http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 7 (7): 1274-1281, 2004
ISSN 1028-8880

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

[1]M.G. Ali, [1]M.Z. Alam [2]R.E.L. Naylor, [2]S. Matthews, [3]A.A. Bhuiya and [1]M.S.A. Talukder
[1]Bangladesh Rice Research Institute, Gazipur, Bangladesh
[2]University of Aberdeen, UK
[3]Patuakhali Science and Technology University, Patuakhali, Bangladesh

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 Toole[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[5-7]. 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

Corresponding Author: Dr. M.Z. Alam, Senior Scientific Officer, Adaptive Research Division, Bangladesh Rice Research Institute, Gazipur, 1701, Bangladesh Email: ardbrri@dhaka.net

11 to 30°C, night and day, respectively[8] and this is the time for sowing Boro rice (i.e. winter rice) in wet soil bed. Alternating temperatures have been reported to increase the rate of germination in millet[9] and celery[10,11] 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[14]. 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[10,11,15]. 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 Bierhuizen[16] 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 pots 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= $(\Sigma nd)/N$, 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 (R^2=0.9866, P<0.001) with time up to 21 days and then most cultivars

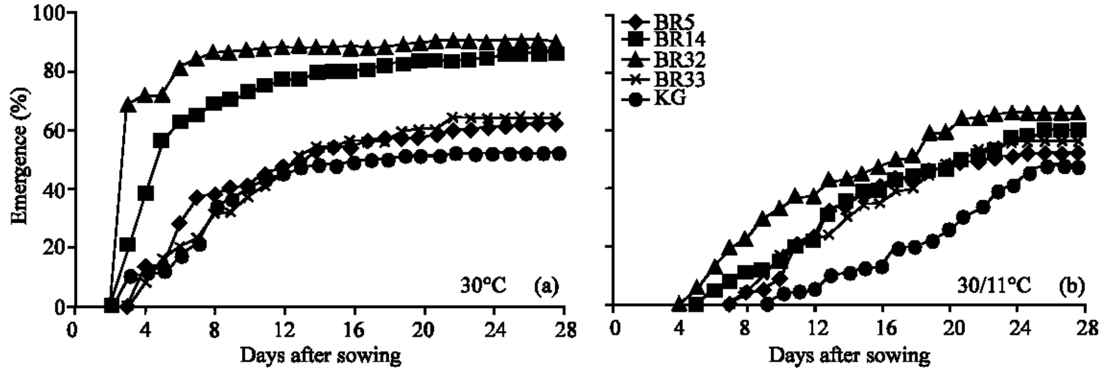

Fig. 1a-b: Effect of constant and alternatng temperatures on emergence (%) of five rice cultivars sown in saturated condition

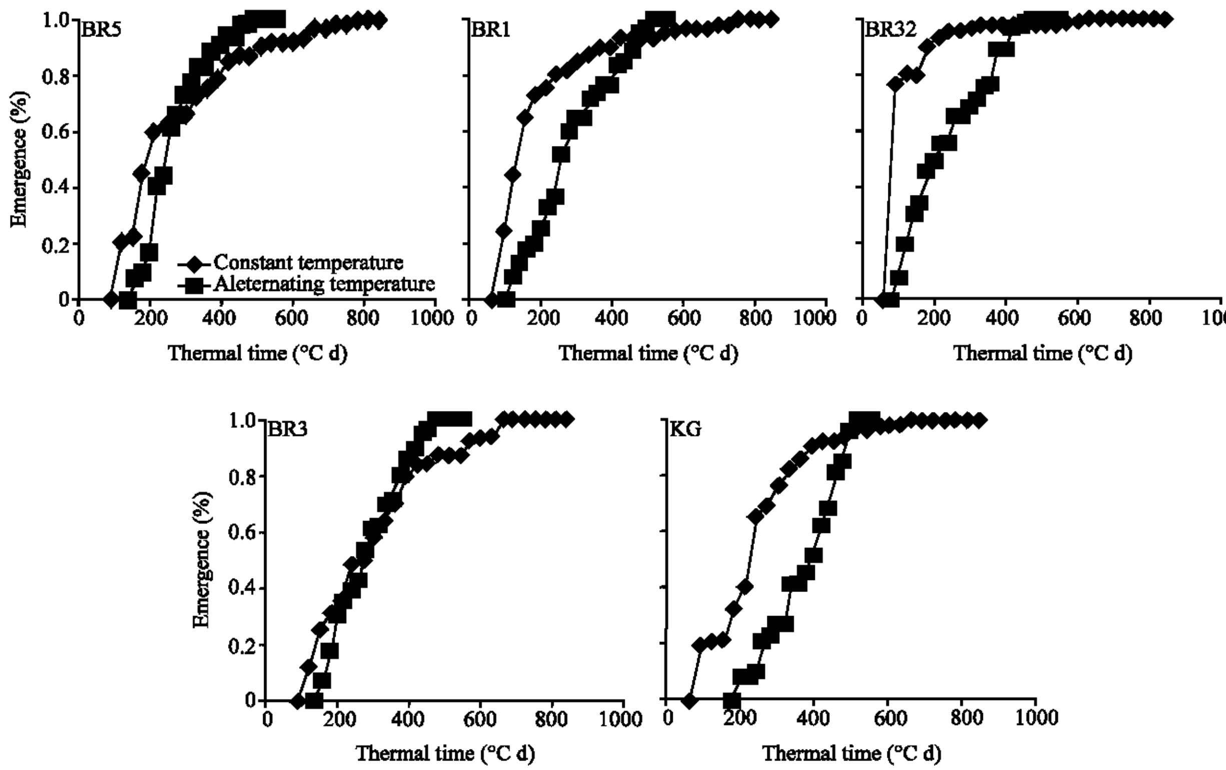

Fig. 2: Effect of thermal times on emergence (%) of five rice cultivars in saturated soil at constant (30°C) and alternating (30/10°C) temperatures

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 ($R^2=0.9955$, $P<0.001$) 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

		Rice cultivar					LSD (0.05)		
Parameter	Temperature regime (°C)	BR5	BR14	BR32	BR33	KG	Cultivar	Temperature	Interaction
Shoot length (cm plant^{-1})	Constant	25.78	28.63	27.10	24.55	17.53	5.26	3.33	NS
	Alternating	9.14	12.19	11.11	13.10	5.59			
Seminal root length (cm plant^{-1})	Constant	2.60	3.00	3.00	2.63	2.33	0.78	NS	1.10
	Alternating	1.75	2.78	2.73	3.88	0.83			
Shoot dry weight (mg plant^{-1})	Constant	7.90	23.96	22.02	17.07	17.67	3.38	2.13	4.77
	Alternating	2.95	9.20	6.95	8.50	3.18			
Root dry weight (mg plant^{-1})	Constant	0.47	1.77	1.30	0.78	1.44	0.35	NS	0.50
	Alternating	0.75	1.94	1.37	1.43	0.92			
Leaf (no. plant^{-1})	Constant	3.00	4.00	4.00	4.00	2.00	0.88	0.55	NS
	Alternating	2.00	3.00	3.00	4.00	1.00			
Adventitious root (no. plant^{-1})	Constant	3.00	10.00	8.00	6.00	4.00	1.80	0.69	NS
	Alternating	2.00	4.00	7.00	5.00	1.00			
Mesocotyl extension (mm plant^{-1})	Constant	6.50	7.00	4.75	3.00	3.50	1.09	1.14	NS
	Alternating	4.25	2.50	2.50	1.00	1.75			

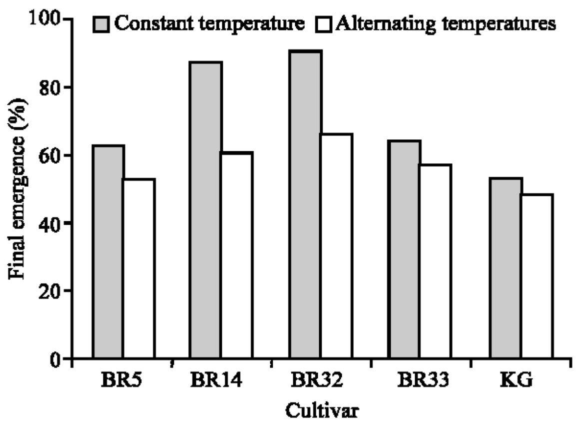

Fig. 3: Effect of constant (30°C) and alternating (30/11°C) temperatures on final emergence of five rice cultivars sown in saturated soil

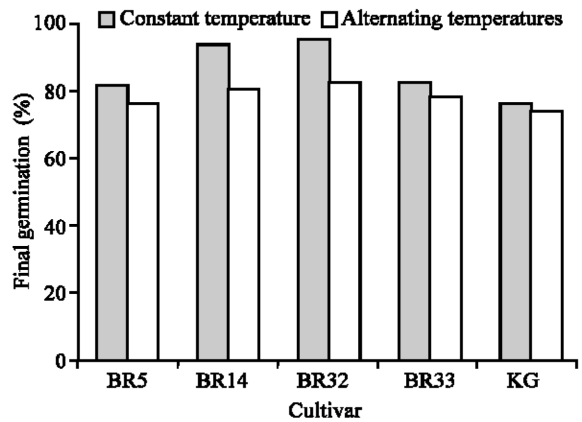

Fig. 4: Effect of constant (30°C) and alternating (30/11°C) temperatures on final percent germination of five rice cultivars sown in saturated soil

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

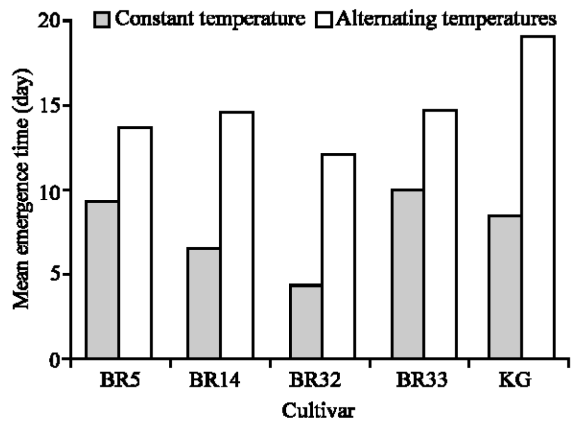

Fig. 5: Effect of constant (30°C) and alternating (30/11°C) temperatures on mean emergence time of five rice cultivars sown in saturated soil

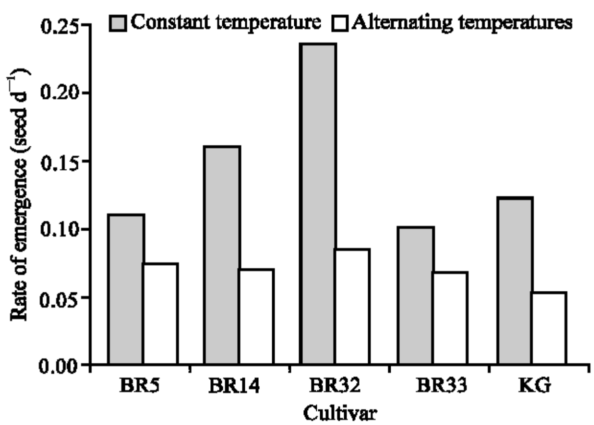

Fig. 6: Effect of constant (30°C) and alternating (30/11°C) temperatures on rate of emergence of five rice cultivars sown in saturated soil

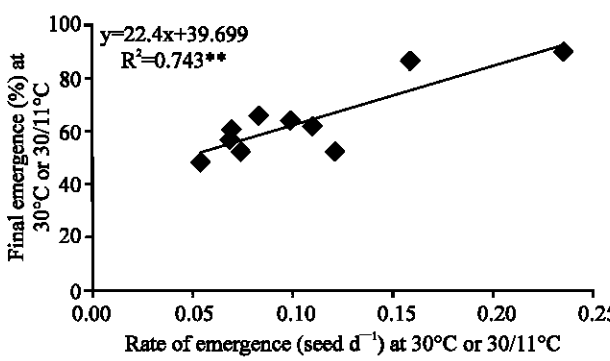

Fig. 7: Relationship between emergence and rate of emergence (1/MET) at 30°C or 30/11°C temperatures of five rice cultivars sown in saturated soil (open symbols represent cultivars at 30/11°C)

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 (26 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).

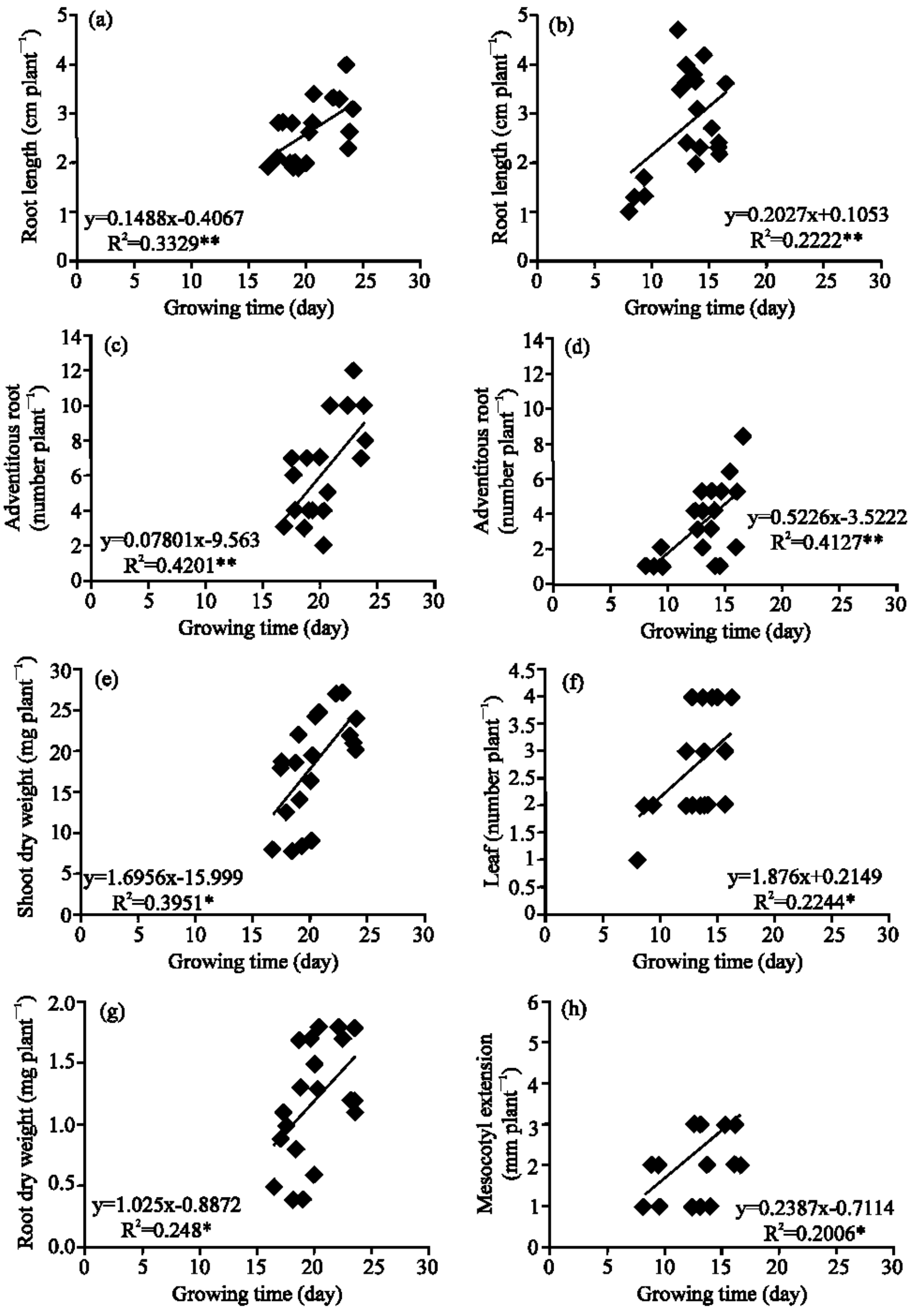

Fig. 8: Relationship between growing time and root length (a) and (b), adventitious root numbers © and (d), shoot dry weight (e), leaf number (f), root dry weight (g) and mesocotyl extension (h) at two temperature regimes of five rice cultivars sown in water saturated soil

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 Junttila[17] and Probert *et al.*[18]. However, Steinbauer and Grigsby[19] found higher germination at alternating temperatures compared to constant temperature. Seeds of many temperate plants, including grasses, require alternating temperatures for maximum germination[20]. Thompson [11] 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[15]. 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[11].

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[21]. The influence of fluctuating temperature may vary within a species; for example strains of cultivated *Apium graveolens*[10] 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.

ACKNOWLEDGMENT

The authors wish to thank the Director General of the Bangladesh Rice Research Institute for providing financial support for the study.

REFERENCES

1. Monteith, J.L., 1979. Soil Temperature and Crop Growth in the Tropics. In: Lal, R. and D.J. Greenland, (Ed.) Soil Physical Properties and Crop Production in the Tropics, pp: 249-262.
2. Danielson, H.R. and V.K. Toole, 1976. Action of temperature and light on the control of seed germination in alta tall fescue (*Festuca arundinacea* Schreb). Crop Sci., 16: 317-320.
3. Ali, Z.I., V. Mahalakshmi, M. Singh, G. Ortiz-Ferrara and J.M. Peacock, 1994. Variation in cardinal temperatures for germination among wheat (*Triticum aestivum*) genotypes. Ann. App. Biol., 125: 367-375.
4. Chaudhary, T.N. and B.P. Ghildyal, 1970. Temperature in relation to seed germination and seedling development in rice. Riso, 19: 165-168.

5. Garcia-Huidobro, J., J.L. Monteith and G.R. Squire, 1982a. Time, temperature and germination of pearl millet. I. Constant temperature. J. Exp. Bot., 33: 288-296.
6. Covell, S., R.H. Ellis, E.H. Roberts and R.J. Summerfield, 1986. The influence of temperature on seed germination rate in grain legumes. I. A comparison of chickpea, lentil, soybean and cowpea at constant temperature. J. Exp. Bot., 37: 705-715.
7. Dunbabin, T., J. Learmonth, R.E.L. Naylor and C.E. Mullins, 1994. Temperature effect on the germination of *Sorghum bicolor* under a constant temperature regime. Asp. App. Biol., 39: 179-184.
8. BBS (Bangladesh Bureau of Statistics), 1999. The Statistical Year Book of Bangladesh, 1998. Statistics Division, Ministry of Planning. (19th Edn.) Dhaka, Government of the People's Republic of Bangladesh, pp: 140-141.
9. Garcia-Huidobro, J., J.L. Monteith and G.R. Squire, 1982B. Time, temperature and germination of pearl millet. II. Alternating temperature. J. Exp. Bot., 33: 297-302
10. Thompson, P.A., 1974a. Germination of celery (*Apium graveolens* L.) in response to fluctuating temperatures. J. Exp. Bot., 25: 156-163.
11. Thompson, P.A., 1974b. Effects of fluctuating temperatures on germination. J. Exp. Bot., 25: 164-175.
12. Ellis, R.H. and S. Barrett, 1994. Alternating temperatures and rate of seed germination in lentil. Ann. Bot., 74: 519-524.
13. Heslehurst, M.R. and R. Hohenhaus, 1989. The Influence of Alternating Temperature on Grain Sorghum Germination. In: Foale, M.A., B.W. Hare and R.G. Henzell, (Eds.) Proceedings of the Australian Sorghum Workshop, Toowoomba, Queensland, 28/2-1/3, 1989, pp: 60-65.
14. Gulliver, R.L. and W. Heydecker, 1972. Establishment of Seedlings in a Changeable Environment. In: Heydecker, W. (Ed.) Seed Ecol. Butterworths and Co. Ltd., London.
15. Thompson, K., J.P. Grime and G. Mason, 1977. Seed germination in responses to diurnal fluctuations of temperature. Nature, London, 267: 147-149.
16. Wagenvoort, W.A. and J.F. Bierhuizen, 1977. Some aspects of seed germination in vegetables. II. The effect of temperature fluctuation, depth of sowing, seed size and cultivar, on heat sum and minimum temperature for germination. Scientia Hort., 6: 259-270.
17. Junttila, O., 1977. Dormancy in dispersal units of various *Dactylis glomerata* populations. Seed Sci. Technol., 5: 463-471.
18. Probert, R.J., R.D. Smith and P. Birch, 1985. Germination responses to light and alternating temperatures in European populations of *Dactylis glomerata* L. I. Variability in relation to origin. New Phytol., 99: 305-316.
19. Steinbauer, G.P. and B. Grigsby, 1957. Interaction of temperature, light and moistening agent in the germination of weed seeds. Weeds, 5: 175-182.
20. Pannangpetch, K. and E.W. Bean, 1984. Effects of temperature on germination in population of *Dactylis glomerata* from N. W. Spain and Central Italy. Ann. Bot., 53: 633-639.
21. Totterdell, S. and E.H. Roberts, 1980. Characteristics of alternating temperatures which stimulate loss of dormancy in seeds of *Rumex obtusifolius* L. and *R. crispus* L. Plant Cell Environ., 3: 3-12.