Results

1. Physical and chemical composition of rice field waters:

Results of the fortnightly analyses for various physical and chemical factors of the rice field water are given in Appendix I. Average values and the range of these factors are given in Table 2. Table 3 gives the one way ANOVA values.

Temperature:

During the study period, the atmospheric temperature fluctuated between 25.8°C and 27.1°C. Water temperature ranged from 24°C to 27°C in Mandihal rice field I, and from 23°C to 27°C in rice field II. Whereas, it ranged between 22°C and 32°C, and 24° and 35°C in Mugad rice field I and II, respectively. There was no significant difference between the temperature values of (F< F0.05) Mandihal and Mugad rice fields (Table 3).
pH:

The pH in all the four rice fields was always alkaline. Values of pH ranged between 7.5 and 8.5 in Mugad rice fields I & II, respectively. Similarly it fluctuated between 7.5 and 7.9, and 7.5 and 8.0 in Mandihal rice field I and II, respectively. Although fluctuation and average values of pH were more in Mugad fields, there was no significant difference between Mandihal and Mugad rice fields ($F < F_{0.05}$).

Carbon dioxide:

The lowest and highest concentration of carbon dioxide were same in all the four rice fields. The average values (Table 2) indicate that of the four rice fields, Mugad rice field II had the lowest and rice field I had the highest CO$_2$ budget. However, Mugad and Mandihal rice fields were similar in nature with respect to carbon dioxide ($F < F_{0.05}$).

Carbonate:

Carbonate was absent in all the rice fields except that of Mugad rice field II where it ranged between 24 and 36 mg 1$^{-1}$. 
Bicarbonate:

Mandihal rice field I and II had average bicarbonate values of 393.7 mg l⁻¹ and 402.1 mg l⁻¹ and that of Mugad rice field I and II had 698 and 577.5 mg l⁻¹ respectively. There was significant difference in the values of all the four paddy fields (F>F 0.05).

Oxygen:

Of the four rice fields, Mugad rice field I had highest amount of oxygen (9.1 mg l⁻¹) and Mandihal rice field I the lowest (5.2 mg l⁻¹). Oxygen concentration ranged between 3.2 - 9.6 mg l⁻¹ in Mandihal rice field I and 4.8 - 8.8 mg l⁻¹ in rice field II. Compared to Mandihal rice fields, Mugad rice fields had more concentration of oxygen and it fluctuated between 3.6 and 15.6 mg l⁻¹ in rice field I, and 5.2 and 12.4 mg l⁻¹ in rice field II of Mugad. However the difference was not significant (F<F 0.05).

Oxidizable Organic Matter:

The average values and ranges of oxidizable organic matter were more in rice fields II compared to those of I. There was significant difference (F>F 0.05) in the four rice fields studied. With respect to oxidizable organic
matter, rice field I of both the places were similar in nature. Similarly rice field II of both places had almost same concentration.

Chloride:

Concentration of chloride was almost similar in the two rice fields of Mugad and comparatively higher than those of Mandihaal fields. Mandihaal rice field II had the lowest concentration of chloride. There was significant difference ($F > F_{0.05}$) in the four rice fields studied.

Sodium:

Similar to chloride, sodium was comparatively more in waters of Mugad rice fields than Mandihaal which differed significantly ($F > F_{0.05}$). Among the two fields of Mandihaal, waters of rice field I had comparatively more sodium concentration. Whereas rice field I and rice field II of Mugad had similar concentration.

Calcium:

Fluctuation and status of calcium were similar to those of sodium and chloride. Mandihaal rice field I had more calcium than rice field II. Although Mugad fields had
significantly higher concentration of calcium than Mandi
hal fields (F>F 0.05) Mandi
hal field I and Mugad field II were similar in nature.

Magnesium:

While Mugad rice field I had the highest concentration of Magnesium, the lowest was in Mandi
hal rice field II. In general Mugad fields had more of magnesium concentration than Mandi
hal. The two rice fields of Mandi
hal were similar in nature (F<F 0.05) with respect to magnesium.

Potassium:

Average values of potassium showed that Mugad rice field II had the highest values and the waters of Mandi
hal rice field II had the lowest. There was significant difference (F>F 0.05) in the values of potassium of the rice fields studied. However, Mandi
hal rice field I, Mandi
hal rice field II and Mugad rice field I were similar in nature, indicating that Mugad field II had significantly higher concentration of potassium.

Hardness:

Fluctuation and status of hardness were similar to the chloride and major cations. The average values of
hardness (Table 2) indicate that of the four fields, Mugad rice field I had the highest and Mandihal rice field II had the lowest. There was significant difference in the values of hardness in the four rice fields (F>F 0.05).  

Silica:

The two rice fields of Mandihal showed similar values (F<F 0.05) whereas Mugad rice field I and II had significant difference (F>F 0.05). Highest and lowest average values were observed in Mugad rice field I and II, respectively (Table 2). With respect to silica, Mandihal I, Mandihal II and Mugad II rice fields were similar in nature.  

Free Ammonia:

Average values of free ammonia remained similar in all the rice fields except Mugad rice field II which had the lowest average values. Though Mandihal rice field II recorded the highest concentration of free ammonia there was no significant difference (F<F 0.05) between Mugad and Mandihal fields.  

Organic nitrogen:

Although average values of organic nitrogen showed that Mugad rice field I had the highest values and that of Mandihal rice field I had the lowest (Table 2), there was no
significant difference in the values of the four rice fields \( F < F_{0.05} \).

Nitrate:

Nitrate was absent in the rice fields of Mandiwal whereas it was recorded in Mugad fields. Amongst the two rice fields of Mugad, rice field I had comparatively more \( F > F_{0.05} \) nitrate concentration than rice field II.

Of the four rice fields under present study, the two rice fields of Mugad village had significantly more concentrations of bicarbonate, chloride, major cations and hardness. Nitrates were present only in the waters of Mugad village. Temperature, pH and carbon dioxide did not show significant difference. Factors like oxygen, silica, free ammonia, oxidizable organic matter and organic nitrogen had indifferent variations.

2. Occurrence and distribution of rice field algae:

A total of 44 genera belonging to Chlorophyceae (18), Bacillariophyceae (12), Cyanophyceae (11) and Euglenophyceae (3) were recorded in the native flora of the 4 fixed rice field waters. Further, the dominant genera were Spirogyra, Closterium and Cosmaium of Chlorophyceae; Gomphonema,
Table 2. Average values and ranges of physical and chemical factors in Mandihal and Mugad rice fields water (June -October 1987).

<table>
<thead>
<tr>
<th>Factors</th>
<th>MANDIHAL Rice Field-I Average</th>
<th>Range</th>
<th>MANDIHAL Rice Field-II Average</th>
<th>Range</th>
<th>MUGAD Rice Field-I Average</th>
<th>Range</th>
<th>MUGAD Rice Field-II Average</th>
<th>Range</th>
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<td>26.0</td>
<td>24-27</td>
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<td>7.5-8.0</td>
<td>7.8</td>
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<td>7.6-8.5</td>
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<td>3.5</td>
<td>1.99-5.98</td>
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<td>&quot;</td>
<td>&quot;</td>
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<td>24.0-36.0</td>
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<td>402.1</td>
<td>384.3-628.3</td>
<td>698.0</td>
<td>555.1-762.5</td>
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<td>5.2-12.4</td>
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<td>3.11-10.0</td>
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<td>2-7</td>
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<td>77.5</td>
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<td>Free Ammonia</td>
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<td>0.05-0.21</td>
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<td>0.0</td>
<td>0.0</td>
<td>9.2</td>
<td>5.4-14.4</td>
<td>2.10</td>
<td>1.8-2.7</td>
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Table 3: Calculated ANOVA values of the physical and chemical factors of rice field water of Dharwad.

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<th>Water temp. °C</th>
<th>pH</th>
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<td>C.D M.D Remark</td>
<td>C.D M.D Remark</td>
<td>C.D M.D Remark</td>
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<td>MD I - MD II</td>
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<td>- - NS</td>
<td>- - NS</td>
</tr>
<tr>
<td>MD I - MG I</td>
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<td>- - NS</td>
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<tr>
<td>MG I - MG II</td>
<td>- - NS</td>
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F = 1.689
F = 1.616
F = 2.403

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<tr>
<th>Stations</th>
<th>Oxid.Org.Matter</th>
<th>Chloride (mg/l)</th>
<th>Potassium (mg/l)</th>
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<tr>
<td>MD I - MD II</td>
<td>1.504 2.37 S</td>
<td>10.41 16.45 S</td>
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<td>MD I - MG I</td>
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<td>1.742 3.33 S</td>
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<td>MG I - MG II</td>
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<td>&quot; 3.90 NS</td>
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F = 9.019
F = 236.08
F = 9.456

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<th>Stations</th>
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<th>Silica (mg/l)</th>
<th>Free ammonia (mg/l)</th>
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<tr>
<td>MD I - MD II</td>
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<tr>
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<td>4.286 9.66 S</td>
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F = 62.928
F = 6.845
F = 1.556

Table F value $F_{3,34}$ at 5% = 2.88
C.D = Critical difference,
M.D = Mean difference, S = Significant, NS = Non-significant.

MD I = Mandihal Rice Field I
MG I = Mugad Rice Field I
MD II = Mandihal Rice Field II
MG II = Mugad Rice Field II
Table 3 (Contd...)

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<tr>
<th>Stations</th>
<th>Carbon dioxide (mg/l)</th>
<th>Bicarbonate (mg/l)</th>
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<td>M.D</td>
<td>Remark</td>
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<tr>
<td>MD I - MD II</td>
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<td>NS</td>
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<td>MG I - MG II</td>
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<table>
<thead>
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</table>

F = 1.111  F = 7.73  F = 3.413

Table F value $F_{3,34}$ at 5% = 2.88 C.D = Critical difference, M.D = Mean difference, S = Significant, NS = Non-significant.

MD I = Mandihal Rice Field I  MG I = Mugad Rice Field I
MD II = Mandihal Rice Field II  MG II = Mugad Rice Field II
Navicula, Cymbella and Hantzschia of Bacillariophyceae and Aphanocapsa, Spirulina, Oscillatoria, Anabaena and Gloeotrichia of Cyanophyceae respectively.

Appendix II gives species distribution in the rice fields of Mandihal and Mugad villages. Of the 106 species represented, 44 genera, 23 species were common to both Mandihal and Mugad rice fields. Of these species of common occurrence, 6 species belong to green algae, 12 species to diatoms and 5 species to blue green algae.

The native algal flora represented by 106 species had dominance in the order of Chlorophyceae > Bacillariophyceae > Cyanophyceae > Euglenophyceae.

The Chlorophyceae:

Fourty six species constituted the Chlorophyceae, of which Spirogyra sp, Closterium acutum, C. lineatum, Cosmarium obtusatum, C. occultum, C. pardalis, C. punctulatum v. subpunctulatum, Euastrum spinulosum v. bellum were common for both the places.
Mandihal rice field I

This rice field supported 30 species of green algae belonging to 18 genera.

Oedogonium minisporum, Pandorina morum, Gloeocystis bannergattensis, Pediasstrum tetras v. tetraodon, Scenedesmus hystrix, Pleurotaenium ovatum v. inermius, P. trabecula, Cosmarium phaseolus, C. subcostatum fa. minus, C. hammeri fa. acuta, Staurastrum sebaldii v. gracile and Uesmidium baileyi fa. tetragonum were observed only in Mandihal rice field I (Appendix II).

In this rice field, Chlorophyceae species were more in the months of June and September (Table 4).

Mandihal rice field II

This rice field supported 23 species of Chlorophyceae belonging to 10 genera. Spirogyra sp. was of very common occurrence, found in the 6 collections out of 9. Closterium leibleinii, Pleurotaenium subcoronulatum, Cosmarium lundelli v. circulare, C. reniforme, v. elevatum, C. subcostatum v. spetsbergense, Staurastrum quadricornutum and S. punctulatum were encountered only from the rice field II. Similar to rice field I, green algal species were more during June and September in rice field II also (Table 4).
Mugad rice field I

A total of 20 species belonging to 10 genera were recorded from this field (Table 4). Species diversity was more in the months of June and July (early period of paddy cultivation). From late tillering period onwards till the harvest, less number of species were observed belonging to the genera *Euastrum* and *Closterium*. Early tillering period was the peak period for the growth. Species of *Oedogonium*, *Penium*, *Gonatozygon*, *Closterium*, *Euastrum*, *Cosmarium*, *Chlorella*, *Spirogyra* and *Mougeotia* were more. *Euastrum spinulosum* v. *vaasii*, *E. pseudospinulosum* sp. nov. and *Cosmarium contractum* v. *pachydermum* were restricted to this rice field (Appendix II).

Mugad rice field II

This rice field had 17 species of greens belonging to genera *Penium*, *Closterium*, *Euastrum*, *Cosmarium*, *Staurastrum*, *Chlorella* and *Spirogyra*. Similar to Mugad rice field I, it showed more number of species in the month of July and in rest of the collections this group was represented by single species. The species encountered only in this field are *Cosmarium bireme* and *C. subspeciosum*. 
Table 4: Monthly occurrence of algal species in the four rice fields of Dharwad.

<table>
<thead>
<tr>
<th>Collection</th>
<th>Chlorophyceae</th>
<th>Bacillariophyceae</th>
<th>Cyanophyceae</th>
<th>Euglenophyceae</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mandi Field I</td>
<td>Mandi Field II</td>
<td>Mugd Field I</td>
<td>Mugd Field II</td>
</tr>
<tr>
<td>June</td>
<td>7 4 3 2</td>
<td>15 5 8 6</td>
<td>4 2 2 1</td>
<td>- -</td>
</tr>
<tr>
<td>June</td>
<td>5 4 7 4</td>
<td>10 12 5 5</td>
<td>5 3 2 2</td>
<td>- 1</td>
</tr>
<tr>
<td>July</td>
<td>2 3 10 8</td>
<td>13 12 4 2</td>
<td>2 3 4 3</td>
<td>2 2</td>
</tr>
<tr>
<td>July</td>
<td>1 2 3 3</td>
<td>6 4 6 6</td>
<td>2 3 1 1</td>
<td>2 -</td>
</tr>
<tr>
<td>August</td>
<td>4 1 1 1</td>
<td>12 9 4 5</td>
<td>2 5 5 2</td>
<td>- -</td>
</tr>
<tr>
<td>August</td>
<td>3 3 2 1</td>
<td>7 6 4 4</td>
<td>3 5 3 2</td>
<td>- -</td>
</tr>
<tr>
<td>September</td>
<td>9 8 1 1</td>
<td>12 11 3 4</td>
<td>5 3 3 1</td>
<td>1 -</td>
</tr>
<tr>
<td>September</td>
<td>5 5 1 1</td>
<td>8 4 4 3</td>
<td>6 5 3 1</td>
<td>- -</td>
</tr>
<tr>
<td>October</td>
<td>3 5 1 -</td>
<td>5 5 2 2</td>
<td>6 3 2 1</td>
<td>1 -</td>
</tr>
<tr>
<td>Genera</td>
<td>18 11 10 7</td>
<td>10 10 10 9</td>
<td>9 10 7 6</td>
<td>3 2</td>
</tr>
<tr>
<td>Species</td>
<td>30 23 20 17</td>
<td>26 27 16 14</td>
<td>13 11 8 7</td>
<td>5 3</td>
</tr>
</tbody>
</table>
The Bacillariophyceae:

A total of 37 species of Bacillariophyceae were recorded. Out of these, Synedra acus, S. ulna, Gomphonema gracile fa. gracile, Navicula cincta, N. cincta v. heufleri, N. exigua, N. dicephala v. sphaerophora, Cymbella hebridica, Hantzschia virgata, Nitzschia fasciculata were most common. Species like Eunotia sudetica, Stauroneis anceps v. hyalina, Pinnularia hemiptera, Cymbella ventricosa, Hantzschia amphioxys v. mugadensis and Surirella robusta v. splendida were restricted to Mugad rice fields. Whereas Synedra acus, Stauroneis anceps v. amphicephala, S. phoencentron fa. capitata, Gomphonema gracile v. auritum, Navicula citrus, N. protracta, N. pupula, N. radiosa, N. rhynchocephala, N. cuspidata, v. conspicua, Pinnularia divergens, P. gibba, P. legumen v. interrupta, P. sagittata, Cymbella leavis, Hantzschia virgata v. capitellata, Nitzschia closterium, N. hybrida were recorded only from Mandihal fields.

Synedra ulna, Achnanthes lanciolata v. elliptica, Caloneis silicula, Gomphonema gracile fa. gracile, Navicula cincta, N. cincta v. heufleri, N. exigua, N. dicephala v. sphaerophora, Cymbella hebridica, Hantzschia amphioxys, H. virgata, Nitzschia fasciculata, N. obtusa v. scalpelliformis fa. parva were common for both the villages.
Mandibhal rice field I

Mandibhal rice field I had the highest number of diatom species. A total of 27 species belonging to 10 genera were observed, of which *Synedra acus*, *S. ulna*, *Gomphonema gracile* v. *auritum*, *Navicula cincta* v. *heufleri*, *Pinnularia gibba*, *Cymbella leavis* were of frequent occurrence.

*Achnanthes lanciolata* v. *elliptica*, *Caloneis silicula*, *Hantzschia amphioxys*, *Nitzschia hybrida*, *N. obtusa* v. *scalpelliformis* fa. *parva* were the rare species. Species like *Gomphonema gracile* v. *auritum*, *Navicula dicephala* v. *sphaerophora*, *N. cuspidata* v. *conspicua*, *Pinnularia gibba* and *Nitzschia closterium* were found during the late tillering period of paddy cultivation. *Navicula citrus*, *N. protracta*, *Pinnularia divergens* and *P. sagittata* were restricted to this field.

Mandibhal rice field II

Ten genera comprising 26 species of diatoms were recorded in rice field II of Mandibhal. *Synedra*, *Navicula* and *Nitzschia* species occurred frequently. *Stauroneis anceps* v. *amphicephala*, *Navicula radiosa*, *Pinnularia legumen* v. *interrupta* and *Hantzschia virgata* v. *capitellata* were restricted to this field (Appendix II). Species diversity decreased towards the end of paddy growth.
Mugad rice field I

The diatoms were mainly constituted by 16 species belonging to 10 genera of which *Navicula cincta* v. *heufleri*, *N. cincta* and *Surirella robusta* v. *splendida* were the dominant forms. *Pinnularia hemiptera* and *Nitzschia obtusa* v. *scalpelliformis* fa. *parva* appeared in the end of paddy growth. *Eunotia sudetica*, *Pinnularia hemiptera*, *Cymbella ventricosa* and *Surirella robusta* v. *splendida* were noticed only in this field (Appendix II). More number of species was recorded in the month of June and July and species diversity decreased towards the end of paddy growth (Table 4).

Mugad rice field II

*Navicula cincta* was observed throughout the study period followed by *Synedra ulna*. Compared to Mugad rice field I, this field showed less species diversity. Of the 14 species, belonging to 9 genera (Appendix II), *Stauroneis anceps* v. *hyalina* was the only species restricted to this field.

Similar to field I of Mugad, species diversity gradually decreased towards the end of paddy growth in this field also except in the month of July where less number of species was recorded.
The Cyanophyceae:

The Cyanophyceae were represented by 15 species of which Anabaena orientalis, Gloeotrichia reciborskii v. longispora, Nostoc commune and Rivularia dura were the heterocystous members. Further Aphanocapsa pulchra, Spirulina meneghiniana, Oscillatoria acuta, O. curviceps, Anabaena orientalis and Gloeotrichia reciborskii v. longispora were of common occurrence.

Mandihal rice field I

This rice field harboured 13 species belonging to genera Aphanothece, Aphanocapsa, Spirulina, Oscillatoria, Lyngbya, Anabaena, Gloeotrichia, Nostoc and Rivularia. Oscillatoria acuta, Anabaena orientalis and Gloeotrichia reciborskii v. longispora had frequent occurrence during the study period and Anabaena iyengarii v. unispora was restricted to this field. Species diversity was more during September and October (Table 4). Further, G. reciborskii v. longispora had a sporadic blooming in this rice field.

Mandihal rice field II

Mandihal rice field II encountered 10 species belonging to 9 genera (Appendix II). Oscillatoria acuta, Anabaena orientalis and Gloeotrichia reciborskii v. longispora occurred
frequently. Further, Coelosphaerium pallidum was observed only in this field. Mandihal rice field II had more number of species during August and September.

**Mugad rice field I**

Among the 8 species recorded in this field, Oscillatoria curviceps, Aphanothece stagnina and Anabaena orientalis had frequent occurrence and A. stagnina formed a permanent bloom. Species diversity was more in the month of August and September (prior to tillering stage of paddy).

**Mugad rice field II**

Of the 7 species recorded, none of these forms occurred frequently. Comparatively moderate number of species were observed in the months of June, July and August. Less species diversity was observed from September and October onwards till the harvesting of paddy.

**The Euglenophyceae:**

Euglenophyceae were poor in occurrence and only seven species were recorded in the present study. These species were restricted to only Mandihal rice field. *Euglena allorgei*, *Phacus acuminatus*, *Trachelomonas charkwensis*, *T. superba* v.
swirenkiana were restricted to Mandihal rice field I. Whereas I. hexangulata and Phacus curvicauda occurred in rice field I. However, Trachelomonas volvocina was common in both the fields (Appendix II).
Plate 1 - 13

The following abbreviations are used in the explanations to the figures.

b = broad; st. = striae; sp. = spore;
Isth = isthmus, het = heterocyst.

All the measurements are given in μm and in the order of breadth x length.
Plate 1

1. *Oedogonium sociale* Wittrock 29.7 X 36.3 sp.  
29-30 Prescott 1951; pl. 32, fig. 7-9,  
p. 174.

2. *Spirogyra* sp. 90 X 150.

3. *Mougeotia* sp. 20.4-45 X 191.4

4. *Ulothrix* sp.

5. *Pandorina morum* Bory 29-34.5 X 41-46  
Prescott 1951; p. 75, pl. I Fig. 23.

6. *Bulbochaete* sp. 18x14

7. *Penium spirostrielatum* Barker 16.5 X 135  
Scott and Prescott 1961; pl.1, fig. 12, p. 9.
scale = 10 μm
= 50 μm (fig 2)
Plate 2

1. Gloeocystis bannergattensis Iyengar 8.5 x 9.  
Iyengar (Desikachary) 1971; fig. 51, p. 148.

2. Pediasastrum tetras (Ehr.) Ralfs var. tetraodon (Corda)  
Rabenh. Cell 20 x 19.  
Philipose 1967; p. 128-129, fig. 45 d.

3. Scenedesmus hystrix Lagerh. 10 x 5.  
Philipose 1967; p. 266-267, fig. 173 b.

Scott and Prescott, pl. 1, fig. 9-10, p.9.

5. Closterium parvulum Näg. var. cornutum (Playf.) Krieg.  
16 x 145.  
Scott and Prescott 1961; pl. 2, fig. 9, p.13.

6. Closterium leibleinii Kütz. 23 x 118.8.  
Irénée – Marie 1938; pl. 5, fig. 6-9, p. 65.

7. Pleurotaenium eugeneum (Turner) W. et G.S.West fa.  
constrictum Scott and Prescott 30 x 330.  
Scott and Prescott 1961; pl. 4, fig. 4, p. 16.

8. Closterium acutum Bre'b. 57 x 125.  
Croasdale 1973; pl. 9, fig. 15, p. 74.

9. Oedogonium minisporum Taft 36.6 x 39.4, cell 16.5 x 39.4  
Prescott 1951, pl. 43, fig. 1, p. 191.
scale = 10 µm
= 50 µm (fig. 4)
Plate 3

1. **Pleurotaenium ovatum** Nordst. var. **inermius** Scott and Prescott 92 x 228, Isth. 42. Scott and Prescott 1961; p. 17, pl. 6, figs. 3 and 4.

2. **Pleurotaenium trabecula** (Ehr.) Nag. 23 x 300, Isth. 16.8 Scott and Prescott 1961; pl. 3, fig. 4, p. 18.

3. **Pleurotaenium subcornulatum** (Turner) W. et G.S. West 60 x 850 Isth. 50. Rino 1971; p. 21, pl. 5, figs. 1-2.

4. **Closterium lineatum** Ehr. 24 x 580 Rino 1971; pl. 16, pl. 3, figs. 4-6.

5. **Cosmarium auriculatum** Reinsch 54.2 x 54.2, Isth. 21.4. Scott and Prescott 1961; pl. 26, fig. 4, p. 54.

6. **Euastrum spinulosum** Delp. var. **bellum** Scott and Prescott 58.5 x 72.8, Isth. 11.4. Scott and Prescott 1961; pl. 10, fig. 5, p. 40.

7. **Euastrum spinulosum** var. **vaasii** Scott and Prescott 48.5 x 57, Isth. 9.9. Scott and Prescott 1961; pl. 10, fig. 6, p. 41.

8. **Chlorella ellipsoidea** Gerneck 4.2 x 5.6 - 8. Prescott 1951; pl. 53, figs. 11-12, p. 236.
Plate 4

1. *Cosmarium contractum* Kirchn. var. *pachydermum* Scott and Prescott 18.5 x 28.5, Isth 5. Scott and Prescott 1961; pl. 27, fig. 6, p. 56.


5. *Cosmarium granatum* Bre'b. 22.8 x 34.2, Isth 5.7, Gronblad and Croasdale 1971; pl. 6, figs. 73-74, p. 14.

6. *Cosmarium obtusatum* Schmidle 45 x 51.4, Isth 14.2 Rine 1971; pl. 9, fig. 9, p. 38.


8. *Cosmarium phaseolus* Bre'b. var. *elevatom* Nordst. 199 x 19.9, Isth. 4.2 Croasdale 1965; pl. 2, figs. 15 and 16, p. 322.


11. *Cosmarium occultum* Schmidle 25.7 x 30, Isth. 7.1 Rino 1971; pl. 12, fig. 10, p. 38.
Plate 4

1. 
2. 
3. 
4. 
5. 
6. 
7. 
8. 
9. scale=10μm
10. 
11.
1. Cosmarium regnellii Wille var. chondrophorum Skuja
   11.4 x 14.9 Isth. 4.2.
   Scott and Prescott 1961; pl. 32, fig. 14, p. 68.

2. Cosmarium subcostatum Lund. var. spetsbergense Borge
   14 x 17, Isth. 4.
   Forster 1965; pl. 8, figs. 4-6, p. 149.

3. Staurastrum sebaldi Reinsch var. gracile Messik.
   357 x 25.7, Isth. 7.1
   Hirano 1959; pl. 46, fig. 23, p. 367.

4. Cosmarium reniforme (Ralfs) Archer var. elevatum W.
   et G.S. West 32 x 61, Isth. 205.
   Förster 1972; pl. 16, fig. 24, p. 560.

   Hirano 1959; pl. 38, fig. 13, p. 299.

6. Desmidium baileyi (Ralfs) Nordst. fa. tetragonum Nordst.
   24 x 19.
   Scott and Prescott 1961; pl. 62, figs. 8 and 9, p. 124.

7. Cosmarium spinuliferum W. et G.S. West 23 x 27, Isth. 4.5
   Bharati and Hegde 1982; pl. 9, fig. 8, p. 752.

8. Cosmarium subcostatum Nordst. fa. minus W. et G.S. West
   15.7 x 17, Isth. 28.
   Förster 1965; pl. 8, fig. 3, p. 149.

9. Cosmarium subspeciosum Nordst. 30 x 42.8, Isth. 9.9
   Scott and Prescott 1961; pl. 30, fig. 6, p.
Plate 6


2. *Trachelomonas superba* (Swir) Deflandre var. *swirenkiana* Deflandre 36 x 41. Prescott 1951; pl. 83, fig. 34; pl. 84, figs. 8 & 9 p. 418.


5. *Trachelomonas volvocina* Ehr. 13 x 13. Prescott 1951; pl. 83, figs. 1, 7 and 8, p. 419.


Plate 7

   Sarode and Kamat 1984; pl. 11, fig. 224, p.93-94.

2. *Achnanthes lanceolata* Bre'b. var. *elliptica* Cleve 18.5 x 31.4, st. 8-10.
   Hustedt 1930; fig. 306 c, p.208.

3. *Eunotia sudetica* (O.Mull.) Hust. 10 x 30, st. 11-12.
   Hustedt 1930; fig. 242, p.182.

4. *Stauroneis anceps* Ehr. var. *amphicephala* (Kutz) V.H. 11 x 39, st. 30-32.
   Sarode and Kamat 1984; pl. 10, fig. 212, p.90.

5. *Caloneis silicula* (Ehr.) Cleve 7 x 37, st. 18-20.
   Hustedt 1930; fig. 362, p.237.

6. *Synedra acus* Kutz. 4.6 x 86.6, st. 30-40.
   Hustedt 1930; fig. 170, p.155.

7. *Gomphonema gracile* Ehr. var. *auritum* A. Br. 5 x 36, st. 8-10.
   Sarode and Kamat 1984; pl. 21, fig. 497, p.185.

8. *Gomphonema gracile* Ehr. var. *gracile* 8 x 46, st. 11.
   Hustedt 1930; fig. 706, p.376.

   Sarode and Kamat 1984; pl. 10, fig. 14, p.91.

    Hustedt 1930; fig. 510, p.298.

11. *Synedra ulna* (Nitzsch) Ehr. 6-7 x 148-150, st. 10-12.
    Hustedt 1930; fig. 159, p.153.
Plate 8

1. *Navicula dicephala* (Ehr.) W. Smith v. *sphaerophora* A. Cl. 9 x 36, st. 14.
   Sarode and Kamat 1984; pl. 13, fig. 268, p.110.

2. *Navicula pupula* Kutz. 11 x 43, st. 18-20.
   Hustedt 1930, fig. 467 a, p.281.

3. *Navicula exigua* (Gregory) O.Müll 8.5 x 30, st. 9-10.
   Hustedt 1930; fig. 538, p.305.

4. *Navicula protracta* Grun. 9.7 x 31.5, st. 16-18.
   Hustedt 1930; fig. 472, p.284.

5. *Navicula cincta* (Ehr.) Kutz. var. *heufleri* Grun. 4.2 x 27, st. 12-17.
   Hustedt 1930; fig. 511, p.298.

6. *Navicula radiosa* Kutz. 15.7 x 90, st. 20.
   Hustedt 1930; fig. 513, p. 299 and 300.

   Sarode and Kamat 1984; pl. 17, fig. 384, p.146.

8. *Navicula rhynchocephala* Kutz. 11.4 x 57, st. 20-25.
   Sarode and Kamat 1984; pl. 14, fig. 308, p. 121.

   Hustedt 1930; fig. 589, p. 321 and 323.

10. *Pinnularia gibba* Ehr. 10 x 54.2, st. 8-10.
    Hustedt 1930; fig. 600, p. 327.
1. *Pinnularia hemiptera* (Kütz.) Cleve 19 x 99, st. 8-10. 
Hustedt 1930; fig. 608, p.329.

Hustedt 1930; fig. 643, p.353.

3. *Cymbella hebridica* (Gregory) Grun. 12.8 x 45.6, st. 18-20. 
Hustedt 1930; fig. 662, p.359.

4. *Hantzschia amphioxys* (Ehr.) Grun. 9.7 x 58, st. 14-16. 
Hustedt 1930; fig. 747, p.394.

5. *Cymbella ventricosa* Kütz. 8.5 x 21.4, st. 8-10. 
Hustedt 1930; fig. 661, p.359.

6. *Nitzschia closterium* W. Smith 4.2 x 59.9, st. 18-22. 
Sarode and Kamat 1984; pl. 25, fig. 584, p.317.

7. *Nitzschia apiculata* (Greg) Grun. 11.4 x 57, st. 13. 
Sarode and Kamat 1984; pl. 25, fig. 580, p.214.

10 x 54, st. 10-12. 
Hustedt 1930; fig. 753, p.395.

*parva* Hust. 6 x 42, st. 8-10. 
Gandhi 1962 a; fig. 39, p.480.

Hustedt 1930; fig. 752, p.395.
1. *Nitzschia fasiculata* Grun. 5.7 x 50, st. 18-20. 
Hustedt 1937; fig. 815, p. 420, 421.

Hustedt 1930; fig. 778, p. 406.

3. *Surirella robusta* Ehr. var. *splendida* (Ehr.) van Heurck 42.6 x 96.6, st. 4-5. 
Hustedt 1930; fig. 851, p. 437.

4. *Hantzschia amphioxys* (Ehr.) Grun. v. *mugadensis* Gandhi 14 x 79. 
Sarode and Kamat 1984; pl. 24, fig. 567, p. 208.

5. *Pinnularia sagittata* Gandhi 10 x 80, st. 11-13. 

6. *Coelosphaerium pallidum* Lemm. cells 3 in diameter 
Prescott 1951; pl. 106, fig. 3, p. 471.

7. *Rivularia dura* Roth ex Born. et Flah. 4 x 2 
Desikachary 1959, pl. 115, fig. 2, p. 551.

8. *Aphanocapsa grevillei* (Hass) Rabenh. 3.2-5.6 diam 
Desikachary 1959; pl. 21, fig. 9, p. 134.
Plate 11

1. Aphanocapsa pulchra (Kutz) Rabenh. 3-4 diameter
Desikachary 1959; pl. 21, fig. 2, p.132.

2. Aphanothece stagnina (Spreng.) A.Br. 7.1 x 18.5.
Desikachary 1959; pl. 21, fig. 10, p.137.

3. Chroococcus turgidus (Kütz.) Nág. 17 x 25.
Desikachary 1959, fig. 6, pl. 26, p.101-102.

4. Spirulina meneghiniana Zonard ex Gomont, 1.4 broad.
Desikachary 1959; pl. 36, fig. 8, p.195.

5. Lyngeya contorta Lemm. 5.7 x 3-5.
Desikachary 1959; pl. 50, figs. 5 and 9, p.290.

6. Lyngeya ceylanica Wille 15.7 x 5.1.
Desikachary 1959; pl. 54, fig. 4, p.299.

7. Oscillatoria curviceps Ag. ex Gomont 12.8 x 3.5.
Desikachary 1959; pl. 39, figs. 9-10, p.209.

8. Oscillatoria acuta Bruhl et Biswas 5.7 x 5.5.
Desikachary 1959; pl. 1, fig. 6a, p.240-241.

9. Gloeotrichia reciborskii Wołoszynska var. longispora
Rao, C.B. 7.1 x 4.
Desikachary 1959; pl. 118, figs. 4-6, p.564.

10. Nostoc commune Vaucher 4.2 x 5.6.
Prescott 1951; pl. 119, fig. 13, p.523.

11. Anabaena orientalis Dixit 7.1 x 7.1 sp. 15.7 broad.
Desikachary 1959; pl. 77, fig. 6, p. 405-412.
1. **Anabaena iyengarii** Bharadwaja var. **unispora** Singh 5.7 x 6.5 het. 5.7 x 8.5 sp. 14 x 31.4. Desikachary 1959; pl. 78, figs. 5 & 7, p. 408.

Present alga shows formation of spores similar to that of the variety. But vegetative cells are slightly bigger than the type (type cells 3.3-5 μm long, 3.3-4.2 broad). It also differs in the nature of heterocysts. Outer walls of the heterocyst are straight and inner walls curved. Spores are much longer than the type (type spores 16.5-20 μm long) and outer walls of the spore are much thickened at the poles.


Differ from the variety in having narrow isthmus (type Isthmus 21 μm broad). Incisions forming the lobes are narrow and deep. It also differs in the central ornamentation wherein the verrucea form a semicircular ring enclosing a ring of 8-10 pores having thick mucilage deposition.

3. **Cosmarium granatum** Bre'b. 20 x 32 Isth. 6. Bruhl & Biswas 1926; pl. 8, figs. 73 & 74, p. 290.

Similar to the Manipur type in dimensions. Differs in that the walls are punctate. Few subapical pores are bigger than the rest. Lateral margins are convex to a greater length, retuse near the apex to make a truncate apical margin.
4. *Cosmarium hammeri* Reinsch fa. *acuta* 23 x 30, Isth 4.2 Turner 1892; pl. 8, fig. 15, p. 53.

Similar to the form in size. Differs by its narrow isthmus (type isthmus 8 μm broad). Unlike the retuse apical region of the lateral margin present alga has almost straight and converging lateral margin.

5. a & b *Staurastrum lunatum* Ralfs 24 x 17 Isth. 5 Hirano 1959; pl. 40, fig. 24, p. 315.

Similar to the Japan species in shape but smaller in size (type cells 25 μm long; 26-50 μm broad; isthmus 8-11 μm broad). Also differs in having less prominent terminal spines to each arm. In top view lateral margins are more concave than the type.


Similar to the variety in shape. Differs in its slightly bigger size (type cells 120-144 μm long; 28-35 μm broad). It also differs in having less number of prominent longitudinal striae which are uniformly spread on the valve (type longitudinal striae 8-14 in 10 μm).
Plate 13

1. Euastrum pseudospinulosum sp. nov.
2. Top view
3. Side view
4. Euastrum pseudospinulosum sp. nov.


Habitatio: Una Cum algis aliis in oryzae agro in regione Mugad, Dharwad.

Cells slightly longer than broad, sinus linear and closed on inner side, open on outer side. Lateral lobes small, broadly rounded with less indentation between them. Apical lobe with median slight incision. Lobes covered with large number of rounded granules. Each semicell with a ring of 8-10 granules on the surface, which surround 3-4 central granules. In side view semicells look subpyriform
Plate 13 (contd...)

with slight bulge on each side bearing the granules. Semicells in vertical view appear subelliptical with median swelling on either side bearing the granules. Cells 45-48 μm long; 39-43 broad; isthums 8-10 μm broad, 25-26 μm thick.

Habitat: With other algae in the rice field of Muğad area, Dharwad.

This plant should be compared with *E. spinulosum* Delp. (Scott and Prescott 1961; pl. 10, fig. 3) and var. *bellum* (Scott and Prescott 1961; p. 40, pl. 10 fig. 5) with which it resembles in shape but differs in having smaller size, less incised lobes, absence of spiny ornamentation and absence of the facial ring of verrucae. It is also comparable with *E. spinulosum* subsp. *spinulosum* var. *burmense* W. et G.S. West (Gronblad and Croasdale 1971; p. 11 fig. 46) but differs in its ornamentation and smaller size. *E. spinulosum* subsp. *africanum* Nordst. var. *minus* Nordst. (Gronblad and Croasdale 1971; p. 11, figs. 43-45) comes very close to this in size but differs in shape and ornamentation. The alga, therefore, is described as a new species of the genus *Euastrum*. 
DISCUSSION

The biological communities in waters would be under frequent variations. The photoautotrophic habit of these organisms and their luxuriant growth in aquatic environment depends on physical and chemical compositions of water. In India considerable hydrobiological studies have been made on the inland water bodies ranging from small ponds, shallow to large lakes, reservoirs and rivers, and have been reviewed by Prasad and Singh (1980). Several workers have correlated the growth of algae with various parameters. Mention may be made of Dickman & Johnson (1975) who suggested that the process of succession results in changes in species composition as the organisms themselves change their own environment. Though alkaline pH favouring the growth of greens was observed by Rao (1955), Zafar (1967) and Philipose (1967), according to Talling (1976) different species respond differently to pH changes. A direct relation between algal growth and calcium is reported by Jyothi (1990). Similarly Wetzel (1975) has found that magnesium is the common divalent cation in freshwaters required by many chlorophyllous plants. While organic matter inhibiting the growth of greens is reported by Sudhakar (1989) and Jyothi (1990), phosphorus limiting the algal production in lakes is suggested by Schindler (1971). Though Horne and Goldman (1972), Reynolds and Walsby (1975)
found more heterocystous blue green algal populations under phosphorus enriched and nitrogen poor conditions, according to Stewart (1974) the requirement of phosphorus for optimal growth of blue greens differs considerably from species to species. Therefore, the best way to understand life in the water is to consider the forms that occur in them separately and such a consideration will give a better picture of their distribution.

There are practically few hydrobiological studies of the tropical rice fields and the results of water analysed for various physical and chemical factors of South India are temperature-25.6°C, pH-alkaline, free CO$_2$-0.28 ppm, CO$_3$-nil, HCO$_3$-19.17 ppm, dissolved O$_2$-5.7 ppm, Cl$_2$-5.0 ppm, silicates-1.24 ppm, phosphate-traces and nitrates-nil (Belṣare, 1986).

According to Begum et al. (1988) flooded rice fields of Bangladesh with high temperature, conductivity, dissolved oxygen, alkalinity and pH favour blue green algae in the months of July and August during rice cultivation period. In their study, green algae (Oedogonium and Cosmarium) were favoured by high temperature, conductivity, dissolved oxygen, free carbon dioxide and pH, whereas low water depth, free carbon dioxide and dissolved oxygen favoured more diatoms in rice fields of Bangladesh.
In the present study Mugad rice field had water source from borewell, and Mandiwal rice fields were getting water from a natural pond. Species diversity was more in the Mandiwal rice fields as compared to Mugad rice fields. Green algae dominated over diatoms and blue greens in all the four rice fields studied and Mugad rice field I was with a permanent bloom of Aphanothece stagnina. Further, rice fields of Mugad and Mandiwal also showed sporadic blooms of Chlorophyceae and Bacillariophyceae. Hence separate discussion of individual groups has been made. Euglenoid members were poorly represented and restricted to only Mandiwal rice fields. Therefore, they have been considered only in the taxonomic aspect of the present study. The other groups of algae which had common occurrence in the rice fields under present study are Chlorophyceae, Bacillariophyceae and Cyanophyceae. An attempt is made to study ecology of these common groups of algae.

**Cyanophyceae:**

The blue green algae are wide spread and often abundant in freshwaters specially in rice field waters. Many plankton, epilithic and epiphytic forms grow rapidly and form blooms (Fogg et al., 1973). Bloom formation is a common phenomenon in smaller water bodies.
In the Mugad and Mandihal rice fields, growth of blue green algae was more in the tillering and harvest period of paddy. Generally blue green algae prefer high temperature, but at the same time they are more adaptive in nature and metabolize most efficiently in the temperature at which they occur (Fogg et al., 1973). Similarly, according to Singh (1974) pH of water influences growth of blue green algae. According to Amma et al. (1966) and Saha and Mandal (1980) in flooded soils, alkaline pH increases the availability of several nutrients which enhance the growth of blue green algae. However, under the present study the Mugad rice fields with comparatively more alkaline pH harboured less number of blue green algae. It may be due to the high values of nitrate concentration as Mandihal rice fields with traces of nitrate, and phosphate content of water showed more number of species. According to Stroener et al. (1978) and Philipsze (1980), decrease in NO₃ and PO₄ concentration with more blue green algae is due to the consumption by algae during their growth.

Mugad rice fields with higher sodium concentration showed less number of species. In contrast to this, Mandihal fields having comparatively less sodium content, had more blue green algal growth. According to Round (1964) higher sodium concentration inhibits blue green algal growth and present study confirms this.
Distribution of blue green algae during paddy cultivation cycle indicated that maximum algal biomass was produced at the panicle initiation stage followed by late tillering and harvest. *Aphanotoce* species was dominant in all the stages of crop growth in the present study agreeing with the work made at CRRI on blue green algal distribution during paddy cultivation cycle. The rice canopy as well as physical and chemical properties of flooded water perhaps create a favourable condition for the luxuriant growth of blue green algae during the panicle initiation state (Matsuguchi et al., 1974; Roger and Reynaud, 1979; Singh and Singh, 1987b). In USSR maximum growth of blue green algae was just before tillering (Prikhodkova, 1971). According to Stewart et al., (1979) more than 125 strains of free living blue green algae are capable of fixing nitrogen and these nitrogen fixers are considered to be important source of fixed nitrogen in waterlogged rice fields.

In the present study *Gloeotrichia* bloom was observed in one of the rice fields (Mandihal). Watanabe et al., (1978) have recorded a yield of 24 tons (fresh wt/ha) of *Gloeotrichia* in the rice fields of Philippines.

In Dharwad rice fields *Anabaena orientalis*, *Gloeotrichia reciborskii* v. *longispora*, *Anabaena iyengarii* v. *unispora*, *Nostoc commune* and *Rivularia dura* were of heterocystous type and *A. orientalis* and *G. reciborskii* v. *longispora* showed sporadic blooms during paddy cultivation.
Chlorophyceae

Various limnological studies show that Chlorophycean members are adaptive to different environmental conditions, and occurrence of these members show their close interaction with a number of physical and chemical soil factors. The four rice fields under present study were alkaline in nature and did not differ significantly with respect to pH (Table 2). In general, the species diversity of greens was more in Mandihal fields as compared to that in Mugad fields. Of the greens, the Conjugales, mostly constituted by desmids, were comparatively more in Mandihal fields. Although desmids preferring acidic waters is reported by many (Stroem, 1924; Pearsall, 1932; Archibald, 1971; Davis, 1973; Hegewald et al., 1976), highest growth was observed by Rao (1955), in waters nearing neutrality (7.5). Zafar (1967) has found more growth of desmids in alkaline waters with a pH range of 8-9 units. Present study is in agreement with the earlier findings as the Mandihal rice field I, with pH nearing neutrality, had more species diversity.

Major cations like calcium, magnesium and sodium were significantly less in Mandihal rice fields. This probably favoured more species of greens, particularly the desmids. Pearsall (1932), Zafar (1967) and Hegewald et al. (1976) have noticed thick growth of desmids in waters poor in calcium. Further,
magnesium inhibiting growth of desmids is reported by Zafar (1967). Present work agrees with these findings. Significantly lower concentrations of sodium, chloride, and reduced hardness in MandihaI rice fields, with more species of desmids indicates that desmids preferred lower levels of these factors. Pearsall (1932) has observed an inverse relation between desmids and nitrates and phosphates. Similar relation holds good for the present study also as MandihaI rice fields, where nitrate and phosphate could not be detected, had more growth of desmids.

Amongst the Chlorophyceae, the Chlorococcales were very poorly represented. In MandihaI rice field I, having lowest nutrient levels, more species of Chlorococcales were observed. Chlorella ellipsoidea was common to the four fields. Present study indicates that the environment of the four rice fields was not suitable for growth of Chlorococcales.
Bacillariophyceae

The distribution pattern of diatoms in the four rice fields was similar to Chlorophyceae and Cyanophyceae. In general more species diversity was seen in Mandihal fields having less nutrient concentrations. Lowest species diversity was in Mugad field II where silica concentration was also lowest (Table 2). This rice field had almost a constant high growth of *Navicula exigua*. Probably growth of this alga depleted silica in the environment, an observation also made by Seenayya (1971). According to Pearsall (1932), diatoms flourish well in waters rich in nitrate, phosphate and silicates. Patrick (1948) has stated that nitrate will be utilized by diatoms. But no such relation is observed by Rao (1955), Singh (1960) and Zafar (1967). In the present study diatom species were more in Mandihal fields where nitrate was not detected.

Similar to Chlorophyceae the diatoms also appeared to prefer lower concentrations of sodium, calcium, magnesium, hardness, chloride, oxygen and bicarbonate. Low levels of oxygen favouring diatoms is also reported by Hosmani and Bharati (1980).

In general the four rice fields of Dharwad in the present study did not differ much in their size and temperature. The water temperature was similar to the temperature of rice
Fig 5.

Water Temperature

Air Temperature

MD = Mandihal Rice field  MG = Mugad Rice field
fields of South India as reported by Belsare (1986). Water temperature was most of the time higher than air temperature. This was possibly due to smaller size and shallowness of the water, as smaller body of water reacts more quickly to the changes in atmospheric temperature (Welch, 1952 and Rao, 1971).

It is also clear that Mandiha1 rice fields, with pond water as a source, had low nutrient level (low bicarbonate, chloride, major cations, hardness and nitrate) and probably because of this, it had more species diversity. Whereas Mugad rice fields with borewell water as source, had comparatively more nutrient concentrations and, therefore, must have had less species diversity, indicating that nature of source water has a major role in the occurrence of rice field algae. Further, frequent blooms are also common in the rice fields of Dharwad.