to the time dependence of its appearance may be due to the relatively few loci involved.

The effects of short duration treatments during the S phase are now being studied with simply inherited marker characters, both linked and unlinked. For this technique to be effectively used, bringing about a high degree of synchronisation of cell division, rapid diffusion of the mutagen and an effective evacuation of the mutagen at the end of the treatment period are essential. It is possible that loci which are not in the S phase may also be affected by the mutagen and hence only the relative frequencies of different classes of mutations can possibly be modified through this approach. The data of the present study are sufficiently promising to warrant a more detailed probe of the use of this technique in altering mutation spectrum.

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STUDIES ON GROWTH AND MUTATION FREQUENCY IN RICE IN TREATMENTS WITH DIMETHYL SULPHOXIDE AND ETHYL METHANE SULPHONATE

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THE introduction of dimethyl sulphoxide (DMSO), as a carrier in medicine[4,6] and a solvent in biological works,[3] has aroused much interest in the field of chemical mutagenesis.[1,2] Earlier reports on DMSO emphasized its low toxicity and absence of any detectable side effect as a result of interaction with several drugs and aromatic compounds[5,10,13] in particular. Probably this led Bhatia[1,2] to assess its potentiating effect on chemical mutagens. The enhanced mutation frequency associated with a high percentage of survival in *Arabidopsis thaliana* realized by Bhatia[1,2] led the present authors to make use of the penetrant-carrier in rice in which the husk hinders the easy and rapid uptake of chemical mutagens.

Swaminathan *et al.*[11] concluded from preliminary studies that DMSO treatment was as toxic as any other chemical mutagen in rice. A more detailed study on the effect of DMSO alone and in combination with EMS carried out since then is presented in this paper.

The unhulled seeds of Tainan-3, a *japonica* variety of *O. sativa* presoaked in water for eight hours were treated with different concentrations of DMSO and DMSO + EMS. The effect of various treatments was measured as percentage reduction of germination, survival and seedling injury in the M_1 generation. The chlorophyll mutation frequency in the M_2 of a lot (seeds presoaked for 16 hours in water followed by treatment with EMS and EMS + DMSO for one hour) has been included so as to assess the effect of the penetrant-carrier on the mutation frequency.

The effect of DMSO alone as measured by the rate of germination, survival and growth rate indicated the carrier to possess local toxicity which followed a linear relationship with the concentration. At lower concentrations, the percentage of germination and survival was either on par with that of control or a little exceeded. However, data on growth rate showed proportionate decrease with increasing dose (Table I). Another feature of interest was that the percentage of seeds showing delayed germination increased with increasing concentration. It is known that higher concentration of DMSO causes high incidence of

lethality in *Arabidopsis*[1,2] and decrease in spore germination in *Lycogala epidendrum*. DMSO, at its lower concentration, has also been reported to accelerate the process of spore

TABLE I
Effect of DMSO on germination survival and seedling injury
(Tainan 3)

Treatment	Treatment period	No. of seeds sown	% of seeds germinated 5th day	% of seeds germinated 10th day	% of seedlings survived	Shoot length on 10th day in cm.
Control	..	100	86	95	90	9·19
DMSO (%)						
1·0	8 hrs.	100	84	94	91	8·14
2·5	,	100	88	99	94	7·26
5·0	,,	100	84	93	90	6·97
10·0	,,	100	82	92	87	6·64
20·0	,,	100	69	89	78	5·75
30·0	.,	100	52	85	71	4·52

germination.[12,14] The present findings also indicate that though DMSO possesses local toxicity, it could enhance the percentage of germination or survival at low concentration levels. However, irrespective of the concentration levels the inherent toxicity was found to be manifested in growth rate. Recent studies of Shilkin *et al.*[9] and Kocsis *et al.*[7] in animal tissues emphasised that DMSO has its local toxicity which is relatively higher in its undiluted form.

Considering the possibility that DMSO facilitates the rapid uptake of chemicals by increasing the membrane permeability, several workers studied the potentiating effect of the carrier. Sciuchetti and Born[8] found that DMSO apparently enhances the response of *Datura tatula* to a growth retardant when it was combined with the retardant. Kocsis *et al.*[7] have clearly demonstrated that DMSO markedly potentiated the toxicity of several aromatic hydrocarbons. The present findings on the effect of DMSO in combination with EMS, indicated, quite in agreement with the earlier reports, a tremendous influence of DMSO in enhancing the effect of EMS as measured by the percentage of germination, survival and growth rate in the M_1 generation (Tables II and III). The degree of potentiating effect appears to increase with increase in the concentration of DMSO. This again is in conformity with the views of Kocsis *et al.*[7] that the potentiating effect on toxicity is very much reduced when DMSO is applied in its diluted form.

TABLE II
Effect of DMSO at different concentrations when combined with EMS
(Tainan 3)

Treatment	Treatment period	No. of seeds sown	% of seeds germinated 5th day	% of seeds germinated 10th day	% of seedling survival	Shoot length on 10th day in cm.
Control	.. ..	100	93	95	91	8·58
EMS 0·4%	.. 8 hrs.	100	81	92	85	5·30
DMSO + EMS (1%)	,,	100	94	97	93	5·98
DMSO + EMS (2·5%)	,,	100	90	90	88	5·02
DMSO + EMS (5%)	,,	100	87	87	76	4·20
DMSO + EMS (10%)	,,	100	82	·86	75	3·39
DMSO + EMS (20%)	,,	100	78	87	69	2·48
DMSO + EMS (30%)	,,	100	73	78	64	1·72

TABLE III
Effect of DMSO in combination with EMS
(Tainan 3)

Treatment	Treatment period	No. of seeds sown	% of seeds germinated 5th day	% of seeds germinated 10th day	% of seedlings survived	Shoot length on 10th day in cm.
Control	.. 3 hrs.	300	80·3	97·0	95·0	10·82
DMSO 5%	.. ,,	300	84·0	97·3	95·6	9·79
EMS (1%)	.. ,	300	53·0	89·0	83·0	6·58
DMSO (5%) + EMS (1%)	,,	300	2·0	57·0	43·0	4·21

The effect of DMSO in enhancing the mutagenic efficiency of chemical mutagens was first reported by Bhatia[1,2] in *Arabidopsis thaliana*. However, the present study on rice, though on a limited scale, suggested that the mutation frequency, as measured on M_2 population basis, remained more or less same both in EMS and EMS + DMSO treatments (Table IV). This

TABLE IV
Frequency of chlorophyll mutations
(Tainan 3)

Treatment	Treatment period	No. of M_1 plant progenies	% of mutants in the M_2 population
Control	..	..	25	0
DMSO 5%	..	1 hr.	77	0
EMS (1%)	..	,,	45	2·21
DMSO (5%) + EMS (1%)	..	,,	61	2·08

observation though contrary to that of Bhatia is to be expected since the membrane permeability might have reached the maximum with water presoaking itself and the additional increase in permeability through DMSO might not influence the rate of absorption. Further, it seems that DMSO does not also cause any reduction in mutation frequency.

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LIQUID METAL MAGNETOHYDRODYNAMIC POWER GENERATOR

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THE theoretical aspect of magnetohydrodynamic power generator using a rectangular channel of uniform cross-section is investigated in this article. The experimental arrangements and the results obtained will be presented elsewhere. The physical problem consists of the flow of a conducting, incompressible, heterogeneous and non-viscous fluid bounded by a rectangular channel made of electrodes and insulating walls in the presence of a transverse magnetic field. The purpose of using an heterogeneous conducting fluid is to achieve increased power output.

The required equations following Rudraiah (1964), using

$$u_x = u \left(\frac{\rho}{\rho_0}\right)^{\frac{1}{2}} \tag{1}$$

$$u_y = v \left(\frac{\rho}{\rho_0}\right)^{\frac{1}{2}} \tag{2}$$

and using small perturbation

$$u_x = u' + U$$
$$u_y = v' \tag{3}$$

where u and v are the x and y components of velocity, ρ is the variable density, ρ_0 is some reference density, and U is the free upstream velocity, become

$$\nabla^2 \Phi = N \left[\frac{\partial \Phi}{\partial \xi} + \left(\frac{\rho_0}{\rho}\right)^{\frac{1}{2}} \frac{\partial \Psi}{\partial \xi}\right] \tag{4}$$

$$\nabla^2 \Psi = - N \left[\frac{\partial \Phi}{\partial \xi} + \left(\frac{\rho_0}{\rho}\right)^{\frac{1}{2}} \frac{\partial \Psi}{\partial \xi}\right] \tag{5}$$

with the boundary conditions

$$\Phi = \pm \Phi_w \quad \zeta = \pm \frac{\pi}{2h} \ (\xi > 0) \tag{6}$$

$$\frac{\partial \Phi}{\partial \xi} = 0 \quad \zeta = \pm \frac{\pi}{2h} \ (\xi < 0) \tag{7}$$

$$\Psi = \pm \frac{\pi}{2h} \quad \zeta = \pm \frac{\pi}{2h} \ (-\infty < x < \infty) \tag{8}$$

where

$$\phi = UBh\Phi, \quad \psi' = Uh\Psi, \quad x = h\xi$$

and $y = h\xi$, ϕ is the electric potential and ψ' is the stream function,

$$N = \frac{\sigma B^2 h}{\rho_0 U}$$

is the interaction parameter, which we assume to be small.

To solve equation (4) we use,

$$\Phi = \Phi_0 + N\Phi_1 + \cdots \tag{9}$$

$$\Psi = \Psi_0 + N\Psi_1 + \cdots \tag{10}$$

$$\rho = \rho_0 + N\rho_1 + \cdots \tag{11}$$

We note that Φ_0 is sufficient (Sutton and Carlson, 1961) to calculate the power output. Thus, equation (4) is solved using the technique of conformal mapping, where we use the transformation

$$e^z = \sin w \tag{12}$$

$$\eta_h = \xi + \frac{\pi}{2h} \tag{13}$$

$$z = \xi + i\eta_h \tag{14}$$

$$w = \xi' + i\eta_h', \quad \eta_h = \frac{\eta}{h} \tag{15}$$

The required solution for the potential is

$$\Phi_0 = 2\Phi_w \frac{\xi' h}{\pi} \tag{16}$$

or in terms of dimensional quantities

$$\phi_0 = 2\phi_w \frac{x'}{\pi} \tag{17}$$

where

$$\xi' = \frac{x'}{h} \quad \eta'_h = \frac{\eta'}{h}.$$