decreases[9,10]. Alternatively, when a magnetic field is applied externally at a given temperature, ferromagnetic order is induced in the MnO_2 layers leading to a decrease in resistance. In the self doped $La_{0.7}MnO_{3-\delta}$, the pronounced GMR effect is attributed to La^{3+} and O^{2-} vacancies which form the scattering centers for the conducting electrons, thereby increasing the resistivity. Applied magnetic field seems to provide sufficient activation energy for the alignment of spins to overcome the additional scattering of conducting electrons.

In the case of multilayer, we propose that there are two factors contributing to the total GMR. The first one is the decrease in the resistances of individual magnetic oxide layers as in the single Ag–LMO film. This value is about 80% at 6T. The second factor is the parallel combination of resistances of the individual magnetic oxide layers separated by the non-magnetic spacer layer. This is about 8–10% thus giving 89% GMR at 6T in the $(Ag–LMO/LMO)_{20}$. The secondary contribution seems to arise from the spin dependent scattering of the conduction electrons at the interface between the ferromagnetic oxide and the nonmagnetic oxide. The order of magnitude of the secondary contribution to the total GMR is about 8–10% which is about the same as that of magnetic/nonmagnetic metal multilayers such as $(Co/Cu)_n$.

In conclusion, we have shown for the first time, a superlattice sequence of magnetic/nonmagnetic oxide multilayer, mimicking the $(Fe/Cr)_n$ superlattices, showing an enhanced GMR compared to the GMR observed in the parent magnetic oxide thin films. We have also shown an anisotropic behaviour in the multilayer oxide films compared to an isotropic behaviour in lanthanum manganate thin films,

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Physiobiochemical aspects of development of hardseededness in *Albizia lebbek*

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Seeds of *Albizia lebbek* exhibit dormancy due to hard seeded coat. Seed development was studied in this species to determine whether the induction of hardseededness precedes or succeeds the attainment of physiological maturity and also whether the hardseededness is an inherent character of the seed or can be escaped by harvesting seeds before its induction. The seeds attained physiological maturity at approximately 230 DAA accompanied by acquisition of germinability. This phase was characterized by rapid accumulation of starch, soluble carbohydrates, proteins and chlorophyll. The onset of hardseededness followed, proceeding gradually until 270 DAA and then increased rapidly. While the soluble carbohydrates and chlorophyll contents declined during this period, the starch and proteins showed an increase. Hardseededness in these seeds seems to be their inherent character as it not only occurred in seeds attached to the parent plant but also in seeds in storage, although considerably delayed in the latter case.

DELAYED germination of seeds due to hard seed coats is a common characteristic of many leguminous seeds. *Albizia lebbek* (L.) Willd. is one such multipurpose tree species in which hardseededness poses a practical problem for germination of its seeds. The occurrence of hardseededness in some seeds indicates that the prevailing environment during seed development plays a significant role in developing a hard seed coat[1-3]. However, information is lacking on the germinability and performance of seeds harvested prior to induction of hardseededness. Thus, the present investigation was undertaken to determine whether seeds attain germinability before the induction of hardseededness, and if so, whether hardseededness could be escaped by harvesting seeds before its induction.

Table 1. The physiobiochemical changes and germination in the seeds of *A lebbek* during development (Mean ± SE)

Stage	Pod fr	Seed wt (mg)		Seed	Chl a+b	Sol sug	Starch	Sol. prot.	Percentage germination after storage (months)*					
(DAA)	wt (g)	Fresh	Dry	MC	mg/g fresh weight)				0	1	2	3	4	5
M_1 (150)	7 28	39 39 ±1 38	7 58 ±0 27	80 92 ±0 17	0 163 ±0 001	32.52 ±0 08	10 33 ±0 005	53.99 ±1 53						
M_2 (170)	7 25	154 81 ±4 45	32 87 ±0 94	78 79 ±0 18	0 154 ±0 002	39 80 ±1 42	23 46 ±0 21	76 05 ±1.43						
M_3 (190)	8 37	231 99 ±5 05	68 72 ±1 78	70.39 ±0 37	0 143 ±0 01	33 42 ±0 68	115 81 ±3 43	127.66 ±1.17	80 00					
M_4 (210)	6 42	272 86 ±12 74	93 13 ±4 76	65 91 ±0 31	0 283 ±0 004	39 28 ±0 38	195.71 ±13 01	177.77 ±1.18	100 00					
M_5 (230)	3 85	177 01 ±5 12	89 50 ±2 59	49 37 ±0 81	0 032 ±0 002	75 39 ±9.33	191 93 ±13 62	241 67 ±6.35	94 67	85 00	81 67	88 33	75 00	10 00
M_6 (250)	3 89	134 38 ±3 27	80.76 ±2 44	39.75 ±1 78	0 081 ±0 002	55 17 ±5.19	125 87 ±16 40	255.24 ±1 15	87 00	77 33	ND	–	–	–
M_7 (270)	3 57	112 59 ±1 87	82 91 ±1 91	26 22 ±0 67	0 027 ±0 0003	56 81 ±3.09	163.94 ±4 80	288 81 ±9 49	85.33	81 33	65.33	60 00	60.00	21 66
M_8 (290)	3 67	111 09 ±1 29	85 79 ±1 53	22 81 ±0 68	0.029 ±0.001	50 63 ±1 68	174 60 ±5 82	355 55 ±1 16	65.00	55.00	35 00	13.33	8 33	0 00
M_9 (310)	2 95	117.18 ±2 84	99 96 ±3 27	14 80 ±0 98	0 030 ±0 0005	58 96 ±3 79	210 01 ±12 50	339 01 ±24 25	0 00	0 00	11 67	10 00	10.00	10 00

DAA – Days after anthesis
ND – Not determined due to accidental loss of seeds.
* – These data represent percentage germination without any treatment. After hot water treatment the germination ranged from 90 to 100%.

The study was undertaken in two subsequent years 1991–1992 and 1992–1993. Careful monitoring of pod and seed development was done beginning at the full-bloom stage and commencing 150 days after anthesis (DAA) when seeds were still minute in size but yet easily separable from the pod. The observations on the development of pod and seeds of *A. lebbek* revealed that development of seeds was delayed until pods had attained almost full growth, after which seeds began to develop rapidly. It required 150 days from anthesis for pods to reach this stage. Thus, pods of *A. lebbek* were collected from a natural stand at Srinagar Garhwal (550 m altitude) at 20-day intervals beginning 150 DAA and continuing until 310 DAA when pods reached a dry stage and started shedding. Stages were identified as M_1, M_2, M_3 310 DAA. Following each harvest, ten randomly chosen pods were analysed for their weight, size and colour. Fifty pods were dissected to liberate their seeds, which were mixed together and analysed for their weight, moisture content, biochemical analyses, germination and storability.

The moisture content of ten randomly chosen seeds was determined by drying them at 80°C for 48 h in an electric oven, after first determining their fresh weight, and calculating by the formulae given by Evans[4]. For germination, seeds were kept in three sets, each set containing 50 seeds, on the top of Whatman no. 1 filter paper in Petri dishes of 9 cm diameter and moistened daily with distilled water. Petri dishes were placed at room temperature, which varied between 17 and 24°C during the course of study. Daily observations were made for monitoring the germination (radical emergence) up to 30 days after sowing. To test the germinability of hard seeds, the seeds were soaked in hot water before placing them for germination. To study the changes in composition during maturation, the contents of chlorophyll, soluble sugars, starch and soluble proteins in freshly harvested seeds were determined. For chlorophyll determination Holm's[5] method, for carbohydrates the Anthrone method[6] and for soluble protein estimation the method given by Lowry *et al.*[7] were used.

As mentioned above, development of seed was delayed until pods attained almost full growth, which took 150 days after anthesis. Pod growth continued for an additional 40 days (M_3 stage) and subsequently ceased, after which the fresh weight of pods started declining (Table 1). In contrast, the fresh weight and dry weight of seeds increased progressively for 60 days until 210 DAA (M_4 stage), and subsequently a significant decline in seed fresh weight was recorded, which reached less than 50% of its maximum fresh weight at the time of seed shedding. However, after reaching a maximum on 210 DAA, the dry weight decreased slightly, which was not statistically significant except in the last stage. The moisture content of the seed started declining 170 DAA, first slowly and then very rapidly. Moisture content declined to 50% at 230 DAA, finally reaching 14.8% on 310 DAA. Maximum pod length and breadth were attained between 170 and 190 DAA; thereafter, while the length remained static, the breadth displayed gradual attenuation. The pod, however, exhibited a series of colour changes from green up to 230 DAA,

Table 2 Coefficient of correlation between various parameters studied during seed development in *A. lebbek* (n = 10 in each case)

	Days after anthesis	Seed dry weight
Starch	0.792****	0.969*****
Sugar	0.650**	0.624*
Protein	0.985*****	0.822****

Levels of significance
p = 0.1*, p = 0.05**, p = 0.01****, p = 0.001*****.

then greenish yellow between 230 and 270 DAA, and finally a dark yellow.

The chlorophyll content was 0.283 mg g^{-1} until 210 DAA. Thereafter, it declined to 0.030 mg g^{-1} fr. wt at the time of pod shedding. Contrary to this, the soluble sugar content, starch and soluble proteins increased during seed development. Statistical analysis of the data shows a positive and highly significant correlation in biochemical constituents and seed development (Table 2). While a decrease was observed for carbohydrates at the maximum seed weight stage, soluble protein content continued to increase until the second last stage. During this period of seed development, a remarkable increase in all biochemical constituents was recorded during the early phase, i.e. between 150 and 230 DAA. It was during this period that seed attained maximum fresh and dry weight. Starch, soluble carbohydrates and soluble proteins all had a positive correlation with seed dry weight, which was highly significant in the case of starch (p = 0.001) and proteins (p = 0.01), indicating that these are the major contributors for the seed dry weight. The increasing trend of soluble sugars, starch and soluble proteins during seed maturation showed the relationship between the synthesis of nitrogenous compounds, i.e., proteins, during maturation (important in the formation of organelles, cytosol and membranes) and the metabolites that participate in vital processes in the seeds, as reported by Chamma *et al.*[8].

The developing seeds attained germinability around 190 DAA as 80% germination was obtained in seeds at this stage without exhibiting any hardseededness. By 210 DAA all seeds had acquired the ability to germinate as 100% germination was recorded at this stage (Table 1). This was the stage when the mean dry weight of the seed was also maximum. Physiological maturity in angiosperms has generally been designated as completion of organic accumulation within the seed as reflected by no further increase in its dry weight[9, 10]. Thus, in the present study it seems that seeds of *A. lebbek* attained physiological maturity around 210 DAA, because seed dry weight was maximum and germination was 100%, but the ability to germinate even prior to this stage indicates that acquisition of germinability preceded attainment of physiological maturity in this case, as increase in seed dry weight between M_3 and M_4 stages was statistically significant. However, this is not an exception, as in some other legumes also the seeds developed the ability to germinate even prior to the attainment of maximum dry weight[11]. Subsequent to 210 DAA, a gradual decline in percentage germination was recorded which was remarkable during the final stage between 290 and 310 DAA, when a 65% decline was recorded in the germinability of seeds and thus the seeds seemed to have attained complete hardseededness at this stage as no germination was recorded without scarification. Thus, there is a clearcut indication that hardseededness in *A. lebbek* is induced after attainment of physiological maturity, characterized by maximum seed dry weight, the M_4 stage. In spite of the onset of hardseededness after the M_4 stage, a high percentage of seeds still exhibited germination ranging from 95% at M_5 stage to 85% at M_7 stage without any scarification. This may be due to the slow progress in development of hardseededness during this period; therefore, seeds can be harvested at these stages.

Seeds harvested at M_4 stage could not be stored viably but those from subsequent stages not only stored well but also exhibited an interesting pattern of germination during storage. Seeds stored at room temperature for five months and tested for their germinability at monthly intervals showed a gradual decline in their percentage of germination with their age in storage, not because of the loss of viability but due to development of hardseededness, which was evidenced by their germination after hot water treatment. This decline in germination was faster in the seeds harvested at advanced stages (e.g. M_8 or M_7 stage) than at an early stage (M_5 stage), as evident by the data in Table 1. After four months in storage, while percentage germination declined only by 20% as compared to freshly harvested seeds at M_5 stage, in case of M_7 and M_8 stages the decline was 30 and 87%. By six months all seeds in storage had developed hardseededness and none germinated without scarification. Thus, hardseededness seems to be an inherent character of these seeds and is not related to its attachment with the parent plant as the process of development of hardseededness continued even after the seed had been detached from the plant and kept in storage. Adams and Rinne[12] have also reported for *Glycine max* that the maturation is an inherent function of the seed, the completion of which does not depend on the association of the seed with the parent plant. Interestingly, here the development of hardseededness was faster when the seeds were attached to plant than in storage.

The evaluation of parameters that allow the visual identification of physiological maturity or some information that contributes significantly to decisions concerning harvest of the seeds is another very important aspect of seed development studies. In many hardwoods, cone/fruit colour was investigated as a workable indicator for maturation, e.g. in five species of *Quercus*[13, 14]. A series of investigations[8] carried out in many agricultural crops, e.g. corn, sorghum, oat, soybean, etc., revealed that the formation of the black layer in corn and sorghum and the changing colour of the fruits and seeds in other species allowed an accurate identification of the physiological maturity of seeds. According to results obtained here, on the basis of pod colour changes in *A. lebbek* it can be concluded that the colour of the pods was closely related to the maximum physiological quality of seeds as they started changing colour from green to yellow around 230 DAA, when seeds had attained physiological maturity. Thus, the time when green pods are not found on the plant any longer can be used to characterize the physiological maturity of seeds, and pods can be collected at this stage. Thus, the overall results obtained here indicate that development of hardseededness in seeds of *A. lebbek* succeeds the attainment of physiological maturity, and it is an inherent character of the seed which can, however, be delayed to some extent by harvesting the seeds immediately after maturation. The colour of the pods served as a workable indicator of maturation.

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Fractal description of seismicity of India and inferences regarding earthquake hazard

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Earthquakes have the quality of fractal structure in their spatial disposition, time sequencing, and magnitude distribution. We analyse the seismicity of India in terms of its spatial fractal structure in various seismic source zones. It is found that the fractal dimensions range between 0.894 and 1.574, indicating that at most the earthquake associated fractures are approaching a two-dimensional space. The low fractal dimension is suggestive of the presence of asperities and barriers of significant sizes in the respective source zones. Using a fractal model the average earthquake slip in primary faults is estimated to be about 3.5 cm/yr in the Himalaya. This gives an average return period of great earthquake of about 285 years. Considering that no great earthquake has occurred in the seismic gaps in the Himalaya for at least 200 years, these gaps are ripe for a future great earthquake to occur within the next hundred years.

To see a world in a grain of sand,
And a Heaven in a wild flower,
Hold Infinity in the palm of your hand,
And Eternity in an hour.

– William Blake

THE earthquakes represent the outcome of complex geomechanical processes having dire consequences for the society. The earth is in an overall steady state of strain, which for most part is caused by plate motions. This is released from time to time in the form of catastrophic motion over faults in the crust, resulting in earthquakes. The structure of the crust is highly inhomogeneous. On a microscale there are crystal defects, cleavages, dislocations, grain boundaries, etc., while on the other end of the scale, i.e. macroscale, by virtue of repeated fracturing and the different shapes of fractures a high degree of heterogeneity of the crust has evolved. The strain field accordingly is also quite heterogeneous. On account of such complexity of the medium, precise prediction of the occurrence of earthquakes in terms of their location, magnitude and time of occurrence is not feasible. Therefore, the earthquakes are describable by statistical means.

Mandelbrot[1] observed that many natural phenomena possess self-similarity at many different scales. He used the term 'fractal' to describe such phenomena. For example, an assemblage of objects with differing sizes and irregular shapes is a fractal set if the number of objects in it with a specified size has a power law dependence on size. The scaling parameter is called the fractal dimension D. The geometry of the fracture surface of rocks is a fractal[1, 2]. The natural rock fracture process is a fractal. Earthquakes are associated with fractals by virtue of the accompanying fracturing of rocks. A fractal distribution is scale-invariant. In such a set the complexity of the part is as great as that of the whole. A fractal function such as a curve or a surface is not dif-