

ECOLOGICAL STUDIES ON THE ALGAE OF ERODED SOILS

By

SYED ZAHIR SHAH



**DEPARTMENT OF BOTANY
UNIVERSITY OF PESHAWAR
1985**

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

In the Name of ALLAH
the most merciful,
the most gracious.

DEDICATION

To the sweet and everlasting memory of one
who is affectionately known in Pakistan as

FATHER OF ALGAE,

I dedicate this work with love and gratitude
to my great teacher (late) Prof:Dr.M.A.F, Faridi
(May his soul rest in eternal peace).

ECOLOGICAL STUDIES ON THE ALGAE
OF ERODED SOILS

BY

SYED ZAHIR SHAH

A thesis submitted in partial fulfilment
of the requirements for the
degree of

DOCTOR OF PHILOSOPHY

IN

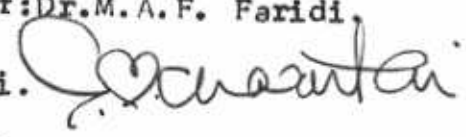
BOTANY

BY

SYED ZAHIR SHAH,

DEPARTMENT OF BOTANY,
UNIVERSITY OF PESHAWAR.

The thesis of Syed Zahir Shah
is approved:-

1. Internal Examiner/Supervisor: (Late) Prof: Dr. M. A. F. Faridi,
2. Internal Examiner: Prof: Dr. S. M. Chaghtai. 
3. External Examiner: 
22.XII.75

ABSTRACT

Six stands were sampled in eroded localities, three in Peshawar Vale and three in the Haro Basin of Potohar Uplands near Lawrencepur, for intensive algal studies. All the stands were dominated by blue-green algae for many reasons, such as high pH, dry and arid conditions, high temperature and desiccation. All the stands were invariably inhabited by Schizothrix - Scytonema communities. The most frequent species were Schizothrix friesii and Scytonema schmidtii. The green algae were represented by Protococcus viridis, Chlorococcum oviforme, C. echinozygotum, C. hypnosporum and Tetracystis isobilateralis, which are mainly unicellular forms. The absence of other green and yellow-green algae was mainly because of high temperature, desiccation, and arid conditions to which these forms are sensitive.

The desiccation in summer coupled with temperature extremes in summer and winter eliminated the vascular plants significantly, but the soil algal flora almost remained unaffected. The algal cover was found

to minimize the puddling effect of rain. The soil algal layer offered no resistance to the infiltration of water and the time taken by water to enter the algae-covered soil and bare soil was found to be the same. The soil surface, protected by algal layer, offered more resistance to the force of the water of run off as compared to bare surface mainly because of the binding of surface particles into a non-erosible layer. The ratio of soil eroded from algae-protected and bare surface was found to be 1:15.

The communities of higher vegetation were also established in all stands; Cynodon dactylon and Plantago ciliata were found to be the most frequent and dominant members of the communities. The coefficient of community was determined for all the pairs of algal and vascular communities. Soil texture was found to be silt loam in all the stands with high silt and sand percentages. All the soils were alkaline with high CaCO_3 proportions.

CONTENTS

Abstract	...	iv
Introduction	...	1
Review of Literature	...	9
Materials and Methods	...	26
Description of Research sites	...	31
Map	...	44
Results and Discussion	...	61
Malkandhere site	...	61
Azakhail site	...	70
Nowshera site	...	77
Lawrencepur sites	...	83
Coefficient of algal community	...	98
Coefficient of vascular community	...	105
Sheet Erosion	...	110
Puddling Effect of Rain	...	112
Infiltration of water	...	115
Conclusion	...	117
Acknowledgements	...	120
Literature cited	...	121
Appendix	...	164
Plates 1-8	...	165-180

INTRODUCTION

Nothing is eternal in this world but the change itself. It is doubtful if man could have survived in an absolutely static nature. Natural processes, including erosion, have brought about the formation of soil from the parent rocks. A basic distinction should be made, however, between the rate of change as it occurs in nature whereby soil binding forces are substantially in balance with those of destruction, and the rate of change precipitated by man in the conquest of his environment. The one is inherently natural and the other must be considered artificial. What takes nature hundreds or even thousands of years to manufacture, man often destroys almost overnight by haphazard use of land and improvident husbandry.

The use of land plays an important role in agriculture. Soil determines how far a society can go in developing its industries, cultural pursuits and social and political organisations. In ignorance and

wastefulness mankind has strode across the face of the earth for about 7000 years of farming, plundering natural resources and driving wild life into extinction. With little knowledge of natural resources and delicate equilibrium between soil formation and land sculpture, he has accelerated the process of erosion (Khan, 1981).

Devastation by erosion has now become so apparent that it has created a serious problem throughout the world and is significant in our country as well. In Pakistan, especially in the upland districts, the situation is getting worse. Every year millions of tons of eroded debris is washed down the plains. The floods have become a recurring feature mainly due to devastation of forests in the hill catchment. Only in the Indus Basin Catchment 44 percent of forests have been ruined (Khan & Chaudhry, 1967). It is estimated that about 35,000 acres of soil is eroded in Pakistan every year (Khan, 1984). The situation is quite alarming and needs immediate attention in this regard.

The damage caused by erosion is not only confined to soil loss, but erosion by water causes at least four types of losses or damages (Foth & Turk, 1972).

1. The water causing the erosion is lost. It might have been useful in crop production had it entered the soil instead of running off the soil.
2. The soil carried away ceases to be of any value in crop production, and furthermore the freshly exposed soil is relatively low in available nutrients at least for a shorter period of time.
3. The soil carried away frequently causes much damage, especially during gully formation, a layer of infertile soil may be deposited over an area of productive soil, thus greatly reducing its power of crop production.
4. The soil removed through erosion may be deposited in streams, harbours, and reservoirs

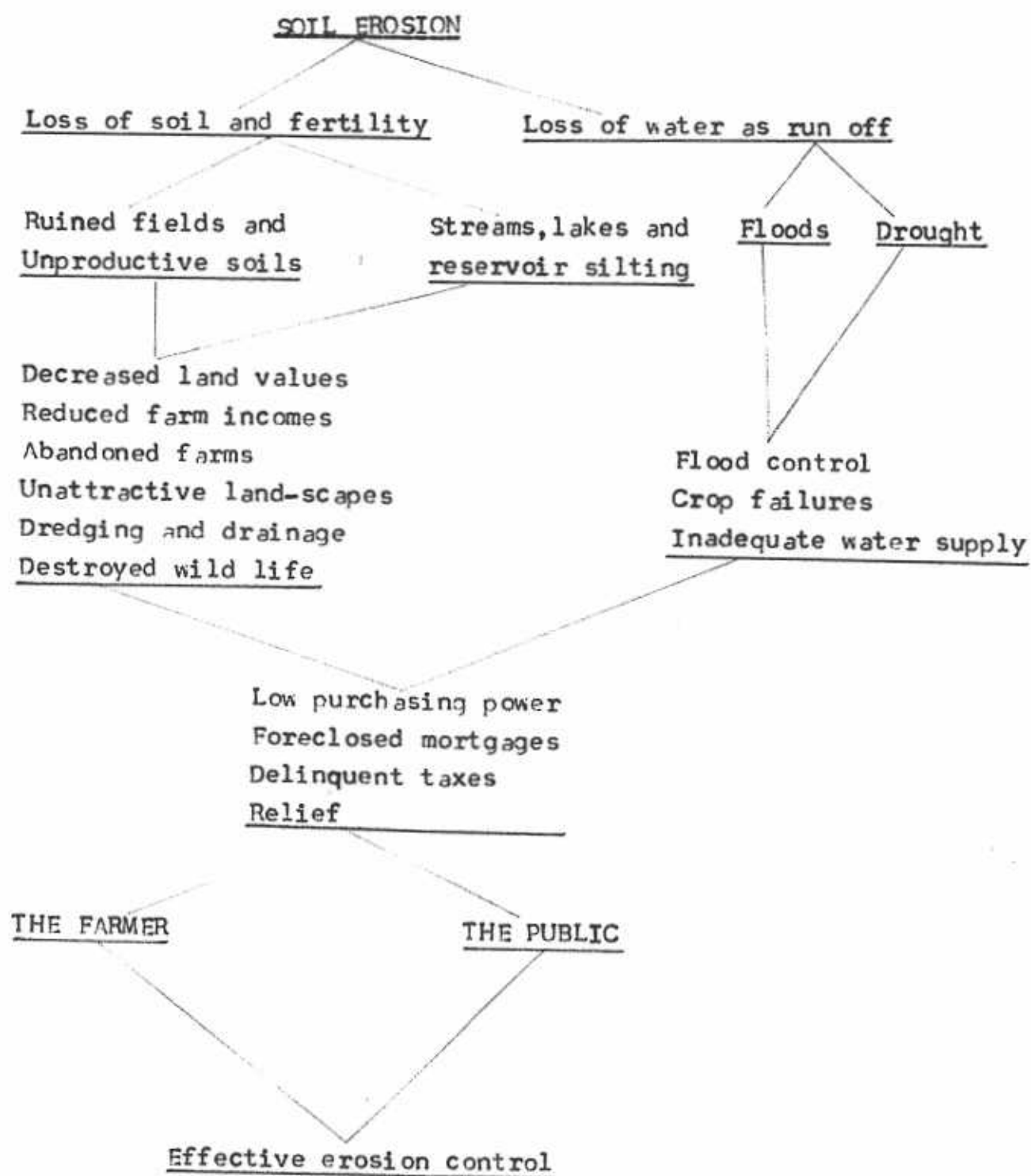
increasing the intensity of floods, impeding navigation and reducing water storage capacity.

The three most active eroding forces are water, wind, and snow. Wind is directly responsible for sand and dust storms. Water erosion is generally considered to manifest itself in two forms i.e. sheet and gully erosion. Usually these two forms represent different stages in the same process; and gullies as a rule, do not appear until sheet erosion has been under way for a considerable time. Gullies, however, sometimes occur without being preceded by sheet erosion; and conversely, sheet erosion has been known to continue indefinitely without the formation of gullies (Ayres, 1936).

Sheet erosion occurs by two processes namely rain drop impact and transportation of soil particles by flowing water (Smith and Wischemier, 1957). The excess of rain water starts flowing down the slope carrying soil and humus with it, resulting in a uniform skimming off of the cream of top soil.

The gully erosion occurs when water starts flowing in a definite channel, where eroding power of a given volume on a given slope is greatly increased. The gullies usually attain a depth of 20 m or more with proportionate width, in a remarkable short time (Khan, 1981).

A diagrammatic representation of soil erosion and its effects, as conceived by Bayer (1935) is shown below.



Soils are not permanent structures. They have an origin and undergo changes in which the algae are involved. New soils exposed by land slips, agricultural techniques, burning and other biotic disturbances are rapidly colonised by algae as they are the primary colonizers. Today soil algae have established their position as bonafide soil microorganisms. They play an important role in primary and secondary succession by acting as an integral part of the colonial synusium. The principal functional attributes of algal communities in soil include primary production, nitrogen fixation and stabilization of soil aggregates by means of extracellular polysaccharides and by the accumulation of organic matter. In addition to the positive influence on soil structure, soil algae are also valuable in agriculture as they contribute to the fertility of the soil by the addition of organic carbon through photosynthesis and organic nitrogen through nitrogen fixation.

Soil algae on the whole have not received the attention they deserved and therefore, with few exceptions,

no remarkable work has been done in this field. Recently a comprehensive work on soil algae has been started in the Department of Botany, University of Peshawar, Pakistan. Taxonomy, physiology, ecology and some other aspects have been studied in detail by Shah (1977), Shams (1977), Shahwar (1977), Jabeen (1978), Marwat et al., (1979), Faridi et al., (1981 & 1983), Anjum (1981), Anjum and Faridi (1982), Anjum and Akhtar (1983) and Sajida (1984).

The purpose of this investigation is to study the ecology of the soil algae in some arid and eroded localities. It aims at determining the types, frequency of occurrence, coverage and some other soil conservation values of protective algal layer.

REVIEW OF LITERATURE

Lyngbye (1819), according to Petersen (1935) had credited Paracelsus, an ancient Greek, as having recorded the earliest known reference to a soil alga, probably a species of Nostoc Vaucher. Dillenius (1741), for the first time, described Nostoc commune Vaucher from the soil. Early studies were purely of taxonomic nature (Agardh, 1812 & 1817; and Lyngbye, 1819). During the mid 19th and early 20th centuries the primary attention remained focussed on taxonomy but description of species of soil algae was also included (Kutzing, 1845 - 1871; Ehrenberg, 1843 & 1854; and Rabenhorst, 1863). Later monographs by Bornet and Flahault (1886-1888), and Gomont (1892) on the Cyanophyceae, by West and West (1897 & 1904) on desmids, by Heering (1907 & 1921) on Vaucheria deCandole, and Geitler (1925 & 1932) on the Cyanophyceae were among the many works in which description of species of algae appeared. Græbner (1895), for the first time, realised the ecological importance of soil algae as pioneers of poor soils. The attention

was now focussed on the physiology and ecology of soil algae.

Most of the soil algae are photoautotrophic, however some possess other nutritional modes. A number of soil algae which are facultative photoheterotrophs or chemotrophs are of widespread occurrence (Treboux, 1905; Bristol-Roach, 1926, 1927 & 1928; Skinner & Gardner, 1930; Parker et al., 1961; Khoja & Whitton, 1971; and Hoare et al., 1972). According to a more careful estimate, about 40-50 percent of green and yellow-green soil algae are facultative chemoheterotrophs (Metting, 1981). The predominance of diatoms and blue-green algae on alkaline soils may be attributed to the richness of these soils in organic and inorganic nutrients (Fritsch, 1922a; Gisl, 1933; Petersen, 1935; John, 1942; Lund, 1945 & 1947; and Mitra, 1951). Concomitantly, predominance of green algae in acid soils may partly be due to the inability of other algae to thrive at low nutrient levels (Petersen, 1935; John, 1942;

Lund, 1947; and Archibald, 1969). The addition of humus to the soil was found both increasing (Bristol-Roach, 1927a; and Skinner, 1932) and decreasing (Petersen, 1935; and Stokes, 1940) the number and kinds of algae. These changes are not due to the direct effect of organic materials but because of the indirect influence of organic materials on moisture retention. The moisture status of the soil also determines whether the addition of inorganic nutrients will stimulate or depress the activity of soil algae (Kaszubiak, 1976; and Cameron & Houghton, 1978). The inorganic nutrients increase the floristic diversity of the soil algae but the extent of diversity varies with type of inorganic nutrient (Gistl, 1932 & 1933).

Microstratification of algal population occurs within the upper millimeters or centimeters of soil profiles, gravel deposits and rocks (Bristol-Roach, 1927 ; John, 1942; Cameron & Blank, 1966 ; Nordin & Blinn, 1972; and Friedmann & Galun, 1974). Yellow-green algae were more abundant below the soil surface than on top (Fritsch,

1992b & and Flint, 1958). Some algal activity occurs even at a depth of 10-15 cm in the soil (Moore & Karrer, 1919, Moore & Carter, 1926; Bristol - Roach, 1927a; Feher, 1936 & 1948; Schwabe, 1960a, 1960b and 1963; and Nordin & Blinn, 1972). The isolation of green (Bristol-Roach, 1927a) and blue-green (Vaidya, 1964) from depths greater than one meter has also been reported. The effect of aspect on the distribution of algae has also been observed (Kabirov & Minibaev, 1976). In wheat fields on clods, yellow-green and green-algae were found to be more abundant on east and west facing surfaces than on south or north-facing surfaces. The pattern of distribution may be, in part, due to by variation in irradiance and moisture.

The photoperiods and the quality of light was found controlling the growth and the distribution of soil algae in laboratory experiments. The differentiation of heterocysts was found to be light dependent in a number of blue-green algae (Fogg, 1951; Lazaroff & Vishniac, 1961; Kale, 1972; and Singh & Viswanathan, 1972).

Wavelengths of 600-700 nanometers at 1300 lux resulted in greatest frequency of heterocysts differentiation in Anabaena ambigua (Kale, 1972) and A. doliolum (Tyagi & Ahluwalia, 1978). The effects of solar radiation on soil algae in region of the spectrum other than visible have also been studied. Soil algae were found to be more resistant to damages by ultraviolet radiation than other microorganisms (Kumar, 1963; and Cameron & Blank, 1966b). In the testing sites of nuclear explosions in Nevada and Japan, soil algae, though severely affected, were comparatively more tolerant of high energy radiation than more complex life forms (Shield et al., 1961; and Akiyama, 1966). The soil algal communities were found to be more resistant to chronic gamma irradiation as compared to higher plant communities (Franz & Woodwell, 1973).

The soil algae, especially the blue-green forms, reportedly possess a wide ecological amplitude with regard to soil moisture (Drouet, 1943 & 1962; Bolyshev, 1952; Moewus, 1953; Zehnder, 1953; Shields, 1957;

Shields et al., 1957; Flint, 1960; Royzin, 1960; Cameron, 1960, 1961, 1962a, 1962b, 1963a, 1963b, 1964a, 1966, 1969a, 1970, 1971, 1972a & 1972b; Durrell, 1962, Friedmann, 1964, 1968, 1971 & 1972; Cameron et al., 1965a, & 1965b; Morelli et al., 1965; Cameron & Blank, 1965 & 1966a; Cameron et al., 1966; Forest & Weston, 1966; Benoit & Cameron, 1967; Friedmann et al., 1967; Cameron et al., 1968; Cameron & Conrow, 1969a & 1969b; Gollerbach & Shtina, 1969; Benoit & Hall, 1970, Cameron & Devaney, 1970; Cameron & King, 1970a & 1970b; Cameron et al., 1970; Novichkova-Ivanova, 1972a & 1972b; Friedmann & Galun, 1974; and Friedmann & Ocampo-Paus, 1976). The soil algae exhibit remarkable longevity. They reportedly resumed growth from soil and herbarium sheets after being stored for 83 years which also demonstrate their remarkable ability to survive prolonged periods of drought (Lipman, 1941; and Bristol, 1919). The diatoms and yellow-green algae are comparatively less tolerant to low water potential (Bristol-Roach, 1928b; Skinner, 1932; Lund, 1945 & 1947; Bredemuhl, 1949, and Friedmann & Galun, 1974).

The soil algae is believed to utilize gaseous water for their maintenance (Fritsch, 1922b and 1936; Friedmann & Galun, 1974; Turner, 1975; and Favali et al., 1978). Some blue-green algae, in soil, have been found to survive five years of continuous high vacuum (Cameron et al., 1970). Carson and Brown (1976) noticed that the distribution of soil algae is not governed by altitude. In order to resist drought, the terrestrial algae develop a number of physiological and biochemical adaptations (Fritsch, 1916 & 1922b; Piercy, 1917; Fritsch & Haines, 1923; Fraymouth, 1928; Petersen, 1935; Evans, 1958 & 1959; Shields & Durrell, 1964; and Novichkova-Ivanova, 1972b). In drought conditions, the moisture absorbing and retaining capacity of algal sheet increases many times (Schroder, 1886; Fritsch, 1922b; and Petersen, 1935).

The soil algae tolerate both extremes of temperature. The species of Stichococcus (Karcher, 1931), Microcoleus, Protococcus, and Schizothrix (Cameron & Blank, 1966b) survived at -195°C in crushed soil. Booth (1946) noted that Microcoleus vaginatus,

Schizothrix sp., and Scytonema ocellatum can tolerate temperatures as high as 113°C, 112°C and 110°C respectively. The tolerance to high temperature increases under dry conditions (Glade, 1914; Izerott, 1937; Zehnder, 1953; DeMeter, 1956; and Trainer, 1962).

The soil algae are specific in their habitat selection. Blue-green algae inhabit the neutral and the alkaline soils (Bolyshhev, 1952; Sdobnikova, 1956; Lund, 1962; Shield & Durrell, 1964; Cameron & Blank, 1966a; Fogg et al., 1973; and Friedmann & Galun, 1974). The organic and inorganic nutrients are amply available in alkaline soils and this seems to be the main reason of blue-green algae dominating these soils (Fritsch, 1922; Gistl, 1933; Petersen, 1935; John, 1942; Lund, 1945 & 1947; and Mitra, 1951). Acidic soils, on the contrary, are devoid of blue-green algae (Whitton and Sinclair, 1975) and are inhabited more by green and yellow-green algae (Petersen, 1915 & 1935; Coyle, 1935; Flint, 1958; Lund, 1962; Shields & Durrell, 1964; and Metting & Rayburn, 1979). The dominance of green - algae on acidic

soils may partly be due to the inability of other groups of algae to survive at low nutrient level (Petersen, 1935; John, 1942; Archibald, 1969; and Lund, 1947). In some cases acidic soils were found dominated by blue-green algae (Jurgensen & Davey, 1968), whereas green-algae dominated the alkaline soils (Pulmaly, 1924). The soil pH seems to control the growth, abundance and the distribution of algae provided sufficient moisture and nutrients are available (Bristol-Roach, 1926; and Koster, 1963), as well as Chlorella vulgaris Beijernick (Durrell, 1962), and Porphyridium sp. (Pringsheim & Pringsheim, 1956) reportedly tolerate high pH. Algae are known to grow well in salt deposits, existing beneath the surface where desiccation and insolation are minimum (Cameron & Blank, 1966a; and Friedmann & Galun, 1974). The occurrence of blue-green algae in peat was controlled by the pH level (Dooley & Houghton, 1974).

The algae improve the soil structure through aggregation of colloids by adding extracellular polysaccharides including filamentous sheaths and individual and colonial mucilages (Martin & Waksman, 1940; Fletcher

& Martin, 1948; Singh, 1961; Bond & Harris, 1964; Marathe, 1970; Anantani & Marathe, 1972a & 1972b; Baily et al., 1973; Venkataraman, 1975; and MacKenzie & Pearson, 1979). The addition of Chlamydomonas mexicana to the soil in large quantities (1-5 kg/ha) improved the structure and the fertility of the soil by binding clays and preventing the formation of hardpan on recently tilled soils (Lewin, 1977). The improved soil structure helps in facilitating the infiltration and percolation of water and thus checks erosion (Elwell et al., 1939; Booth, 1941a & 1941b; Fletcher & Martin, 1948; and Singh, 1961). The algae inhabited soils are rich in nutrients and possess greater capacity for retaining water (Gael et al., 1980). According to Booth (1941b) the samples of algae-covered soils from eroded farm land in Oklahoma contained 8.9 percent water as compared to 1.3 percent by bare soils. Singh (1961) further confirmed the findings of this type.

The soil algae prevent the loss of ammonia and leaching out of nitrates by converting them into organic nitrogen (Waksman, 1952; and Marathe & Anantani, 1975).

Increase in the phosphate content of the algae-inhabited soils was also noticed (Fuller & Rogers, 1952). Soil algae add sufficient carbon to the soil (Prasad, 1949; and Fuller & Rogers, 1952). In eastern United States, algae-covered soil under fescue grass was found containing more carbon and nitrogen than the soil without algae cover (Reddy & Giddens, 1975). Soil algae significantly contribute to the enrichment of the soil by adding nutrients (Osmanova & Gladyshev, 1978) and by conserving them too (Jorden et al., 1980). Algae add considerable amount of organic matter to the soil (Marathe & Khushaldas, 1975). Psammophytic algae were the principal participants of organic matter formation in wind blown sands (Osmanova & Sdobnikova, 1977). Shubert and Starks (1980) recommended the importance of soil algae in succession and soil genesis.

Algae help in binding the soil. The mucilage discharged from Schizothrix, Plectonema, Phormidium and some other species helped in the aggregation of soil (Osmanova & Sdobnikova, 1977). The algal communities of

Sandy, arid and semiarid soils reportedly brought about considerable aggregation of loose and unbound soil particles (Anantani & Marathe, 1972b). The soil algae reportedly stabilize the soil crust of abandoned fields and other wastelands (Elwell et al., 1939; and Faridi et al., 1983). Soil algae were found to colonize sands of Oahu coast in United States (MacEntee & Bold, 1978).

Algae have proved very effective in conditioning the soil. They have been used as green manure on cotton fields in Tashkent (Kuchkarova, 1962; and Tret'yakova, 1970). Upto 90 percent of the photosynthetic production of an alga under ideal conditions, is converted to extracellular biopolymers improving 5-15 percent of yield of cotton and potatoes (Fogel et al., 1976). The initial inoculum grew to 50-200 kg/ha after 3-4 weeks resulting in the saving of water upto 35-40 percent, reducing the erosion and lowering the salt table (Lewin, 1977). The role of algae in the reclamation of saline and sodic-saline soils in India have been studied by Singh (1950 & 1961).

The blue-green algae were found associated with asymbiotic dinitrogen fixation (Jagnow, 1973; and Yoshida et al., 1973). The number of the species of soil algae accredited with the fixation of nitrogen range from 25 to 47 (Singh, 1961; Shtina, 1968 & 1972; and Anjum & Faridi, 1982). Anabaena and Nostoc were found to enrich the soil with bound nitrogen (Osmanova & Sdobnikova, 1977). The amount of nitrogen fixed is directly proportional to the abundance of algae in the soil and according to an estimate upto 18 million filaments of Cylindrospermum licheniforme were found in a gram of soil in India (Singh, 1961). There are some factors which affect the nitrogen-fixing potential of soil algae. In a laboratory experiment, growth and nitrogen fixation by blue-green algae in soil was enhanced upon adding the inorganic nutrient solution (Granhall & Henriksson, 1969). The fixation of nitrogen by blue-green algae also increases under low oxidation-reduction potentials which are associated with waterlogged soils (Stewart & Pearson, 1970; and Fogg et al., 1973). The pH of soil controls the

nitrogen-fixing activities of algae (Brannon, 1945; Lund, 1962; Shields & Durrell, 1964; Gollerbach & Shtina, 1969; Fogg et al., 1973; and Zimmerman, 1979). Nitrogen-fixing blue-green algae are widely distributed in both tropical and temperate areas, but are more abundant in tropics (Watanabe & Yamamoto, 1971). Algae which do not fix nitrogen contribute indirectly both amino and inorganic nitrogen to the soil (Fletcher & Martin, 1948; and Shields et al., 1957). Nitrogen collected from a four year old soil algal crust was 0.18 percent compared to 0.06 percent nitrogen from fallow soil without algal crust (Reddy & Giddens, 1975). Soil algal communities were responsible for an increase in nitrogen level from 77-133 percent in desert (Marathe & Anantani, 1975).

Algae were found playing important role in soil genesis and succession (Danin, 1978); and Shubert & Starks, 1980). Algal vegetation forms initial successional stage on substrates which are poorer in plant nutrients, including recent volcanic deposits and bedrocks. The surface forms are the primary colonizers of barren infertile

soils denuded of macrovegetation (Osborne, 1950). Trueb (1888) reported that blue-green algae were the first colonists after a volcanic eruption on the island of Krakoa. Fritsch (1907) observed that by the progressive death and decay the algae rapidly prepared the soil conducive to the growth of higher plants. Fritsch and Salisbury (1915) found that soil algae were the first colonizers on burned heath in England. Different types of soil algal species dominated the chasmolithic, epilithic, enedaphic and epedaphic microenvironments forming the climax communities (Shields et al., 1957; Cameron & Blank, 1966a; Friedmann, 1972; and Friedmann & Galun, 1974). The soil algae play an important role in secondary succession as they add organic matter and nitrogen to the soil which in turn help in the retention of moisture and thus making the habitat suitable for the establishment of seeds (West & West, 1897; Fritsch & Salisbury, 1915; Fletcher & Martin, 1948; Aleksandrova, 1951; Bolyshev, 1952 & 1955; Gollerbach, 1953; Singh, 1961; Mayland et al., 1966; and Bolyshev & Novichkova-Ivanova, 1978).

The importance of algae in altering the physical environment of the soil has recently been spelled out and since then extensive studies have been made on this group of plants. The change in the structure and texture of the soil is pronounced largely because of the abundance of soil algal flora. In a gram of soil collected from the surface, the number of blue-green algae ranged from 48,000 to 96,000 whereas at a depth of 5-10 mm same amount of soil contained 1,600-13,300 algae (Jurgensen & Davey, 1968). The tillage certainly affects the algal population of the soil. The number of blue-green algae fluctuated from 0-180 per gram in cultivated silt loam (Metting, 1979) to 67-160,000 per gram in uncultivated silt loam soils in eastern Washington (Zimmerman et al., 1980).

The texture of the soil seems to be an important factor in controlling the distribution and the floristic diversity of blue-green algae (James, 1935; Shields & Durrell, 1964; Durohit et al., 1979). The floristic diversity is also affected by the soil moisture, temperature,

pH, organic carbon and total nitrogen (Gistl, 1932 & 1933; and Bunt, 1954). The application of chemical fertilizers is believed to reduce the floristic diversity (Schlichting, 1973). According to some the cultivation does not seem to affect the composition of algal communities of soil (Willson, 1957; and Willson & Forest, 1957) but Metting (1979) observed otherwise. The correlation of quantitative and qualitative changes in soil algae with other biological components in field and forest environment was investigated by Hunt et al., (1979).

In Pakistan, Faridi et al., (1981) isolated 31 species of soil algae from auriferous alluvials of the river Indus near Attock Fort. Anjum (1981) reported 245 species from different localities in N.W.F.P. Many species of blue-green algae accredited with soil binding characteristics have also been recorded from a vast variety of habitats from Peshawar (Shah, 1977; Shahwar, 1977; Jabeen, 1978; and Anjum & Faridi, 1982). The soil algal flora of different crop fields in NWFP has also been studied thoroughly (Marwat et al., 1977; Shams, 1977; Anjum & Akhtar, 1983; and Sajida, 1984).

MATERIALS AND METHODS

For the present investigation 6 research sites were selected in different localities. A total 50 soil strips of 2 cm^2 each were collected from each site, from the top 2 cm layer of the soil crust for algal study. The samples were sacked and brought to the laboratory in polythene bags with minute holes for aeration. Each strip was thoroughly examined under the compound microscope for algal vegetation. A slide measuring 7.50×2.00 cm was mounted with the algal crust. Care was taken to remove as much soil as possible from the lower side of the crust. In order to make the identification and the study easy the plant material was spread but with most possible care not to dislodge a chunk, no matter how small it was, from its original position. An eye piece micrometer consisting of squarish divisions (each of $12.5\text{ }\mu\text{m}$ in $45\times$) was used and the algal crust mounted on the slide was then divided into small squares of one square millimeter. In each square the

coverage value of each species in Daubenmire's scale (1959) was recorded. On the basis of this study the relative values of frequency and coverage and summation value of each species was calculated according to Cox (1967). An almost similar technique had already been used for the study of the communities of corticulous lichens (Culberson, 1955).

In each research site puddling effect of water was determined by allowing 10 ml water to fall drop-wise. The water was dropped from burette, from a height of one meter, in 15 minutes time. The depressions thus made by falling water were filled with molten wax. After solidification, the volume of wax was indicating the volume of depression was determined. The weight of the soil displaced was also calculated. The community of higher vegetation was established in each research area. For this purpose line quadrat technique was applied. A quadrat measuring 50 x 20 cm was used. The number of plants of each species were also recorded in each quadrat. Daubenmire's (1959)

scale was used for determining the coverage classes of the plants in each quadrat. The relative values of density, frequency and canopy coverage and importance values of each species were calculated following Cox (1967).

The soil texture was determined by ASTM Method D 422-63 suggested by the American Society for Testing and Materials (1964). The CaCO_3 percentage in the soil was determined according to USDA Handbook (1954) while pH and available P_2O_5 and K_2O was determined according to Jackson (1962).

The coefficient of community was calculated according to the formula used by Motyka et al., (1950) and Culberson (1955):

$$\text{Co-efficient of community} = \frac{2W}{a+b} \times 100$$

The calculations are based on the pattern of distribution of the common species in two stands. W is the

lowest value of each pair of percentage of the species occurring in both stands and $a+b$ is the sum of all the species percentages in both stands. The first value (w) is doubled and then divided by the second value ($a+b$), the result was multiplied by 100, which gave the coefficient of community for each pair of stands.

The coefficient of community both for algal and vascular vegetation was determined separately. The degree of similarity was expressed by the ratio of percentages shared by the common species of two communities to the total percentages of all the species occurring in both the communities.

Experiments regarding infiltration were carried out. Six tests were made in each of the research sites, three in algal covered and three in bare soils. For this purpose thin tin cylinders with a diameter of 14 cm and a depth of 8 cm were used. The cylinders were pushed into the soil with a rotating motion to a depth of about 2 cm. Care was taken not to disturb

the algal crust. To keep the soil within the cylinder undisturbed by the pouring water, about one half of it was covered with a thick filter paper. Water was added in 250 ml amounts. The time was calculated for each 250 ml of water which soaked into the soil. The total amount of water used was 2 litre in each case.

Experiments for sheet erosion were conducted in algal protected and bare soil, so as to determine the loss of soil from these areas. For this purpose, two plots one protected by algal layer and the other bare were selected in each research site. One meter long trough with a diameter of 16 cm was used. One millimeter wide pores were uniformly made in the bottom of the trough throughout the length. A total 50 litre water was poured in the trough and allowed to flow out from the pores at the ground level. The stream of run off water coming from the trough was received in a tank at a distance of 5 meters. Slope of the plots was kept uniform. To calculate the quantity of eroded soil, the run off water was shaken well, so that eroded soil may be dispersed

uniformly, Three samples of one litre each were taken in graduated cylinders from each type of runoff water. Hydrometer technique was applied for the determination of sand, silt and clay percentages (Cox, 1967). Weight of empty and full cylinders were noted. After complete sedimentation of soil in cylinders in a period of one week, the pure water was evaporated from each cylinder and the weight of settled soil was calculated. From the data obtained, absolute and percentage weight of the soil was calculated.

DESCRIPTION OF RESEARCH SITES

I. Peshawar vale

Peshawar basin lies between $33^{\circ} 40'$ and $34^{\circ} 35'$ north latitudes and $71^{\circ} 15'$ and $72^{\circ} 50'$ east longitudes. The saucer shaped basin of Peshawar is formed by the Kabul river and its tributaries. It is a large depression comprising the whole of Peshawar and Mardan districts and some parts of the neighbouring tribal territories.

It stretches over approximately 4160 square km in area extending 120 km along east west and 83 km north and south. It is surrounded on all sides by barren hills varying in height from 1231 to 1847 m, except on the east, where the boundary is open to the river Indus and thus offers an easy access to the vast plains of the Potohar Uplands.

Because of the complex nature of genesis, it is difficult to conclude whether the basin was produced by faulting or by down-wrapping. Coulson (1941) is of the view that the tremendous weight of the detritus and sediments poured on to it in the Pleistocene period may have been heavy enough to depress its valley floor. However Said and Majid (1977) are of the opinion that in addition to the tectonics a variety of other processes have played part in its evolution.

Peshawar vale constitutes the extreme north - western tip of the Indo-Gangetic synclinalorium. The valley floor, 283-370 m has more or less uniform surface, covered by a variety of materials, ranging from loess

to fan gravels, river and fine alluvium. The rock outcrops, related with faults in the bottom of the geosyncline, are common in the area. In the Pleistocene period river alluvium, Piedmont alluvium, lake alluvia and loess were deposited and subsequently partially eroded. In the Holocene, river and piedmont alluvia were deposited and erosion of older materials were continued. The area is tectonically unstable and many frequent uplifts and down-wraps have occurred. Many fault scraps have been active until recent time.

The Kabul river which practically drains the whole basin flows through the centre of the vale in a south easterly direction and joins river Indus at Attock Khurd. Before it emerges from the Mohmand and Mulagori hills on the basin floor at Warsak, it is already carrying the combined drainage of the entire southern face of the Hindu Kush. On entering the plains it splits into three branches namely Sardaryab, Naguman and Shah Alam rivers. These branches join to form a

single stream downward from Charsadda town near Nisatta. The Swat river which is the main tributary of Kabul originates in the Swat hills, and flows to the left until it joins the River Kabul at Charsadda. Below this point till it empties into the Indus, the joint Kabul-Swat River flows in a single Channel known as the Landai. Downstream from Nowshera, the Landai has cut out for itself a deep channel, enclosed by steep banks.

Other important tributaries of the Kabul as it flows through the Peshawar basin are the Bara river, which drains most of the south western part of the valley, and the Kalpani stream and its tributaries from the north. The river Bara arises in the Tirah hills, just south of the main Sufaid Koh range and flows north east ward, passing with-in a few kilometers of Peshawar, before joining the Kabul river on its right side near Akbarpura. The Kalpani and its main tributary,

the Maqam carry the drainage of the middle eastern area of the basin.

Other hill torrents fall into basin at many places from the surrounding Afridi, Moh-mand, Khattak and Bunir ranges.

Physiography:

Peshawar vale is classified into the following sub-regions (Dichter and Popkin, 1967).

1. Central lowland:- The flat centrally located low land constitutes the major part of the basin, and is chiefly overlaid with a medium to fine unstratified sandy loam. This sub-region is further divided into three regions i.e. Yousafzai Plain, Doaba and Hashtnagar.
2. Piedmont Zone:- The central low land is circumscribed by the Piedmont Zone. It is composed of a series of alluvial fans, which have coalesced and constitute the transitional zone. In this

region soils show an orderly textural sequence from coarse or moderately coarse near the mountain base to moderately fine or fine materials along the lower piedmont slopes.

3. **Sar-i-Maira:-** This sub-region is composed of the sand stone bridge forming the eastern boundary of the valley. It is undulating sand plain, extending to River Kabul on the south and merging gradually with Yousufzal Plain to the north and west.
4. **Indus Plain:-** Situated between the Sar-i-Maira and the Indus River lies the Indus Plain. The soil materials consist entirely of fine flood plain deposits from the Indus.

Climatology:

Peshawar valley has a hot subtropical continental climate, which is semi-arid in the north western

corner and sub-humid in the remaining parts. As the valley is almost entirely surrounded by high land, therefore it is subjected to unique climatic conditions, particularly with regard to the distribution of summer rain fall. The eastern part receives comparatively more rain fall i.e. 71 cm than the western parts which receive 35-40 cm annually. The climatic pattern, characteristic of the valley, is analysed on the basis of four periods (Dichter and Popkin, 1967).

1. Cold Weather Period:- (December-March).

Winter of the valley is relatively cold. The daily minimum temperature sometimes drops down 0°C . Cyclonic depressions appear, resulting in low clouds and intermittent rain, often lasting for a week or more.

2. Transitional period (April-June):- After the middle of March the temperature increases rapidly and by the end of April, the daily maximum temperature reaches 38°C . The temperature peaks

Peshawar

Months	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
Max.Temp.	17.3	17.2	23.9	29.1	34.4	39.4	37.3	35.3	32.9	30.1	34.8	19.5	-
Min.Temp.	2.0	4.5	9.7	14.1	18.0	24.5	26.0	25.2	21.5	41.6	6.7	2.8	-
Rainfall	19.3	42.9	79.9	46.2	21.9	8.9	20.2	29.8	22.6	16.5	15.4	11.9	331.5
R.Humidity	63.5	58.7	57.4	50.9	37.9	38.0	53.1	62.1	55.5	49.1	54.0	62.2	-

Potohar Plateau

Max.Temp.	17.0	18.6	25.9	28.1	36.8	40.0	35.2	34.6	34.4	25.8	25.6	19.5	-
Min.Temp.	3.3	5.4	10.3	15.2	20.6	24.6	25.3	23.2	20.9	14.0	7.0	3.3	-
Rainfall	65.2	65.3	68.0	50.1	33.5	55.2	198.8	235.7	98.2	15.0	10.3	28.4	923.7
R.Humidity	91	83	79	58	33	34	76	78	67	59	68	80	-

in June, extending beyond 45°C during day time. The night temperature continues to rise and towards the end of the period it reaches 28°C . During this period humidity remains low.

3. Monsoon Period (July - September):- The maximum temperature falls to some extent, but humidity is quite high due to occasional conventional showers, coupled with frequent cloudiness. This condition usually prevails till the end of September. The diurnal range during this period falls to 10°C or even less.

4. Transitional period (October - November):- This part of the year is characterised by infrequent rains, clear sky and mild surface winds. The temperature falls rapidly and by the end of November daily minimum reaches 0°C .

Soils

Most soils of the valley range from medium to moderately fine in texture. They possess some granular

elements near the surface and are calcareous. Their development is usually weak and no evidence of clay transport is visible in the profile. They range in colour from yellowish brown and brown to greyish brown. The layers of lime concretions occur in most profiles. Most of the soils are alkaline ranging in pH from 7.80 to 8.40 (Table 3). The organic matter content of most soils is low (Elbersen, 1967).

a. Malkandhere

Malkandhere, one of the research sites, is located west of N.W.F.P. Agricultural University at a distance of about 10 km north-west of Peshawar City. The area lies on the raised bank of a seasonal stream locally called Naria Khwar, the ecology of which has already been studied by Chaghtai and Khattak (1983). The seasonal stream runs south north forming the east boundary of the research area. The stream originates from among the dry hills of Targi-Sar and Gandah Gallah, which lies 27 km south-west of Peshawar and belong to Hindu Kush range of mountains. The khwar on its way down the hills passes through the tribal area of Malak Din Khel, Kamari and Qamber Khel, then flows through Peshawar valley and finally enters a tributary of River Kabul at village Pirbala about 8 km north-west of Peshawar. The water flows in it during rain season alone and it remains dry for the rest of the part of the year. In summer it is heavily flooded with rain water. The stream drains the north eastern part of the Khyber Agency. The south

and the western parts of the research area are in cultivation, where different crops especially the wheat and the sugar cane are grown. A variety of trees such as species of Dalbergia, Tamarix and Populus are also found growing. In the north the research area is bounded by the grave yard of Faqir Baba where patches of native vegetation, comprising species of Acacia, Ziziphus and Capparis are noticed.

The research area comprises a flat raised piece of land which is badly eroded by water causing gully and sheet erosion. The area is covered by thin veneer of loose soil, below which lies a layer of sand mixed with pebbles of various sizes. The thickness of each of these layers varies from 1 to 2 m. In places the second layer is exposed because of the complete wash away of the upper layer.

The soil is silt loam in texture with considerably low clay and high silt percentages. The percentages

of sand, silt and clay are 29.0, 56.20 and 14.80 respectively (Table 2). The soil is susceptible to erosion largely because of high proportions of silt and sand. It is alkaline in nature with a pH of 8.10 and the percentage of CaCO_3 is 10.00. The area is dry and arid because of low annual precipitation and high summer temperature (Dichter & Popkin, 1967). The soil contains 11 ppm of P_2O_5 , while exchangeable K_2O is 274 ppm (Table 3).



b. Azakhail

This research site is situated near Azakhail Bala village in Peshawar Vale, south of river Kabul, about 20 km east of Peshawar city. The area on the west is bounded by a seasonal stream locally called Landay Khwar, which is about 5 km long, originates in the khairadin Maira and flows for the most part of its course in an incised channel. The seasonal stream after leaving the pied-mont Scrap near the Azakhail Bala village and flowing over a very low angled fan, finally ends in the swampy flood plains, north of the research area. Almost the entire region of the research area is covered by loess which is subjected to very severe erosion, resulting in typical badland landscape.

The land is undulating and the soil is very light. The soil is silt loam in texture; the percentages of sand, silt and clay is 28.80, 60.00 and 11.20 respectively. It is alkaline with pH 8.00 and the percentage of

CaCO_3 is 11.00. Available P_2O_5 is 5 ppm and exchangeable K_2O is 246 ppm in the soil (Table 3).

The deposits of the research area have a very close correlation with Potohar deposits (Said and Majid, 1977). The surface deposits are pale yellow silt stone, forming the parent material of the soil. Occasionally it is overlain by gravels and thick mantle of loess. It consists of hard and stiff bands, 2-15 cm thick of silt stone and sand stone, that attains a maximum thickness of 25 meter. In sections which are exposed along the torrents, the clay bands stand out prominently, due to their resistance to weathering, while the sandy layers are etched out. In some places the horizontal sand stone beds are crossed by vertical and oblique dykes of fine silty materials. The high percentage of silt suggests that the soil is basically formed by wind blown material loess, that has been primarily derived from the igneous rocks of the neighbouring area, but mainly from the previously glaciated parts of the Chitral, Swat, Dir, Hazara and Indus Kohistan (Said and Majid, 1977).

In some places especially the low lying area, the land is levelled by the local inhabitants and is brought under cultivation, where wheat is commonly grown during winter. Woody plants such as species of Dalbergia, Morus, Tamarix etc. are also cultivated. In the raised land trees and shrubs are absent, mainly because of disturbance and exposure.

c. Nowshera

The research site comprises raised and flattened land lying south to river Kabul, nearly 40 km south east of Peshawar. The area spreads over 10 square kilometers, reaching the foothills of Khattak-Chirat ranges to the south and forming a gentle slope to the north. In the west it extends upto the raised undulating land of Azakhail. In places depressions of various sizes occur. The soil is heavily eroded by rain water causing sheet and gully erosion. Baboo Khwar, the main seasonal stream of the area, originates at the foot of Khattak-Chirat hills, runs to the north and finally enters river Kabul near Nowshera. The stream is heavily flooded during rainy season in July and August and remains dry for the rest of the year. It drains major part of the area. It gradually deepens as it proceeds toward the north. Infrequent barani cropping is found in some places.

Table 2:- Physical characteristics of soils.

Stand	Sand (%)	Clay (%)	Silt (%)	Soil class
Malkandhere	29.00	14.80	56.20	Silt Loam
Azakhail	28.80	11.20	60.00	Silt Loam
Nowshera	19.00	8.00	73.00	Silt Loam
Lawrencepur I	26.40	13.20	60.40	Silt Loam
Lawrencepur II	20.80	9.00	70.20	Silt Loam
Lawrencepur III	22.80	8.20	69.00	Silt Loam

The soil is silt loam in texture with sand, silt and clay occurring in the proportions 19,73 and 8 percent respectively. It is alkaline in nature, with pH 8.2 and contains 12 percent CaCO_3 . P_2O_5 is 5ppm while exchangeable K_2O is 337 ppm in the soil.

Table 3:- Chemical characteristics of the soils.

Stand	pH	CaCO ₃ (%)	P ₂ O ₅ (ppm)	K ₂ O (ppm)
Malkandhere	8.1	10.0	11	274
Azakhail	8.0	11.0	5	246
Nowshera	8.2	11.5	5	337
Lawrencepur I	8.1	12.9	9	332
Lawrencepur II	7.9	11.5	13	290
Lawrencepur III	7.8	12.2	8	315

II. Potohar Uplands

The open undulating plains of the Potohar Uplands are situated between the Himalayan foothills in the north and east and Salt Range in the south. River Indus flowing from north to south forms their western boundary. The Uplands lie about 305 meters higher than the alluvial plains on the other side of the Salt Range. The area of the Potohar Uplands is about 11200 square kilometer, comprising the whole of Attock district and large parts of Rawalpindi, Jhelum and Mianwali districts. Neither truly mountain nor truly plain, the Upland combines elements of both and the variety of the natural landscape is unique in Pakistan. Passing across the Potohar Upland from the foot hills in the east to the Indus River in the west are situated valleys of Haro and Soan rivers. South of the Haro river, the spur of Kalachitta Range thrusts across the plains toward Rawalpindi.

The complex geological history of mountain building, alluvial and loessial deposition and erosional cycles of the Potohar, resulted in a varied landscape of mountains and stony plateaux, level alluvial plains and undulating sand plains and profusely dissected uplands. The pattern of these features shows a marked regional alignment, being controlled by the rock. The main drainage of Potohar are Haro and Soan rivers which unlike other rivers of the area are eroding and not depositing the materials.

Gully and sheet erosion, which are not only very common but severe also, have disturbed almost entire land of the region. Only a few parts of the Uplands remained unaffected by erosion. Most of the erosion here is of geological scale, which is continually spreading rapidly. The unsuitable agriculture practices, accompanied by overgrazing have accelerated the pace of erosion. It is estimated that above two million acres of cultivated land have been lost in these Uplands

(Khan, 1984). There is very little water available for irrigation, inspite of the fact that the Potohar Upland receives heavier rain fall than the rest of the plains of the country. It is mainly because of the wastage of large amount of water by run off due to undulating surface. The river beds lie so far below the general level of the land that it is impracticable to raise water from them. Even if this difficulty is overcome, the roughness of the terrain will make the effective distribution of water almost impossible. Barani cropping is consequently more common than in any other region of the Indus Plains.

The depth of the bedrock mainly determines the nature of the land form in the Potohar Uplands. In places where the bedrock lies near the surface, its lithology and attitude influence both landforms and soils. Crossing the region are five zones, in which the surface influence of bedrock strata is particularly prominent. These are arcuate in form and lie parallel

to the Salt Range. The northern most of these bedrock-controlled zones includes the Gandgarh Range and the mountain at Attock; it under lies the Sarcoda ridge near Attock city. The second zone comprises the Kalachitta Range and the rock plains lying at its feet. It extends from the Indus river to the Himalayan foot hills near Taxila. The third includes the bedrock plains extending from the Indus near Makhad and Khushal Garh towards the foot hills near Kahuta. Its highest point is the Khairi Murat Range. The fourth comprises at least three separate, elongated bedrock-controlled plains in Gujar Khan and Chakwal regions. The fifth includes the bedrock plains of Talagang region.

In places between these zones, where the bedrock is covered by the deposition of alluvium and loess, lie basin plains and dissected basin plains. The bedrock is exposed in some places as a result of erosion by the Haro and Soan rivers and their tributaries.

11 different land forms have been mapped in the Potohar Uplands (Fraser, 1957).

Soils

The soils of Potohar Uplands are of alluvial, loessial and residual origin. Yellow brown deposits of very fine sand and loamy very fine sand are found in some places in the vertically eroded faces and pinnacles, characteristics of loess. In many other places the surface deposits are definitely of alluvial origin. The coarse and moderately coarse alluvial materials are sandstone-derived residual materials and are widely spread over the western and central parts of the Uplands. In the east dark brown medium and moderately fine alluvial materials are very common. The residual materials of silt loam and silty clay loam texture are more common in the east than in the west (Fraser, 1957).

Climatology

There are great extremes of climate; the summer being very hot and the winter very cold. The rainfall is capricious and the monsoon rains are light and some-times almost missing, resulting in a condition unfavourable for vegetation. In such types of climate, hard and resistant species can survive. The rain fall varies from year to year, with average being between 46-64 cm (Frase, 1957).

Lawrencepure:

This research site is situated west of Haro river in the Haro Basin, nearly two km south of the National High Way from Peshawar to Rawalpindi. The Haro Basin of Potohar Uplands is traingular in shape and is formed by the basins of Haro river and that of Nandnakas. The basin is bounded by the Sarwala ridge on the west, south and south east sides are surrounded by Kalachitta Range. To the north and north east, it rises gradually approaching the Haripure

Basin. Haro river constitutes the main drainage system of the area.

Land of the research area is undulating and the soil is extensively eroded, deeply dissected and badly gullied, having deep and shallow cuts resulting in land fragmentation. Where the area is some what flat, it has been brought under cultivation, which is entirely dependent on rain water and therefore only winter crops, mainly wheat and barely are grown. Soil erosion has been further accelerated by overgrazing, poor management of farming and removal of vegetation through cutting. Gully erosion is continually extending, cutting the land and rendering it unfit for cultivation. The gullies are wide spread and profusely branched. The depth of the gullies varies and some are as deep as 30 m. There is very little remains of the original surface because of severe deep erosion. The presence of live stock and human population is very great. Most unlikely and unsuitable spots are being cultivated, such as high uneroded panicles of alluvium, flanks of gullies and pockets of alluvial soil in the bare rock plains.

Rain is the main agent of water erosion in the area. The wind deposited loess are brown in colour and alkaline in nature. It is silt loam in texture with high silt and low clay percentages. The entire area is dry and the summer temperature goes beyond 45°C.

RESULTS AND DISCUSSION

1. Malkandhere site

The algal layer helps in stabilising the surface of soil through the aggregation of colloids which is caused by the addition of extracellular polysaccharides including filamentous sheaths and individual and colonial mucilages (Martin & Waksman, 1940; Baily et al., 1973; Venkataraman, 1975; and MacKenzie & Pearson, 1979). The algae add humus to the soil which is of utmost importance for retaining water and the formation of the bed for the establishment of the seeds of higher plants (West & West 1897; Fritsch & Salisbury, 1915; Fletcher & Martin, 1948; Aleksandrova, 1951; Singh, 1961; and Bolyshev & Novichkova-Ivanova, 1978) and this consequently reduces erosion and improves infiltration and percolation of water (Elwell et al., 1939; Booth, 1941a & 1941b; Fletcher & Martin, 1948 and Singh, 1961).

The algal cover develops extensively in spring and autumn when temperature is moderate and sufficient moisture is available in the soil and the seasonal fluctuation do not significantly change the abundance and the distribution of soil algae. The desiccation in summer, coupled with the temperature extremes in summer and winter eliminates the vascular plants significantly but the soil algae almost remain unaffected, as they can fairly cope with these environmental conditions (Drouet, 1937). In comparison with vascular plants, the soil algae seem to be more tolerant to high energy radiation (Shields et al., 1961; Akiyama, 1966).

A. The algal vegetation

The algal vegetation varies in appearance. The regenerating algal crust which is usually confined to more disturbed places was blue-green, whereas mature algal crust was found to be dark blue in colour.

The area is inhabited by Schizothrix-Scytonema community dominated by Schizothrix friesii and Scytonema schmidtii (Table 4). The leading dominant i.e. S. friesii is more evenly distributed and covers the land more than the codominant. The summation values incorporating the two very important attributes of the community of the two dominants are far greater than the other algal inhabitants of the area and it hints at a greater potential of competition and adaptation these two species possess. S. friesii like many other blue-green algae, possesses a sticky and mucilagenous sheath which enables it to survive in high summer temperature and extremely low moisture conditions. Furthermore the

filaments of S. friesii occur in bundles usually lying parallel to one another; each bundle is enclosed in a thick, branched and slippery mucilagenous sheath which further enhances its moisture absorbing and retaining potential. The mucilagenous sheath of the blue-green algae absorbs moisture rapidly when the supply is abundant and retains it throughout drought periods (Fritsch, 1922b).

Of the soil algae found inhabiting the area, only two namely Protococcus viridis and Chlorococcum oviforme belong to Chlorophyta, whereas about 82 percent of the whole lot are the members of Cyanophyceae. The domination of blue-green algae may largely be attributed to the alkalinity of the soil, because neutral and alkaline soils not only favour the establishment of blue-green algae, they rather hamper the growth of green algae (Bolyshv, 1968; Sdobnikova, 1956; Lund, 1962; Shields & Durrell, 1964; Cameron & Blank, 1966a; Fogg et al., 1973; and Friedmann & Galun, 1974).

In alkaline soils more organic and inorganic nutrients are available, but the greater efficiency of blue-green algae to utilize them seems to provide them an edge over the green algae (Fritsch, 1922a; Gistl, 1933; Petersen, 1935; and Mitra, 1951). In a laboratory experiment, the addition of inorganic nutrients was found to enhance the growth of blue-green algae far more than the green algae (Granhall & Henriksson, 1969).

The two species of green algae encountered in the research site are unicellular and rarely form colonies. All species of blue-green algae with the exception of Chroococcus minutus and C. pallidus are filamentous. Chroococcus and Schizothrix possess two species each, Scytonema is represented by three species, whereas the remaining genera possess one species each.

Apparently the absence of diatoms and yellow-green algae, which are equally terrestrial forms, seems to be astounding but its sole reason is the scarcity of moisture in the soil as they are less tolerant to low water potential and aridity (Lund, 1945 & 1947; and Friedmann & Galun, 1974).

Table 4: Attributes of algal vegetation of Malkandhere site.

Species	Frequency	Relative Frequency	Coverage	Relative Coverage	Summation value
<u>Schizothrix friesii</u>	1.00	11.04	6.25	36.82	47.86
<u>Scytonema schmidtii</u>	0.95	20.49	3.75	22.09	32.58
<u>Schizothrix fuscescence</u>	0.90	9.94	2.11	12.43	22.37
<u>Lyngbya palmarum</u>	0.90	9.94	1.50	8.83	18.77
<u>Phormidium fragile</u>	0.95	10.49	1.12	6.59	17.08
<u>Scytonema bohneri</u>	0.50	5.52	1.19	7.01	12.53
<u>Scytonema stuposum</u>	0.50	9.94	0.27	1.59	11.53
<u>Protococcus viridis</u>	0.85	9.93	0.23	1.35	11.28
<u>Chlorococcum oviforme</u>	0.80	8.81	0.15	0.88	9.69
<u>Chroococcus minutus</u>	0.60	6.62	0.21	1.23	7.85
<u>Chroococcus pallidus</u>	0.70	7.73	0.19	1.11	8.84

B. Vascular vegetation

The area is arid with low annual rain fall (35-40 cm) and high summer temperature. It is inhabited by Stipa-Plantago community dominated by Stipa capensis and Plantago ciliata (Table 5). S. capensis, a plant of Mediterranean climate, has outcompeted other herbs. Its highest importance value is mainly because of its high relative values of all the three attributes of the community. The plant has well developed root system and therefore perpetuates well in comparatively dry and hostile summer. The population of this dominant species largely consists of many young plants which show quite uniform distribution. P. ciliata, the codominant of the community has got an edge over other members on account of its unpalatable nature, which may partly be held responsible for its high importance value. This plant is mainly associated with grass land communities (Sagar & Harper, 1960) and shows tolerance to high temperature and low moisture conditions (Stewart, 1958).

Cynodon dactylon, primarily a species of exposed habitats has very low importance value, in spite of its ability to compete other herbs in dry and open conditions (Chaghtai et al., 1978; Woodhouse, 1968; and Ramakrishanan & Singh, 1966). Its low importance value can be justified by its high palatable nature, on account of which it has to bear the heavy burden of grazing. Herniaria hirsuta, a plant of dry habitats (Bhopal & Chaudry, 1977; Stewart, 1958) has lowest importance value mainly because of the lowest values of the community attributes. Proximity of the crop fields and light texture of the soil could be partly held responsible for the presence of Calendula arvensis, as the plant is an annual weed of the winter crops (Luthra, 1933; and Chaghtai & Khattak, 1983). Low density coupled with high canopy coverage indicates the presence of comparatively fewer but healthy growing plants of Peganum harmala. Malcolmia cobulica was found growing in relatively moist places.

Some other associates of the community are Leptaleum filifolium, Astragalus tribuloides and Cousinia minuta.

Table 5: Attributes of vascular vegetation in Malkandhere site.

Species	D	RD	F	RF	CC	RCC	IV
<u>Stipa caensis</u>	44.51	50.39	0.68	35.69	0.302	45.68	131.76
<u>Plantago ciliata</u>	31.82	36.02	0.54	28.81	0.195	29.50	94.33
<u>Malcolmia cobulica</u>	4.24	4.80	0.23	12.30	0.062	9.37	26.48
<u>Calendula arvensis</u>	1.13	1.27	0.09	4.67	0.012	1.81	3.16
<u>Notoceras bicornis</u>	1.58	1.78	0.10	5.04	0.017	2.57	9.39
<u>Leptaleum filifolium</u>	2.86	3.23	0.08	3.78	0.012	1.81	8.82
<u>Astragalus tribuloides</u>	0.38	0.43	0.03	1.62	0.002	0.30	2.35
<u>Peganum harmala</u>	0.44	0.50	0.05	2.252	0.042	6.35	9.37
<u>Herniaria hirsuta</u>	0.27	0.30	0.01	0.68	0.001	0.15	1.13
<u>Filago pyramidata</u>	0.38	0.43	0.03	1.41	0.002	0.30	2.14
<u>Cousinia minuta</u>	0.34	0.38	0.03	1.78	0.008	1.21	3.37
<u>Cynodon dactylon</u>	0.38	0.43	0.03	1.62	0.006	0.90	2.95

(D, Density; RD, Relative density; F, Frequency; RF, Relative frequency;
CC, Canopy coverage; RCC, Relative canopy coverage; IV, Importance value).

2. Azakhail site

A. The algal vegetation

The barren undulating land bears rich algal flora, covering the land surface like a black carpet. The algal vegetation is disturbed by the activities of grazing animals and local inhabitants. Disturbance is more pronounced in the pathways and in the sides and the bottoms of the gullies. The undisturbed places bear comparatively rich algal vegetation.

Temperature remains very high in the dry months of summer and goes beyond 45°C accompanied by prolonged spell of drought, yet the algal vegetation is not significantly changed, mainly because of the fact that soil algal flora can tolerate both extremes of temperature (Cameron and Blank, 1966b; Glade, 1914; Izerott, 1937; Zehnder, 1953; De Meter, 1956; Trainor, 1962).

The area is inhabited by Schizothrix-Scytonema community, dominated by Schizothrix friesii and

Scytonema schmidtii (Table 6). S. friesii, the leading dominant of the community, has got highest summation value mainly because of the high coverage value, as the filaments of this plant occur in bundles occupying more space.

Of the total 14 species isolated from the area, only 4 were green algae i.e. Protococcus viridis, Chlorococcum hypnosporum, C. echinozygotum, and Tetracystis isobilateralis; the rest of the species were blue-green. P. viridis was frequently found in groups of two, four or more on account of the slow separation of the product of division. The cells of this species can withstand prolonged desiccation without undergoing any change (Fritsch, 1922), and it becomes possible largely because of the fact that this species meets most of its moisture requirements by the absorption of atmospheric vapours (Schmid, 1927).

The absence of filamentous green algae is mainly because of their inability to compete blue-green forms

in high pH and dry and arid conditions, which incidentally favour the growth of blue-green algae.

Chroococcus minutus and C. pallidus are unicellular or a fewcelled colonial forms. In either case the cells retain their individual envelopes. The low summation values of these plants is mainly because of their low coverage.

Almost all the filamentous forms of blue-green algae reported here possess mucilagenous sheaths, which help in their survival during unfavourable season of dry summer. Nostoc muscorum shows world wide distribution (Round, 1973), its low summation value is mainly because of low relative coverage.

Species	Frequency	Relative frequency	Coverage	Relative coverage	Summation value
<u>Schizothrix friesii</u>	0.95	10.32	6.39	27.78	38.10
<u>scytonema schmidtii</u>	1.00	10.86	3.75	16.30	27.16
<u>Phormidium fragile</u>	0.75	8.15	2.11	9.17	17.32
<u>Lyngbya palmarum</u>	0.80	8.69	1.93	8.39	17.08
<u>Nostoc muscorum</u>	0.55	5.97	2.53	11.0	16.97
<u>Schizothrix telephoroids</u>	0.65	7.66	1.67	7.26	14.92
<u>scytonema bohneri</u>	0.45	4.89	1.83	9.95	14.83
<u>Aphanothece naegeli</u>	0.95	10.32	0.15	0.65	10.97
<u>Chlorococcum hyposporum</u>	0.80	8.69	0.19	0.82	9.51
<u>Chroococcus pallidus</u>	0.60	0.52	0.14	0.60	7.12
<u>Protococcus viridis</u>	0.50	5.43	0.25	1.08	6.53
<u>Chroococcus minutus</u>	0.45	4.89	0.33	1.43	6.32
<u>Chlorococcum echinozygotum</u>	0.35	3.80	0.29	1.26	5.06
<u>Tetracystis isohilateralis</u>	0.40	4.34	0.09	0.39	4.73

B. Vascular vegetation

The area is inhabited by Plantago - Cynodon community, dominated by Plantago ciliata and Cynodon dactylon (Table 7). The community supports 12 species of which 4 are grasses. Plantago ciliata, the leading dominant of the community, is a species of mainly grassland communities and grows fairly well in dry places. The highest values of density and frequency of this species show the presence of greater number of individuals and their uniform distribution. Unpalatable nature, coupled with highest relative values of density and frequency accounts for its highest importance value. It seems that the plant favours alkaline soils.

The area is under intense pressure of grazing. Overgrazing and palatable nature of Cynodon dactylon, a codominant species, may account for its low importance value. Calendula arvensis is an annual weed of winter crops and has escaped from the nearby cultivated fields.

Malcolmia cobulica, Astragalus tribuloides and Eragrostis citriformis are other important members of the community.

Linum strictum and Lactuca dissecta have very low densities, which may be probably because of dry and arid conditions these species are unable to tolerate.

Species	D	RD	F	RF	CC	RCC	IV
<u>Plantago ciliata</u>	133.72	76.61	0.97	36.05	0.46	48.56	161.24
<u>Cynodon dactylon</u>	15.24	8.73	0.66	24.53	0.30	31.23	64.49
<u>Astragalus tribuloides</u>	3.30	1.89	0.13	4.83	0.03	2.62	9.34
<u>Calendula arvensis</u>	11.29	6.46	0.38	14.12	0.06	6.62	27.20
<u>Malcolmia cobulica</u>	8.25	4.72	0.34	12.63	0.07	6.83	24.18
<u>Fagonia critica</u>	0.80	0.45	0.06	2.23	0.02	1.47	4.15
<u>Cenchrus ciliaris</u>	0.51	0.29	0.04	1.48	0.01	1.15	2.92
<u>Scabiosa olivieri</u>	0.38	0.21	0.03	1.11	0.005	0.52	1.84
<u>Filago pyramidata</u>	0.35	0.20	0.03	1.11	0.003	0.31	1.62
<u>Bromus japonicus</u>	0.25	0.14	0.02	0.74	0.003	0.31	1.19
<u>Lactuca dissecta</u>	0.29	0.16	0.02	0.74	0.001	0.10	1.00
<u>Linum strictum</u>	0.16	0.09	0.01	0.37	0.002	0.21	0.67

(D, Density; RD, Relative density; F, frequency; RF, Relative frequency;
CC, Canopy coverage; RCC, Relative canopy coverage; IV, Importance value).

3. Nowshera site

A. The algal vegetation

The surface of the soil supports algal vegetation, which is usually found in patches of varying sizes as a result of disturbance by the grazing animals. Annuals and some perennial grasses are believed to interfere with the continuity of algal layer. Undisturbed large size algal layers were commonly noticed on the steep slopes, which were somewhat protected.

The environmental conditions prevailing here are almost similar to those of Malkandhere and Azakhail. The summer is dry and hot; temperature rises beyond 45°C , accompanied with desiccation, which results in almost disappearance of vascular vegetation. The winter is cold, the frost is common and occasionally the mercury drops down the freezing point. December and January are the coldest months.

The entire algal vegetation is composed of blue-green algae, and is represented by all the three forms, i.e. unicellular, colonial and filamentous.

Diatoms, green and yellow-green algae are absent, mainly because of high pH, dryness and aridity, as they are reportedly susceptible to these conditions.

The area is inhabited by Schizothrix - Scytonema community, dominated by Schizothrix friesii with Scytonema schmidtii as codominant. The summation value of S. friesii was found to be the highest, largely because of the highest value of coverage. The filaments of this species occur in bundles, occupying more space, which justifies its high coverage value. The high frequency of S. schmidtii indicates that this plant is more evenly distributed, but the main reason of this species playing second fiddle to S. friesii is its low coverage value.

Aphanothece naegelli, a colonial form, was found to be present and as evenly distributed as the

codominant but its low summation value is largely because of its very low coverage. Other unicellular forms, such as Chroococcus varius, C. pallidus, C. minutus and Synechococcus aeruginosus have high relative values of frequency, but due to their unicellular nature, they occupy little space, which may account for their low coverage values (Table 8). The lowest summation value of Phormidium tenue is mainly because of its lowest values of both the parameters of the community.

Species	Frequency	Relative Frequency	Coverage	Relative Coverage	Summation value
<u>Schizothrix friesii</u>	0.70	7.29	6.20	28.37	36.65
<u>Scytonema schmidtii</u>	0.90	9.37	4.7	21.72	31.09
<u>Scytonema stuposum</u>	0.60	6.35	2.21	10.10	16.35
<u>Lynbya palmarum</u>	0.75	7.81	1.80	8.27	16.08
<u>Anabaena variabilis</u>	0.60	6.25	1.93	8.82	15.07
<u>Schizothrix telephoroids</u>	0.40	4.16	1.50	6.86	11.02
<u>Aphanothece naegeli</u>	0.90	9.37	0.25	1.14	10.51
<u>Synechococcus aeruginosus</u>	0.80	8.85	0.33	1.50	10.35
<u>Anabaena anomala</u>	0.25	2.60	1.59	7.27	9.87
<u>Chroococcus pallidus</u>	0.80	8.30	0.12	0.54	8.84
<u>Chroococcus minutus</u>	0.75	7.81	0.15	0.68	8.49
<u>Chroococcus varius</u>	0.70	7.20	0.21	0.96	8.16
<u>Phormidium corium</u>	0.45	4.68	0.34	1.55	6.23
<u>Phormidium fragile</u>	0.35	3.64	0.13	0.59	4.24
<u>Phormidium tenue</u>	0.25	2.60	0.23	1.05	3.65
<u>Aphanothece pallida</u>	0.35	3.64	0.11	0.50	4.14

B. The vascular vegetation

The area is inhabited by Plantago - Cynodon community, dominated by Plantago ciliata and Cynodon dactylon (Table 9). The highest importance value of P. ciliata is equally shared by all the three attributes of the community. It regenerates in spring and dominates the area. It has got an edge over other herbs mainly because of its fondness for dry conditions and its unpalatable nature. In dry and exposed habitats, C.dactylon should have flourished well but it ebbed largely due to grazing.

Calendula arvensis, an important member of the community, is an annual weed of the crops of cold season. Its presence is because of the nearby cultivated fields where from it has escaped. Malcolmia cobulica and Astragalus tribuloides are other important members of the community.

Table 9: Attributes of vascular vegetation of Nowshera site.

Species	D	RD	F	RF	CC	RCC	IV
<u>Plantago ciliata</u>	124.73	77.68	0.95	33.21	0.47	56.83	167.72
<u>Cynodon dactylon</u>	14.57	9.07	0.72	25.17	0.168	20.31	54.55
<u>Malcolmia cobulica</u>	2.93	1.82	0.22	7.69	0.037	4.47	13.98
<u>Astragalus tribuloides</u>	2.96	1.84	0.21	7.34	0.036	4.35	13.53
<u>Calendula arvensis</u>	10.00	6.22	0.45	15.73	0.065	7.85	29.80
<u>Trigonopogon gracilis</u>	0.12	0.07	0.01	0.34	0.0009	0.10	0.51
<u>Stipa capensis</u>	2.30	1.43	0.13	4.54	0.025	3.02	8.99
<u>Filago pyramidata</u>	1.67	1.04	0.08	2.79	0.011	1.33	5.16
<u>Cenchrus ciliaris</u>	0.12	0.07	0.01	0.34	0.005	0.60	1.01
<u>Leptaleum filifolium</u>	0.50	0.31	0.04	1.39	0.003	0.36	2.06
<u>Herniaria hirsuta</u>	0.53	0.33	0.03	1.04	0.006	0.72	2.09
<u>Faconia critica</u>	0.12	0.07	0.01	0.34	0.0009	0.10	0.51

(D, Density; RD, Relative density; F, frequency; RF, Relative frequency;

CC, Canopy coverage; RCC, Relative canopy coverage; IV, Importance value).

4. Lawrencepur sites I, II & III

A. Algal vegetation

The open surface of the soil was found blank-
eted by the algal layer which in most of the places was
found restricted to patches, as a result of disturbance
caused by the activities of human beings and the grazing
animals. The process of recolonization of algae was
also very slow, partly due to disturbance and partly
because of harsh environmental conditions; the unprotec-
ted bare soil was, therefore, more susceptible to
erosion. On the bare soil the puddling effect of water
was found to be very great as compared to soil protected
by algal layer.

The bottoms and sides of gullies support poor
algal vegetation, mainly because of washing by the water
of run off. Sharp and steep slopes supported comparat-
ively rich algal growth, chiefly because of their inacc-
essibility to grazing animals.

The research site showed great resemblance in terms of pH, CaCO_3 content, texture and aridity of soil and the temperature extremes in summer and the winter with those of the other three sites namely Malkandhere, Azakhail and Nowshera.

The Communities

Blue-green algae dominated all the three stands sampled. A number of factors such as pH, extreme temperature accompanied with prolonged desiccation may be held responsible for the dominance of blue-green algae (Drouet, 1937; Bolyshhev, 1952; Sdobnikova, 1956; Lund, 1962; Fogg *et al.*, 1973; and Friedmann & Galun, 1974). Once the blue-green algae cover the ground, they do not permit other forms of algae to get established and remain abundant in the dry and hot months of July and August (Khan, 1983). The soil surface is sealed off by the coating of mucilaginous blue-green algae, which by the production of copious mucilage has a stabilizing effect on the soil (Round, 1973).

All the three stands were found inhabited by Schizothrix-Scytonema community dominated by Schizothrix friesii and Scytonema schmidtii (Table 10, 11 & 12). Species of Schizothrix and Scytonema can tolerate temperature as high as 112°C and 110°C respectively (Booth, 1946), which may partly account for the dominance of these plants. The high coverage values of these species may also be held responsible for shooting them into dominance. Nostoc is generally regarded as a seasonal dominant and frequently found in moist places (Singh, 1961; Round, 1973). It is represented by single species, viz. Nostoc muscorum in this area with comparatively low summation value which is partly because of its vulnerability to high temperature in summer (Venkataraman, 1964).

The summation values of the species of Chroococcus, Aphanothece and Synechococcus, which occur mostly as unicellular forms, are comparatively low, mainly because of their low relative values of coverage.

Protococcus viridis was the only representative of green algae. The presence of P. viridis can largely be due to its ability to withstand prolonged desiccation and absorption of atmospheric vapours (Fritsch, 1922b; and Schmid, 1927). The alkalinity and the aridity may account for the absence of diatoms, green and yellow-green algae, as the acidity and the low pH of the soil favour green algae (Petersen, 1915 & 1935; Coyle, 1935; Flint, 1958; Shields & Durrell, 1964; and Metting & Raybourn, 1979).

Table 10: Attributes of algal vegetation of Lawrencepur site I.

Species	Frequency	Relative frequency	Coverage	Relative coverage	Summation value
<u>Schizothrix friesii</u>	0.85	13.07	5.91	30.27	43.34
<u>Scytonema schmidtii</u>	0.95	14.61	4.73	24.23	38.84
<u>Anabaena anomala</u>	0.60	9.23	2.92	17.95	24.18
<u>Scytonema crustaceum</u>	0.75	11.53	1.38	7.06	18.59
<u>Nostoc muscorum</u>	0.30	4.61	1.92	9.83	14.44
<u>Phormidium ambiguum</u>	0.30	4.61	1.62	8.29	12.90
<u>Aphanothece naegeli</u>	0.60	9.23	0.39	1.99	11.22
<u>Synechococcus aeruginosus</u>	0.65	10.00	0.15	0.76	10.76
<u>Chroococcus pallidus</u>	0.60	9.23	0.11	0.56	9.79
<u>Protococcus viridis</u>	0.35	5.38	0.18	0.92	6.30
<u>Chroococcus minutus</u>	0.30	4.61	0.13	0.66	5.27
<u>Chroococcus varius</u>	0.25	3.84	0.08	0.40	4.24

Species	Frequency	Relative Frequency	Coverage	Relative Coverage	Summation Value
<u>Schizothrix friesia</u>	0.90	13.95	3.75	19.83	33.78
<u>Scytonema schmidtii</u>	0.65	10.07	3.95	20.88	30.95
<u>Scytonema bohneri</u>	0.50	7.75	2.81	14.55	22.60
<u>Nostoc muscorum</u>	0.60	9.30	1.75	9.25	18.55
<u>Aphanothece naegellii</u>	0.55	8.52	1.85	9.78	18.30
<u>Anabaena anomala</u>	0.35	5.42	2.12	11.21	16.63
<u>Phormidium fragile</u>	0.55	8.52	0.93	4.91	13.43
<u>Schizothrix telephoroides</u>	0.45	6.97	1.21	6.39	13.36
<u>Synechococcus aeruginosus</u>	0.70	10.85	0.14	0.74	11.59
<u>Chroococcus pallidus</u>	0.45	6.97	0.11	0.58	7.55
<u>Chroococcus minutus</u>	0.35	5.42	0.08	0.42	5.84
<u>Protococcus viridis</u>	0.40	6.20	0.21	1.11	7.31

Species	Frequency	Relative Frequency	Coverage	Relative Coverage	Summation Value
<u>Schizothrix friesii</u>	0.85	14.40	4.22	23.82	38.22
<u>Scytonema schmidtii</u>	0.80	13.55	3.75	21.17	34.72
<u>Scytonema bohneri</u>	0.60	10.16	2.91	16.43	26.59
<u>Nostoc muscorum</u>	0.35	5.93	2.11	11.91	17.84
<u>Phormidium fragile</u>	0.35	5.93	2.01	11.34	17.27
<u>Schizothrix telephoroids</u>	0.45	7.62	1.31	7.39	15.01
<u>Synechococcus aeruginosus</u>	0.60	10.16	0.16	0.90	11.06
<u>Scytonema stuposum</u>	0.45	7.62	0.51	2.87	10.49
<u>Aphanothece naegeli</u>	0.50	8.47	0.32	1.80	10.27
<u>Protococcus viridis</u>	0.35	5.93	0.21	1.18	7.11
<u>Chroococcus pallidus</u>	0.35	5.93	0.08	0.45	6.36
<u>Chroococcus minutus</u>	0.25	4.23	0.12	0.67	4.90

B. The vascular vegetation

The vascular vegetation is composed of the annuals and the perennials. Most of the shallow rooted annuals are washed away by the water of run off during heavy rains particularly in gullies. The light textured soil fails to retain moisture for a longer period of time. With the onset of summer, the amount of rainfall declines and the soil is gradually depleted in moisture. Most of the annuals complete their life cycles in short period of time for tiding over the harsh inhospitable conditions of drier and hot summers.

All the perennials are grasses. Woody species such as Prosopis glandulosa, Ziziphus numularia, Acacia modesta, Capparis decidua are sporadic. Dalbergia sissoo was also noticed especially in the low lying moist places. Z. numularia, P. glandulosa, A. modesta and C. decidua are common species of the semiarid localities. P. glandulosa grows successfully in arid conditions (Troup, 1921), as this species does not depend entirely on

the availability of surface moisture, but can extend its roots at least 20 m into the soil, to reach and tap the underground fresh water (Went, 1955; and Meinzer, 1927). These species have greatly been damaged because of chopping and grazing. In case the area remains protected, these species would have dominated the area.

Cynodon dactylon was the leading dominant in two of the three stands sampled (Tables 13, 14 & 15). The third stand was dominated by Plantago ciliata with Cynodon dactylon as codominant. The dominance of C. dactylon can mainly be because of its superb capability of competition in open and dry places and its remarkable tolerance to desiccation and high temperature (Burton, 1944; Anon, 1958; Ramakrishnan & Singh, 1966; and Woodhouse, 1968). Overgrazing and palatable nature of this species have affected its importance value in the third stand (Table 15), yet it has managed to outcompete other herbs in at least two stands. P. ciliata, like other plantains, is believed to be associated with grassland communities (Sagar & Harper, 1960).

Species	D	RD	F	RF	CC	RCC	IV
<u>Cynodon dactylon</u>	13.94	15.99	0.541	15.19	0.378	14.94	46.12
<u>Filago pyramidata</u>	17.47	20.04	0.347	9.47	0.19	7.50	37.01
<u>Erianthus griffithii</u>	1.70	1.95	0.164	4.50	0.598	23.63	30.18
<u>Astragalus tribuloides</u>	6.11	7.93	0.341	9.57	0.21	8.30	25.80
<u>Plantago ciliata</u>	8.23	9.44	0.30	8.42	0.092	3.63	21.49
<u>Medicago aschersoniana</u>	6.00	7.81	0.188	5.94	0.14	6.95	19.70
<u>Bromus laeonicus</u>	6.29	7.21	0.288	8.08	0.11	4.34	19.63
<u>Scabiosa olivieri</u>	5.05	5.79	0.241	6.76	0.103	4.07	16.62
<u>Silene arenosa</u>	3.58	4.10	0.20	5.61	0.07	2.76	12.47
<u>Chrysanthemum serrulatum</u>	0.83	0.95	0.076	2.13	0.228	9.01	12.09
<u>Cenchrus ciliaris</u>	2.11	2.42	0.135	3.79	0.112	4.42	10.63
<u>Lactuca dissecta</u>	0.94	1.07	0.088	2.47	0.025	0.98	4.52
<u>Arenaria serpyllifolia</u>	1.29	1.48	0.064	1.79	0.027	1.06	4.33
<u>Malcolmia cobulica</u>	0.70	0.80	0.058	1.62	0.021	0.83	3.25
<u>Ifloga spicata</u>	1.00	1.14	0.052	1.46	0.015	0.59	3.19
<u>Calendula arvensis</u>	0.94	1.07	0.041	1.15	0.024	0.94	3.16
<u>Herniaria hirsuta</u>	0.64	0.73	0.047	1.32	0.006	0.23	2.28

Species	D	RD	F	RF	CC	RCC	IV
<u>Cynodon dactylon</u>	21.37	22.13	0.66	21.49	0.35	27.77	71.39
<u>Plantago ciliata</u>	40.76	42.22	0.68	22.14	0.30	23.80	88.16
<u>Medicago laciniata</u>	9.11	9.47	0.47	15.30	0.10	7.93	32.66
<u>Filago pyramidata</u>	9.55	9.89	0.358	11.66	0.08	6.34	27.89
<u>Malcolmia cobulica</u>	3.18	3.29	0.161	5.24	0.05	3.96	12.49
<u>Cenchrus ciliaris</u>	1.37	1.41	0.096	3.12	0.08	6.34	10.87
<u>Cousinia minuta</u>	2.94	3.04	0.12	3.90	0.05	3.96	10.90
<u>Cymbopogon lawarancusa</u>	1.29	1.33	0.10	3.25	0.09	7.14	11.72
<u>Astragalus tribuloides</u>	1.57	1.62	0.125	4.07	0.03	2.38	8.07
<u>Desmostachya bipinnata</u>	0.84	0.87	0.044	1.43	0.06	4.76	7.06
<u>Asphodelus tenuifolius</u>	0.96	0.99	0.04	1.30	0.015	1.19	3.48
<u>Scabiosa olivieri</u>	0.68	0.70	0.048	1.56	0.012	0.95	3.21
<u>Linum strictum</u>	0.84	0.87	0.04	1.30	0.017	1.34	3.51
<u>Bromus japonicus</u>	0.60	0.62	0.048	1.56	0.01	0.79	2.97
<u>Arenaria serpyllifolia</u>	0.88	0.91	0.04	1.30	0.008	0.63	2.84
<u>Tragopogon gracilis</u>	0.40	0.41	0.02	0.65	0.01	0.79	1.85
<u>Lactuca dissecta</u>	0.20	0.20	0.02	0.65	0.002	0.15	1.00

Species	D	RD	F	RF	CC	RCC	IV
<u>Cynodon dactylon</u>	21.54	27.56	0.842	37.65	0.37	41.76	106.97
<u>Plantago ciliata</u>	30.83	39.45	0.386	17.26	0.12	13.54	70.25
<u>Cymbopogon javarancusa</u>	3.80	4.86	0.207	9.25	0.12	13.54	27.65
<u>Desmostachya bipinnata</u>	4.52	5.78	0.204	9.12	0.11	12.41	27.41
<u>Medicago aschersoniana</u>	7.64	9.77	0.232	10.37	0.069	7.78	27.92
<u>Bromus japonicus</u>	3.68	4.70	0.047	3.30	0.029	3.27	11.27
<u>Filago pyramidalis</u>	3.18	4.06	0.058	2.59	0.018	2.03	8.68
<u>Scabiosa olivieri</u>	1.14	1.45	0.077	3.44	0.017	1.91	6.80
<u>Cechrus ciliaris</u>	0.46	0.58	0.040	1.78	0.014	1.58	3.94
<u>Linum strictum</u>	0.49	0.62	0.043	1.92	0.006	0.67	3.21
<u>Tragopogon gracilis</u>	0.34	0.43	0.03	1.34	0.003	0.33	2.10

This species was recorded from all the three stands and possessed comparatively high importance values. It appears in spring and grows well in arid localities. Its high importance values were largely because of its unpalatable nature, its ability to grow in drier places and its endurance to high temperature and low moisture conditions (Stewart, 1958).

Filago pyramidata is a co-dominant in one of the stand (Table 13) and its high importance value is mainly because of its highest value of relative density. Medicago aschersoniana was reported from two stands (Tables 13 & 15); while Medicago laciniata was noticed in one stand (Table 14). These species invade the moist sites quite early in winter and then spread to drier habitats, where they persist for a longer period of time (Chaghtai & Khattak, 1983). The presence of these plants may be attributed to the fact that their seeds may have spread from the nearby crop fields as they are annual weeds of winter crops. Calendula arvensis and Herniaria hirsuta are reported from one stand. The presence of C. arvensis,

an annual weed of the crops of cold season, may largely be attributed to the light soil and the proximity of the crop fields, which serve as a source of seeds (Luthra, 1933). It has got a strong tap root system and once it reaches the area it gets itself firmly established (Chaghtai & Khattak, 1983). The abundance of H. hirsuta, an annual winter weed, may be attributed to the dryness of the area (Rhopal & Chaudri, 1977; and Stewart, 1958). Cenchrus ciliaris, a plant of exposed and dry habitats (Chaghtai et al., 1983), was invariably noticed in all the three stands.

Desmostachya bipinnata was present in only one of the stands (Table 14). This plant grows in exposed and dry places (Salim & Shahid, 1973) and is an indicator of soil moisture conditions (Hussain, 1964). In spite of high rainfall in Potohar Plateau xeric conditions prevail there, which are chiefly because of the poor retention of moisture by the upper porous layers of the soil. D. bipinnata overcomes this situation by sending down

its roots into the deeper layers of the soil (Chaghtai et al., 1978). In this plant roots are three to eight times the size of the aerial parts (Hussain, 1964). Its low importance value is largely because of its palatable nature which makes the cattle graze upon it.

Cymbopogon jamarancusa, a plant of slightly alkaline soils (Hussain, 1964), was reported from two stands (Tables 14 & 15). Malcolmia cobulica, an annual winter weed, was present in two stands. It appears early in winter and remains confined to relatively moist places. Its very low importance values may be probably because of the drier conditions to which it seems to be sensitive. Some other weeds recorded were Astragalus tribuloides, Scabiosa olivieri, Lactuca dissecta, Linum strictum, Arenaria serpyllifolia, Silene arenosa and Ifloga spicata. These species fail to give a significant impression which is quite clear from their low importance values.

Coefficient of algal community

Lawrencepur stands II and III

A highest value of coefficient of community was recorded for stands II and III of Lawrencepur, both supporting Schizothrix - Scytonema communities dominated by Schizothrix friesii and Scytonema schmidtii collectively. (Tables 11 & 12). The highest value of coefficient of community between these two stands indicates the highest degree of similarity (85 percent), which is further manifested by a relatively greater number of species they shared (Tables 16 & 17). The two communities support 12 species each, out of which 11 are common to both the stands, which may largely account for the highest degree of similarity. The higher values of coefficient of community and degree of similarity is mainly because of the proximity of the two stands.

Malkandhere and Azakhail stands

The value of coefficient of community which

manifests the degree of similarity between the two stands was found to be 60. They shared 8 species (47 percent). Both the communities are dominated by Schizothrix friesii and Scytonema schmidtii collectively (Tables 4 & 6). Of a total number of 14 species recorded in Azakhail stand, 8 are common to Malkandhere stand (Table 17). The coefficient of community is high on comparative basis because of the relatively high degree of similarity.

Lawrencepur stands I and II

A comparatively higher coefficient of community was observed for the communities of Lawrencepur stands I and II (Table 16). Both the stands are inhabited by Schizothrix - Scytonema communities. The two communities shared 9 species i.e. 66 percent of the total number of species occurring in both the communities (Table 17). The higher value of coefficient of community is mainly because of the proximity of the stands and the similar environmental conditions prevailing there. Both the communities support the same number of species which may

partly account for relatively high degree of similarity.

Azakhail and Lawrencepur stand II

The coefficient of community for the stands of Azakhail and Lawrencepur stand II was found to be 67 (Table 16). Both the communities were dominated by Schizothrix friesii and Scytonema schmidtii collectively (Tables 6 & 11). Of the total number of 12 species present in Lawrencepur stand II, 10 are common to the Azakhail stand. The community of Azakhail was more open than the community of Lawrencepur stand II, because of its early successional status, and therefore offers more niches than the later stand.

Azakhail and Nowshera stands

There are 8 species common to the communities of Azakhail and Nowshera stands (Table 17). The value of degree of similarity (36 percent) and the coefficient of community (54) is comparatively low (Tables 16 & 17).

The number of common species apparently gives an impression of high degree of similarity, but in fact both the communities shared 36 percent of the total number of species occurring in them. The low degree of similarity is largely because of the marked difference in the species the two communities support.

Malkandhere and Lawrencepur stand I

The lowest value of coefficient of community was recorded for the stands of Malkandhere and Lawrencepur stand I. Both the stands are inhabited by Schizothrix-Scytonema communities collectively. The two communities only share 5 species (28 percent) among them which is a record lowest of all the pairs of stands compared here (Table 17). A very low coefficient of community (39), reflects the magnitude of dissimilarity in the species composition exhibited by these stands (Table 16).

A comparatively low value of W coupled with high value of $a + b$ is largely responsible for low coefficient of

community. The main reason for low value of W is that the pattern of dispersion of the common species in the two communities touches both the extremes.

Table 16: The matrix of values of coefficient of algal community.

	Malkandhere <u>Sch-Scy</u>	Azakhail <u>Sch-Scy</u>	Nowshera <u>Sch-Scy</u>	Lawrencepur I <u>Sch-Scy</u>	Lawrencepur II <u>Sch-Scy</u>	Lawrencepur III <u>Sch-Scy</u>
Malkandhere <u>Sch-Scy</u>	--	60	50	39	42	52
Azakhail <u>Sch-Scy</u>	--	--	54	50	67	62
Nowshera <u>Sch-Scy</u>	--	--	--	52	58	57
Lawrencepur I <u>Sch-Scy</u>	--	--	--	--	69	65
Lawrencepur II <u>Sch-Scy</u>	--	--	--	--	--	79
Lawrencepur III <u>Sch-Scy</u>	--	--	--	--	--	--

(Sch, Schizothrix; Scy, Scytonema)

Table 17: The matrix of the number of common species, and average values of the percentage values of common species.

	<u>Malkandhere</u> <u>Sch-Scy</u>	<u>Azakhail</u> <u>Sch-Scy</u>	<u>Nowshera</u> <u>Sch-Scy</u>	<u>Lawrencepur I</u> <u>Sch-Scy</u>	<u>Lawrencepur II</u> <u>Sch-Scy</u>	<u>Lawrencepur III</u> <u>Sch-Scy</u>
<u>Malkandhere</u> <u>Sch-Scy</u>	--	8(47)	7(35)	5(28)	7(44)	8(54)
<u>Azakhail</u> <u>Sch-Scy</u>	--	--	8(36)	7(37)	10(63)	10(63)
<u>Nowshera</u> <u>Sch-Scy</u>	--	--	--	8(40)	9(47)	9(47)
<u>Lawrencepur I</u> <u>Sch-Scy</u>	--	--	--	--	9(66)	8(50)
<u>Lawrencepur II</u> <u>Sch-Scy</u>	--	--	--	--	--	11(85)
<u>Lawrencepur III</u> <u>Sch-Scy</u>	--	--	--	--	--	--

(Sch, Schizothrix; Scy, Scytonema)

Coefficient of vascular community

Azakhail and Nowshera stands

A maximum value of coefficient of community (86) was observed for the communities of Azakhail and Nowshera stands (Table 18). Both the communities were dominated by Plantago ciliata and Cynodon dactylon collectively. They shared 8 species i.e. 50 percent of the total species (16), occurring in both the communities (Table 19).

Lawrencepur stands II and III

A relatively high value of coefficient of community was recorded for Cynodon - Plantago and Plantago - Cynodon communities (Table 18). The two communities not only support a maximum number of species, but also shared 12 species (71 percent) among them—a maximum of all the pairs of communities, yet the coefficient of community is comparatively low (65), mainly because of relatively low value of W and high value of $a + b$. The $a+b$ value

which is the sum of the percentages of the total number of species in the two stands is higher because of comparatively greater number of species which the two stands support. The low value of W can be attributed to the pattern of distribution of the species in the two stands.

Malkandhere and Lawrencepur stand III

There are 4 species common to Stipa-Plantago and Plantago-Cynodon communities, and this constitutes 20 percent of the total number of species occurring in the two communities (Table 19). The lowest degree of similarity gives an idea of the lowest value of coefficient of community, yet the coefficient of community is comparatively high mainly because of the high value of W and low value of $a+b$.

Malkandhere and Lawrencepur stand I

A minimum value of coefficient of community (20)

was observed for the Stipa - Plantago and Cynodon - Filago communities (Table 18). There are 7 species (32 percent) common to both the communities (Table 19). Both the communities support 22 species. The lowest value of coefficient of community is primarily because of the low value of W coupled with high value of $a + b$.

Table 18: The matrix of values of coefficient of vascular community.

	Malkandhere Sti-Plan	Azakhail Plan-Cyn	Nowshera Plan-Cyn	Lawrencepur I Cyn-Fil	Lawrencepur II Cyn-Plan	Lawrencepur III Plan-Cyn
Malkandhere Sti-Plan	--	41	49	20	34	24
Azakhail Plan-Cyn	--	--	86	42	62	50
Nowshera Plan-Cyn	--	--	--	42	58	48
Lawrencepur I Cyn-Fil	--	--	--	--	57	48
Lawrencepur II Cyn-Plan	--	--	--	--	--	65
Lawrencepur III	--	--	--	--	--	--

(Sti, Stipa; Plan, Plantago; Cyn, Cynodon; Fil, Filago)

Table 19: The matrix of the number of common species; the figures in parentheses are the percentage values of common species.

	Malkandhere Sti-Plan	Azakhal Plan-Cyn	Nowshera Plan-Cyn	Lawrencepur I Cyn-Fil	Lawrencepur II Cyn-Plan	Lawrencepur III Plan-Cyn
Malkandhere Sti-Plan	--	6(33)	9(60)	7(32)	6(26)	4(20)
Azakhal Plan-Cyn	--	--	8(50)	10(53)	10(53)	8(50)
Nowshera Plan-Cyn	--	--	--	8(38)	7(32)	6(33)
Lawrencepur I Cyn-Fil	--	--	--	--	10(42)	8(38)
Lawrencepur II Cyn-Plan	--	--	--	--	--	12(71)
Lawrencepur III Plan-Cyn	--	--	--	--	--	--

(Sti, Stipa; Plan, Plantago; Cyn, Cynodon; Fil, Filago)

Sheet Erosion

In a field experiment, 50 litres of the water of run off from algae-covered plot appeared almost clear and contained only 50 g of soil; whereas the same quantity of the water of run off from bare surface was found to be quite muddy and contained 725 g of soil in a unit time.

The soil binding quality of the algae is largely because of the organic matter they add to the soil. The soil algae are usually considered primary colonizers and add organic carbon through photosynthesis and organic nitrogen through nitrogen fixation. They usually form closely intertwined rope-like bundles in the soil which help in binding the soil particles (Lee, 1980). Furthermore, the soil algae are characterized by the secretion of mucilagenous substances which alongwith other organic excretions from their bodies proved to be very effective in cementing the soil grains into aggregates (Daubenmire, 1965). The well-aggregated soil having a slippery texture due to the presence of extramucilagenous sheath seems

to resist the force of the water of run off more effectively; and this factor alone may account for the different rate of erosion of soil from bare and algae-inhabited soils which comes out to be 15:1.

Puddling Effect of Rain

In order to study the puddling effect of rain, an attempt has been made to simulate the conditions prevailing in nature as much close as possible. The detail of the result obtained on bare soil is as follows:-

- i. Duration of experiments = 15 minutes.
- ii. Total number of drops poured = 180
- iii. Time interval between two successive drops = 5 sec.
- iv. Weight of one drop = 0.06 g
- v. Height from which drops were poured = 1 m
- vi. Force with which each drop struck the soil = 6×10^{-4} N
(N = Newton).
- vii. Diameter of single puddle = 1.6 cm
- viii. Area of single puddle = 1.88 cm^2
- ix. Weight of soil displaced in 15 minutes = 2.5 g
- x. Weight of soil displaced/ m^2 (in 15 minutes) = 13.3 kg
- xi. Weight of soil displaced per hectare = 133000 kg
- xii. Replicates = 3

The crumbling of soil aggregates, because of the impact of rain drops, is significantly reduced by the presence of algal layer cover on the soil. The mucilage of soil algae and other organic compounds which they add to the soil stabilize the soil particles (Daubenmire, 1965). This stabilized surface reduces the intensity of rain drops and thus helps in checking displacement of soil and erosion. On algae covered soil, no puddling effect was noticed; whereas the same volume of water, when dropped on bare surfaces, resulted in fair displacement of soils making puddles of various sizes (Table 20). The difference in results is primarily because of the fact that algae covered soil resisted more efficiently to the effect of water drops than the bare surfaces. A considerable amount of the soil displaced due to puddling is lost in sheet erosion.

Table 20: Puddling on bare soils.

	Quantity of water poured (ml)	Height (m)	Volume of puddle (ml)	Weight of soil displaced (g)
Malkandhere	10	1	1.90 ± 0.43	2.50
Azakhail	10	1	2.50 ± 0.43	3.00
Nowshera	10	1	1.20 ± 0.61	1.50
Lawrencepur I	10	1	1.01 ± 0.45	1.30
Lawrencepur II	10	1	2.30 ± 0.57	2.80
Lawrencepur III	10	1	1.80 ± 0.69	2.20

Infiltration of Water

Results of infiltration tests on algaecovered and bare soils indicate that water took almost the same time to enter both types of soils and the rate of infiltration was not slowed down by the presence of an algal crust (Table 21).

Table 21: Infiltration of water

Stand	Time (minutes) of infiltration of water	
	Algae-covered soil	Bare soil
Malkandhere	30.50	30.00
Azakhail	29.75	28.25
Nowshera	23.25	23.00
Lawrencepur I	32.25	31.75
Lawrencepur II	25.00	24.00
Lawrencepur III	26.50	26.00

CONCLUSION

1. Dry and arid localities were found dominated by the communities of blue-green algae largely because of their tolerance to these conditions and their ability to flourish well in high pH. Yellow-green algae and diatoms were found absent mainly because of their susceptibility to the adverse environmental conditions.
2. The only green alga found associated with blue-green forms was Protococcus viridis, which had managed to keep pace with the blue-green forms chiefly because of its ability to use gaseous water.
3. Schizothrix friesii and Scytonema schmidtii were the dominant and frequent members of the algal communities.
4. The algal communities were dominated by filamentous blue-green forms. Unicellular and colonial forms were less frequent. No filamentous green alga was recorded.

5. The algal communities were found in patches of various sizes mainly because of biotic disturbances. In undisturbed places the algal vegetation flourished well covering almost the entire land.
6. The soil algal flora was found to be more tolerant to high temperature and desiccation as compared to vascular vegetation.
7. The algal layer was found to bind the soil surface particles into non-erosible layer. The ratio of soil loss by sheet erosion from algae-protected and bare surface was found to be 1:15.
8. The puddling effect of rain was greatly minimised by the presence of algal layer.
9. The higher vegetation was mainly composed of annuals appearing in early spring and completing their life cycles before the onset of summer.
10. The most frequent and dominant species recorded was Plantago ciliata. It had outcompeted other herbs. Perennial forms were rare and Cynodon

dactylon was relatively more common than the others.

In spite of its ability to compete other herbs in open and dry habitats, C. dactylon has comparatively low importance value largely because of the heavy grazing pressure it has to bear.

11. The soil was silt loam in texture in all the stands, with high silt and low clay contents. It was alkaline in nature and CaCO_3 percentage was comparatively high.

ACKNOWLEDGEMENTS

I am greatly indebted to my Supervisor, Prof: Dr.M.A.F. Faridi for suggesting the problem, guidance, encouragement, valuable suggestion and criticism throughout the course of these investigations. I wish to express my sincere gratitude for the unfailing help I have received from Prof: Dr.S.M. Chaghtai. He was kind enough to guide whenever I needed his help.

Special thanks are due to Dr. Miss Ghazala Anjum for providing literature, her help and guidance. I would like to reflect my thanks to my colleagues, friends and students particularly Prof: Muhammad Ibrar, Prof:Dr.Jehandar Shah, Prof: Sardar Hussain Shah, Prof: Abdus Sadiq and Prof: H.R, Khattak for their help in one way or the other.

I am obliged to the University of Peshawar and Principal, Islamia College, Peshawar for allowing me as a full time Ph.D. Scholar. Thanks are also due to Dr. Islam Mahmood Khan, Chairman Botany Department for providing the necessary facilities for the research work. I am thankful to Mr. Bashir Ahmad for typing the final manuscript.

LITERATURE CITED

- Agardh, C.A. 1812. *Disposito Algarum Suecial. Lundae.*
- Agardh, C.A. 1817. *Synopsis Algarum Scandinaviae. Lundae.*
- Akiyama, M. 1966. Some algal vegetation of gamma-irradiated field and natural strongly radioactive district in Japan. *Bull. Shimane Univ. Nat. Sci.*, 16: 20-31.
- Aleksandrova, I.V. 1951. The process of humus formation in several primitive mountain soils. *Pochvovedenie* 1951 : 604-616.
- Anantani, Y.S. and K.V. Marathe. 1972a. Observations on algae of some arid and semi-arid soils of Rajasthan. *J. Univ. Bombay*, 41: 88-91.
- Anantani, Y.S. and K.V. Marathe. 1972b. Soil aggregation effects of some algae occurring in the soils of Kutch and Rajasthan. *J. Univ. Bombay*, 41 : 94-100.
- Anjum, G. 1981. Studies on some soil algae of N.W.F.P. Pakistan. Ph.D. Thesis, Univ. of Pesh., Peshawar.

- Anjum, G. and M.A.F. Faridi. 1982. Some heterocystis blue-green algae fixing atmospheric nitrogen, from soils of N.W.F.P. (Pakistan). Reg. Plant Sci. Conf. Bot. Deptt. Univ. of Pesh., Peshawar 19 p.
- Anjum, G. and M.A.F. Faridi, 1982. The genus Chlorosarcinopsis from the soils of D.I. Khan and Peshawar. Reg. Plant Sci. Conf. Bull. Bot. Deptt. Univ. of Peshawar pp. 19.
- Anjum, G. and Y. Akhtar, 1983. Some soil algae from the sugar cane fields of Mardan District. Pakistan, 8 : 185-207.
- Anonymous, 1958. Introduced grasses and legumes. Section 5: Series Pasture and Land plants. Phillips Petroleum Co., U.S.A., 25 p.
- Anonymous. 1964. Book of ASTM Standards. Part II. Bituminous materials for highway construction, water-proofing, and roofing; Soil, Philadelphia.
- Archibald, P.A. 1969. A study of the algal flora of bogs with special refrence to the genus Chlorococcum. Ph.D. Dissertation, Univ. of Texas, Austin.

- Ayres, Q.C. 1936. Soil erosion and its control. McGraw-Hill Book Comp., Inc. New York. 1-19 p.
- Baily, D., A.P. Mazurak and J.R. Rosowski. 1973. Aggregation of soil particles by algae. J. Physcol., 9: 99-101.
- Baver, L.D. 1935. Soil Erosion in Missouri Mo. Agr. Exp. Sta. Bull. 349, 66 pp.
- Benoit, R.E. and R.E. Cameron, 1967. Microbial ecology of some dry valley soils of Antarctica. Proc. 1967: 3.
- Benoit, R.E. and C.L. Hall, Jr. 1970. The microbiology of some dry valley soils of Victoria Land, Antarctica. In: M. Holdgate (ed.). Antarctic ecology. Academic Press, NY.
- Bhopal, F.G. and M.N. Chaudri. 1977. Flora of Pothohar and the adjoining areas. Part I, The Centrospermae. Pak. Systematics, 1: 38-128.
- Bolyshev, N.M. 1952. The origin and evolution of takyr soils. Pochvovedenie, 5: 403-417.

- Bolyshev, N.N. 1955. The origin and evolution of takyr soils. Moscow Univ. Press, Moscow.
- Bolyshev, N.N. 1968. Algae and their role in the foundation of soils. Moscow Univ. Press., Moscow.
- Bolyshev, N.N. and L.N. Novichkova - Ivanova. 1978. The algal flora of initial stages of soil formation on blanket loams under the condition of a lysimeter. Bot. Zurn. (Moscow & Leningrad). 63: 690-696.
- Bond, R.D. and J.R. Harris. 1964. The influence of the microflora on physical properties of soils. I. Effects associated with filamentous algae and fungi. Austral. J. Soil Res., 2: 111-122.
- Booth, W.E. 1941a. Algae as poineers in plant succession and their importance in erosion control. Ecology, 22: 38-46.
- Booth, W.E. 1941b. Revegetation of abandoned fields in Kansas and Oklahoma. Amer. J. Bot., 28: 415-423.
- Booth, W.E. 1946. The thermal death point of certain soil inhabiting algae. Proc. Montana Acad. Sci., 5/6: 21-23.

- Bornet, E. and C. Flahault. 1886-1888. Revision des Nostocaceae Heterosystees. Ann. Sci. Nat. Ser. VII. Bot. I, III, IV, VII.
- Brannon, M.S. 1945. Factors affecting growth and distribution of Myxophyceae in Florida. Proc. Florida Acad. Sci., 8: 296-303.
- Bredemuhl, I. 1949. Über die verbreitung der Erddiatomeen. Arch. Microbiol. 14: 407-449.
- Bristol, B. M. 1919. On the retention of vitality by algae from old stored soils. New Phytol. 18: 92-107.
- Bristol-Roach, B.M. 1926. On the relation of certain soil algae to some soluble carbon compounds. Ann. Bot. 60: 149-200.
- Bristol-Roach, B.M. 1927a. On the algae of some normal English soils. J. Agric. Sci., 17: 563-598.
- Bristol-Roach, B.M. 1927b. On the carbon nutrition of some algae isolated from soil. Ann. Bot. 41: 509-517.

Bristol-Roach, B.M. 1928a. On the influence of light and of glucose on the growth of a soil algae. *Ann. Bot.* 42: 317-345.

Bristol-Roach, B.M. 1928b. The present position of our knowledge of the distribution and function of algae in the soil. *Proc. Ist. Inter. Cong. Soil. Sci.*, 3: 30-38.

Bunt, J.S. 1954. A comparative account of the terrestrial diatoms of Macquarie Island. *Proc. Linn. Soc. New South Wales*, 79: 40-53.

Burton, G.W. 1944. Seed production of several southern grasses as influenced by burning and fertilization. *Amer. Soc. Agron. J.*, 36: 523-529.

Cameron, R.E. 1960. Communities of soil algae occurring in the Sonoran Desert in Arizona. *J. Arizona Acad. Sci.*, 1: 85-88.

Cameron, R.E. 1961. Algae of the Sonoran Desert in Arizona. Ph.D. Dissertation, Univ. of Arizona, Tucson.

- Cameron, R.E. 1962a. Species of Nostoc Vaucher occurring in the Sonoran Desert in Arizona. Trans. Amer. Microscop. Soc., 81: 379-384.
- Cameron, R.E. 1962b. Soil studies - Microflora of desert regions. J.P.L. Space Programs Summary. No. 37-15. Vol. IV: 12-20.
- Cameron, R.E. 1963a. Algae of southern Arizona. Part I. Introduction-Blue-green algae. Rev. Algol. N.S., 6: 282-318.
- Cameron, R.E. 1963b. Morphology of representative blue-green algae. Ann. New York Acad. Sci., 108: 412-420.
- Cameron, R.E. 1964a. Terrestrial algae of southern Arizona. Trans. Amer. Microscop. Soc., 133: 212-218.
- Cameron, R.E. 1964b. Algae of southern Arizona. Part II. Algal flora (exclusive of blue-green algae). Rev. Algol. N.S., 7: 151-177.
- Cameron, R.E. 1966. Soil studies - desert microflora. XIII. Identification of some algae from Antarctica. J.P.L. Space Programs Summary 37-40, IV: 123-133.

- Cameron, R.E. 1969. Abundance of microflora in soils of desert regions. J.P.L. Tech. Report. 32-1378.
- Cameron, R.E. 1970. Soil microbial ecology of Valley of 10,000 Smokes, Alaska. J. Arizona Acad. Sci., 6: 11-40.
- Cameron, R.E. 1971. Antarctic soil microbiological and ecological investigations. In: L. Quam (ed.). Research in Antarctica, AAAS, Washington, D.C.
- Cameron, R.E. 1972a. Ecology of blue-green algae in Antarctic soils. In: T.V. Desikachary (ed.). The taxonomy and biology of blue-green algae. Symposium at Madras, India.
- Cameron, R.E. 1972b. A comparison of soil microbial ecosystems in hot, cold, and popular desert regions. In: L.E. Rodin (ed.). Ecophysiological foundation of ecosystem productivity in arid Zones. Leningrad, Nauka.
- Cameron, R.E. and G.B. Blank. 1965. Soil studies-Microflora of desert regions. VIII. Distribution and abundance of desert microflora. J.P.L. Space Programs Summary 37-34, IV: 193-201.
- Cameron, R.E. and G.B. Blank. 1966a. Desert algae; Soil Crusts and diaphanous substrata as algal habitats. J.P.L. Tech. Report, 32-971.

Cameron, R.E. and G.B. Blank. 1966b. Soil studies. Desert microflora. XI. Desert soil algae survival at extremely low temperature. J.P.L. Space Programs Summary 37-37, IV: 174-181.

Cameron, R.E. and H.P. Conrow, 1969a. Antarctic dry valley soil microbial incubation and gas composition. Antarctic J.U.S. 4: 28-33.

Cameron, R.E. and H.P. Conrow, 1969b. Soil moisture, relative humidity, and microbial abundance on dry valleys of Southern Victoria Land. Antarctic J.U.S. 4: 23-28.

Cameron, R.E. and J.R. Devaney. 1970. Antarctic soil algal crusts: scanning electron and optical microscope study. Trans. Amer. Microscop. Soc., 89: 264-273.

Cameron, R.E., D.R. Gensel and G.B. Blank. 1966. Soil studies - Desert microflora. XII. Abundance of microflora in soil samples from the Chile Atacama Desert. Supportive research and advance development. J.P.L. Space programs Summary 37-38, IV: 140-147.

- Cameron, R.E. and J.A. Houghton. 1978. The effects of fertilizers on the algal flora of peat. *Proc. Roy. Irish Acad. Ser. B*, 78: 233-246.
- Cameron, R.E. and J. King. 1970a. Soil microbial ecology of Wheeler Valley, Antarctica. *Soil Sci.*, 109: 110-120.
- Cameron, R.E. and J. King. 1970b. Microbiology, ecology and microclimatology of soil sites in dry valleys of Southern Victoria Land, Antarctica, In: M.Holdgate (ed.). *Antarctic ecology*. Academic Press, London.
- Cameron, R.E., J. King and C.N. David. 1970. Microbiology, ecology and microclimatology of soil sites in dry valleys of Southern Victoria Land, Antarctica. In: M.W. Holdgate (ed.). *Antarctic ecology*. Academic Press, N.Y.
- Cameron, R.E., C.N. David and J.King 1968. Soil toxicity in Antarctic dry valleys. *Antarctic J.U.S.* 3: 164-166.

- Cameron, R.E., F.A. Morelli and G.B. Blank. 1965a.
Soil studies-microflora of desert regions.
IV. Soil extract as a culture medium. J.P.L.
Space Programs Summary 37-32, IV: 202-208.
- Cameron, R.E., F.A. Morelli and G.B. King. 195 b. Soil
studies-Desert microflora. VI. Abundance of
microflora in an area of soil at White Mountain
Range, California. J.P.L. Space Programs
Summary 37-32, IV: 212-214.
- Carson, J.L. and R.M. Brown. Jr. 1976. The correlation
of algae and fern spores with meteorological
conditions on the Island and Hawaii. Pacific
Sci., 30: 197-205.
- Chaghtai, S.M. and S.H. Shah. 1978. Determination of
coefficient of community for the plant comm-
unities of the graveyards of Peshawar District.
J.Sci. Tech., 2(1-2): 1-6.
- Chaghtai, S.M., S.H. Shah and M.A. Akhtar. 1978.
Phytosociological study of the graveyards
of Peshawar District, NWFP, Pakistan. Pak.
J.Bot., 10: 17-30.

- Chaghtai, S.M. and H.R. Khattak. 1983. Ecology of a dry stream bed in Peshawar, Pakistan. Pak. J. Bot., 15 (2): 93-98.
- Chaghtai, S.M., N. Muhammad and H.R. Khattak. 1983. Phytosociology of the Muslim graveyards of Kohat Division, NWFP, Pakistan. Pak. J. Bot., 15 (2): 99-108.
- Coulson, A.L., 1941. The underground water supply of Peshawar and Mardan Districts of N.W.F.P. (Records of the Geological Survey of India, No. 74).
- Cox, G.W. 1967. Laboratory Manual of General Ecology. Wm. C. Brown Co. Publishers, Iowa, 165 p.
- Coyle, E.E. 1935. Algae of some Ohio Soils, Ph.D. Dissertation, Ohio State Univ., Columbus.
- Culberson, W.L. 1955. The corticolous communities of lichens and bryophytes in the Upland forests of northern Wisconsin. Ecol. Monog., 25: 215-231.

- Danin, A. 1978. Plant species diversity and plant succession in a sandy area in the Northern Negev. *Flora (Jena)*, 167 (5): 409-422.
- Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. *Northwest Sci.*, 33: 43-46.
- Daubenmire, R. 1965. *Plants and Environment*. John Wiley & Sons, New York. pp. 35-36.
- DeMeter, O. 1956. Über Modificationen bei Cyanophyceen. *Arch. Microbiol.*, 24: 105-133.
- Desikachary, T.V. 1959. *Cyanophyta*, Ind. Council of Agric. Res. New Delhi.
- Dichter, D. and N.S. Popkin. 1967. *The North-West Frontier of West Pakistan - A study in regional geography*, Clarendon Press, Oxford, U.K.
- Dillenius, J.J. 1741. *Historia muscorum*. Oxonii.
- Dillwyn, L.W. 1809. *British confervae*. London.

- Dooley, F. and J.A. Houghton, 1974. The physiology of some blue-green algal isolates from peat. *Brit. Phycol. J.*, 8: 295-300.
- Drouet, F. 1937. The Brazilian myxophyceae. *Amer. J. Bot.*, 24: 598-608.
- Drouet, F. 1943. Myxophyceae of eastern California and western Nevada. *Florida Mus. Nat. Hist. Bot. Ser.*, 20: 145-176.
- Drouet, F. 1962. The oscillatoriaceae and their distribution in Antarctica. *Polar record II*: 320-321.
- Durohit, K., J. Ree, and G.P. Mishra. 1979. An ecological survey of soil algae of Sagar. *Geo. Bios. (Jodhpur)*, 6 (3): 97-100.
- Durrell, L.W. 1962. Algae of Death Valley. *Trans. Amer. Microscop. Soc.*, 81: 268-273.
- Durrell, L.W. 1963. Algae in tropical soils. *Trans. Amer. Microscop. Soc.*, 83: 79-85.

- Ehrenberg, G.G. 1843. Verbreitung und einfluss des mikroskopischen lebens in Sud-und Nordamerika. Abh. Berl. Akad.
- Ehrenberg, G.G. 1854. Mikrogeologie. Leipzig.
- Elberson, W.W. 1967. Reconnaissance Soil Survey of Peshawar Vale, Peshawar and Mardan District (Soil Survey of Pakistan, Lahore).
- Elwell, H.M., J.W. Slosser and H.A. Daniel. 1939. Revegetative and gully-control experiments in the Red Plains Region. Soil Conservation, 5: 17-20.
- Evans, J.H. 1958. The survival of freshwater algae during dry periods. I. An investigation of the algae of five small ponds. J. Ecol., 46: 149-167.
- Evans, J.H. 1959. The survival of fresh water algae during dry periods. II. Drying experiments, III. Stratification of algae in pond margin litter and mud. J. Ecol., 47: 55-81.

- Faridi, M.A.F., G. Anjum and T. Mahmood, 1983. Some soil-binding algae from Lawrencepur, Pakistan. *J. Pure Appl. Sci.*, 2 (2): 1-10.
- Faridi, M.A.F., A.R. Anjum and G. Anjum, 1981. Algae associated with alluvial gold of Indus at Attock. *Geol. Bull. Univ. Peshawar*, 14: 151-157.
- Favali, M.A., N. Barbieri and M. Bassi. 1978. A green alga growing on a plastic film used to protect archeological remains. *Int. Biodeterio. Bull.*, 14: 89-92.
- Feher, D. 1936. *Über die Algenflora des Waldbodens.* *Silva*, 24: 101-104.
- Feher, D. 1948. Researches on the geographical distribution of soil microflora. II. The geographical distribution of soil algae. *Erdeszeti kiserletek*, 48: 57-93.
- Fletcher, J.E. and W.P. Martin. 1948. Some effects of algae and molds in the rain-crust of desert soils. *Ecology*, 29: 95-100.

- Flint, E.A. 1958. Biological studies of some tussock grassland. IX. Algae. Preliminary observations. New Zealand. J. Agric. Res., 1: 991-997.
- Flint, E.A. 1960. Microbiology of some soils from Antarctica. Nature, 188: 767-768.
- Fogel, S., P.L. Foster, P. Schenck and W.W. Walker. 1976. Soil treatment methods: Production of algal biopolymers. U.S. Patents 3,958,364 and 3,969,844.
- Fogg, G.E. 1951. Growth and heterocyst production in Anabaena cylindrica Lemm. III. The cytology of heterocysts. Ann. Bot., 15: 23-35.
- Fogg, G.E., W.D.P. Stewart, P. Fay and A.E. Walsby. 1973. The blue-green algae. Academic Press, New York.
- Forest, H.S. and C.R. Weston, 1966. Blue-green algae from the Atacama Desert of northern Chile. J. Phycol., 2: 163-164.

- Foth, H.D. and L.M. Turk. 1972. Fundamentals of soil science. John Wiley and Sons, Inc. New York. pp. 345-374.
- Franz, E.H. and G.M. Woodwell. 1973. Effects of chronic gamma radiation on the soil algal community of an oak-pine forest. *Radiation Bot.* 13: 323-329.
- Frase, I.S. 1957. Landforms, soils and land use of the Indus Plain. West Pak. Survey Div. Minis. Food and Agric. Govt. of Pakistan.
- Fraymouth, J. 1928. The moisture relations of terrestrial algae. III. The respiration of certain lower plants, including terrestrial algae, with special reference to the influence of drought. *Ann. Bot.*, 42: 75-100.
- Friedmann, E.I. 1964. Xerophytic algae in the Negev Desert. Abs. 10th. Int. Bot. Congr. (1964): 290-291.

- Friedmann, E.I. 1968. Endolithic algae in calcareous desert rocks. *Amer. Zool.*, 8: 79A.
- Friedmann, E.I. 1971. Light and scanning electron microscopy of the endolithic desert algal habitat. *Phycologia*, 10: 411-428.
- Friedmann, E.I. 1972. Ecology of lithophytic algal habitats in middle, eastern and north American deserts. IN: L.F. Bodin (ed.). *Eco-physiological foundation of ecosystems productivity in arid zone*. U.S.S.R. Acad. Sci., Nauka, Leningrad.
- Friedmann, E.I. and M. Galun. 1974. Desert algae, lichens and fungi. In: G.W. Brown, Jr. (ed.). *Desert biology II*. Academic Press, New York.
- Friedmann, E.I., Y. Lipkin and R. Ocampo-Paus. 1967. Desert algae of the Negev (Israel). *Phycologia*, 7: 185-200.

- Friedmann, E.I. and R. Ocampo-Paus. 1976. Endolithic blue-green algae in the dry valleys: Primary producers in the Antarctic desert ecosystems. *Science*, 193: 1247-1249.
- Fritsch, F.E. 1907. The role of algal growth in the colonization of new ground and in the determination scenery. *Georg. J. (London)* 30: 531-548.
- Fritsch, F.E. 1916. The morphology and ecology of an extreme terrestrial form of Zygnema (Zygozonium) erectum (Kütz) Hansg. *Ann. Bot.*, 30: 135.
- Fritsch, F.E. 1922a. The terrestrial algae. *J. Ecol.*, 10: 220-236.
- Fritsch, F.E. 1922b. The moisture retention of terrestrial algae. I. *Ann. Bot.*, 36: 1-20.

- Fritsch, F.E. 1936. The role of the terrestrial alga in nature. In: Essays in geobotany in honor of W.A. Setchell. Univ. of Calif., Berkeley.
- Fritsch, F.E. and G.M. Haines. 1923. The moisture relations of terrestrial algae. II. Ann. Bot., 37: 683-728.
- Fritsch, F.E. and W. Salisbury. 1915. Further observations on the heath association *Hinheadcomion*. New Phytol., 14: 116.
- Fuller, W.H. and R.N. Rogers. 1952. Utilization of the phosphorus of algal cells as measured by the Neubauer technique. Soil Sci., 74: 417-430.
- Gael, A.G., E.A. Shtina and N.I. Petrova. 1980. The minusinsk pine forests and the distribution of algae in them. Biol. Nauki (Moscow) 0(3): 86-95.
- Geitler, L. 1925. Cyanophyceae. IN: A. Pascher (ed.). Die Süßwasserflora Deutschlands, Österreich und der Schweiz, Cyanophyceae.

- Geitler, L. 1932. Cyanophyceae. In: Rabenhorst (ed.).
Kryptogamenflora von Deutschland, Österreich
under der Schweiz. Akad. Verlags Gesellschaft
Leipzig 14: 673-1056.
- Gistl, R. 1932. Zur Kenntnis der erdalgen. Arch.
Microbiol. 3: 634-649.
- Gistl, R. 1933. Erdalgen und dungung. Arch. Mikrobiol.,
4: 348-378.
- Glade, E. 1914. Zur kenntnis der Gattung Cylindrospermum.
Beitr. Biol. Pflanzen. 12: 295-343.
- Gollerbakh, M.M. 1953. The role of algae in soil
processes. Trudy Inst. Mikrobiol. (Moscow)
1951: 98-108; 221-222.
- Gollerbakh, M.M. and E.A. Shtina. 1969. Soil algae.
Acad. Sci. U.S.S.R., Moscow.
- Gomont, M. 1892. Monographie des Oscillatoriees.
Ann. Sci. Nat. Ser. VII. Bot. Tom: 15-16.

- Graebner, P. 1895. Studien uber die norddeutsche heide.
Bot. Jahrb. Syst. 20: 500.
- Granhall, W. and E. Henriksson. 1969. Nitrogen-fixing
blue-green algae in Swedish soils. Oikos, 20:
175-178.
- Heering, W. 1907. Die Susswasseralgen Schleswing -
Holsteins. II. Chlorophyceae, Jahrb. Hamburg
Wiss. Anst. 24: 103-131.
- Heering, W. 1921. Siphonocladales, Siphonales. In: A.
Pascher (ed.). Die Susswasserflora Deutschlands,
Osterreich und der Schweiz. 7: Chlorophyceae.
4: 1-103.
- Hoare, D.S., S.L. Hoare and A.J. Smith. 1972. Heterotrophic
potentialities of blue-green algae. In: T.V.
Desikachary (ed.). The taxonomy and biology
of blue-green algae. Symp. at Univ. of
Madras, India.
- Hussain, S.M. 1964. Ecological survey of the vegetation
of Nagarparkar. Pak. J. For., 14: 243-276.

- Hunt, M.E. G.L. Floyd and B.B. Stout. 1979. Soil algae in field and forest environments. Ecology, 60: 362-375.
- Izerott, H. 1937. Untersuchungen zum Wasserhaushalt von Prasiola crispa. Jahrb. Wiss. Bot., 84: 254-275.
- Jabeen, T. 1978. Soil binding algae of Peshawar University. M.Sc. Thesis, Univ. of Pesh., Peshawar.
- Jackson, M.L. 1962. Soil Chemical Analysis. Constable & Co. Ltd., London. 498.p.
- Jagnow, G. 1973. The influence of irrigation and crop rotation on the humus and nitrogen balance and soil productivity in the Sudan Gezira. Z. Pflanzen. Boden Kd., 134: 20-32.
- James, E.J. 1935. An investigation of the algal growth in some naturally-occurring soils. Beih. Bot. Centralbl., 53: 9-553.
- John, R.P. 1942. An ecological and taxonomic study of the algae of British soil. I. The distribution of the surface growing algae. Ann.Bot., 6: 323-349.

- Jordan, C., F. Golley, J. Hall and J. Hall. 1980.
Nutrient screening of rainfall by the canopy
of an Amazonian rain forest, Venezuela.
Biotropica, 12(1): 61-66.
- Jurgensen, M.F. and C.B. Davey, 1968. Nitrogen-fixing
blue-green algae in acid forest and nursery
soils. *Canad. J. Microbiol.* 14: 1179-1183.
- Kabirov, R.P. and R.G. Minibaev. 1976. Effect of the
nanorelief on characteristics of soil algae.
Bot. Z. 61: 373-377.
- Kale, S.R. 1972. Effect of light on the development
of heterocysts in *Anabaena ambigua* Rao.
In: T.V. Desikachary (ed.). The taxonomy and
biology of blue-green algae. Univ. of Madras,
India.
- Kärcher, H. 1931. Über die Kalteresistenz einiger Pilze
und Algen. *Planta* 14: 515-516.
- Kaszubiak, H. 1976. The influence of mineral fertilizers
on microorganisms in various conditions of
the soil environment. *Pol. J. Soil. Sci.*, 9:
41-46.

- Khan, A.R. and M.A.H. Chaudhry. 1967. Farming erodible lands in West Pakistan. West Pak. Agric. Deptt. Pak. Inter. Printers Lahore.
- Khan, H.U. 1981. Erosion. The Gomal Univ. J. Res. 1: 1-8.
- Khan, M.F.K. 1984. Pakistan. An economic geography. Sir Syed Ahmad Acad., pp. 83-85.
- Khan, M. 1983. Algae Today. Bishen Singh Mahendra Pal Singh, Dehra Dun, India. pp. 1-14.
- Khoja, T. and B.A. Whitton. 1971. Heterotrophic growth of blue-green algae. Arch. Mikrobiol. 79: 280-282.
- Koster, J.T. 1963. Antillean Cyanophyceae from salt-pans and marine localities. Blumea, 12: 45-56.
- Kuchkarova, M.A. 1962. The algal flora of rice fields in the Tashkent region. Uzbeksk. Biol. Surn., 1: 35-38.

- Kumar, H.D. 1963. Effects of radiation in blue-green algae. I. The production and characteristics of a strain of Anacystis nidulans resistant to ultraviolet radiation. Ann. Bot., 27:723-733.
- Kutzing, F.T. 1845-1871. Tabulae phycologicae. Nordhausen.
- Lazaroff, N. and W. Vishniac. 1961. The effect of light on the development cycle of Nostoc muscorum, a filamentous blue-green alga. J. Gen. Microbiol., 25: 365-374.
- Lee, R.E. 1980. Phycology. Cambridge Univ. Press, London, pp. 52-54.
- Lewin, R.A. 1977. The use of algae as soil conditioners. CIBASIO. Trans., 3: 33-35.
- Lipman, C.B. 1941. The successful revival of Nostoc commune from a herbarium specimen eighty-seven years old. Bull. Torrey, Bot. Club., 68:664-666.
- Lund, J.W.G. 1945. Observation on soil algae. I. The ecology, size and taxonomy of British soil diatoms. New Phytol., 44: 196-219.

- Lund, J.W.G. 1947. Observations on soil algae. II. Notes on groups other than diatoms. *New Phytol.* 46: 35-60.
- Lund, J.W.G. 1962. Soil algae. In: R. Lewin (ed.). *Physiology and biochemistry of algae*. Academic Press, New York.
- Luthra, J.C. 1933. *Punjab Weeds and their Control*.
- Lyngbye, H.C. 1819. *Tentamen hydrophytologiae danicae. Hafniae*.
- MacEntee, F.J. and H.C. Bold. 1978. Some microalgae from sand. *Texas J. Sci.*, 30: 167-174.
- Mackenzie, H.H. and H.W. Pearson. 1979. Preliminary studies on the potential use of algae in the stabilization of sand wastes and wind blow situations. *Abst. Brit. Phycol. Soc. Winter Meeting. Brit. Phycol. J.*, 18: 126.
- Marathe, K.V. 1970. Role of some blue-green algae in soil I aggregation. In: T.V. Desikachary (ed.). *Taxonomy and biology of blue-green algae. Symposium at Madras, India*.

- Marathe, K.V. and Y.S. Anantani. 1975. Algal crusts as nitrogen sources in some arid soils of India. J. Univ. Bombay, 44: 44-49.
- Marathe, K.V. and C. Khushaldas. 1975. Observations in the algal crusts of Nagpur soils. J. Univ. Bombay, 44: 66-76.
- Martin, J.P. and S.A. Waksman. 1940. Influence of microorganisms on soil aggregation and soil erosion. Soil Sci., 50: 29-47.
- Marwat, K.B., M. Ahmad and S.Z. Shah. 1979. The soil algae in tobacco fields in Peshawar Valley, Pak. Tobacco, 3(1): 21-25.
- Mayland, H. F., T.M. McIntosh and W.H. Fuller. 1966. Fixation of isotopic nitrogen on a semi-arid soil by algal crust organisms. Soil Sci., Soc. Amer. Proc., 30: 56-60.
- Meinzer, O.E. 1927. Plants as indicators of ground water. U.S.G.S. Water Supply Paper 577.95 p.

- Metting, B. 1979. A comparative study of algal communities on cultivated and uncultivated portions of Schumacher silt loam. Ph.D. Dissertation, Washington State Univ., Pullman.
- Metting, B. 1981. The systematic and ecology of soil algae. *Bot. Rev.*, 47 (2): 195-312.
- Metting, B. and W. Rayburn. 1979. Algal communities and soil microenvironments in an eastern Washington silt loam. *Soil Sci.*, 127: 74-78.
- Mitra, A.K. 1951. The algal flora of certain Indian soils. *Indian J. Agric. Sci.*, 21: 357-373.
- Moewus, L. 1953. About the occurrence of freshwater algae in the semidesert around Broken Hill. (N.S.W., Australia.) *Botanika Notiser*, 4: 399-416.
- Moore, G.T. and N. Carter. 1926. Further studies on the subterranean algal flora of the Missouri Botanical Garden. *Ann. Missouri Bot. Gard.*, 13: 101-117.

Moore, G.T. and J.L. Karrer. 1919. A subterranean algal flora. Ann. Missouri Bot. Gard., 6: 281-307.

Morelli, E.A., R.E. Cameron, and G.B. Blank. 1965.
Soil studies-Microflora of desert regions.
III. Microorganisms in Valley 10,000 Smokes
Desert. J.P.L. Space Programs Summary 37-32,
IV: 196-202.

Motyka, J., B. Dobrazanski and S. Zawadzki. 1950.
Wstępne badania nad łąkami południowoschodniej
Lubuszczyzny. Preliminary studies on the
meadows in the south-east of the province.
Lublin. Univ. Mariae Curie- Skłodowska Ann.
Sect. E., 5: 367-447.

Nordin, R.N. and D.W. Blinn. 1972. Analysis of a saline
tall grass prairie ecosystem. IV. Preliminary
investigation of soil algae. Proc. North
Dakota Acad. Sci., 25: 8-17.

Novichkova-Ivanova, L.N. 1972a. Soil and aerial algae
of polar deserts and arctic tundra. In: F.E.
Wielgolaski and T. Rosswall (ed.). Proc. IV.
Intl. Meet. on the Biological Productivity
of Tundra. IBP Leningrad.

- Novichkova-Ivanova, L.N. 1972b. Soil algae of middle Asia deserts. In: L.E. Rodin (ed.). Physiological foundation of ecosystems productivity in arid zones. Sci. Publ. House Nauka, Leningrad.
- Osborne, B.O. 1950. Range cover tames the rain drop. U.S. Soil Conser. Serv., Oper & Res. Bur.
- Osmanova, R.A. and A.I. Gladyshev. 1978. Some data on the biomass of algae in flood plain soils of the central course of the Amy Darya River. *Ekologiya* (2): 20-36.
- Osmanova, R.A. and N.V. Sdobnikova. 1977. Algae in the Meshkhed sands of the south western Turkmen SSR. *Probl. Osvo. Pustyn.*, 1: 54-55.
- Parker, B.C., H.C. Bold and T.R. Deason. 1961. Facultative heterotrophy in Chlorococcacean algae. *Sci.* 133: 761-763.
- Petersen, J.B. 1915. Studien uber Danske aerofile alger. *Mem. Acad. Roy. Sci. Lett. Danenark.* VII, 12: 272-379.
- Petersen, J.B. 1935. Studies on the biology and taxonomy of soil algae. *Dansk. Bot. Arkiv.*, 8: 1-80.

- Piercy, A. 1917. The structure and mode of life of a form of *Hormidium flaccidum* A. Braun. Ann. Bot., 31: 513-537.
- Ponser, H.B. and A.H. Sparrow, 1964. Survival of *Chlorella* and *Clamydomonas* after acute and chronic gamma radiation. Radiation Bot. 4: 253-257.
- Prasad, S. 1949. Nitrogen recuperation by blue-green algae in soils of Bihar and their growth on different types of soil. J. Proc. Inst. Chemists (India) 21: 135-140.
- Presscott, C.W. 1951. Algae of the Western Lakes Area, exclusive of desmids and diatoms. Sci. Bloomfield Hills, Michigan.
- Pringsheim, E.G. and C. Pringsheim. 1956. Kleine Mitteilungen uber Glagellaten und Algen. IV. *Porphyridium cruentum* und *Porphyridium marinum* Arch. Mikrobiol., 24: 169-173.
- Pulmaly, A.D. 1924. Le *Chlorococcum humicola* (Nag) Rabenh. Rev. Algol., 1: 107-114.

- Rabenhorst, L. 1863. Kryptogamenflora von Sachsen, der Oberlausitz, Thurnigen and Nordbohlen mit Berucksichtigung der benachbarten Lauder. Leipzig.
- Ramakrishnan, P.S. and V.K. Singh. 1966. Differential response of the edaphic ecotypes in Cynodon dactylon (L). Pers. to soil calcium. New Phytol., 65: 100-108.
- Reddy, G.B. and J. Giddens. 1975. Nitrogen fixation by algae in fescue grass soil crusts. Soil Sci. Soc. Amer. Proc., 39: 654-656.
- Round, F.E. 1973. The biology of the algae. Arnold London. pp. 59-62.
- Royzin, M.B. 1960. Microflora of the rocks and primitive soils in the high mountain arctic desert. Bot. Zurn., (Moscow and Leningrad) 45: 997-1008.
- Sagar, G.R. and J.L. Harper. 1960. Factors affecting the germination and early establishment of plantains (Plantago lanceolata, P. media, and P. major), in The Biology of Weeds (ed.) J. L. Harper. Blackwell Scientific Publications, Oxford. 256 p.

- Said, M. and M. Majid. 1977. The Pleistocene history of the terrestrail deposits of Bar Daman Area, Peshawar Valley. J. Sci. and Tech., 1: 39-47.
- Sajida, A. 1984. Some soil algae from maize fields of Peshawar. M.Sc. Thesis, Univ. of Pesh., Peshawar.
- Salim, K.M. and R.G. Shahid. 1973. A winter flora of Cherat Hills. Part II. Pak. J. For., 23: 267-282.
- Schlichting, H.E. 1973. Algae in tobaccoo beds. Trans. Amer. Microscop. Soc., 92: 528-531.
- Schmid, G. 1927. Zur Oekologie der Luftalgen. Ber. Deutsch. Bot. Ges. 45: 518-533.
- Schroder, G. 1886. Über die Auströcknungs fähigkeit der Pflanzen. Untersuch. Bot. Inst. Tübingen. 2:1.
- Schwabe, G.H. 1960a. Blaualgen des Des Boden. Forschungen and Fortschritte 34: 194-197.
- Schwabe, G.H. 1960b. Zur Autotrophen Vegetation in ariden Boden. Blaualgen und lebenstaum. IV. Osterr. Bot. Z., 107: 281-309.

- Schwabe, G.H. 1963. Blaualgen der phototrophen Grenzschicht. Blaualgen und Lebenstaum. VII. Pedobiologia, 2: 132-152.
- Sdobnikova, N.V. 1956. Soil algae of the takyrs in the northern part of the Twianian lowland. Thesis, Akad. Nauk. S.S.S.R., V.L. Kamarov Bot. Inst., Leningrad.
- Shah, S.Z. 1977. The culture of soil algae of rice fields of Peshawar. M.Sc. Thesis, Univ. of Pesh., Peshawar.
- Shahwar, D. 1977. Soil algae of arid fields of Peshawar. M.Sc. Thesis, Univ. of Pesh., Peshawar.
- Shams, N. 1977. Soil algae of wheat fields of Peshawar. M.Sc. Thesis, Univ. of Pesh., Peshawar.
- Shields, L.M. 1957. Algal and lichen flora in relation to nitrogen content of certain volcanic and arid range soils. Ecology, 38: 661-663.
- Shields, L.M. and L.W. Durrell. 1964. Algae in relation to soil fertility. Bot. Rev., 30: 92-128.

- Shields, L.M., L.W. Durrell and A.H. Sparrow. 1961.
Preliminary observations on radio sensitivity
of algae and fungi in soils from the Nevada
test site. *Ecology*, 42: 440-441.
- Shields, L.M., C. Mitchell and F. Drouet. 1957. Alga
and lichen stabilised surface crust as soil
nitrogen source. *Amer. J. Bot.*, 44: 489-498.
- Shtina, E.A. 1968. The distribution and role of nitro-
gen-fixing blue-green algae in soils of the
temperate zone of the USSR. *Trans. 9th Inter.
Cong. Soil Sci. Adelaide, Australia II.*
- Shtina, E.A. 1972. Some peculiarities of the distribution
of nitrogen-fixing blue-green algae in soils.
In: T.V. Desikachary (ed.). *The taxonomy and
biology of blue-green algae. Symposium at Univ.
Madras, India.*
- Shubert, L.E. and T.L. Starks. 1980. Soil algal relation-
ships from surface mined soils. *Brit. Phycol.
J.*, 15: (4): 417-428.
- Singh, R.N. 1950. Reclamation of "Usar" lands in India
through blue-green algae. *Nature*, 165: 325-326.

- Singh, R.N. 1961. Role of blue-green algae in nitrogen economy of India. Indian Council Agric. Res., New Delhi, India.
- Singh, R.N. and I. Viswanathan. 1972. Heterocyst differentiation in Campylopus lathornse Ghose. In: T.V. Desikachary (ed.). The taxonomy and biology of blue-green algae. Madras India.
- Skinner, C.E. 1932. The soil as a habitat for growth of green algae. Soil Sci., 34: 25-28.
- Skinner, C.E. and C. Gardner. 1930. The utilization of nitrogenous organic compounds and sodium salts of organic acids by certain soil algae in darkness and in light. J. Bacteriol. 19: 161-179.
- Smith, D.D. and W.H. Wischemier. 1957. Factors effecting sheet and rill erosion. Amer. Geophys. Union. Trans. 38: 889-896.
- Stewart, R.R. 1958. The Flora of Rawalpindi District, West Pakistan. Frontier Exchange Press Ltd., Rawalpindi, 163 p.

Stewart, W.D.P. and H.W. Pearson. 1970. Effects of aerobic and anaerobic conditions on growth and metabolism of blue-green algae. Proc. Roy. Soc. London, 175: 293-311.

Stokes, J.L. 1940. The influence of environmental factors upon the development of algae and other microorganisms in the soil. Soil. Sci. 49: 171-184.

Trainor, F.R. 1962. Temperature tolerance of algae in dry soil. News Bull. Phycol. Soc. Amer., 15: 3-4.

Treboux, C. 1905. Organische Säuren als Kohlenstoffquelle bei Algen. Ber. Deutsch. Bot. Ges., 23: 432 p.

Tret'yakova, A.N. 1970. Biological principles of using algae for manuring unirrigated soils. Trudy Kirov. S-Kh. Inst., 22: 137-150.

Treub, M. 1888. Notice sur la nouvelle Flore de Krakatau. Ann. Jard. Bot. Buitenzorg. 7: 211.

- Troup, R.S. 1921. The Silviculture of Indian Trees.
Vol. II. Leguminosae (Caesalpinaceae) to
Verbenaceae. Clarendon Press, Oxford, U.K.,
399 p.
- Turner, B.D. 1975. Energy flow in arboreal epiphyte
communities: An empirical model of net
primary productivity in the alga Pleurococcus
on larch trees. *Oecologia*, 20: 179-188.
- Tyagi, V.V.S. and A.S. Ahluwalia, 1978. Heterocyst
formation in the blue-green alga Anabaena
doliolum: A study of some aspects of photo-
regulation. *Ann. Bot.*, 42: 1333-1342.
- USDA, 1954. Handbook 60. Method 23C, pp. 105.
- Vaidya, S.M.W. 1964. Ecology of algae in Indian soils
with special reference to the light factor.
Ph.D. Dissertation, Univ. of London.
- Vaucher, J.P. 1803. *Historie de conferves*. Geneva.

Venkataraman, G.S. 1964. Thermal resistance and viability of microalgae. *Phykos*, 3: 26-28.

Venkataraman, G.S. 1975. The role of blue-green algae in tropical rice cultivation. In: W.D.P. Stewart (ed.). Nitrogen Fixation by free-living microorganisms. IBP Program 6, Cambridge Univ. Press.

Waksman, S.A. 1952. Soil Microbiology. John Wiley and Sons, Inc. New York. 356 pp.

Watanabe, A. 1965. Studies on the blue-green algae as green manure in Japan. *Proc. Nat. Acad. Sci. India*. 35: 361-369.

Watanabe, A. and Y. Yamamoto. 1971. Algal nitrogen fixation in the tropics. In: T.A. Lie and E.G. Mulder (eds.). Biological nitrogen fixation in natural and agricultural habitats. Plant and Soil Special Volume.

Went, F.W. 1955. The ecology of desert plants. *Sci. Amer.*, 192: 68-75.

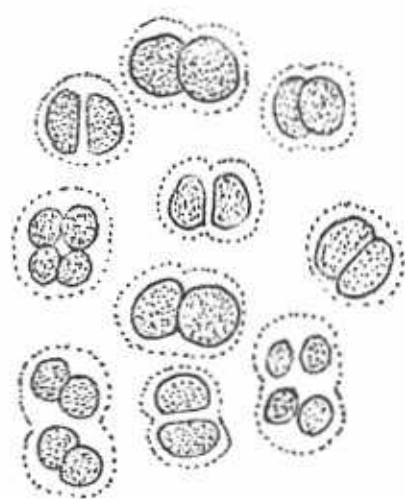
- West, W. and G.S. West. 1897. Welwitsch's African freshwater algae. J. Bot., 35: 1-183.
- West, W. and G.S. West. 1904. A monograph of the British Mesmidiaceae. London.
- Whitton, B.A. and C. Sinclair. 1975. Ecology of blue-green algae. Sci. Prog., 62 (247): 429-446.
- Willson, D.L. 1957. A survey of the soil algae of two vegetation types in central Oklahoma. Ph.D. Dissertation, Univ. of Oklahoma, Norman.
- Willson, D.L. and H.S. Forest. 1957. An exploratory study on soil algae. J. Ecol., 38: 309-313.
- Woodhouse, Jr., W.W. 1968. Long-term fertility requirements of coastal bermudagrass (Cynodon dactylon): I. Potassium. Agron. J., 60: 508-512.
- Yoshida, T., R.A. Roncal and E.M. Bautista. 1973. Nitrogen fixation in a Philippine soil. Proc. 2nd Asian Soil Conf. Indonesia.

- Zehnder, A. 1953. Beitrag zur Kenntnis von Mikroclima und Algen Vegetation des nackten Gestein in den Tropen. Ber Schweiz. Bot. Ges., 63: 5-26.
- Zimmerman, W.L. 1979. Selective studies of asymbiotic nitrogen-fixing soil cyanophytes in a temperature climate. M.S. Thesis, Washington State University, Pullman.
- Zimmerman, W.L., B. Metting and W.R. Rayburn. 1980. The occurrence of blue-green algae in Whitman County, Washington soils. Soil Sci., 130: 11-18.

APPENDIX

Plate I

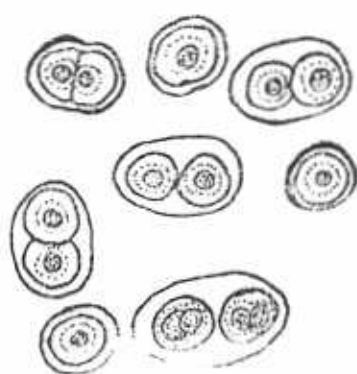
Plant	Fig.No.
<u>Chroococcus minutus</u> x 1000	1
<u>C. pallidus</u> x 1800	2
<u>C. varius</u> x 1400	3
<u>Synechococcus aeruginosus</u> x 450	4



1



2



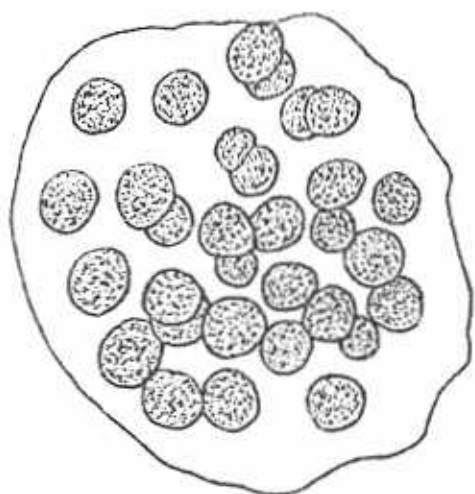
3



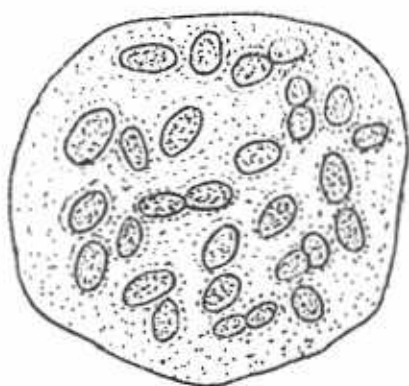
4

Plate 2

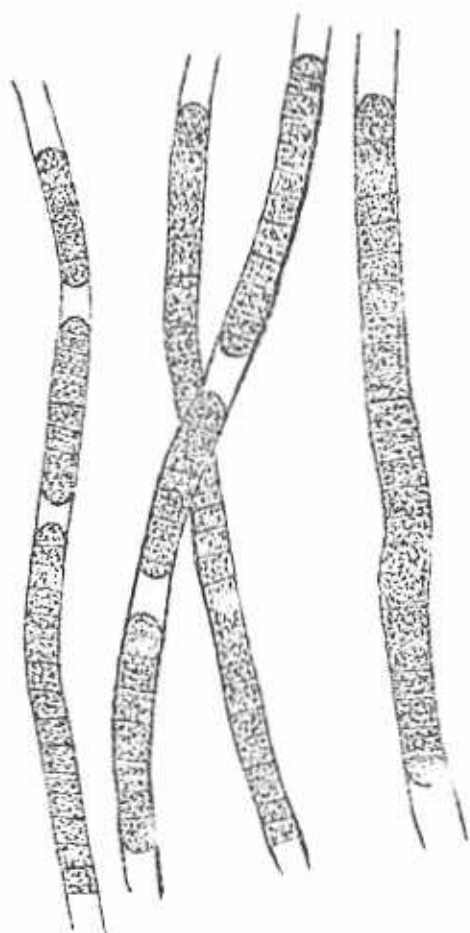
Plant	Fig.No.
<u>Aphanothece</u> <u>naegelli</u> x 800 1	
<u>A.pallida</u> x 1250 2	
<u>Lyngbya</u> <u>palmarum</u> x 2000 3	
<u>Symploca</u> <u>cartilaginea</u> x 1300 4	



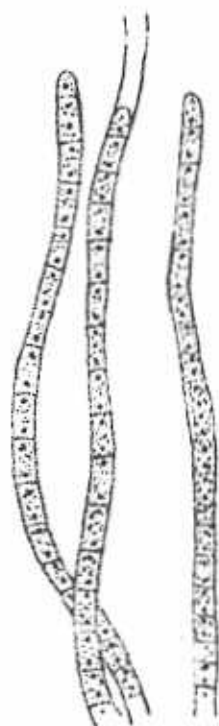
1



2



3



4

Plate 3

Plant		Fig.No.
<u>Phormidium</u> <u>ambiguum</u> x 1200	...	1
<u>P. corium</u> x 1000	...	2
<u>P. fragile</u> x 2500	...	3
<u>P. tenue</u> x 650	...	4

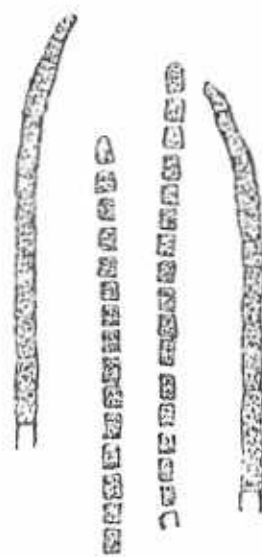
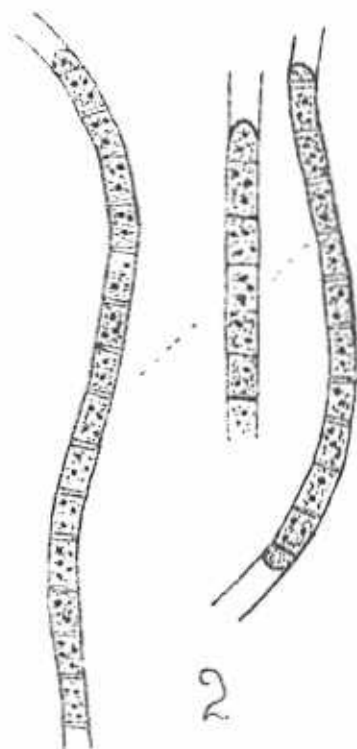
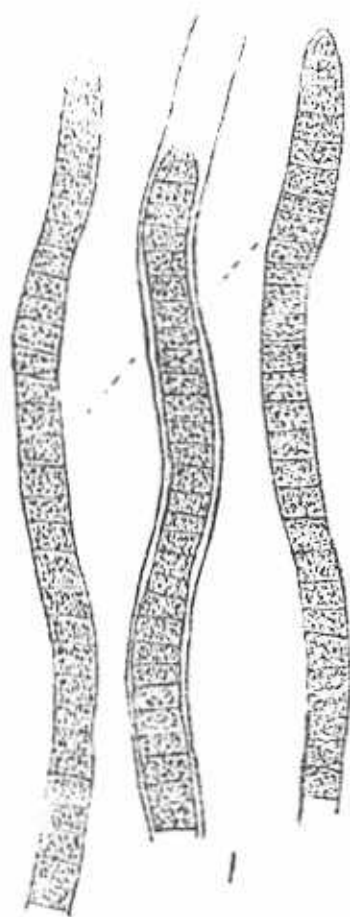
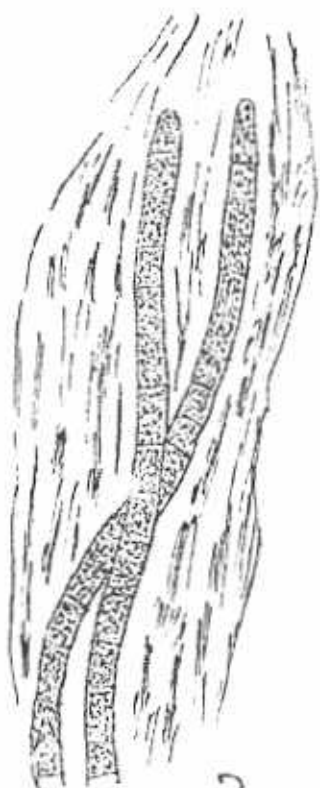
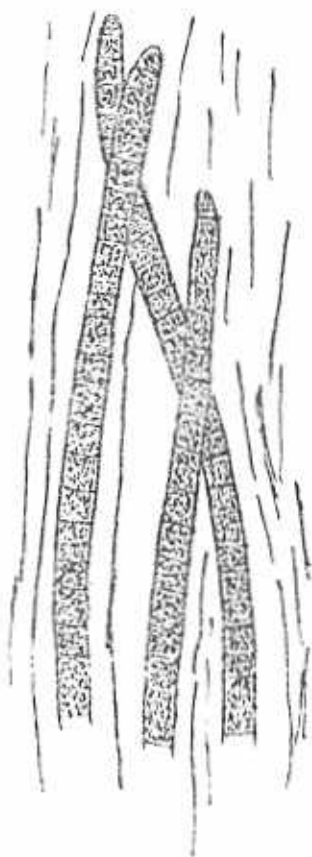


Plate 4

Plant		Fig.No.
<u>Schizothrix friesii</u> x 1000		1
<u>S. fuscescens</u> x 1650		2
<u>S. telephoroides</u> x 1300		3



2



3

Plate 5

Plant		Fig.No.
<u>Nostoc muscorum</u> x 1500		1
<u>Anabaena anomala</u> x 2000		2
<u>A. variabilis</u> x 1250		3

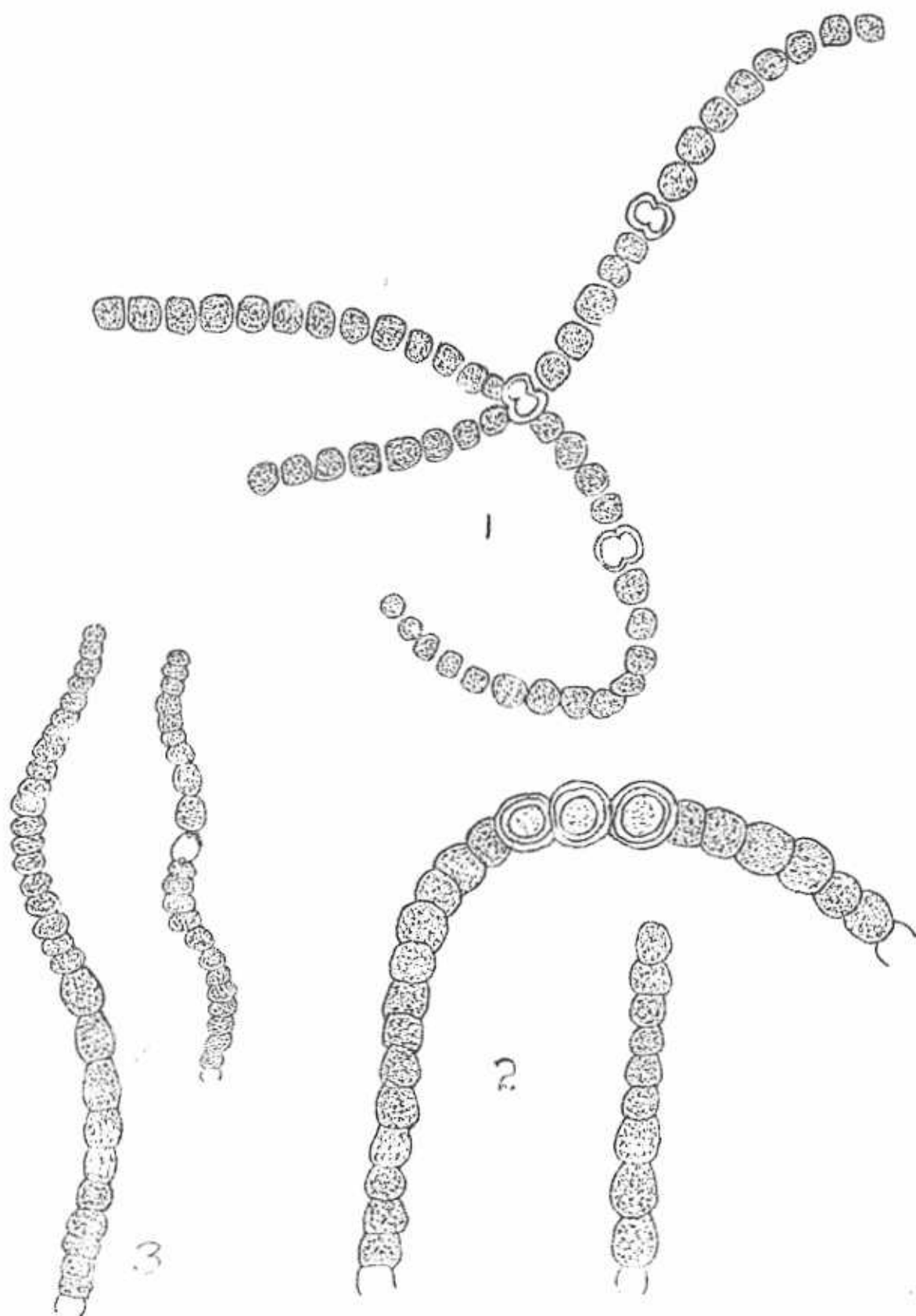


Plate 6

Plant	Fig.No.
<u>Scytonema bohneri</u> x 500 ...	1
<u>Scytonema schmidtii</u> x 725 ...	2

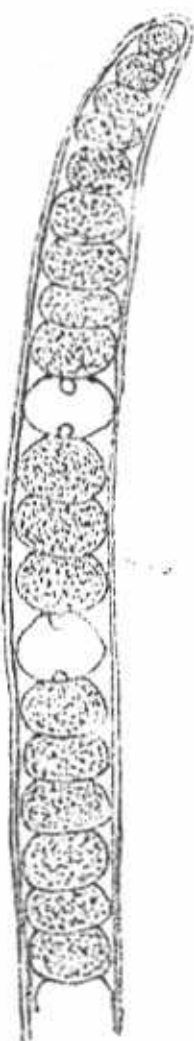
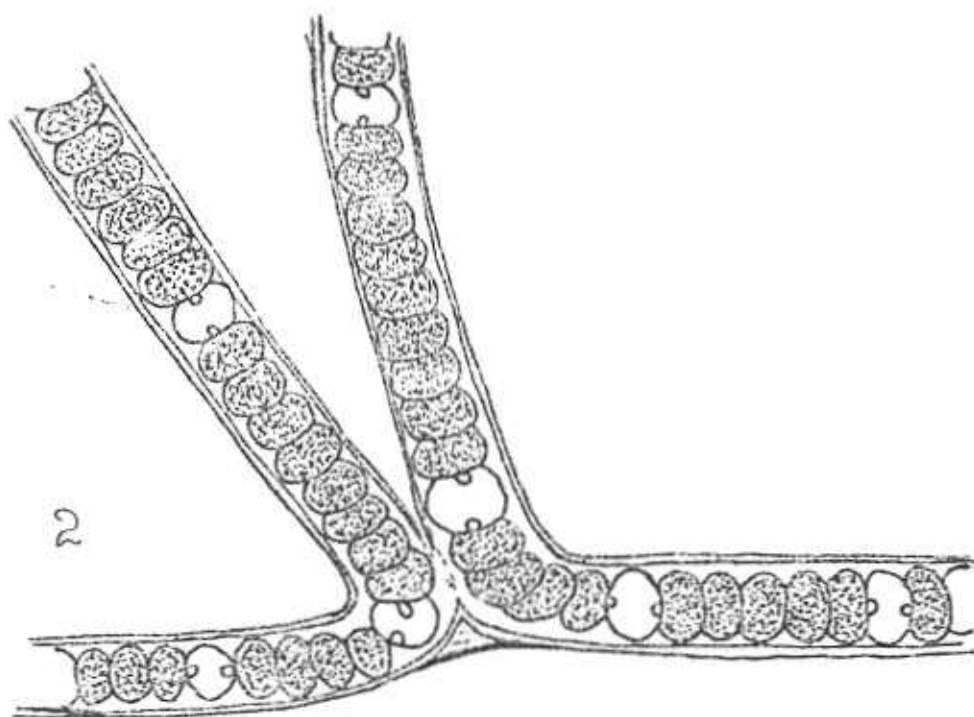
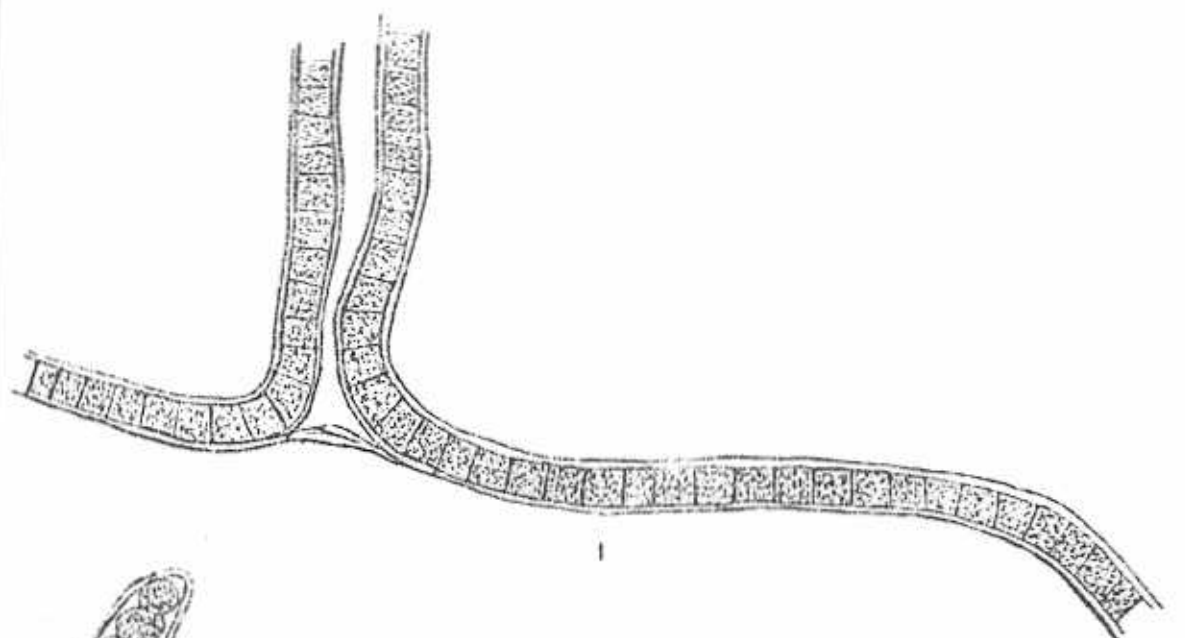


Plate 7

Plant

Fig. No.

Scytonema stuposum x 660

....

1

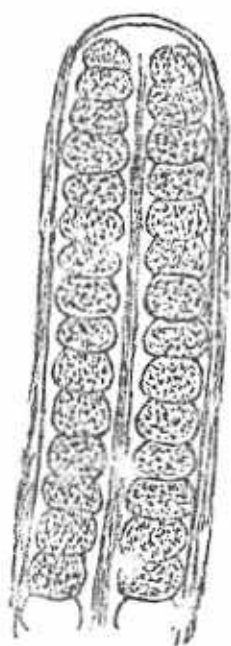
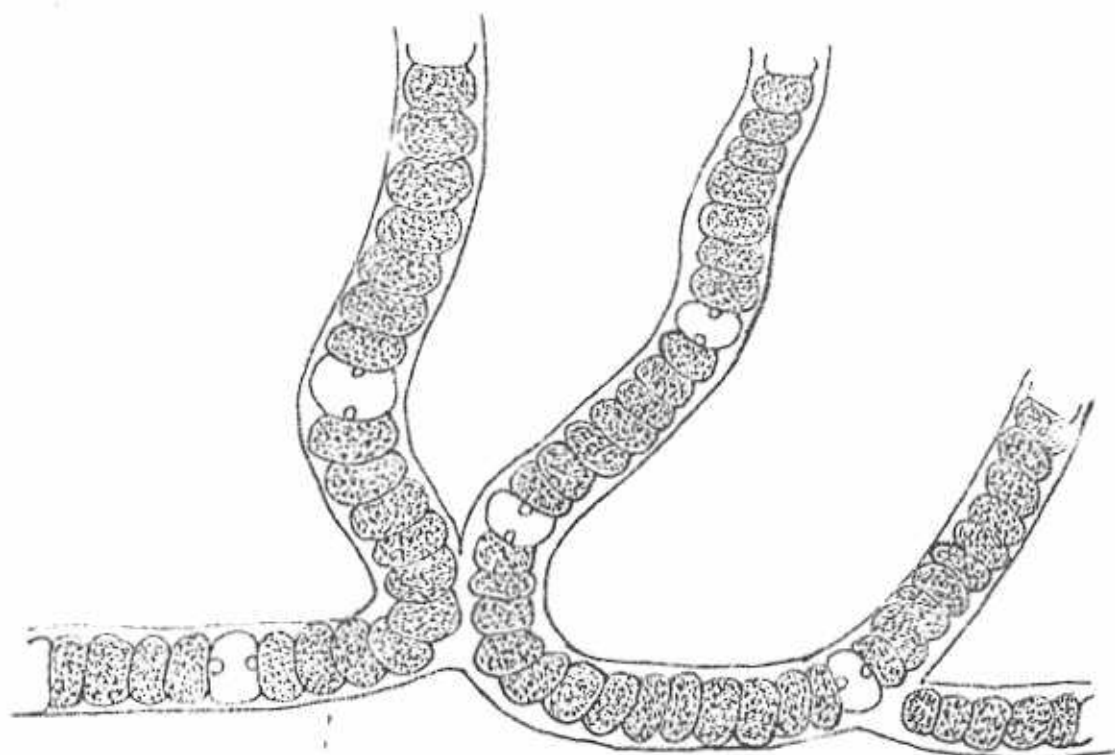


Plate 8

Plant	Fig.No.
<u>Protopoccus viridis</u> x 1500	1
<u>Tetracystis isobilateralis</u> x1000 ...	2
<u>Chlorococcum echinozygotum</u> x 450 ...	3
<u>C. hypnosporum</u> x 700	4
<u>C. oviforme</u> x 650	5

