The Effect of Constant and Alternating Temperatures on Emergence and Early Seedling Growth of Five Bangladeshi Rice Cultivars in Water Saturated Soil

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Abstract: Emergence and early seedling growth of five Bangladeshi rice cultivars were evaluated at two temperature regimes: constant (30°C) and alternating (30/11°C) in water saturated soil which would facilitate in cultivar selection for winter sown rice (Boro rice) in Bangladesh. This study was conducted at the University of Aberdeen, UK during 2000. Percentage emergence at constant temperature increased up to certain days and then most cultivar maintained plateau of constant emergence. Significantly higher emergence was recorded in cvs. BR14 and BR32. Similar trend was observed at alternating temperatures. The progress of emergence as expressed as thermal time (°C d) was also found more similar in the two temperature regimes which demonstrated the major role of temperature on emergence. The final percentage emergence was observed significantly and consistently higher in constant than in alternating temperatures. Similar result was obtained for final percentage germination (% emerged + % germinated but not emerged). The rate of emergence (the reciprocal of mean emergence time) was significantly higher in constant temperature and was about two folds that at alternating temperatures. Cultivar BR32 was appeared as fastest emerging cultivars. A significant and positive relationship was observed between rates of emergence at both temperature regimes which indicated that the faster emerging cultivars had higher percentage germination in soil. Most of the seedling growth parameters studied at the end of experiment were performed better at constant than at alternating temperatures. Cultivar BR32 appeared more promising in both temperature regimes. The seedling growth parameters, measured at the end of the experiment, were significantly related to growing time. Therefore, it could be concluded that the differences observed among temperature regimes as well as cultivars are the expression of a common variable response system which may vary in its expression on genetic make up and/or environmental influence from cultivar to cultivar.

Key words: Rice, constant and alternating temperatures, emergence, early seedling growth

INTRODUCTION

Rice crop establishment consists of the processes from the sowing of the seed through germination, pre-emergence seedling growth and early post-emergence seedling growth to give an established crop. The level of establishment achieved is the result of the interaction between the seed and the environmental conditions. Two features of the seed influence the outcome, the genetic makeup and the seed quality. The two dominant environmental factors that interact with the seed to affect the outcome are temperature and moisture.

Temperature is the main environmental factor governing the germination of seeds in moist soil[1]. Danielsen and Tooler[2] showed that germination of tall fescue declined at higher and lower temperature compared to its optimum germination temperature. Fourteen winter wheat genotypes had greater percentage germination (above 80%) in favourable temperatures between 10 and 32°C, tested on a temperature gradient plate[3]. There is, however, little detailed in the literature describing the pattern of response of rice seed germination to constant temperatures. Chaudhary and Ghildyal[4] have reported that the optimum range for seed germination of rice is 20-35°C. This germination percentage was greatly reduced at either end, beyond this range.

Seed germination response to constant temperatures has been explained by accumulated thermal time for several crop species[5,6]. The effect of constant temperature on rice seed germination and establishment have been understood but the temperature in the field is hardly ever constant, that is, temperature fluctuates on the diurnal basis. During winter months (November to February) in Bangladesh temperature fluctuates between

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11 to 30°C, night and day, respectively[6] and this is the time
for sowing Boro rice (i.e. winter rice) in wet soil bed. Al-
ternating temperatures have been reported to increase
the rate of germination in millet[6] and celery[6,11] but may
be different in their effects than that of constant
temperatures, as for lentil[12] and sorghum[13] or may
decrease the rate of germination[6,9]. Rapid germination
and subsequent rapid emergence of seedlings is important
in order to minimize the effects of 1) soil crusting, which
inhibits or prevents emergence, 2) pathogen attack while
the seed is germinating and 3) non-uniform emergence.

Three effects of alternating temperatures have been
reported, two being well documented[6,11,13]. First, some
seed populations remain dormant when held at a constant
temperature. Second, exposure to alternating temperatures
has been reported to increase the maximum fraction that
germinates in a seed population. There has been little
direct evidence for a third effect—an increase in rate of
germination in response to fluctuations in temperature. In
some studies, effects on rate of germination have not
been distinguished from effects on final germination and
in others, responses have been attributed to temperature
amplitude without regard to differences in mean
temperature between various treatments imposed.
Moreover, Wagenvoort and Bierhuizer[14] found no effect
of alternating temperature on the germination rate of
17 species of vegetable. No reports seem to be available
on the influence of alternating temperature on emergence
or on seedling growth of rice cultivars. Therefore, the
present study aimed to compare constant (30°C) and
alternating temperatures (30/11°C) and to test whether
fluctuating soil temperature (typical of night and day
temperatures during winter season in Bangladesh)
influence seedling emergence and early seedling growth
of rice cultivars in water saturated soil.

MATERIALS AND METHODS

This study was conducted at the University of
Aberdeen, UK during 2000. Seed lots of five rice cultivars
e.g. BR5, BR14, BRRI dhan32 (designated as BR32), BRRI
dhan33 (designated as BR33), modern high yielding
cultivars and Kalaghora (designated as KG), a traditional
cultivar, were used in this study. Seeds of all cultivars
were produced in different growing seasons during March
to December 1997 in Bangladesh and were stored in a
refrigerator maintained at 4°C before the start of the
experiment. Seed lots of all cultivars were surface sterilized
prior to any test by using the following procedure.

Seed lots were screened and mechanical and insect-
damaged seeds were removed. Seeds were then surface
sterilized by immersing in 1% sodium hypochlorite
solution for 1 min. Then they were rinsed in distilled water
for two one-minute periods. The glass vials containing the
distilled water used for seed rinsing had been sterilized for
20 min in an autoclave at 120°C and 1.5 bar pressure
before use.

Soil used in this study was collected from Scottish
Agricultural College, Aberdeen, UK. The soil type was
sandy-loam with pH 5.75. The soil was air dried for
10 days and then sieved through a 2 mm sieve. Plastic
cups measuring 12.5×12.5×11.5 cm (height) (B.E.F.
Products Limited, England) were filled with 1100 g of the
sieved and unsterilized soil to 2 cm from the uppermost
edges and then lightly compacted. Four replicates of
25 seeds of each cultivar were placed over the soil
equidistantly in each pot and covered with 1 cm deep soil
similarly lightly compacted. The soil was kept moist by
placing the pots in a tray containing water maintained to
a depth of 5 cm. The experiment was conducted in
two-controlled temperature chambers maintained at
constant (30±1°C) or alternating (30/11±1°C) temperatures,
but with one photo period (11 h day/13 h night). The
chambers were kept illuminated by means of artificial light
during day time (11 h). The pots were arranged in a
Completely Randomized Design in each chamber. A
seedling was counted as emerged when the shoot tip
(coleoptile) was visible on the soil surface. Emergence
was counted at intervals of 24 h until 28 days had
elapsed. At the end of the experiment, the soil was
carefully washed with running tap water and any
remaining germinated but unmerged seeds were counted.

Observations on leaf number, adventitious root
number, mesocotyl extension and length and dry matter
content of roots and shoots of the seedlings were
recorded on the emerged seedlings at the end of the
experiment (28 days). Mean emergence time (MET) was
calculated as MET= (2nd/N), where N is the number of
emerged seeds on each day, d is the number of days from
the beginning of the test and N is the total number of
emerged seeds and the rate of emergence was determined
as 1/MET.

Statistical analysis: This experiment was analyzed as a
split plot design with the temperature regimes as the main
plots in GENSTAT. The correlations between various
plant characteristics were studied using graphical routines
in Microsoft Excel.

RESULTS

Emergence: The percentage emergence at constant
temperature (30°C) increased curvilinearly (R²=0.9866,
P<0.001) with time up to 21 days and then most cultivars
Fig. 1a-b: Effect of constant and alternating temperatures on emergence (%) of five rice cultivars sown in saturated condition

Fig. 2: Effect of thermal times on emergence (%) of five rice cultivars in saturated soil at constant (30°C) and alternating (30/10°C) temperatures

Maintained plateau of constant emergence (Fig. 1a) up to final day of emergence counting (28 days). Cultivars differed significantly (P<0.001) in their percentage emergence. At the final count, cvs. BR14 and BR32 had more than 85% emergence compared with the other three cultivars and cv. KG had the lowest percentage emergence (52%) at this temperature (Fig. 1a). Cultivars BR5 and BR33 had intermediate percentage emergences of about 60%.

Similarly, the percentage emergence in alternating temperature regime (30/11°C) increased curvilinearly (R²=0.9955, P<0.001) up to 24 days when a constant percentage emergence was maintained up to final count. The final emergence of all cultivars was significantly (P<0.001) lower than that seen at 30°C, more so for the better emerging cultivars at 30°C (BR14 and BR32) resulting in a greater similarity in emergence over time between cultivars at 30/11°C than at 30°C (Fig. 1b). When
Table 1: Effect of constant and alternating temperatures on seedling growth parameters for five rice cultivars sown in saturated soil

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Temperature regime (°C)</th>
<th>Rice cultivar</th>
<th>LSD (0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BR5</td>
<td>BR14</td>
<td>BR32</td>
</tr>
<tr>
<td>Shoot length (cm plant⁻¹)</td>
<td>Constant</td>
<td>25.78</td>
<td>28.65</td>
</tr>
<tr>
<td></td>
<td>Alternating</td>
<td>9.14</td>
<td>12.19</td>
</tr>
<tr>
<td>Seminal root length (cm plant⁻¹)</td>
<td>Constant</td>
<td>2.60</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>Alternating</td>
<td>1.75</td>
<td>2.78</td>
</tr>
<tr>
<td>Shoot dry weight (mg plant⁻¹)</td>
<td>Constant</td>
<td>7.90</td>
<td>25.96</td>
</tr>
<tr>
<td></td>
<td>Alternating</td>
<td>2.95</td>
<td>9.20</td>
</tr>
<tr>
<td>Root dry weight (mg plant⁻¹)</td>
<td>Constant</td>
<td>0.47</td>
<td>1.77</td>
</tr>
<tr>
<td></td>
<td>Alternating</td>
<td>0.75</td>
<td>1.94</td>
</tr>
<tr>
<td>Leaf (no. plant⁻¹)</td>
<td>Constant</td>
<td>3.00</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>Alternating</td>
<td>2.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Adventitious root (no. plant⁻¹)</td>
<td>Constant</td>
<td>3.00</td>
<td>10.00</td>
</tr>
<tr>
<td></td>
<td>Alternating</td>
<td>2.00</td>
<td>4.00</td>
</tr>
<tr>
<td>Mesocotyl extension (mm plant⁻¹)</td>
<td>Constant</td>
<td>6.50</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>Alternating</td>
<td>4.25</td>
<td>2.50</td>
</tr>
</tbody>
</table>

Fig. 3: Effect of constant (30°C) and alternating (30/11°C) temperatures on final emergence of five rice cultivars sown in saturated soil

emergence time was expressed as thermal time (°C d) and normalized with final emergence percentage, the progress of emergence was more similar in the two temperature treatments (Fig. 2).

The final percentage emergence of all cultivars was significantly (P<0.001) and consistently higher in constant temperature than in alternating temperatures. The overall mean of all cultivars in constant temperature was 70.8% with a wide range (52-90%) compared to a mean in alternating temperatures of 56.4% and a range of 48-66% (Fig. 3). In constant temperature, cv. BR32 gave the highest percentage emergence (90%), followed by cv. BR14 (86%) and lowest was recorded for cv. KG (52%). A similar trend was seen in alternating temperatures at a lower level.

**Final percentage germination:** The final percentage germination (% emerged + % germinated but not emerged) was significantly (P<0.001) higher in constant temperature than in alternating temperatures (Fig. 4). The highest final

percentage germination were obtained in cvs. BR32 and BR14 (more than 90%) at constant temperature. These two cultivars also gave similar higher percentage germination at alternating temperatures of about 80% (Fig. 4). Again the least Germination was observed for KG in both temperature regimes.

**Mean emergence time (MET) and rate of emergence:** The MET in alternating temperatures was greater (14-18 days) than in constant temperature (5-10 days) (Fig. 5), indicating a faster emergence at constant temperature. Consequently, the rate of emergence (the reciprocal of MET) was significantly higher in constant temperature (0.1442 seeds d⁻¹) and about twice that at alternating temperatures (0.0694 seeds d⁻¹) (Fig. 6). Cultivars differed significantly (P<0.001) in MET and consequently in rate of emergence. Cultivar BR32 was observed with highest rates of emergence in both temperatures followed by cv. BR14. In contrast, cvs. KG, BR5 and BR33 had slow rates of emergence (Fig. 6). The relationship between rate of
emergence and final percentage emergence at 30 or 30/11°C was significant and positive (Fig. 7), indicating that the faster emerging cultivars had higher percentage emergence in soil. In alternating temperatures those cultivars that emerged more slowly showed lower final percentage emergence, as indicated by their positions on lower part of the regression line (Fig. 7).

**Seedling growth parameters:** Results on the following seedling growth parameters studied, measured at the end of the experiment (day 28) (Table 1).

**Seedling size:** The mean shoot lengths over all cultivars were higher (P<0.001) in constant temperature (25 cm) than in alternating temperature (12 cm). In the constant temperature, cvs. BR14 and BR32 produced similar higher shoot lengths of about 28.63 and 27 cm. In alternating temperatures shoot lengths were more contrasted. Cultivar BR14 produced shoot with highest (P<0.001) length and lowest was seen in cv. KG (Table 1). For each cultivar the mean seminal root lengths were more similar in both temperature regimes than in the case for shoot length. Cultivars BR14, BR32 and BR33 produced significantly longer seminal roots than the other two cultivars at both temperatures.

**Seedlings dry weight:** Shoot dry weight (mg seedling$^{-1}$) was significantly (P<0.001) higher in constant temperature than alternating temperatures. At constant temperature, cvs. BR14 and BR32 gave higher shoot dry weight (around 23 mg seedling$^{-1}$) in comparison with other cultivars (P<0.001). The lowest (8 mg seedling$^{-1}$) was observed in cv. BR5. In alternating temperatures cv. BR14 again produced the highest (P<0.001) shoot dry weight while, the lowest shoot dry weights were recorded with cvs. BR5 and KG. The total root dry weight (mg seedling$^{-1}$) was higher at alternating temperatures than at constant temperature (P<0.05). Cultivar BR14 gave significantly (P<0.001) higher root dry weight than other cultivars in both temperature regimes. Cultivar BR5 had the lowest dry weight (Table 1).

**Leaf number:** Leaf number per seedling was higher in constant temperature than alternating temperatures. On an average, in constant temperature 4 leaves per seedling were observed whereas 3 leaves were noted in alternating temperatures. The higher (P<0.001) leaf numbers were recorded with cvs. BR14, BR32 and BR33 in both temperatures while lower number of leaves were seen in cv. KG (Table 1).
Adventitious root number: The number of adventitious roots per seedling was higher (P<0.001) in constant temperature than at alternating temperatures. Cultivar BR14 had the highest number of adventitious root at constant temperature whereas at alternating temperatures cv. BR32 produced more than the other cultivars (Table 1).

Mesocotyl extension: Mesocotyl extension (mm seedling⁻¹) was greater (P<0.001) at constant temperature than that at alternating temperatures. Cultivars BR14 and BR5 produced longer mesocotyls than other cultivars at both temperatures; the lowest was in cv. BR33 (Table 1).
Cultivar BR32 appeared more promising in both temperature regimes regarding its relatively better performance at all parameters studied, very closely followed by cv. BR14. Cultivars KG and BR5 performed poorly in most cases.

Relations of growing time (GT) to seedling growth parameters: The relationships between growing time and different seedling growth parameters were examined. Only a few measures of seedling growth were found to be significantly related to growing time measured in days. The growing time was significantly related to root length and adventitious root number at both temperature regimes (Fig. 8a-d). However, significant relationships between growing time and leaf number and mesocotyl extension were seen only at alternating temperatures (Fig. 8f and h). Shoot dry weight and root dry weight were significantly related with growing time only at constant temperature (Fig. 8e and g).

DISCUSSION

The results presented here compare the responses of five rice cultivars to constant temperature (30°C) and fluctuating temperatures (30/11°C). Percentage emergence (Fig. 3) and percentage final germination (Fig. 4) were higher in constant temperature, compared to alternating temperatures. This agrees with the reports of Juntila[13] and Probert et al.[14]. However, Steinhauer and Grigsby[15] found higher germination at alternating temperatures compared to constant temperature. Seeds of many temperate plants, including grasses, require alternating temperatures for maximum germination[16]. Thompson[17] reported that seeds of some species fail to germinate at constant temperature and many germinate better in conditions which include daily fluctuating temperature, or germinate over wider temperature ranges. Diurnal fluctuations in temperature may initiate or accelerate germination and the effectiveness of the stimulus varies according to the amplitude of fluctuation and the presence or absence of light[18]. No reports seem to be available on the influence of alternating temperature on emergence or on seedling growth of rice cultivars. However, the present study suggested that the extreme range of the alternating temperatures used (30/11°C) might reduce germination and emergence[19].

The rate of emergence was higher in two cultivars at constant temperature, compared to alternating temperatures (Fig. 6). The low temperature was chosen to represent an extreme and so there is a possibility that damage rather than short thermal time might be the reason for slowing the rate of emergence at these temperatures as well as most of the plant parameters studied here.

The performance of seed in the seedbed is an interaction between the intrinsic characteristics of the seed lots and the environmental conditions in the seedbed. Two measures of performance are of special agronomic importance: the proportion of the seeds sown which emerge and how long they take to emerge. In field conditions, variability is compounded by the fact that seeds are distributed throughout the soil and their exposure to temperature fluctuations will be modified by variations in incident radiation, vegetative canopy and soil moisture content. In many species, sensitivity to alternating temperatures has been shown to be dependent on other environmental factors, particularly light[20]. The influence of fluctuating temperature may vary within a species; for example strains of cultivated Apium graveolens[21] display considerable differences in their relative responses to constant and fluctuating temperatures.

The temperature responses identified and described for these five rice cultivars may be due to variation of thermal temperatures which were dependent more on constant temperature rather than alternating temperatures. The physiological basis of these responses are not clear. It is, however, arguable that all of them are expressions of a common response system which is temperature dependent and which may vary in its expression genotypically and/or environmentally from cultivar to cultivar.

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REFERENCES


