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## Interactive Effects of Nitrogen, Water Stress and Temperature in the Germination of *Bauhinia* Seeds

By

H. M. EL-SHARKAWI and K. A. FARGHALI \*)

With 3 Figures

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### Summary

EL-SHARKAWI H. M. & FARGHALI K. A. 1987. Interactive effects of nitrogen, water stress and temperature in the germination of *Bauhinia* seeds. – *Phyton* (Austria) 27 (1): 139–153, with 3 figures. – English with German summary.

Three factorial interactions of matric water potential ( $\Psi_m$ ), temperature (T) and ambient nitrate concentration ( $\text{NO}_3^-$ ) in the germination of *Bauhinia variegata* L. seeds were studied. Criteria investigated in germination included emergence and elongation of both radicle and plumule as well as allocation of dry matter to each, and its corresponding depletion from storage tissue. ( $T \times \text{NO}_3^-$ ) interaction had no significant effect on both radicle and plumule emergence and ( $\Psi_m \times \text{NO}_3^-$ ) interaction had no effect on radicle emergence and plumule elongation. The same is true for ( $T \times \Psi_m \times \text{NO}_3^-$ ) interaction in plumule elongation. The magnitude of effect (share) of each of the single factors or the combination of any two-factorial interaction varied according to the level of the third factor (or the two other factors in case of the single factors). This also varied according to the organ and the phase of germination (emergence, elongation or allocation of dry matter). Among the clear examples of such variation of role are: 1.:  $\text{NO}_3^-$  concentration accelerates plumule emergence at different  $\Psi_m$  levels, but not so with radicle, 2.: ( $\Psi_m \times \text{NO}_3^-$ ) interaction effect on radicle emergence shows up only at 33° C (while it existed at 27–37° C in plumule emergence and, 3.: ( $T \times \Psi_m$ ) interaction effect at high  $\text{NO}_3^-$  concentrations (750–1000 ppm) has a greater role in the elongation of radicle but not so with plumule.

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\*) H. M. EL-SHARKAWI, K. A. FARGHALI, Botany Department, Faculty of Science, Assiut University, Assiut, Egypt 71516.

### Zusammenfassung

EL-SHARKAWI H. M. & FARGHALI K. A. 1987. Wechselbeziehungen von Stickstoff, Wasserstreß und Temperatur bei der Keimung von *Bauhinia*-Samen. – *Phyton* (Austria) 27 (1): 139–153, mit 3 Figuren. – Englisch mit deutscher Zusammenfassung.

Es wurden die Wechselbeziehungen von matrikalem Wasserpotential ( $\Psi_m$ ), Temperatur (T) und Nitratkonzentration der Umgebung ( $\text{NO}_3^-$ ) bei der Keimung von Samen von *Bauhinia variegata* L. untersucht. Erfaßt wurden Auftreten und Streckung von Radicula und Plumula und deren Trockengewichtszunahme sowie die Entnahme von Trockensubstanz aus dem Speichergewebe.  $T \times \text{NO}_3^-$  hatte keinen signifikanten Effekt auf das Auftreten von Radicula und Plumula,  $\Psi_m \times \text{NO}_3^-$  war auf das Erscheinen der Radicula und der Streckung der Plumula ohne Wirkung, letztere wird auch durch  $T \times \Psi_m \times \text{NO}_3^-$  nicht beeinflußt. Der Anteil jedes einzelnen Faktors oder einer Kombination von zwei Faktoren ändert sich nach Maßgabe des dritten Faktors (oder, bei nur einem Faktor, der beiden anderen Faktoren). Als gute Beispiele hiefür seien genannt: 1.:  $\text{NO}_3^-$  beschleunigt das Erscheinen der Plumula bei verschiedenen  $\Psi_m$ , aber nicht bei der Radicula; 2.:  $\Psi_m \times \text{NO}_3^-$  wirkt auf das Durchbrechen der Radicula nur bei 33° C, auf die Plumula jedoch bei 27–37° C; 3.:  $T \times \Psi_m$  wirkt bei hohen  $\text{NO}_3^-$ -Konzentrationen (750–1000 ppm) deutlicher auf die Streckung der Radicula, nicht jedoch auf die Plumula.

### Introduction

Under natural conditions, multifactorial effects and interactions are the rule rather than an exception. Coincidence of optimal level of two or more factors certainly is the critical event in biological responses to environmental factors. Accordingly, the multifactorial experiments and elucidation of interactions are a primary goal for any biologist aiming to embark his investigations on realistic basis rather than abstraction.

Among the complex of environmental factors, temperature, light and nitrates (either singly or in combination) are some natural factors which influence weed seed dormancy and germination (ROBERTS & BENJAMIN 1979, VINCENT & ROBERTS 1979). Nitrate reduction, absorption and accumulation are well-known as a process sensitive to external stress (RHODES & MATSUDA 1976, HEUER & al. 1979), ultimately influenced by respiration (MINOTTI & al. 1969) and hence strongly affected by temperature. Nitrate accumulates in plant tissues in response to increasing ambient nitrate concentration (CANTLIFFE 1972b, CHANTAROTWONG & al. 1976) and extremes of low and high temperatures (MATTAS & PAULI 1965). EGLEY (1984) indicated that nitrate exerted its effect via conversion to nitrite within the seed and that the rate of nitrate conversion may be a limiting factor in the germination of common purslane seeds. Although much work has been done elucidating the effects of environmental factors on nitrate assimilation (HALLMARK & HUFFAKER 1978) yet very little is encountered in pertinent literature on the interaction between nitrate and any of the environmental factors in affecting germination of seeds.

The aim of the present work is to study the interactive effects of two environmental factors (temperature and soil matric water potential,  $\Psi_m$ ) and ambient nitrate concentration in the seed incubation medium on the germination of *Bauhinia variegata* L. seeds. This tree (S. F.: *Caesalpinioideae*), well known as an ornamental tree grown in many temperate countries, has a widespread natural distribution in the tropics. It grows in a wide range of poor soils, alkaline or acidic, and fully germinates under a wide range of optimal temperatures, high water potential (0 bar) and on nitrate deficient soils (ADAMS 1979).

### Materials and Methods

The mature seeds of *Bauhinia* were pretreated with  $10^{-3}$  mercuric chloride solution, thoroughly washed and embedded on chemically pure filter paper in sterilized glass petri dishes 11 cm in diameter. Each dish contained 10 seeds to which was added 20 ml. of treatment solution (of a certain water potential), which was found adequate to support the seeds during the period of investigation (maximum germination was reached after 20 days) as the dishes were always covered during incubation. Soil matric water potential was simulated in this experiment by using solutions of polyethylene glycol the merits of which are discussed elsewhere (PARMER & MOORE 1968, LAWLOR 1969; SHARMA 1973 and EL-SHARKAWI & SPINGUEL 1977). Solutions of PEG-4000 (Union Carbide Corp., U.S.A.) in concentrations that give particular levels of water potential ranging between -2 and -15 bar were prepared for this purpose. The germination of seeds was tested at the potential levels. 0 (control), -2, -5, -10 and -15 bars. Solutions at the same water potential levels containing nitrate (supplied as  $\text{KNO}_3$ ) in concentrations: 0 (control), 250, 500, 750 and 1000 ppm were prepared for use in testing the effect of ambient  $\text{NO}_3^-$  concentration. Seeds were incubated in dark at constant temperatures (27° C, 33° C and 37° C). Three dishes were assigned at random to each treatment combination at every incubation temperature. Incubators with air circulation were used. The investigation, therefore, included 75 treatment combinations covering the three factors used in this investigation (water potential,  $\text{NO}_3^-$  concentration and temperature).

Radicle emergence is taken as the criterion for germination success. Plumule emergence and elongation is equally important in order that seedling establishment is ascertained through utilisation of light energy. The dry matter accumulation in both radicle and plumule is taken, likewise, a criterion for normal growth. Changes in dry matter content of such organs under different treatment levels will indicate the degree of build up of material in plumule and radicle (through translocation) corresponding to depletion from storage tissue. Accordingly, the above mentioned parameters were measured as characteristics of germination.

Germination of *Bauhinia* seeds failed at  $-15$  bar under  $33^{\circ}\text{C}$  (optimum temperature). On reaching maximum germination, the germinated seeds were counted (as %), and both radicle and plumule were excised, their fresh and corresponding dry weights (oven-dry at  $85^{\circ}\text{C}$ ) were determined. The same was done for the remaining part of the seed (storage tissue) exclusive of the testa. The dry weight for each organ is expressed as percentage of total dry weight of germinating seeds for each treatment combination.

Statistical inferences necessary to evaluate the effects and relative roles (shares) of single factors and of their interactions on germination phases included: analysis of variance (F values) and coefficient of determination,  $\eta^2$  respectively (OSTLE 1963).

## Results

### A. Radicle and plumule emergence:

The emergence of radicle and plumule of *Bauhinia* showed more response to high water potentials (0 to  $-2$  bar) and relatively high temperatures ( $33^{\circ}\text{C}$  to  $37^{\circ}\text{C}$ ) as well as to different nitrate concentrations (Figure 1-A and Figure 2-A). At the optimum temperature ( $33^{\circ}\text{C}$ ) and relatively high  $\Psi_m$ ,  $\text{NO}_3^-$  concentration ranging between 0 to 500 ppm are obviously more effective in the emergence of radicle and plumule. Plumule emergence gradually decreased with decreasing water potential. It failed at  $\Psi_m = -5$  bar under both  $27^{\circ}\text{C}$  and  $37^{\circ}\text{C}$  and at  $-15$  bar under  $33^{\circ}\text{C}$ . Radicle emergence is sensitive to  $\text{NO}_3^-$  concentration and decreased  $\Psi_m$  under different temperatures, where it failed with 750 ppm  $\text{NO}_3^-$  at  $\Psi_m = -5$  bar under  $27^{\circ}\text{C}$ , at  $-10$  bar under  $37^{\circ}\text{C}$  and at  $\Psi_m = -15$  bar under  $33^{\circ}\text{C}$ .

Plumule emergence is obviously more sensitive to different factors tested than radicle emergence. Temperature (T), matric potential ( $\Psi_m$ ) and nitrate concentration ( $\text{NO}_3^-$ ) have highly significant effects on both plumule and radicle emergence. The same is true for ( $T \times \Psi_m$ ) and the three factorial ( $T \times \Psi_m \times \text{NO}_3^-$ ) interaction (Table 1). On the other hand, the interaction ( $\Psi_m \times \text{NO}_3^-$ ) has a highly significant effect only in plumule emergence. This indicates that  $\text{NO}_3^-$  accelerates plumule emergence at different  $\Psi_m$  levels, but not so in case of radicle emergence.

The magnitude of the relative effects of each factor and the factorial interactions on radicle and plumule emergence (as indicated by  $\eta^2$  values) is quite versatile. The relative role of  $\Psi_m$  is predominant in plumule and radicle emergence ( $\eta^2 = 0.54$  and  $0.51$ , respectively) but that of temperature is subdominant ( $\eta^2 = 0.25$  and  $0.32$ , respectively). The role of ( $T \times \Psi_m \times \text{NO}_3^-$ ) interaction was relatively low and that of other factorial interactions in the emergence of both radicle and plumule is a minor one.

The effects of each of the three bifactorial interactions ( $\Psi_m \times \text{NO}_3^-$ ,  $T \times \text{NO}_3^-$  and  $T \times \Psi_m$ ) are throughout significant at the 1% level with two



Table 1

F and  $\eta^2$  values for the effect of T,  $\Psi_m$  and  $\text{NO}_3^-$  concentration and their interactions on the emergence, elongation and weight of plumule and radicle of *Bauhinia*.

Organ	Treatment	Emergence		Elongation		Weight	
		F	$\eta^2$	F	$\eta^2$	F	$\eta^2$
Radicle	T	496.4**	0.25	357.0**	0.49	173.2**	0.34
	$\Psi_m$	716.5**	0.54	153.6**	0.31	106.8**	0.32
	$\text{NO}_3^-$	4.6**	0.01	21.8**	0.06	15.8**	0.06
	$T \times \Psi_m$	46.8**	0.07	23.0**	0.09	17.2**	0.10
	$T \times \text{NO}_3^-$	0.4	0.00	2.2*	0.01	2.1*	0.02
	$\Psi_m \times \text{NO}_3^-$	14.5**	0.04	1.7	0.02	4.9**	0.06
	$T \times \Psi_m \times \text{NO}_3^-$	14.3**	0.09	1.3	0.02	4.4**	0.10
Plumule	T	247.0**	0.32	656.7**	0.38	181.6**	0.24
	$\Psi_m$	262.7**	0.51	472.0**	0.41	256.0**	0.52
	$\text{NO}_3^-$	4.1**	0.01	34.1**	0.04	20.5**	0.06
	$T \times \Psi_m$	9.5**	0.04	50.0	0.09	6.4**	0.03
	$T \times \text{NO}_3^-$	0.6	0.00	5.1**	0.01	4.5**	0.02
	$\Psi_m \times \text{NO}_3^-$	0.9	0.01	6.7**	0.02	7.8**	0.06
	$T \times \Psi_m \times \text{NO}_3^-$	6.9**	0.11	5.9**	0.04	4.4**	0.07

\* = Significant at 5% confidence level

\*\* = Significant at 1% confidence level.

exceptions ( $\Psi_m \times \text{NO}_3^-$  effect on radicle emergence at 33° C and  $T \times \Psi_m$  effect on plumule emergence at 500 ppm. ambient  $\text{NO}_3^-$  concentration are significant at the 5% level). However, the relative role of each interaction differs according to the level of the third factor. Thus, ( $T \times \text{NO}_3^-$ ) interaction is highest in the emergence of both organs at 37° C and least in the emergence of radicle at 33° C (Table 2). The relative role of ( $T \times \text{NO}_3^-$ ) interaction in both radicle and plumule emergence is highest at -5 and -10 bar ( $\eta^2 = 0.96, 0.97$  and  $0.97, 0.96$ , respectively). The ( $T \times \Psi_m$ ) interaction has the major effect on plumule emergence in absence of nitrate and with 750 ppm  $\text{NO}_3^-$  ( $\eta^2 = 0.88$  and  $0.85$ , respectively). At  $\text{NO}_3^- = \text{Zero}$  to 500 ppm., ( $T \times \Psi_m$ ) interaction has the highest effect on radicle emergence ( $\eta^2 = 0.90, 0.91$  and  $0.95$ , respectively). This indicates that the plumule and radicle emergence respond differently to such interaction under different levels of  $\text{NO}_3^-$  nutrient concentrations.

#### B. Elongation of radicle and plumule:

It is quite evident in the literature that elongation of the embryonic axis depends mainly on the hormonal activity and de novo enzyme synthesis

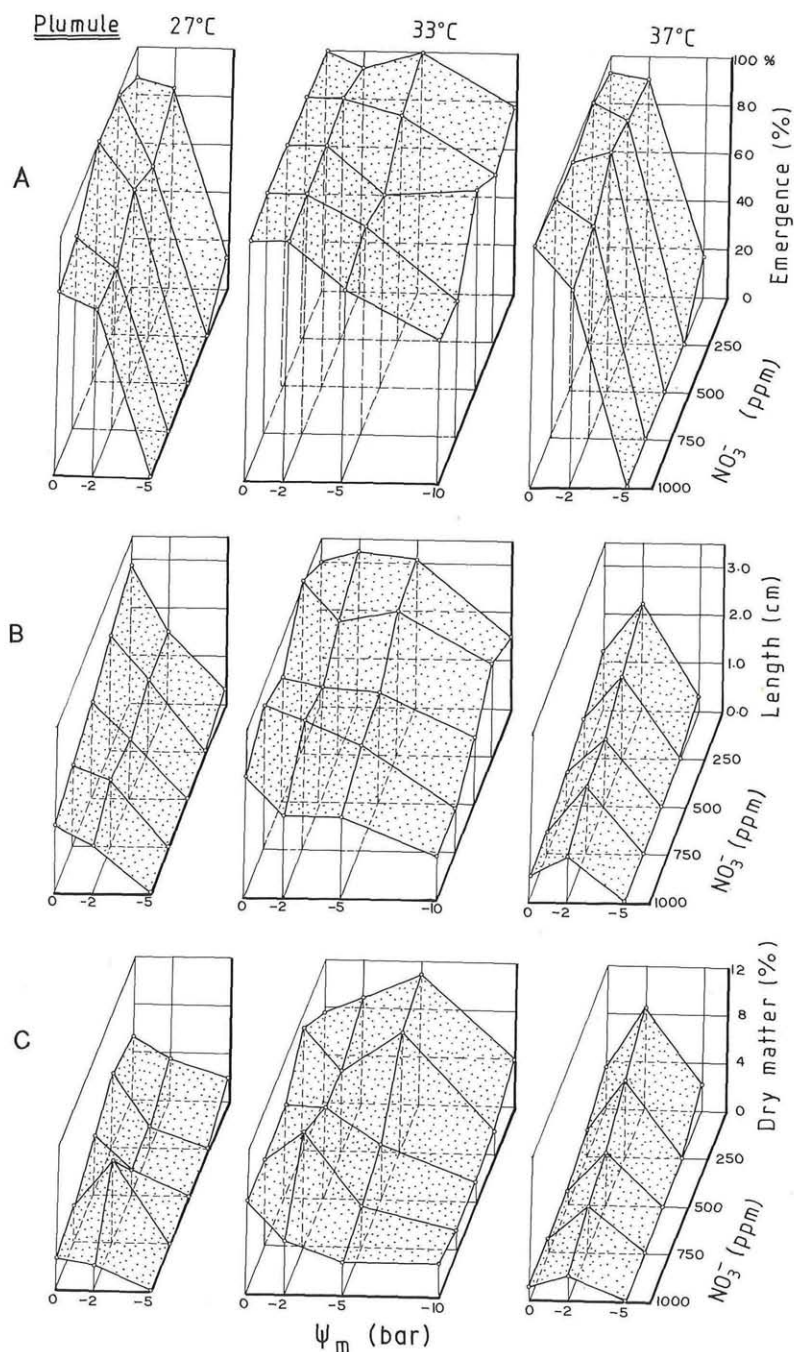


Fig. 1. Plumule characteristics during seed germination of *Bauhinia* at different temperatures (T), matric potentials ( $\Psi_m$ ) and nitrate concentrations ( $\text{NO}_3^-$ ). (Dry matter as % of seedlings dry weight.)

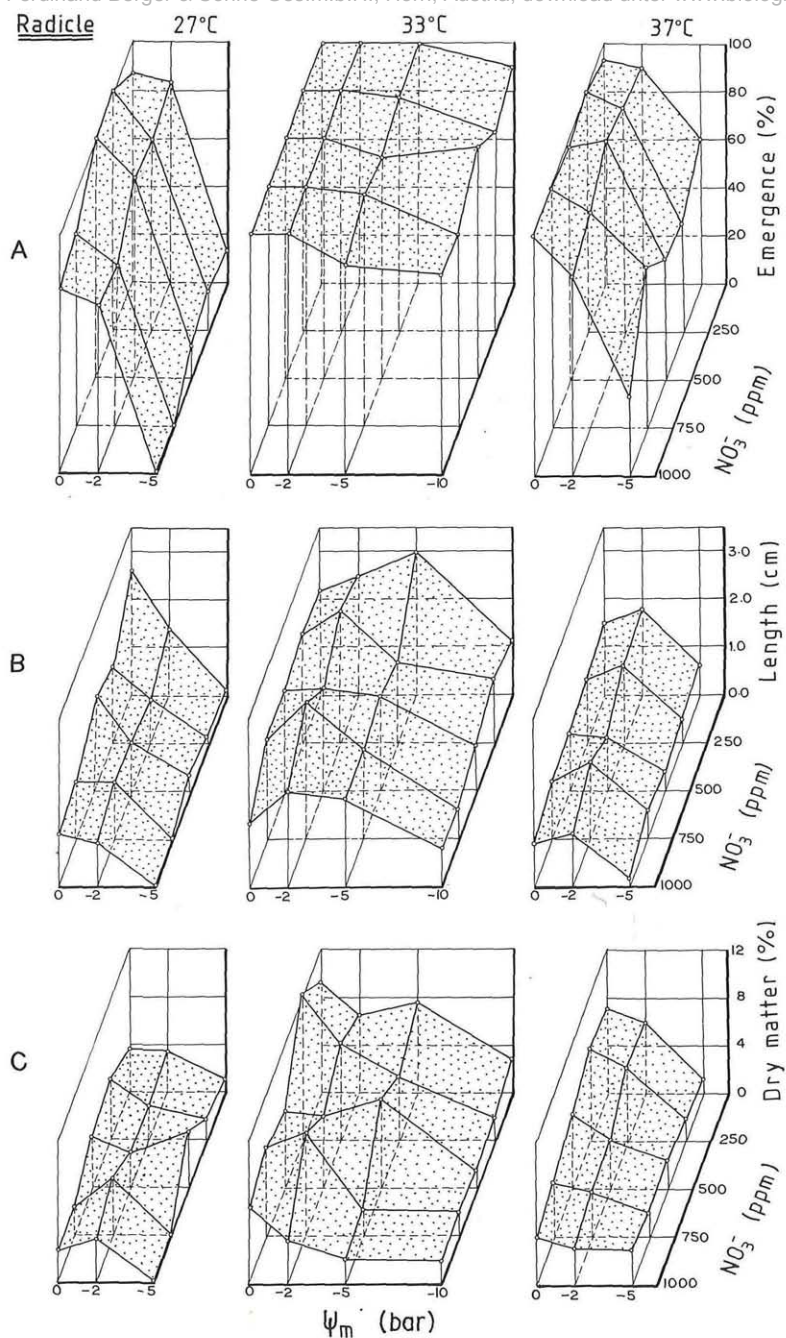


Fig. 2. Radicle characteristics during seed germination of *Bauhinia* at different temperatures (T), matric potentials ( $\psi_m$ ) and nitrate concentrations ( $\text{NO}_3^-$ ). (Dry matter see legend to Fig. 1.)

Table 2

$\eta^2$  values for the effect of two factorial interactions on emergence, elongation and weight of plumule and radicle in germinating *Bauhinia*-seeds at different levels of the third factor.

Organ	Third factor	$(\Psi_m \times NO_3^-) : T$				$(T \times NO_3^-) : \Psi_m$				$(\Psi_m \times T) : NO_3^-$				
		27	33	37	°C	0	-2	-5	-10	0	250	500	750	1000
								bar				ppm		
Plumule:	Emergence	0.64	0.80	0.97	0.97	0.58	0.64	0.97	0.96	0.88	0.65	0.59	0.85	0.74
	Elongation	0.95	0.71	0.84	0.91	0.91	0.77	0.90	0.89	0.78	0.80	0.79	0.87	0.91
	Weight	0.98	0.77	0.82	0.94	0.94	0.76	0.88	0.84	0.70	0.91	0.92	0.93	0.89
Radicle:	Emergence	0.92	0.91	0.97	0.97	0.58	0.70	0.96	0.97	0.90	0.91	0.95	0.79	0.80
	Elongation	0.88	0.86	0.88	0.88	0.78	0.82	0.98	0.93	0.88	0.97	0.86	0.89	0.93
	Weight	0.83	0.94	0.80	0.80	0.77	0.90	0.86	0.97	0.93	0.92	0.80	0.94	0.92



during seed germination (see WILKINS 1969) and, ultimately, on the changes of environmental factors and/or their interactions. The response of radicle and plumule elongation to the factors under investigation are shown in Figures (1-B and 2-B). Temperature at 33° C exerted the highest effect on the elongation of both radicle and plumule especially at relatively high water potentials ( $\Psi_m = 0$  to  $-5$  bar) and absent or relatively low nitrate in the medium 0 to 250 ppm). Radicle and plumule elongation was best at 27° C with  $\Psi_m = 0$  bar, but at 37° C elongation was more with  $\Psi_m = -2$  bar. Generally radicle elongation was slower than that of plumule.

The effects of T,  $\Psi_m$  and  $\text{NO}_3^-$  as well as their interactions on radicle elongation was highly significant, whereas only each of the single factors (T,  $\Psi_m$ ,  $\text{NO}_3^-$ ) and the ( $T \times \Psi_m$ ) interaction have highly significant effects on plumule elongation. Also, ( $T \times \text{NO}_3^-$ ) interaction has just significant effect ( $P < 0.05$ ) on plumule elongation (Table 1). Likewise, while the relative role of T and  $\Psi_m$  is greater in the elongation of both radicle and plumule, it is the effect of T which was dominant and that of  $\Psi_m$  was subdominant ( $\eta^2 = 0.49$ , 0.31, respectively) in plumule elongation. The effect of  $\Psi_m$  is nearly equally dominant as T ( $\eta^2 = 0.41$ , 0.38, respectively) in radicle elongation. This indicates that plumule elongation is more sensitive to temperature than radicle elongation.

The effects, of the bifactorial interactions on plumule and radicle elongation, at different levels of the third factor, are thought significant at the 1% level. The relative role of ( $\Psi_m \times \text{NO}_3^-$ ) in plumule elongation seems to be highest ( $\eta^2 = 0.95$ ) at 27° C, less at 37° C ( $\eta^2 = 0.84$ ) and least at 33° C ( $\eta^2 = 0.71$ ). The same is not true with radicle elongation where ( $\Psi_m \times \text{NO}_3^-$ ) interaction effect is nearly equal at all temperatures ( $\eta^2 = 0.88-0.86$ ).

( $T \times \text{NO}_3^-$ ) interaction effect on plumule elongation was relatively lower at  $\Psi_m = -2$  bar ( $\eta^2 = 0.77$ ), but it has the highest effect on radicle elongation at moderate  $\Psi_m$  levels ( $-5$  and  $-10$  bar) where  $\eta^2$  values reached 0.98 and 0.93, respectively. In absence of stress (0 bar), its effect on radicle elongation was the least ( $\eta^2 = 0.78$ , Table 2).

The relative role of the interaction ( $T \times \Psi_m$ ) was high at higher  $\text{NO}_3^-$  levels (750 to 1000 ppm) where  $\eta^2$  value reached 0.87 and 0.91, respectively. Its effects, however, was relatively low in the elongation of plumule ( $\eta^2 = 0.78$ ). This effect was highest ( $\eta^2 = 0.97$ ) at  $\text{NO}_3^- = 250$  ppm. in case of radicle elongation. Therefore, nitrate availability even at relatively low concentrations should be critical for radicle elongation but the reverse is true for plumule elongation when a significant ( $T \times \Psi_m$ ) interaction exists.

### C. Allocation of dry matter content in seed organs:

The growth rate and dry matter accumulation in the embryonic axis is corresponding to the decrease (depletion) of dry matter in the storage tissue. Translocation of metabolites into the embryonic axis, and accumulation of dry matter there, seems to be high at 33° C, particularly under high matrix

potentials ( $\Psi_m = 0$  and  $-2$  bar) and low nitrate concentrations (0 to 250 ppm, Figures 1-C and 2-C). Generally, dry matter accumulation in both radicle and plumule decreases gradually with decreasing water potential and increasing  $\text{NO}_3^-$  concentration. The maximum dry matter accumulation in the radicle was 12.2% of the total seedling weight at  $\Psi_m = 0$  bar and  $33^\circ\text{C}$  (when the  $\text{NO}_3^-$  level in the medium was 250 ppm). In plumule, dry matter was 11.0% of the seedling weight at  $\Psi_m = -5$  bar at the same temperature under  $\text{NO}_3^-$  starvation. A corresponding maximum depletion of dry matter in the storage tissue was observed (77.5% of the seedling weight) at  $33^\circ\text{C}$  in absence of water stress ( $\Psi_m = 0$  bar) and at 250 ppm  $\text{NO}_3^-$ . In general, minimum dry matter depletion (Fig. 3) is observed at relatively low matric potentials and high  $\text{NO}_3^-$  concentrations.  $33^\circ\text{C}$  seems to be the optimal temperature for dry matter depletion from the storage tissue.

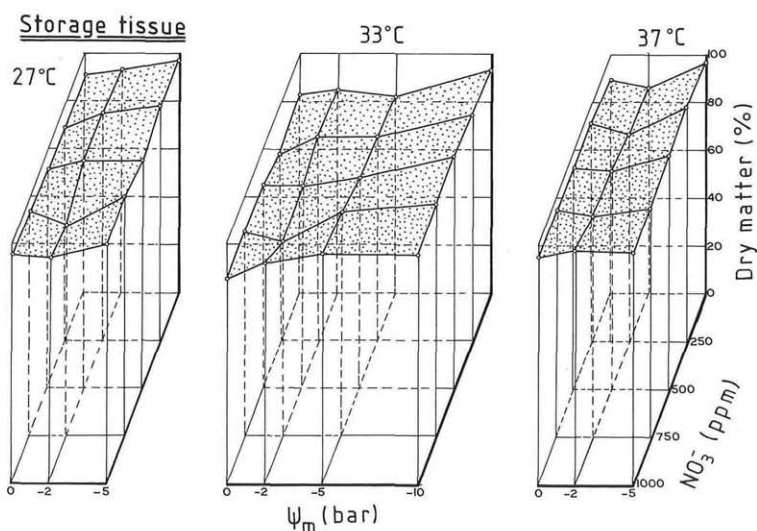


Fig. 3. Changes in storage tissue weight of *Bauhinia* seeds during germination at different temperatures, ( $T$ ), matric potentials ( $\Psi_m$ ) and nitrate concentrations ( $\text{NO}_3^-$ ). (Dry matter see legend to Fig. 1.)

The effect of the tested factors and their interactions on dry matter accumulation in radicle and plumule are highly significant (Table 1). That of ( $T \times \text{NO}_3^-$ ) interaction, however, was just significant in case of the plumule. The relative role of  $\Psi_m$  in the accumulation of dry matter in both radicle and plumule was dominant ( $\eta^2 = 0.51$ ) and that of temperature was subdominant ( $\eta^2 = 0.24$ ). Other factors has a relatively minor role especially ( $T \times \text{NO}_3^-$ ) interaction.

The effects of the bifactorial interactions on the accumulation of dry matter in the embryonic axis, at different levels of the third factor, are through significant at the 1% level, with one exception ( $\Psi_m \times \text{NO}_3^-$  effect on radicle weight at 37° C).

The ( $\Psi_m \times \text{NO}_3^-$ ) interaction effect was relatively higher at 27° C in case of plumule ( $\eta^2 = 0.98$ ) and at 33° C in case of radicle ( $\eta^2 = 0.94$ , Table 2). That of ( $T \times \text{NO}_3^-$ ) was highest at  $\Psi_m = 0$  bar in case of plumule ( $\eta^2 = 0.94$ ). With radicle the effect of this interaction was highest at  $\Psi_m = -10$  bar ( $\eta^2 = 0.97$ ).

The minimum, though high, effect of ( $T \times \Psi_m$ ) interaction was in absence of  $\text{NO}_3^-$  for plumule ( $\eta^2 = 0.70$ ) and at 500 ppm for the radicle ( $\eta^2 = 0.80$ ).

Table 3

F and  $\eta^2$  for the effect of T,  $\Psi_m$ ,  $\text{NO}_3^-$  and their interactions on the dry matter content of storage tissue in *Bauhinia*.

Treatment:	T	$\Psi_m$	$\text{NO}_3^-$	$T \times \Psi_m$	$T \times \text{NO}_3^-$	$\Psi_m \times \text{NO}_3^-$	$T \times \Psi_m \times \text{NO}_3^-$
F	32.6	88.6**	0.6	53.4**	1.8	1.4	1.3
$\eta^2$	0.09	0.37	0.01	0.45	0.02	0.02	0.04

The effects of (T,  $\Psi_m$ ,  $\text{NO}_3^-$ ) and their interactions on the dry matter content of the storage tissue are shown in Table 3. T,  $\Psi_m$  and ( $T \times \Psi_m$ ) interaction has a highly significant effect in this respect, but  $\text{NO}_3^-$  has no significant effect. The relative role of ( $T \times \Psi_m$ ) interaction was predominant ( $\eta^2 = 0.45$ ) and  $\Psi_m$  was subdominant ( $\eta^2 = 0.37$ ).

( $\Psi_m \times \text{NO}_3^-$ ) interaction effect is highly significant at 27° C and 33° C (Table 4). Its relative role was higher at 33° C ( $\eta^2 = 0.81$ ) than at other temperatures, which is reflected in the magnitude of dry matter depletion from storage tissue in favor of the embryonic axis.

( $T \times \text{NO}_3^-$ ) interaction has a highly significant effect on the dry matter content of storage tissue at  $\Psi_m = 0$  and  $-2$  bar and a just significant effect at  $\Psi_m = -5$  bar. The relative role of ( $T \times \text{NO}_3^-$ ) interaction is minimized with decreasing water potential ( $\eta^2 = 0.87$  to  $0.06$ ).

The effect of ( $T \times \Psi_m$ ) interaction on dry matter content of storage tissue is highly significant at  $\text{NO}_3^-$  concentrations: 0, 250 and 750 ppm, while its effect is just significant at concentrations: 500 and 1000 ppm ( $\eta^2 = 0.53$ ). At  $\text{NO}_3^-$  level of 750 ppm ( $T \times \Psi_m$ ) interaction has its maximal relative role ( $\eta^2 = 0.78$ ).

Table 4

F and  $\eta^2$  values for the interactive effect of two factors on storage tissue dry matter in *Bauhinia* at different levels of a third factor under investigation.

Treatment:	$(\Psi_m \times \text{NO}_3^-)$ (on T (° C))			$(T \times \text{NO}_3^-)$ on $\Psi_m$ (bar)			$(T \times \Psi_m)$ on $\text{NO}_3^-$ (ppm)					
Third factor:	27°	33°	37°	0	-2	-5	-10	0	250	500	750	1000
F	5.7**	9.1**	1.4	14.1**	4.7**	2.3**	0.6	5.1**	5.6**	2.6*	8.1**	2.5*
$\eta^2$	0.73	0.81	0.39	0.87	0.69	0.51	0.06	0.70	0.71	0.53	0.78	0.53



## Discussion

During seed germination, nitrate assimilation is sensitive to the multifactorial external conditions, alternatively on the activity of nitrate and nitrite reductase enzymes. Nitrate reductase increases with nitrate concentration (CHONTAROTWONG & al. 1976), and inactivated as ambient nitrate disappears or temperature is elevated above optimum (BEEVERS & al. 1965, ONWUEME & al. 1971). Clearly, there is a response of radicle and plumule emergence, in the present study, to the optimum temperature (33° C), as well as high water potentials at different  $\text{NO}_3^-$  concentrations. Nitrites are reported to stimulate germination of some seeds (HENDRICKS & TAYLORSON 1974, ROBERTS & BENJAMIN 1979) and promotion of germination by nitrate treatments has been suggested as due to the conversion to nitrite within the seed. The nitrate reductase inhibition under water stress was attributed to both a direct inhibition and a reduction rate in enzyme synthesis which lead to nitrate accumulation in the plant cells with harmful effects (LEMAIRE 1969). Therefore, plumule emergence in *Bauhinia* seeds is found to be sensitive to  $\text{NO}_3^-$  concentrations under different levels of water stress and at different temperatures than radicle emergence. Each of  $T$ ,  $\Psi_m$  and  $\text{NO}_3^-$ , as single factors, has a highly significant effect on the emergence of radicle and plumule. The effect of ( $T \times \Psi_m$ ) interaction is highly significant on plumule and radicle emergence, but their responses to this interaction is quite different under various levels of  $\text{NO}_3^-$  concentration. ( $\Psi_m \times \text{NO}_3^-$ ) interaction has a highly significant effect on plumule emergence only, which indicates that  $\text{NO}_3^-$  accelerate plumule emergence, but not so in case of radicle. A highly significant effect of ( $T \times \Psi_m \times \text{NO}_3^-$ ) interaction on plumule and radicle emergence shows efficient  $\text{NO}_3^-$  assimilation during seed germination. The relative role of  $\Psi_m$  is predominant in plumule and radicle emergence (Table 1).

Tissue dehydration was found to reduce both nitrate and nitrite reductase synthesis, and an enzyme-inactivating system (BARDZIK et al. 1971) is attributed to an adjustive ability to water stress. In *Betula verrucosa*, INGESTED & LUND (1979) found a close agreement between the rate of nitrogen supply and consumption on one hand and growth rate on the other hand. Apparently, 33° C exerted the highest effect on the elongation and dry matter accumulation of radicle and plumule in *Bauhinia*, especially at relatively high water potentials and even absent or low  $\text{NO}_3^-$  concentration in the medium. This may be attributed to increased reductase enzyme activity. In general, radicle elongation was slower than that of plumule regardless of prevailing conditions.

The effect of single factors ( $T$ ,  $\Psi_m$  or  $\text{NO}_3^-$ ) as well as their mutual interactions on radicle elongation are highly significant. The same is true with plumule elongation except for ( $\Psi_m \times \text{NO}_3^-$ ) and ( $T \times \Psi_m \times \text{NO}_3^-$ ) interactions. This indicates that the response of plumule elongation to  $\text{NO}_3^-$

may be nullified under reduced  $\Psi_m$  or under interaction of  $\Psi_m$  with temperature, but the reverse is true in radicle elongation. The role of temperature is dominant in plumule elongation, but that of  $\Psi_m$  is predominant in radicle elongation. Evidently,  $\text{NO}_3^-$  availability should be critical for radicle elongation under water stress (due to the sensitivity of nitrite and nitrate reductase to  $\Psi_m$ ), which is not the case for plumule elongation.

T,  $\Psi_m$ ,  $\text{NO}_3^-$  singly and their interactions have highly significant effects on dry matter accumulation in radicle and plumule. Only T,  $\Psi_m$  and their interaction has a highly significant effect on dry matter depletion from storage tissue. The effect of  $\Psi_m$  on dry matter accumulation is predominant in both organs of the embryonic axis, whereas the effect of (T  $\times$   $\Psi_m$ ) interaction is predominant in changes of dry matter content of storage tissue.

Obviously, the (T  $\times$   $\Psi_m$   $\times$   $\text{NO}_3^-$ ) interaction has a greater relative role in the emergence and dry matter content in radicle and plumule than other interactions (Table 1). However, its role is far relatively less than that of ( $\Psi_m$   $\times$  T) interaction in the elongation of the embryonic axis. This is a clear distinction between emergence and elongation of the embryonic axis as far as the ( $\Psi_m$   $\times$  T) interaction effect is concerned.

Generally, the relative role of ambient nitrate (*in vitro*) or its interaction with other factors was minor in the behaviour of *Bauhinia* seedling's growth which indicates that growth is independent of external  $\text{NO}_3^-$  (as supplied nitrogen element). This is quite contrary to the finding of INGESTED & LUND (1979) mentioned above. The difference in this respect may be due to adaptability or nature of taxon. The storage tissue of most leguminosae, however, is rich in nitrogen compounds (*in vivo*). This can be the cause of such a different result which makes the growth of the embryonic axis of *Bauhinia* independent of ambient  $\text{NO}_3^-$  concentration.

## References

- ADAMS R. (Ed.) 1979. Tropical legumes: Resources for the future. – National Academy of Sciences, Washington, D.C., U.S.A.
- BARDZIK J. M., MARSH J. H. & HAVIS J. R. 1971. Effects of water stress on the activities of three enzymes in maize seedlings. – Plant Physiol. 47: 828–831.
- BEEVERS L., SCHRADER L., FLESHER D. & HAGEMAN R. H. 1965. The role of light and nitrate in the induction of nitrate reductase in radish cotyledons and maize seedlings. – Plant physiol. 40: 691–698.
- CANTLIFFE J. 1972. Nitrate accumulation in spinach grown at different temperatures. – Amer. Soc. Hortic. Sci. J. 97: 674–676.
- CHANTAROTWONG W., HUFFAKER R. C., MILLER B. L. & GRANSTEDT R. C. 1976. In vivo nitrate reductase activity in relation to nitrate uptake, nitrate content, and in vitro nitrate reductase activity in intact barley seedlings. – Plant Physiol. 57: 519–522.

- EGLEY G. H. 1984. Ethylene, nitrate and nitrite interactions in the promotion of dark germination of common purslane seeds. – *Annals of Botany* 53: 833–840.
- EL-SHARKAWI H. M. & SPRINGUEL I. 1977. Germination of some crop plant seeds under reduced water potential. – *Seed Sci. and Technol.* 5: 677–688.
- HALLMARK W. B. & HUFFAKER R. C. 1978. The influence of ambient nitrate, temperature and light on nitrate assimilation in sudangrass seedlings. – *Physiol. Plant.* 44: 147–152.
- HENDRICKS S. B. & TAYLORSON R. B. 1974. Promotion of seed germination by nitrate, nitrite, hydroxylamine and ammonium salts. – *Plant Physiol.* 54: 304–309.
- HEUER B., PLAUT Z. & FEDERMAN E. 1979. Nitrate and nitrite reduction in wheat leaves as affected by different types of water stress. – *Plant Physiol.* 46: 318–323.
- INGESTED T. & LUND A. 1979. Nitrogen stress in birch seedlings I: Growth technique and growth. – *Physiol. Plant.* 45: 137–148.
- LAWLOR D. W. 1969. Plant growth in polyethylene glycol solutions in relation to the osmotic potential of the root medium and leaf water balance. – *J. Exp. Bot.* 20: 895–911.
- LEMAIRE F. 1969. Effect of nitrites on plants. – *Annales Agronomiques (Paris)* 20: 317.
- MATTAS R. E. & PAULI A. W. 1965. Trends in nitrate reduction and nitrogen functions in young corn (*Zea mays* L.) plants during heat and moisture stress. – *Crop. Sci.* 51: 181–184.
- MINOTTI P. L., WILLIAMS D. C. & JACKSON W. A. 1969. The influence of ammonia on nitrate reduction in wheat seedlings. – *Planta (Berlin)* 86: 267–271.
- ONWUEME I. C., LAUDE H. M. & HUFFAKER R. C. 1971. Nitrate reductase activity in relation to heat stress in barley seedlings. – *Crop. Sci.* 11: 195–200.
- OSTLE B. 1963. Statistics in research. – The Iowa state Univ. Press, Ames, Iowa, U.S.A.
- PARMER M. T. & MOORE R. P. 1968. Carbowax 6000, mannitol and sodium chloride for simulating drought conditions in germination studies of corn (*Zea mays* L.) of strong and weak vigor. – *Agron. J.* 60: 192–195.
- RHODES P. R. & MATSUDA K. 1976. Water stress, rapid polyribosomes reduction and growth. – *Plant physiol.* 58: 631–635.
- ROBERTS E. H. & BENJAMIN S. K. 1979. The interaction of light, nitrate and alternating temperature on the germination of *Chenopodium album*, *Capsella bursapastoris* and *Poa annua* before and after chilling. – *Seed Sci. and Technol.* 7: 379–392.
- SHARMA M. L. 1973. Simulation of drought and its effect on germination of five pasture species. – *Agron. J.* 65: 982–987.
- VINCENT E. M. & ROBERTS E. H. 1979. The influence of chilling, light and nitrate on the germination of dormant seeds of common weed species. *Seed Sci. and Technol.* 7: 3–14.
- WILKINS M. B. 1969. The physiology of plant growth and development. – Tata McGraw-Hille. Bombay, New Delhi.

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Autor(en)/Author(s): El-Sharkawi H. M., Farghali K. A.

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