wheatgrass areas was also much less variable than in the sage areas examined.

Visual examination in the field indicated an average of 71% algal cover for the sage area and 80% for the crested wheatgrass area. Biomass values for the sage area ranged from 95.7 kg/ha to 239 kg/ha and averaged 159 kg/ha. It should be pointed out that these data were collected in July, a period at which algal biomass values would be expected to approach their yearly minimum due to the very dry conditions which prevailed. A follow-up

analysis of standing crop of soil algae will be conducted in the winter and spring of 1973, periods during which it would be assumed that algal standing crop would be near maximum for these investigative areas.

Growth of algal crusts *in situ*

Studies of the growth rates of algal crusts were initiated in the early spring of 1972.

The percentage of kill for bacteria and fungi appeared to be in excess of 93% in all cases, with the majority of treatments resulting in kills of 98% or greater. Rate of kill for the algal component of the system was quite successful, yielding reductions of algal numbers in excess of 99% in all cases (Table 2).

In conjunction with this experiment the percent algal cover and algal biomass at each of the experimental sites were also determined and appear in Table 1.

Following treatment the sites were fenced and both the killed plot and an adjacent control plot were monitored on a weekly or near-weekly basis for algal biomass, soil moisture, carbon and nitrogen content. Soil moisture was determined for depths of 0-1, 2-3, and 4-5 cm. All other samples were removed from the upper 1 cm of soil on an area basis. Data presented for algal biomass and moisture content is current; however, a back-log of carbon and nitrogen samples exists at the time of submission of this report. Currently available data for each of the investigative sites are presented in Figures 7, 8, 9, and 10 (DSCODE A3ULA04).

Algal biomass appears to be at a minimum in Curlew Valley during the period extending from mid-July to mid-September. The onset of relatively regular and significant precipitation in late September and early October resulted in a distinct increase in algal biomass.

Data available at this time indicate that the algal biomass correlates with total carbon in the upper 1 cm. Figures 7-10 suggest that moisture content of the soil below 1 cm has little effect on algal production, compared to surface moisture. Algal biomass increased rapidly following any significant rainfall event during the period of this study.

Plots treated with methyl bromide showed little variation with respect to untreated control plots. This may be the result of several factors. First, it is possible that the techniques employed are not capable of resolving the variations which exist. This is not, however, thought to be the case since previous application of this method has

been successful. A second explanation is that the chlorophyll content of the killed algae, upon which our estimation of biomass hinges, may not have had sufficient time to degrade, perhaps due to lack of moisture required to support the activities of decomposers which are essential to the breakdown of the material. If this is the case it is expected that as moisture becomes more available and temperature rises with the onset of the spring of 1973, a divergence in algal biomass will be observed with regard to the treated and control plots. It should be mentioned that in recent field observations of control and treated plots following a rainfall event it was very apparent, even to several untrained observers in the party, that the untreated control areas quickly developed a bright green appearance while the adjacent treated plots remained a dull gray, characteristic of all plots prior to rewetting.

Initiation of growth by desert algal crusts following rewetting

Considerable controversy has existed among investigators regarding the rapidity with which desert algal soil crusts and lichen flora resume growth, photosynthesis and nitrogen fixation following a rainfall event.

These experiments were conducted to establish the lag time following rewetting and resumption of growth and to establish the lag time between rewetting and the onset of measurable photosynthetic activity.

All values are reported in terms of kg per ha (Figure 11). Pertinent controls were included in the experiments and are indicated in conjunction with the Figures supplied.

It should be pointed out that by using algal-lichen crusts which had been subjected to an extended period of dessication one must consider the values obtained for recovery times to represent minimum recovery rates of the organisms under what might be described as very adverse preconditioning treatment.

Controls which had not been rewet showed no change in biomass whether in light or darkness; however, the rewet control placed in the dark exhibited a decrease in algal biomass over the course of the experiment. This decrease has been attributed to death and decomposition of algal cells by heterotrophic organisms such as bacteria and fungi present in the samples which must be assumed to have resumed activity concurrently with the algal component under study.

Table 1. Transect Results

Zone Number	Vegetation Type	Quadrats Surveyed	Percent Algal Cover	Algal Biomass (Kg/ha)
1*	*Agr cri***	12		
	Atr con	14-15	80	96
	Sit hys	33-34		
2*	*Agr cri*	09		
	Atr con	38-39	80	96
		55-56		
		64-65		
3*		58		
	Agr cri	72	80	97
		77		
		84-85		
4	*Agr cri*	01	80	97
5	*Art tri*			
	Atr con	05-06	82	144
	Chr vis			
	Sit hys			
6	*Art tri*	09-10		
	Atr con	12-13	74	144
	Sit hys	25-26		
7	*Atr con*	24-33	61	192
	Sit hys			
8	*Art tri*			
	Atr con	29-30	73	191
	Chr vis	47-48		
	Sit hys			
9	*Art tri*(dead)	41-51-52	73	96
	Sit hys			
10	*Art tri*	56-66-65	78	169
	Atr con			
11	*Art tri*	57-58		
	Atr con	67-68	78	216
	Chr vis			
12	*Art tri*	59-60	80	167
	Ely cin			
13	*Art tri*(dead)	86-87	41	96
	Hal glo	94-95		
14	*Art tri*	81-91	67	96
	Sit hys			
15	*Sit hys*	91-92	70	239

*Zones 1-3 are located in the Southern Validation Grass Area while zones 4-15 are located in the Southern Validation Sagebrush Area

**Abbreviations used as indicated below:

Agr cri = *Agropyron cristatum*
Art tri = *Artemisia tridentata*
Atr con = *Atriplex confertifolia*
Chr vis = *Chrysothamnus vascidiflorus*
Ely cin = *Elymus cinereus*
Hal glo = *Halogeton glomerata*
Sit hys = *Sitanion hystrix*

Table 2. Effect of methyl bromide treatment on microbial populations

Site	Sage 1	Sage 2	Greasewood	Crested Wheat
	Average Total Number of Bacterial Colonies			
Before	152×10^5	45×10^5	126×10^5	39×10^5
After	171	203×10^3	540	673×10^2
% Kill	99+	93	99+	98
Control	149×10^5	51×10^5	106×10^5	49×10^5
Medium used:	Euglena Agar			
Before	71×10^5	40×10^5	32×10^5	51×10^5
After	329	75×10^2	24×10^2	94×10^3
% Kill	α100	99	99	98
Control	26×10^5	41×10^5	29×10^5	48×10^5
Medium used:	Burk's N-free Agar			
	Average Total Number of Fungal Colonies			
Before	17×10^5	64×10^5	30×10^4	37×10^5
After	86	21×10^2	86×10^1	42×10^2
% Kill	α100	α100	α100	α100
Control	6×10^5	7×10^5	51×10^5	29×10^5
Medium used:	Euglena Agar			
	Average Total Number of Algae Per Gram Soil			
Before	10^5	10^5	10^5	10^5
After	10^2	10^2	10^2	10^2
% Kill	99	99	99	99
Control	10^5	10^5	10^5	10^5
Medium used:	Soil-water extract			

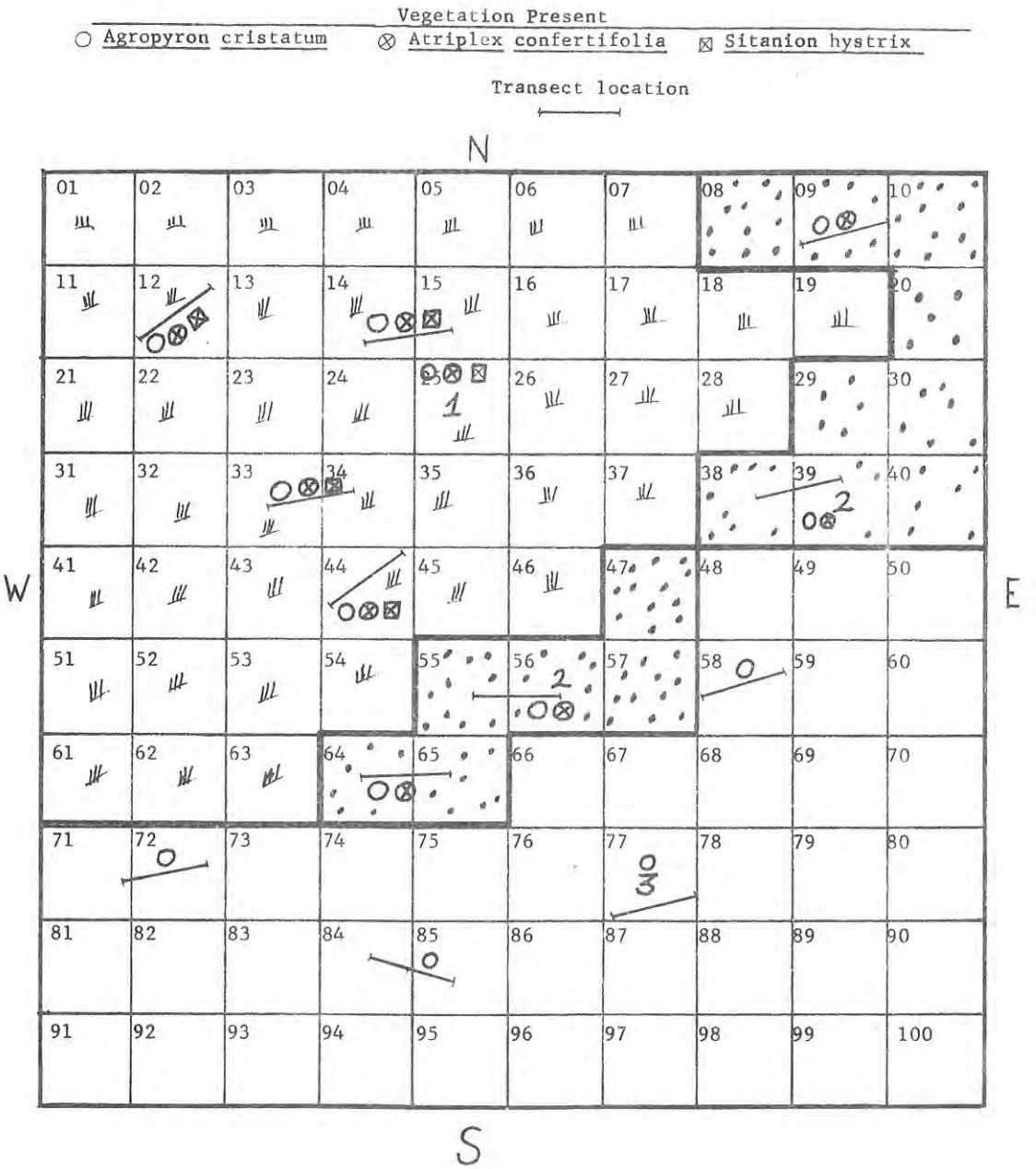

Figure 5. Transect locations in southern grass area.

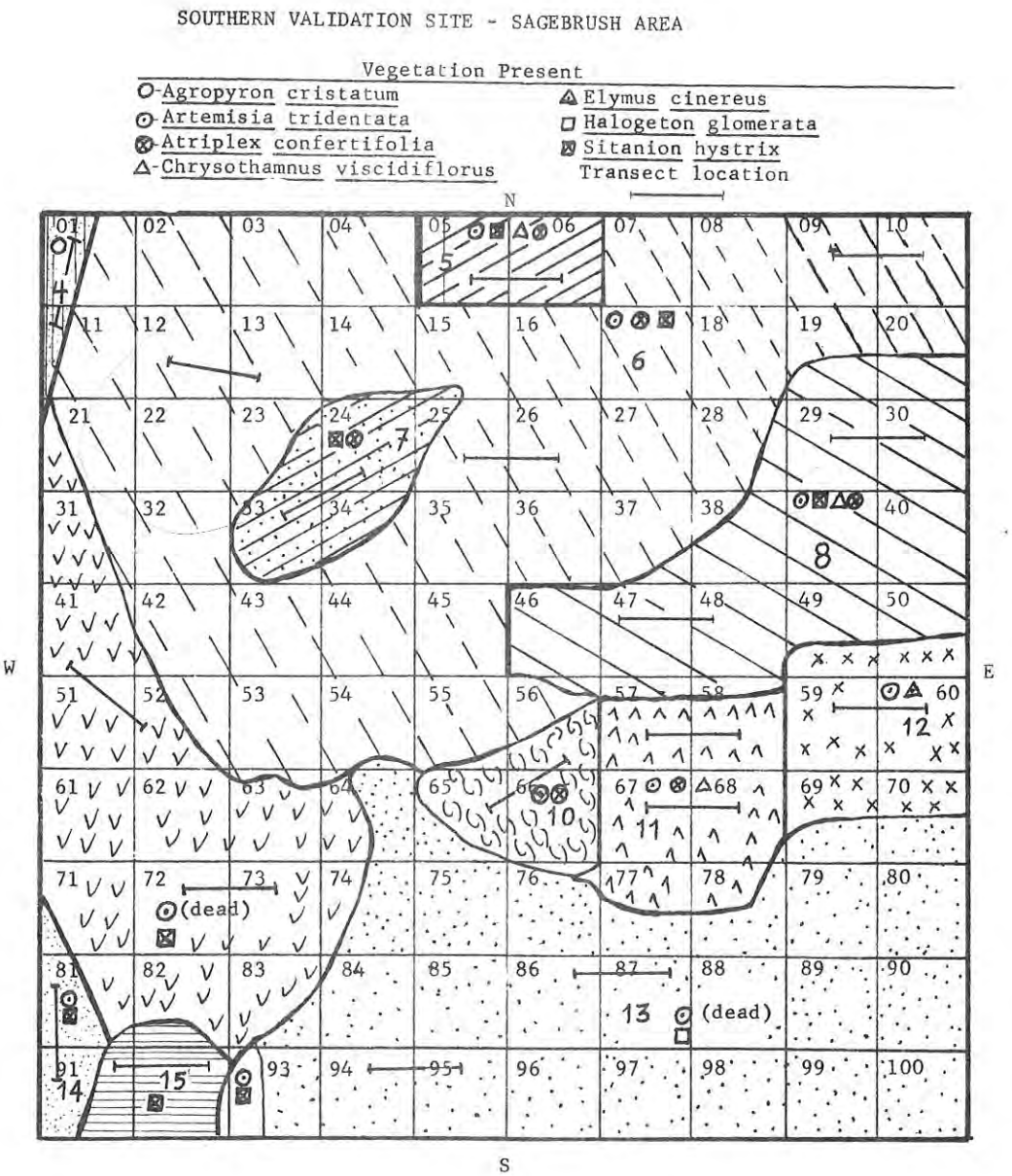

Figure 6. Transect locations in southern sage area.

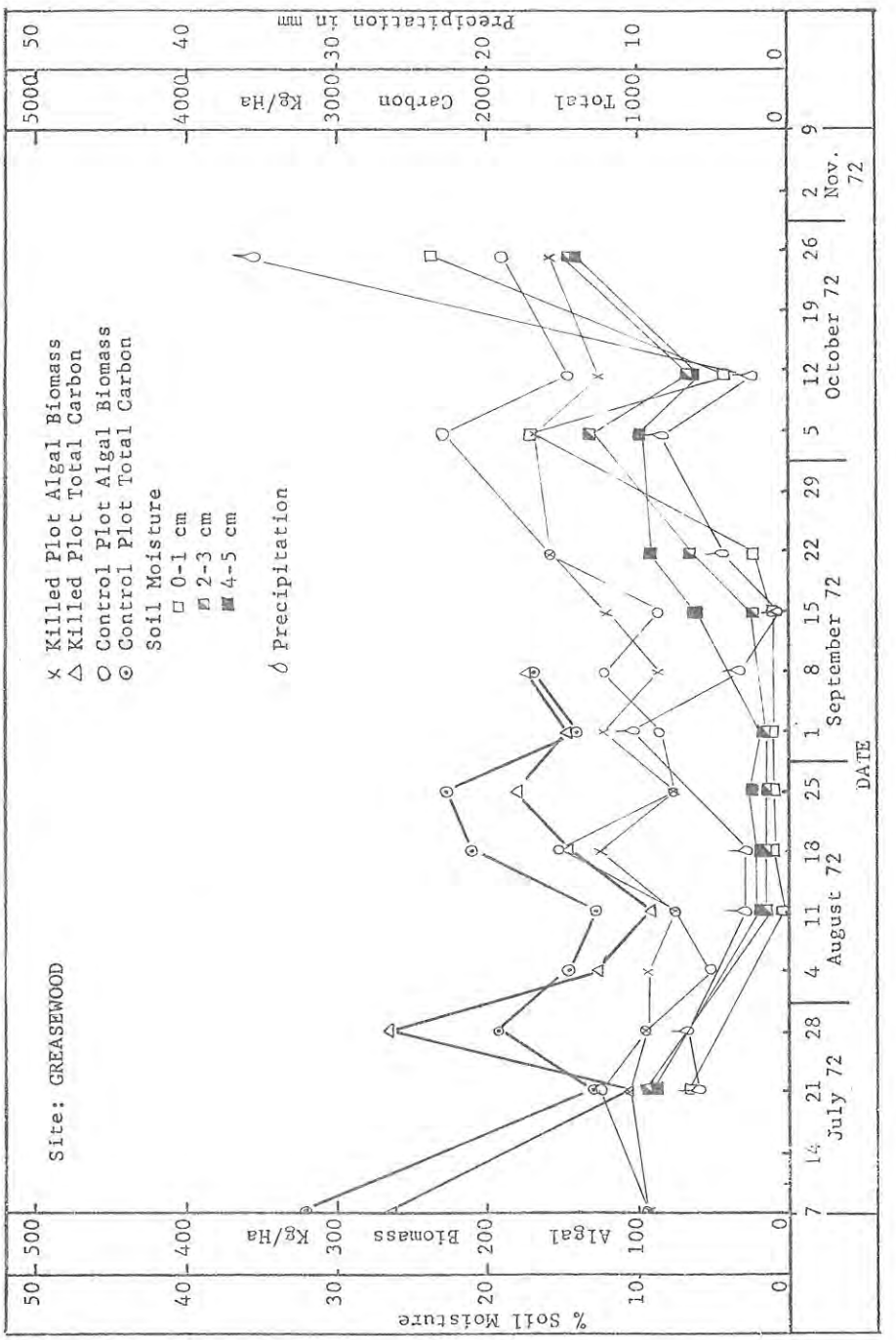

Figure 7. Biological and physical events recorded at the Greasewood intensive study site.

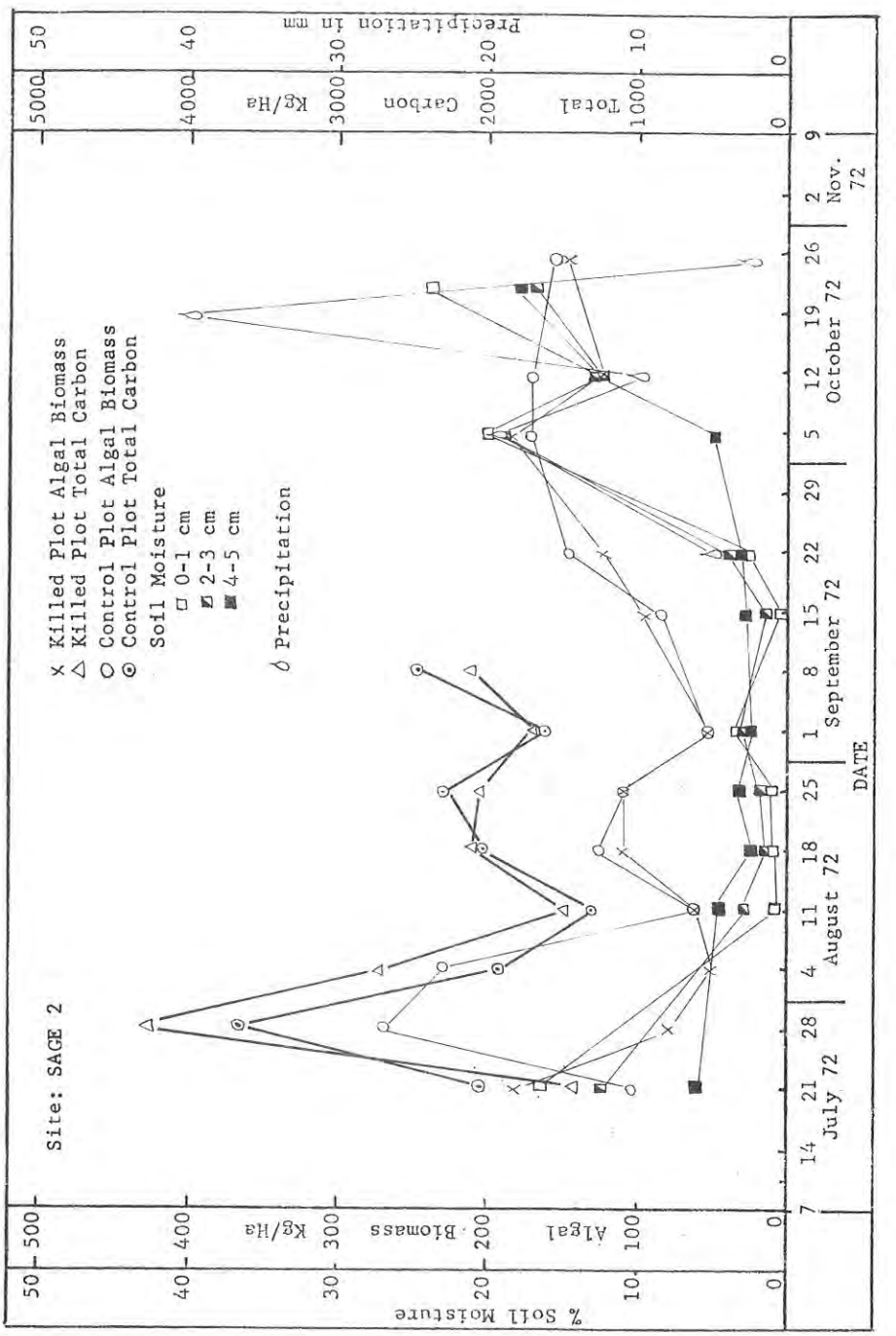

Figure 8. Biological and physical events recorded at the sage 2 intensive study site.

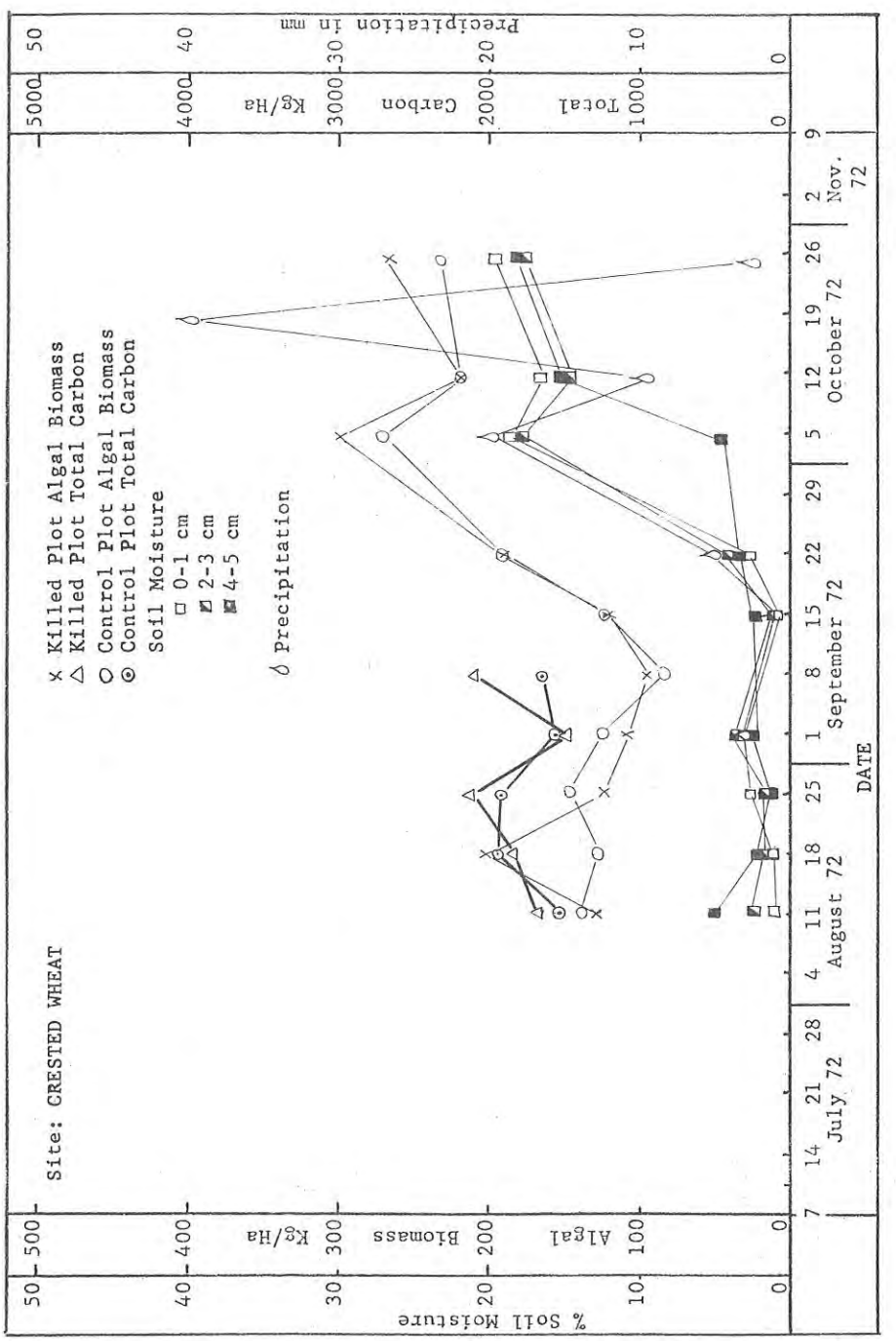

Figure 9. Biological and physical events recorded at the crested wheat study site.

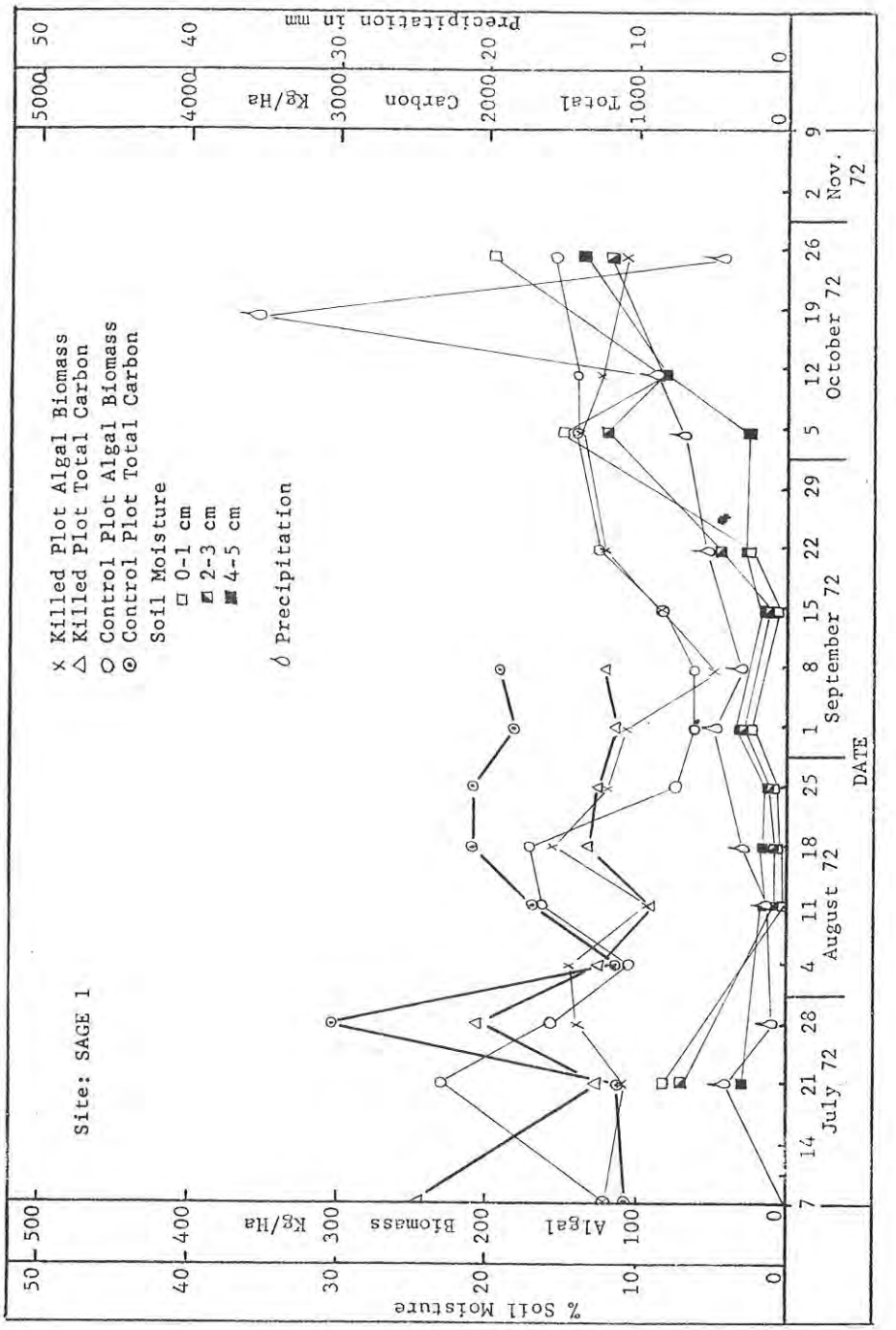

Figure 10. Biological and physical events recorded at the sage 1 intensive study site.

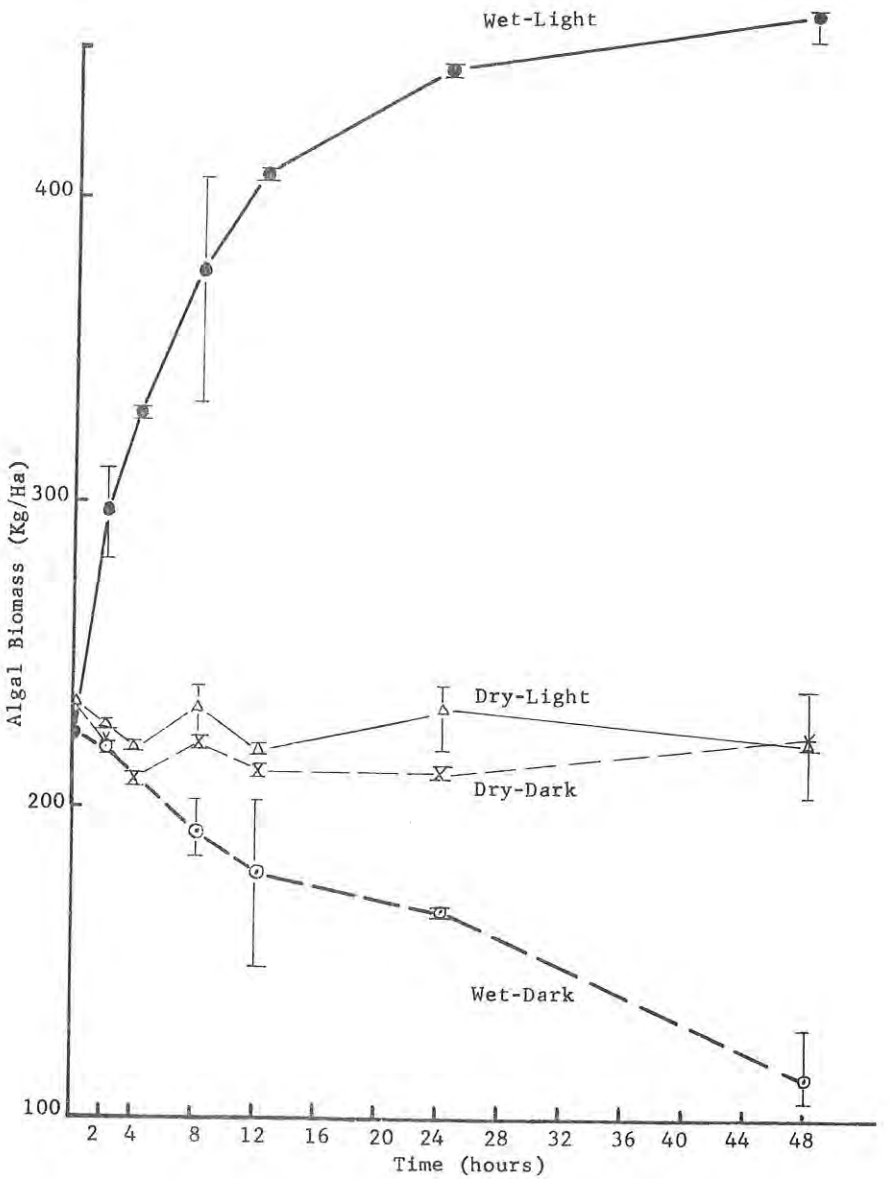

Figure 11. Increase in algal biomass following rewetting of algal crust.

The very rapid initial increase in algal biomass of the system tapered off sharply after 24 hr and virtually plateaued in 48 hr. This truncation of growth is not, however, thought to be the case under field conditions. The decreased growth rate apparently reflects a limitation of available carbon dioxide as a result of the experiment being carried out in a sealed vessel whose gas volume was quite restrictive relative to the rather large amount of algal material present. It is possible that some other, non-defined factor was responsible for early flattening of the curve. Other experiments are currently underway to resolve this question.

It is apparent that the rate of increase in primary producers in the light surpasses their rate of decomposition under conditions of either light or darkness. Under field conditions the time course of the experiments would represent four daylight periods of 12 hr each of four "natural" days, while the dark phase of the experiment would represent four consecutive natural nights.

It is apparent from the data that the increase in biomass of algal crust material occurs rapidly following rewetting and the obvious inference is that photosynthetic "tool-up time" for the algal crust is quite short, only a matter of minutes. This is not however, proven by the experiment.

Initiation of carbon fixation by algal crusts following rewetting

In order to examine the lag time between rewetting and the onset of carbon fixation (photosynthesis) by the algal crust the previously-described experimental design was altered to allow for addition of radioactive carbon dioxide to the system. Results were expressed in counts/min/mg chlorophyll to adjust for variation in algal content from reaction vessel to reaction vessel (Figure 12). See Figure 4 (page 9) for methodology.

No significant photosynthetic activity was observed during the first 10 min following rewetting, counts from light-incubated cultures being equivalent to those of controls. After 30 min of incubation, however, cultures incubated in the light showed marked uptake of label which continued for 24 hr. The initial, rapid uptake was followed by a decline in rate and probably reflects a limitation of label-enriched carbon dioxide in the reaction chamber during the course of the experiment. Nevertheless the experiment clearly indicates that a relatively short tool-up time is required for the initiation of photosynthetic activity and incorporation of carbon by the desert algal crusts examined.

Experiments employing these techniques are currently underway to establish the effect of pH, salinity, and temperature on carbon fixation by algal crusts.

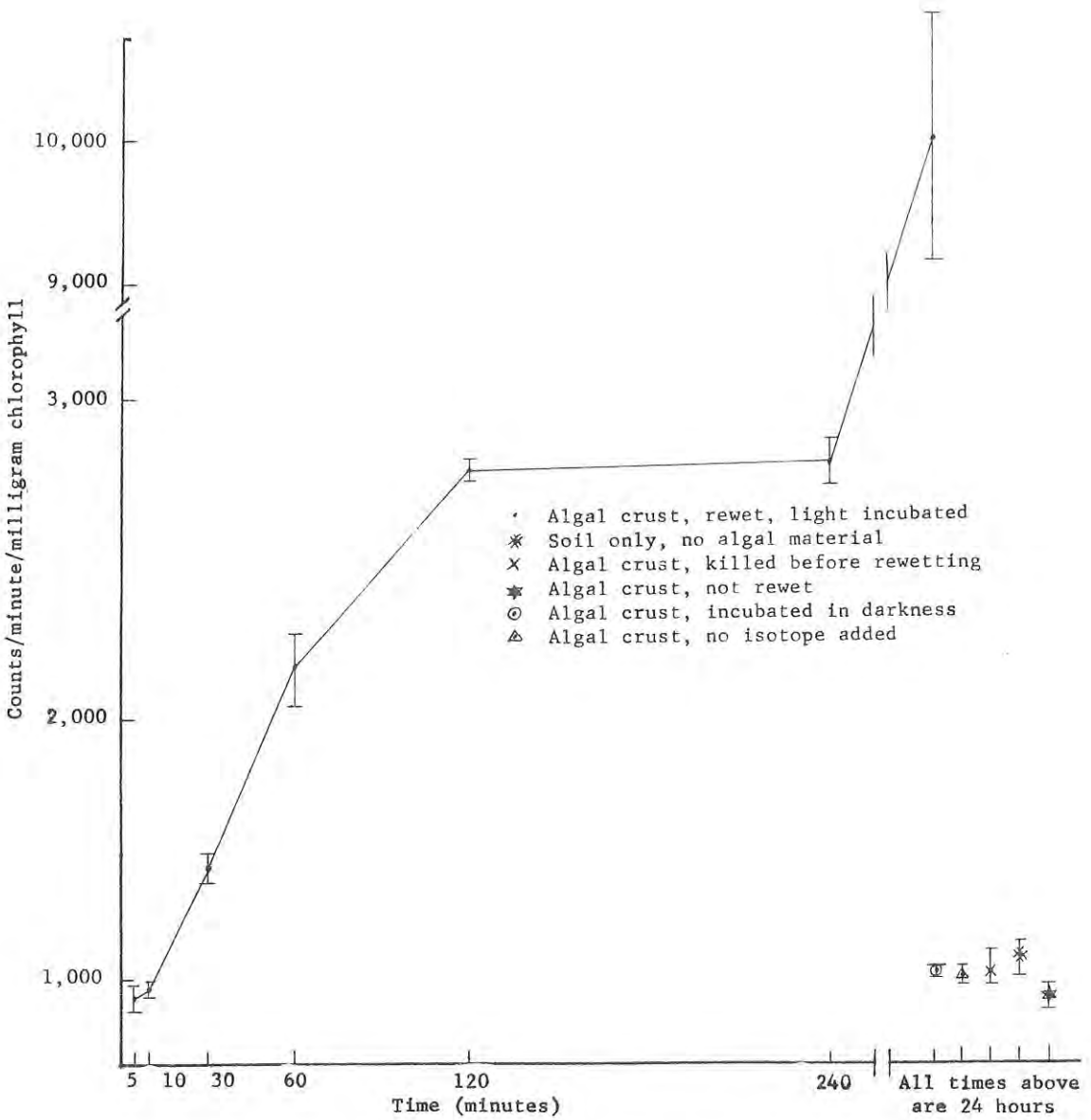

Figure 12. Initiation of carbon fixation by dried algal crusts following rewetting.

DISCUSSION

Techniques developed during the 1971 research period have been employed during the 1972 period with considerable success under both field and laboratory conditions. It is clear from observations during the current investigative period that algal crusts contribute significantly to the soil surface carbon content and overall biomass values of the cold desert ecosystem. Predictions from preliminary experimentation during 1971 have been verified by field and laboratory activity during the current research period.

Although not mentioned in this report, the investigators have developed the means by which the algal component of the soil crust system can be grown and harvested in quantity under laboratory conditions. This will greatly facilitate examination of the effects of pH, salinity, temperature and other environmental parameters governing growth of algal materials.

Establishment of the exceedingly short tool-up time required for initiation of photosynthetic activity and growth of the algal crust organisms suggests that they may be of great importance in terms of short-term carbon and nitrogen additions to the surface soils of cold desert regions.

The establishment of the rapid upsurge in carbon fixation following rewetting of dry algal crusts may account for the relatively high values for heterotrophic organisms, particularly bacteria and fungi, reported in the upper 1 cm of soil in the progress report of 1971 research (Lynn and Cameron, 1972).

While it has not yet been proven, it is to be expected that a similar rapid initiation of nitrogen fixing activity exists for the algal soil crust and this nitrogen production may prove very important in terms of degradation of higher plant litter on surface soils by way of providing a favorable C:N ratio for decomposer activity. It is noteworthy that the algal symbiont of *Collema tenax* is *Nostoc*, a known nitrogen fixing blue-green alga, and that most other gelatinous lichens, of which both *Dermatocarpon* and *Fulgensia* are representatives, are known nitrogen fixers (Henriksson, 1951, and Scott, 1956). *Nostoc* also exists as a free-living alga and by simple microscopic examination of the soil crusts appears to constitute roughly 0.5% of the algal soil crust component at the investigative sites.

EXPECTATIONS

Work will continue in the areas presented in this research report, especially in the area of nitrogen fixation by algal crusts. Facilities are now available for this research, and techniques employed by Dr. Don Porcella to measure nitrogen fixation under field conditions will be implemented as part of our program.

The monitoring of the manipulated investigative sites with regard to changes in algal biomass, nitrogen and carbon will be continued and additional work regarding the contribution by algal soil crusts to the nitrogen balance of the investigative sites is being initiated.

Several trips to other Biome sites to obtain suitable materials to establish the contributions of the algal soil crusts in these areas are anticipated.

The extent to which pH, salinity, nutrient availability and temperature affect the productivity of algal soil crusts will be established during the 1973 investigative period.

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