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

By

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With 3 Figures

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Summary

EL-SHARKAWI H. M. & FARGHALI K. A. 1987. Interactive effects of nitgrogen, 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 (Ψ_m), temperature (T) and ambient nitrate concentration (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. ($T \times NO_3^-$) interaction had no significant effect on both radicle and plumule emergence and ($\Psi_m \times NO_3^-$) interaction had no effect on radicle emergence and plumule elongation. The same is true for ($T \times \Psi_m \times NO_3^-$) 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.: NO_3^- concentration accelerates plumule emergence at different Ψ_m levels, but not so with radicle, 2.: ($\Psi_m \times NO_3^-$) 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 NO_3^- concentrations (750–1000 ppm) has a greater role in the elongation of radicle but not so with plumule.

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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 (Ψ_m), Temperatur (T) und Nitratkonzentration der Umgebung (NO_3^-) bei der Keimung von Samen von *Bauhinia variegata* L. untersucht. Erfaßt wurden Auftreten und Strekkung von Radicula und Plumula und deren Trockengewichtszunahme sowie die Entnahme von Trockenbsubstanz aus dem Speichergewebe. $T \times NO_3^-$ hatte keinen signifikanten Effekt auf das Auftreten von Radicula und Plumula, $\Psi_m \times NO_3^-$ war auf das Erscheinen der Radicula und der Streckung der Plumula ohne Wirkung, letztere wird auch durch $T \times \Psi_m \times NO_3^-$ 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.: NO_3^- beschleunigt das Erscheinen der Plumula bei verschiedenen Ψ_m, aber nicht bei der Radicula; 2.: $\Psi_m \times NO_3^-$ 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 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 mutlifactorial 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 (ROBERST & BENJAMIN 1979, VINCENT & ROBERTS 1979). Nitrate reduction, absorption and accumulation are well-known as a process sinsitive 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 exterted 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.

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The aim of the present work is to study the interactive effects of two environmental factors (temperature and soil matric water potential, Ψ_m) and ambient nitrate concentration in the seed incubation medium on the germination of *Bauhinia variegata* L. seeds. This tree (S. F.: *Caesalpinoideae),* 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. O (control), –2, –5, –10 and –15 bars. Solutions at the same water potential levels containing nitrate (supplied as KNO_3) in concentrations: O (control), 250, 500, 750 and 1000 ppm were prepared for use in testing the effect of ambient 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, 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.

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Germination of *Bauhinia* seeds failed at –15 bar under 33° 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° 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, η^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° C to 37° C) as well as to different nitrate concentrations (Figure 1-A and Figure 2-A). At the optimum temperature (33° C) and relatively high Ψ_m, 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 Ψ_m = –5 bar under both 27° C and 37° C and at –15 bar under 33° C. Radicle emergence is sensitive to NO_3^- concentration and decreased Ψ_m under different temperatures, where it failed with 750 ppm NO_3^- at Ψ_m = –5 bar under 27° C, at –10 bar under 37° C and at Ψ_m = –15 bar under 33° C.

Plumule emergence is obviously more sensitive to different factors tested than radicle emergence. Temperature (T), matric potential (Ψ_m) and nitrate concentration (NO_3^-) have highly significant effects on both plumule and radicle emergence. The same is true for (T × Ψ_m) and the three factorial (T × Ψ_m × NO_3^-) interaction (Table 1). On the other hand, the interaction (Ψ_m × NO_3^-) has a highly significant effect only in plumule emergence. This indicates that NO_3^- accelerates plumule emergence at different Ψ_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 η^2 values) is quite versatile. The relative role of Ψ_m is predominant in plumule and radicle emergence (η^2 = 0.54 and 0.51, respectively) but that of temperature is subdominant (η^2 = 0.25 and 0.32, respectively). The role of (T × Ψ_m × 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 (Ψ_m × NO_3^-, T × NO_3^- and T × Ψ_m) are throughout significant at the 1% level with two

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Table 1

F and η^2 values for the effect of T, Ψ_m and NO_3^- concentration and their interactions on the emergence, elongation and weight of plumule and radicle of Bauhinia.

Organ	Treatment	Emergence		Elongation		Weight	
		F	η^2	F	η^2	F	η^2
Radicle	T	496.4**	0.25	357.0**	0.49	173.2**	0.34
	Ψ_m	716.5**	0.54	153.6**	0.31	106.8**	0.32
	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
	$T \times NO_3^-$	0.4	0.00	2.2*	0.01	2.1*	0.02
	$\Psi_m \times NO_3^-$	14.5**	0.04	1.7	0.02	4.9**	0.06
	$T \times \Psi_m \times NO_3^-$	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
	Ψ_m	262.7**	0.51	472.0**	0.41	256.0**	0.52
	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
	$T \times NO_3^-$	0.6	0.00	5.1**	0.01	4.5**	0.02
	$\Psi_m \times NO_3^-$	0.9	0.01	6.7**	0.02	7.8**	0.06
	$T \times \Psi_m \times NO_3^-$	6.9**	0.11	5.9**	0.04	4.4**	0.07

* = Significant at 5% confidence level
** = Significant at 1% confidence level.

exceptions ($\Psi_m \times NO_3^-$ effect on radicle emergence at 33° C and $T \times \Psi_m$ effect on plumule emergence at 500 ppm. ambient 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, ($T \times NO_3^-$) 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 ($T \times NO_3^-$) interaction in both radicle and plumule emergence is highest at –5 and –10 bar (η^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 abscence of nitrate and with 750 ppm NO_3^- (η^2 = 0.88 and 0.85, respectively). At NO_3^- = Zero to 500 ppm., ($T \times \Psi_m$) interaction has the highest effect on radicle emergence (η^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 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

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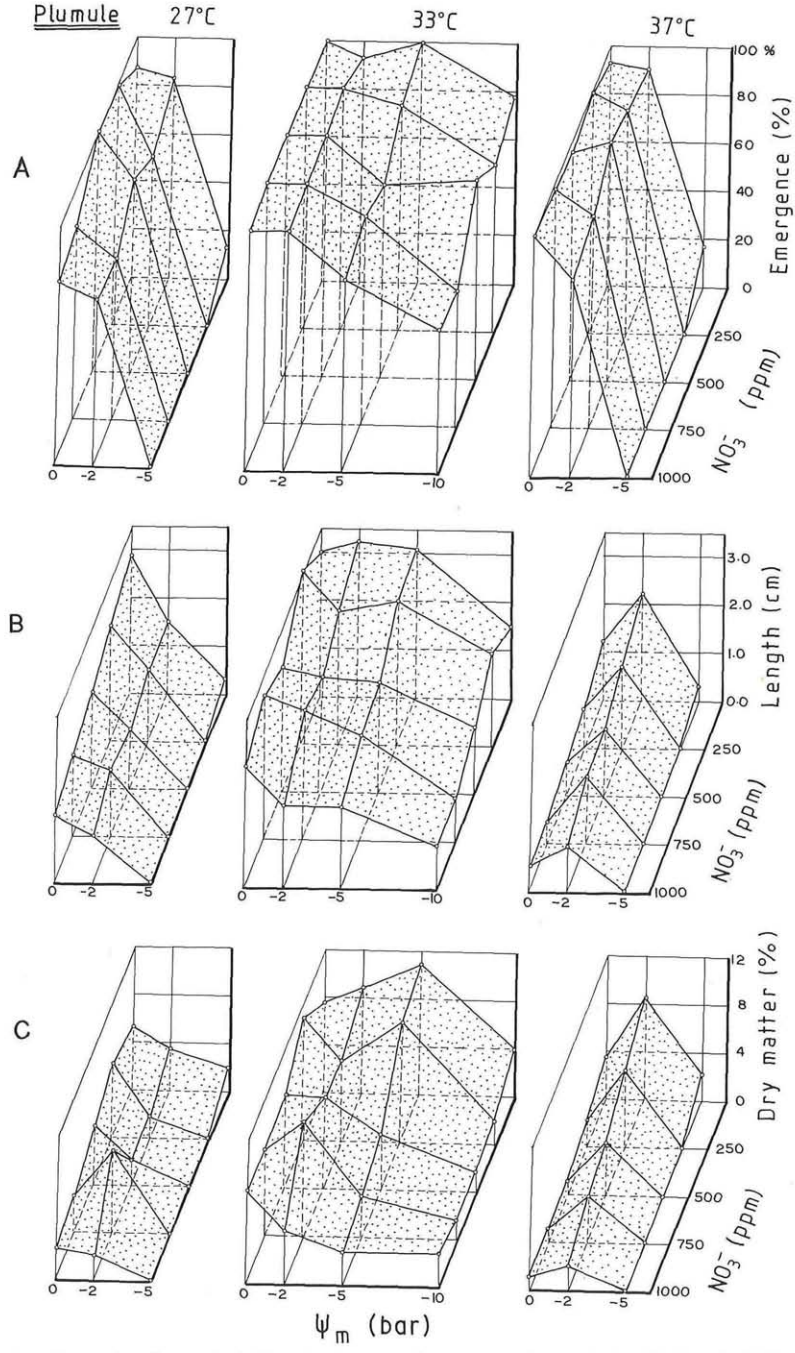

Fig. 1. Plumule characteristics during seed germination of *Bauhinia* at different temperatures (T), matric potentials (Ψ_m) and nitrate concentrations (NO_3^-). (Dry matter as % of seedlings dry weight.)

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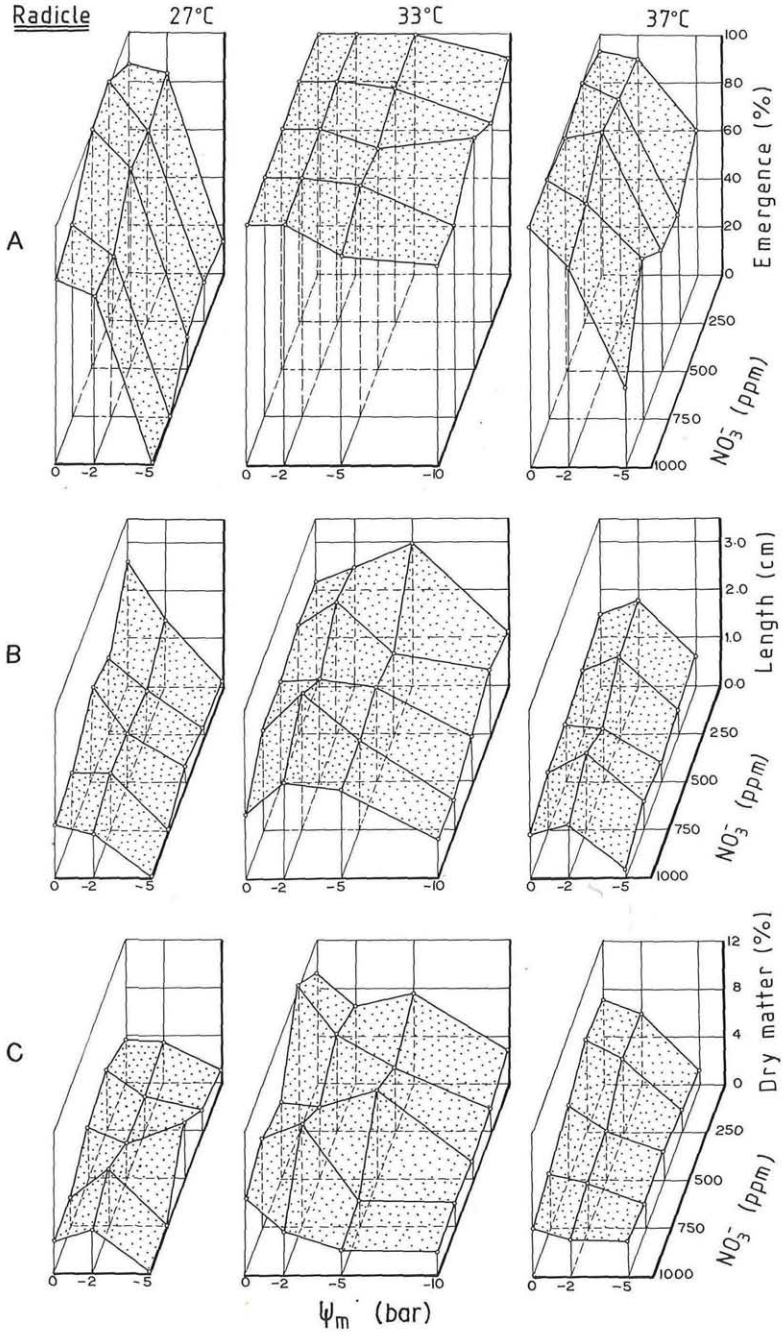

Fig. 2. Radicle characteristics during seed germination of *Bauhinia* at different temperatures (T), matric potentials (Ψ_m) and nitrate concentrations (NO_3^-). (Dry matter see legend to Fig. 1.)

Table 2

η^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.

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

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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 (Ψ_m = 0 to –5 bar) and abscent or relatively low nitrate in the medium 0 to 250 ppm). Radicle and plumule elongation was best at 27° C with Ψ_m = 0 bar, but at 37° C elongation was more with Ψ_m = –2 bar. Generally radicle elongation was slower than that of plumule.

The effects of T, Ψ_m and NO_3^- as well as their interactions on radicle elongation was highly significant, whereas only each of the single factors (T, Ψ_m, NO_3^-) and the (T × Ψ_m) interaction have highly significant effects on plumule elongation. Also, (T × NO_3^-) interaction has just significant effect ($P<0.05$) on plumule elongation (Table 1). Likewise, while the relative role of T and Ψ_m is greater in the elongation of both radicle and plumule, it is the effect of T which was dominant and that of Ψ_m was subdominant (η^2 = 0.49, 0.31, respectively) in plumule elongation. The effect of Ψ_m is nearly equally dominant as T (η^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 throught significant at the 1% level. The relative role of (Ψ_m × NO_3^-) in plumule elongation seems to be highest (η^2 = 0.95) at 27° C, less at 37° C (η^2 = 0.84) and least at 33° C (η^2 = 0.71). The same is not true with radicle elongation where (Ψ_m × NO_3^-) interaction effect is nearly equal at all temperatures (η^2 = 0.88–0.86).

(T × NO_3^-) interaction effect on plumule elongation was relatively lower at Ψ_m = –2 bar (η^2 = 0.77), but it has the highest effect on radicle elongation at moderate Ψ_m levels (–5 and –10 bar) where η^2 values reached 0.98 and 0.93, respectively. In abscence of stress (0 bar), its effect on radicle elongation was the least (η^2 = 0.78, Table 2).

The relative role of the interaction (T × Ψ_m) was high at higher NO_3^- levels (750 to 1000 ppm) where η^2 value reached 0.87 and 0.91, respectively. Its effects, however, was relatively low in the elongation of pulmule (η^2 = 0.78). This effect was highest (η^2 = 0.97) at 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 × Ψ_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 matric

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potentials (Ψ_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 NO_3^- concentration. The maximum dry matter accumulation in the radicle was 12.2% of the total seedling weight at Ψ_m = 0 bar and 33° C (when the NO_3^- level in the medium was 250 ppm). In plumule, dry matter was 11.0% of the seedling weight at Ψ_m = –5 bar at the same temperature under NO_3^- starvation. A corresponding maximum depletion of dry matter in the storage tissue was observed (77.5% of the seelding weight) at 33° C in abscence of water stress (Ψ_m = 0 bar) and at 250 ppm NO_3^-. In general, minimum dry matter depletion (Fig. 3) is observed at relatively low matric potentials and high NO_3^- concentrations. 33° C seems to be the optimal temperature for dry matter depletion from the storage tissue.

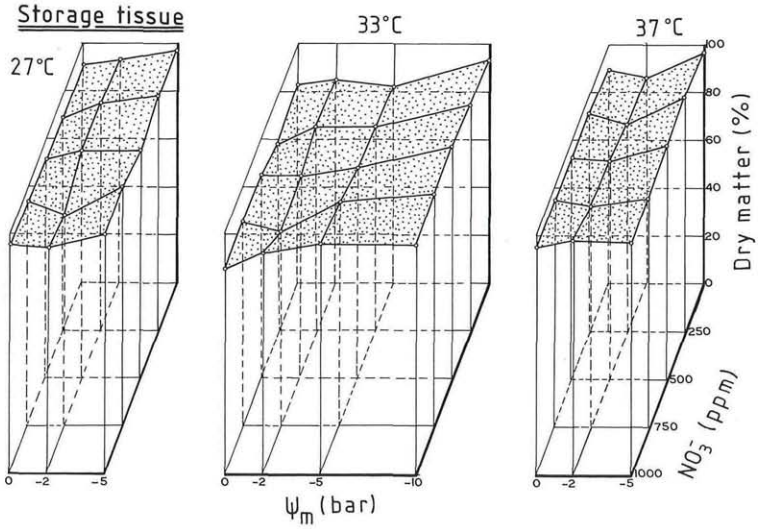

Fig. 3. Changes in storage tissue weight of *Bauhinia* seeds during germination at different temperatures, (T), matric potentials (Ψ_m) and nitrate concentrations (NO_3^-). (Dry matter see legend to Fig. 1.)

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 × NO_3^-) interaction, however, was just significant in case of the plumule. The relative role of Ψ_m in the accumulation of dry matter in both radicle and plumule was dominant (η^2 = 0.51) and that of temperature was subdominant (η^2 = 0.24). Other factors has a relatively minor role especially (T × NO_3^-) interaction.

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The effects of the bifactorial interactions on the accumulation of dry matter in the embryonic axis, at different levels of the third factor, are throught significant at the 1% level, with one exception ($\Psi_m \times NO_3^-$ effect on radicle weight at 37° C).

The ($\Psi_m \times NO_3^-$) 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 ($T \times NO_3^-$) 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 abscence of NO_3^- for plumule ($\eta^2 = 0.70$) and at 500 ppm for the radicle ($\eta^2 = 0.80$).

Table 3

F and η^2 for the effect of T, Ψ_m, NO_3^- and their interactions on the dry matter content of storage tissue in Bauhinia.

Treatment:	T	Ψ_m	NO_3^-	$T \times \Psi_m$	$T \times NO_3^-$	$\Psi_m \times NO_3^-$	$T \times \Psi_m \times NO_3^-$
F	32.6	88.6**	0.6	53.4**	1.8	1.4	1.3
η^2	0.09	0.37	0.01	0.45	0.02	0.02	0.04

The effects of (T, Ψ_m, NO_3^-) and their interactions on the dry matter content of the storage tissue are shown in Table 3. T, Ψ_m and ($T \times \Psi_m$) interaction has a highly significant effect in this respect, but NO_3^- has no significant effect. The relative role of ($T \times \Psi_m$) interaction was predominant ($\eta^2 = 0.45$) and Ψ_m was subdominant ($\eta^2 = 0.37$).

($\Psi_m \times NO_3^-$) 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.

($T \times NO_3^-$) 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 ($T \times NO_3^-$) 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 NO_3^- concentrations: 0, 250 and 750 ppm, while its effect is just significant at conentrations: 500 and 1000 ppm ($\eta^2 = 0.53$). At NO_3^- level of 750 ppm ($T \times \Psi_m$) interaction has its maximal relative role ($\eta^2 = 0.78$).

Table 4

F and η^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:	($\Psi_m \times NO_3^-$) (on T (° C)			($T \times NO_3^-$) on Ψ_m (bar)				($T \times \Psi_m$) on 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*
η^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

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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 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 NO_3^- concentrations under different levels of water stress and at different temperatures than radicle emergence. Each of T, Ψ_m and 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 NO_3^- concentration. ($\Psi_m \times NO_3^-$) interaction has a highly significant effect on plumule emergence only, which indicates that NO_3^- accelerate plumule emergence, but not so in case of radicle. A highly significant effect of ($T \times \Psi_m \times NO_3^-$) interaction on plumule and radicle emergence shows efficient NO_3^- assimilation during seed germination. The relative role of Ψ_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 abscent or low 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, Ψ_m or NO_3^-) as well as their mutual interactions on radicle elongation are highly significant. The same is true with plumule elongation except for ($\Psi_m \times NO_3^-$) and ($T \times \Psi_m \times NO_3^-$) interactions. This indicates that the response of plumule elongation to NO_3^-

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may be nullified under reduced Ψ_m or under interaction of Ψ_m with temperature, but the reverse is true in radicle elongation. The role of temperature is dominant in plumule elongation, but that of Ψ_m is predominant in radicle elongation. Evidently, NO_3^- availability should be critical for radicle elongation under water stress (due to the sensitivity of nitrite and nitrate reductase to Ψ_m), which is not the case for plumule elongation.

T, Ψ_m, NO_3^- singly and their interactions have highly significant effects on dry matter accumulation in radicle and plumule. Only T, Ψ_m and their interaction has a highly significant effect on dry matter depletion from storage tissue. The effect of Ψ_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 ($T \times \Psi_m \times NO_3^-$) 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 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 NO_3^- concentration.

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