DISCUSSION

Seed preservation in eastern India and coastal belt of our country is a very serious problem due to high relative humidity and high temperature which accelerate the physiological deterioration of seeds and ultimately a seed loses their vigour and viability in quick succession. Storage of seed in low humidity and low temperature would slow down the ageing process but such facilities are very expensive for small and marginal farmers and they store their bulk quantities of seeds in cloth bag. As the seeds are highly hygroscopic in nature, they absorb a lot of moisture from the atmosphere which coupled with high temperature accelerate the ageing process of seeds.

Seed storage is a serious problem, especially, in eastern part and coastal belts of our country. Seeds stored in gunny bags and cloth bags absorb a lot of moisture from the humid atmosphere, which coupled with high temperature hasten the ageing process of seeds. But well dried seeds stored in moisture impervious containers, deteriorate at a slower rate than that of uncontrolled storage (gunny and cloth bag). The availability of controlled storage is problematic to the small and marginal farmers residing at the rural areas. Looking into the aforesaid background attempts have been made to develop an easy and inexpensive method of seed invigoration treatments (wet and dry) for the maintenance of vigour, viability and yield potential of sesame seeds (cv. Rama and B-67). In earlier studies, it is suggested that physiological treatments invigorate the seed and improve seed performance possibly by preventing the deteriorative senescence of the seed through reduction of oxidative damage to biomembranes and vital biomolecules there by improving germinability and boosting field establishment, growth and ultimately crop productivity (Wilson and McDonald, 1986a; Zhang et al., 1993; Mandal et al., 1999, 2000, 2010; De et al., 2003; Mishra et al., 2008).

Pre-storage dry seed invigoration treatment of sesame (cv. Rama and B-67) seeds with aspirin, bleaching powder and red chilli powder have been found to be very effective in controlling seed deterioration during subsequent storage. Basu, Mandal and other co-workers demonstrated that dry-dressing of seeds with halogenated compounds such as bleaching powder and iodinated calcium carbonate
has been successful in a number of harvest fresh non-leguminous crop seeds. Dry-dressing treatment with crude plant material and some pharmaceutical products also showed positive results in controlling seed deterioration (Pal and Basu, 1993, 1994; Mandal et al., 1999, 2000).

Sesamum seeds were dry-dressed with finely powdered chemicals *viz.* bleaching powder @ 2g/kg of seed and *para*-amino-benzoic acid @ 500mg/kg of seed, pharmaceuticals *viz.*, aspirin @ 50 mg/kg of seed and ascorbic acid @ 500 mg/kg of seed) and crude plant materials *viz.*, red chilli powder @ 1g/kg of seed, lemon leaf powder @ 2g/kg of seed and spinach leaf powder @ 2g/kg of seed were employed to one-month-old seed as a pre-storage treatment.

Pre-storage dry physiological seed treatments with finely powdered chemicals, pharmaceutical formulations and crude plant materials on high-medium vigour sesamum seeds have been found to be very effective in controlling seed deterioration and improving field performance of the resultant crop.

Basu, Mandal and other co-workers demonstrated that dry-dressing of seeds with halogenated compound such as bleaching powder and iodinated calcium carbonate has been successful in a number of harvest fresh non-leguminous crop seeds (Mandal and Basu, 1986; Biswas *et al.*, 2012; Guha *et al.*, 2012; Guha and Mandal, 2013).

In the present study, pre-storage dry treatments especially, aspirin, bleaching powder and red chilli powder are effective in controlling seed deterioration and improved field performance and productivity of sesamum (cv. Rama and B-67).

Regarding the pre-storage treatment, most of the dry and wet treatments in both the cultivars (cv. Rama and B-67) are very much effective in slowing down seed deterioration under subsequent storage conditions. They have also significantly improved field performance over untreated control. Among the treatments aspirin, bleaching powder and red chilli powder has shown better results in improving storability and field performance of sesamum. The trend of results are more or less same in both the cultivars.
Unlike pre-storage seed invigoration treatment, mid-storage seed invigoration treatments were also given to 5-month-old sesamum seeds. Most of the mid-storage dry and wet treated seeds showed beneficial effect on germinability and field performance over untreated control.

Studies in the present laboratory with the treated (hydration-dehydration treatments) and untreated seeds of a range of crop seeds (Basu, 1976; Basu et al., 1974; Dasgupta et al., 1976) confirmed the beneficial effects of the treatment on the maintenance of vigour and viability of sesamum. Mid-storage wet treatment in high-medium or medium vigour sesamum seeds have been found effective in improving storability and field performance. The wet treatments are effective in medium vigour wheat seeds reported earlier by Mandal and Basu (1982; 1987). It is however, been shown that the physiological age of the seed at time of treatment is a crucial factor, which determines the effectiveness of treatments (Basu and Dasgupta, 1974; Basu 1994).

The physiological seed treatments, depending on the kind of seed and initial seed vigour status, would significantly extend storability and improve subsequent crop performance. Dry physiological treatments are only effective when employing to harvest fresh high vigour or high-medium vigour seed. Mid-storage hydration-dehydration treatments (wet) are very much effective in slowing down seed deterioration under subsequent storage conditions (Basu, 1976; Mandal and Basu, 1982, 1986; Ramamoorthy and Basu, 1984, 1996).

Pre-storage (harvest-fresh) dry physiological treatments in high-medium vigour sesamum seeds with chemicals, pharmaceutical formulations and crude plant materials have been found to be very effective in controlling seed deterioration and improving field performance of the resultant crop. It has been found that most of the dry physiological seed treatments especially, aspirin, bleaching powder and red chilli powder showed significant improvement on vigour, viability and productivity of sesamum. These results confirm the earlier observations made by the present laboratory (De et al., 1998, 2003; Mandal et al., 1999, 2000, 2010; Kapri et al., 2003; Saha et al., 2006; Biswas et al., 2012; Guha et al., 2012; Guha and Mandal, 2013) on the efficacy of dry treatments for the maintenance of vigour, viability and productivity of several other agricultural and horticultural crop seeds.
However, physiological seed treatments, depending on the kind of seed and initial seed vigour status, would significantly extended storability and improve subsequent crop performance. Dry physiological treatments are only effective when employing to harvest fresh high vigour or high-medium vigour seed. Mid-storage hydration-dehydration treatments (wet) are very much effective in slowing down seed deterioration under subsequent storage conditions (Basu, 1976; Mandal and Basu, 1982, 1986; Ramamoorthy and Basu, 1984, 1996). But leguminous seeds are less responsive to wetting-drying especially when long term duration are employed resulting in soaking injury (Powell et al., 1984; Legesse, 1991 and Armstrong and McDonald, 1992). Further, hydration-dehydration treatment of harvest fresh seeds also adversely affected their storability due to soaking injury. But mid-storage modified hydration-dehydration such as moist sand conditioning-drying and moist sand conditioning-soaking-drying treatments of 5-month-old medium-vigour seed has shown very effective in maintaining vigour, viability and improving field performance. This confirms the earlier report from the present laboratory on the beneficial effect of invigoration of soybean seed for alleviating soaking injury and improving germinability and productivity (Saha and Basu, 1984 and Saha et al., 1990).

**Important manifestation of physiological treatment**

Usually little difference in germinability between treated and untreated seed is noted immediately after treatment (before ageing condition). However, with relatively prolonged soaking durations, the rate of emergence and early seedling growth may be initially higher than the control. Highly significant treatment effects are noted when the seed is subjected to accelerated ageing or stored under natural ambient temperature and humidity regimes. The manifestation of treatment effects were higher germination percentage, reduced percentage of morphologically abnormal seedlings and greater uniformity of growth and development. These are indeed the normal manifestations of high vigour seed (Delouche et al., 1967; Heydecker, 1972). In physiological and biochemical studies, greater membrane integrity as evidence by lowered electrical conductance of seed leachate, leaching of sugar and amino acid, lower production of volatile aldehyde and lower lipid peroxidation and greater enzymes activity (dehydrogenase) were recorded in treated seeds. The crop raised
from treated seeds were also significantly higher field establishments, yield per unit area and other yield attributes than that from the untreated control.

**Relationship between vigour, viability, field emergence and yield**

Seed vigour is a qualitative attribute of the seed which is most intimately related to seed viability (Heydecker, 1972) and loss of viability is usually preceded by loss of vigour. Therefore an understanding of vigour is basic to the elucidation of the mechanisms of loss of viability. Vigour is that quality of the seed which is responsible for rapid, uniform germination, increased storability, good field emergence and ability to perform well over a wide range of field conditions (Perry, 1978 and McDonald, 1980).

The germination ability and vigour of a seed lot is related indirectly to performance in the yield. Reductions in seed vigour lead to slower and less uniform seedling emergence in brussels sprouts (Powell et al., 1991) and in onion (Wheeler and Ellis, 1992). According to Benjamin (1982), uniformity of size and earliness of harvest resulting from use of seed of high vigour and viability of crops such as lettuce, carrot and brassicas. Finch-Savage and McQuistan (1988) studied the performance of carrot seeds of different germination rates and concluded that fast-germinating seeds within a seed lot gave better emergence than the slow-germinating seeds. Ford and Hicks (1992) reported that corn plant failed to emerge uniformly yielded 11 per cent less grain than those that emerge uniformly. When yield loss occurs, seed vigour is indirectly related to yield by reducing final emergence, plant emergence rate or by causing uneven emergence.

Loss of viability affects crop yield by reducing plant stand per unit area because of poor germinability and by adversely affecting vigour of the surviving seedlings, which may be ultimately carried over to the agricultural yield. The present findings on sesamum confirm earlier observation that the treated seeds (Basu and Dasgupta, 1974; Mandal et al., 2010; De et al., 2003; Sengupta et al., 2005; Kapri et al., 2005; Mishra et al., 2008 Biswas et al., 2012; Biswas and Mandal, 2012; Guha et al., 2012; Layek et al., 2012; Guha and Mandal, 2013) showed significant difference in germination percentage over control and the same as reflected upon field performance and productivity.
In bean, Rodriguez and McDonald (1989) noted that low vigour seeds produced fewer nodules, less nodule weight and less dinitrogen fixation culminating in less plant growth and yield. Tekrony and Egli (1991) reported that low seed vigour contributed to reduced forage or grain yield, or had no effect. Alizaga et al., (1987) obtained five vigour grades by subjecting soybean seeds to ageing at 16 percent moisture content and 30°C for different durations, with each grade having more than 70 percent germination and recorded a decrease in most growth parameters with decreasing seed vigour, seed yield from plants grown from aged seed was lower than that from unaged seed. In the present investigation, the results of the field experiments with sesame seeds a significant increase in yield and other yield attributes have been noted in plants raised from the treated seeds than the untreated control. The significant increase in yield was not merely due to an increased plant population because of higher viability but also an effective maintenance of the intrinsic vigour of the seed. Even a very stable character such as 1000-seed weight was significantly higher in the crop raised from the treated seeds. This is a special significance in view of the fact that the control plants suffered less interplant competition because of lower population density.

In the present study and our earlier studies in other crops, the viability maintaining seed treatments, even when they showed moderate differences in germinability, significantly increased agricultural yield. The yield differences recorded in those experiments may not be solely attributed to viability differences, however, but also to as yet undefined effects of physiological seed invigoration.

**Mode of action pre-sowing treatments**

Henckel (1972) and Henckel and Ivanitskaya (1976) have shown the beneficial effects of pre-sowing wetting-drying treatments on the performance of plants under stress conditions. According to Henckel (1972) the beneficial effects of pre-sowing treatments were associated with the formation of more high energy compounds, increased DNA in the growing points, less activity ribonuclease activity and active protein synthesis, higher mitochondrial activity and better preservation of cellular ultrastructure with allied sequential changes in the elasticity and viscosity of the protoplasm. The improvement caused by pre-sowing wetting-drying treatment in carrot was attributed by Austin et al., (1969). Similar observations have been made by
Hutchinson (1969) in interpreting the improved field emergence of one variety of carrot and two varieties of sweet corn. Studies in the present laboratory (Basu and Dasgupta, 1974; Mandal and Basu, 1982) and those of several other workers (Ray, 1982; Goldsworthy et al., 1982) suggested that the beneficial effects of pre-sowing soaking might also be obtained with shorter soaking duration. Chatterjee and Singh (1983) and Mandal and Basu (1987) reported that 6-8 h pre-sowing soaking treatment in water considerably improved field performance. Falkenstein and Steiner (1985) also noted the beneficial effect of some presprouting treatments on grain yield of winter and spring wheat.

The beneficial effects of wetting-drying treatment in carrot was attributed by Austin et al., (1969) to pre-enlargement of embryo along with advancement of the germination process. The observation of Hegarty (1970) in carrot and maize would support the views of Austin et al., (1969). As regards, embryo enlargement as a reason of the beneficial effect to pre-sowing treatment, it needs to be studied whether such an explanation would hold good for seed in which the embryo is already fully developed.

Biochemical evidence in favour of germination advancement by hydration-dehydration pre-treatments have been greatly emphasized by Osborne and and coworkers (Osborne et al., 1974; Sen and Osborne, 1974). According to Sen and Osborne (1974), the rate of RNA and protein synthesis in wetted-dried rye embryos were similar to those in embryos continuously germinated for the same period of total hydration. Heydecker (1974) was also of the opinion that hydration caused an advancement of the germination process which was compatible with the subsequent drying back. Kattimani et al., (1999) reported that pre-soaking treatment with 1% solution of sodium and potassium nitrate for 24 h would produce more vigorous seedlings, higher dry matter accumulation and root length as compared to unsoaked and water soaked seeds of Withania somnifera.

Considerable evidence exists that repair of DNA, protein, membranes and enzymes occurs during imbibitions. Increasing seed moisture content hastens the repair process (Ward and Powell, 1983). Oxygen also increases the repair of high moisture lettuce (Ibrahim et al., 1983) and high moisture wheat (Petruzzeelli, 1986) seeds suggesting that respiratory activity is an essential component of repair.
Mode of action of hydration-dehydration treatments

The present method of seed treatment is different from the pre-sowing wetting-drying treatments. The treatment has to be given after the seeds are stored for several months and there should be a time gap between treatment and sowing.

So far as the mode of action of the mid-storage hydration-dehydration treatment is concerned, there are two possibilities namely (i) enzymatic repair of biochemical lesions and (ii) counteraction of lipid peroxidation reactions.

(i) Enzymatic repair of biochemical lesions

Sivritepe and Dourado (1994) found that humidification of aged pea seeds decreased chromosomal aberrations, avoid imbibitional injury and improved seed viability. Rao et al., (1987b) found that a reversal of chromosome damage (induced during seed ageing) accompanied partial hydration of lettuce seeds to 33 - 44% that also increased the rate of root growth and decreased frequency of abnormal seedlings. Chiu et al., (1995) found that hydration effected membrane repair in watermelon scavenging enzymes. Villiers (1974) and Villiers and Edgcumbe (1975) observed that in fully imbibed seeds, repair of vital bioorganelles would take place and as a result storage life of the seed would be extended. In dry-stored seeds, in the absence of a repair mechanism, the damage to molecules would accumulate. Villiers (1974) showed that when dry-stored lettuce seeds were fully imbibed not only was the senescence stopped but a definite reversal of the damage to the chromosomes and membranes took place. This has been considered to be due to the activity of a repair system in the hydrated seeds rather than a mere stabilization of the macromolecular structures by hydration. Any repair of biochemical lesions require protein synthesis which depends on pre-existing enzyme protein. Activation of pre-existing enzyme is useful in breakdown of toxic substances accumulated in the seeds during previous dry storage. Scavenging of free radicals by super-oxide dismutase (SOD) during seed hydration as in radiation studies (Krizala et al., 1983), may also lead to reduced free radical damage. Pan and Basu (1985) have, however, indicated the absence of de novo protein synthesis in moisture equilibrated-dried lettuce seed. But the involvement of pre-existing enzyme protein in the repair process cannot be ruled out.
(ii) **Counteraction of lipid peroxidation reaction**

Lipid peroxidation is an oxidative deterioration of polyunsaturated lipid. Peroxidation involves the direct reaction of oxygen and lipid to form free radical intermediates and to produce semi-stable peroxides. There is a distinct possibility of involvement of free radical induced lipid peroxidation reactions in seed deterioration (Pammenter *et al*., 1974; Basu, 1976; Berjak, 1978; Buchvarov and Gantcheff, 1984; McDonald, 1999). Peroxidation of membrane lipids would increase permeability (Van Staden *et al*., 1976) and decrease membrane fluidity (Dobretsov *et al*., 1977). Seed invigoration treatments may improve storability by controlling free radical reactions and consequent peroxidative damage to lipoprotein cell membranes. Villiers (1972) suggested the deterioration of biomembrane in aged seeds due to peroxidation of phospholipid. Roberts (1972) supported the above view and reported that oxygen pressure could be the cause of loss of membrane integrity in old seed. Rudrapal and Basu (1979, 1982) showed greater lipid peroxidation reactions in deteriorating wheat and mustard seeds. The oxidative deterioration of polyunsaturated lipids in cellular components, involving the reactions of free radical intermediates, could be a primary reason of senescence of the cell as reported by Tappel (1973).

Harman and Mattick (1976) and Berjak (1978) implicated free radical and lipid peroxidation reactions in the deterioration of pea and maize seeds respectively. Both the loss of membrane integrity and a decrease in proportion of unsaturated fatty acid have been reported as seeds deteriorate. Fatty acid content decreased with accelerated ageing in slash pine (Marquez-Millano *et al*., 1991) and in bean (Lin and Pearce, 1990). However, contrasting results have been reported. No changes in the relative proportion of fatty acids were found in peanut seeds after accelerated ageing (Perez and Aguello, 1995). Priestley and Leopold (1983) found no change in fatty acids content of aged soybean seeds and Powell and Harman (1985) reported no consistent association between the accumulation of peroxides and loss of phospholipids with seed ageing in pea. Priestley *et al*., (1980) argued that the greater peroxidation could be a post-mortem event. Nakayama *et al*., (1981) demonstrated a gradual breakdown of phospholipids in soybean seeds stored at 35°C at a moisture content of 13 per cent. Increased lipid peroxidation in soybean seed after ageing was also observed by Dadlani and Agrawal (1983), who pointed out that the initial higher
α-tocopherol in a soybean cultivar of better storability, in comparison to a poor storer, might account for the decrease of phospholipids and lower malondialdehyde content in the former. Further showed that deterioration of soybean axes was always less when seeds were dry permeated with α-tocopherol or butylated hydroxytoluene which would suggest a close relationship between lipid peroxidation and seed ageing.

Rudrapal and Basu (1979, 1980, 1981) showed that the viability maintaining property of physico-chemical treatments was always associated with a lowered lipid peroxidation in embryo as well as whole seeds of wheat and mustard. Wilson and McDonald (1986b) proposed a model of lipid peroxidation in seed ageing in which it was suggested that seed deterioration would take place during ageing via lipid peroxidation and increased free radical flux during ageing would be concurrent with accumulation of both co-oxidative injury and oxygenated fatty acids. The enzymatic degradation of such fatty acids upon hydration would result in further seed damage due to free radical and toxic secondary product formation. Jeng and Sung (1994) reported that artificially aged peanut seeds tend to have a greater level of lipid peroxidation and subsequently accumulate more peroxides. They suggested that this phenomenon could be linked to the ageing stimulated activities of peroxide scavenging enzymes. Lipid peroxidation has been suggested as the cause of loss of sunflower (Bailly et al., 1996) and soybean (Sung, 1996) seed viability. Khan et al., (1996) showed that the loss of viability and declining vigour were associated with increase in lipid peroxidation and free radical build up which was confined to the testa than the cotyledon of soybean seed.

The seed hydration can bring about radical quenching has been shown in radiobiological experiments (Ehrenberg, 1961; Cook, 1963; Haber and Randolph, 1967). According to Ehrenberg (1961), the enhanced mobility of free radicals upon hydration would facilitate their recombination into harmless non-radical products. Scavenging of free radicals by superoxide dismutase (SOD) during seed hydration, as recorded in radiation studies (Krizala et al., 1983), may also lead to reduced free radical damage during subsequent storage. Benson (1990) reported that, seed possess detoxification enzymes such as superoxide dismutase (which can destroy the peroxide free radical itself by catalase or peroxidase action), or the glutathione peroxidase/reductase system which can neutralize lipid hydroperoxides. Puntalaro and Boveris
(1990) have demonstrated a correlation between reduction in SOD actively produced in the first two hours of imbibition and decrease in vigour in deteriorating seeds. On the basis that dry seeds do not appear to have any SOD activity.

Noteworthy, products of lipid peroxidation include volatile aldehydes. There compounds are products of free radical attack on storage lipids and membranes causing the degradation of fatty acids to smaller and smaller volatile carbon products such as hexanal, pentanal and butanal. The detection of volatile aldehydes during seed germination has been suggested as a seed vigour test (Wilson and McDonald, 1986a) and can quantify the incidence of weathering in soybean seed (Tyagi, 1992b). Esashi et al., (1997) examined five crop seeds and detected the production of 11 volatile aldehyde compounds with seed ageing. The presence of such volatile aldehydes have been readily demonstrated by trapping them with reagent like MBTH (3-methyl-2-benzothiazolinone hydrazone) followed by spectrophotometric analysis (Harman et al., 1982; Wilson and McDonald, 1986a; Pal and Basu, 1989; Sur and Basu, 1990a). Seed invigoration treatments always showed significantly lower post-ageing volatile aldehyde production than in the untreated control, thereby implying reduced lipid peroxidation by such treatment. The highly significant negative correlation between soybean seed vigour and hydroperoxide level and identification of hexanal, pentanal, butanal as thermal breakdown products of the hydroperoxides (Hailstones and Smith, 1988) would lend support to the concept of lipid peroxidation as a major reason for seed ageing. Gardner et al., (1990) examined that seedling growth of soybean is inhibited by E-2-hexanal during germination. Since deteriorating dry seeds release volatiles during storage, hermetic storage in seed banks may inadvertently cause the accumulation of these destructive compounds there by enhancing seed deterioration (Zhang et al., 1993).

**Mode of action of dry physiological treatments**

Dry dressing of seeds with halogenated compound such as bleaching powder (major ingredient calcium hypochlorite) or iodinated calcium carbonate has been successful in controlling seed deterioration of a number of harvest fresh non-leguminous crop seeds (Rudrapal and Basu, 1980; Mandal and Basu, 1986). The efficacy of very low concentration of iodine vapour on storability of seeds was suggested by Basu and Rudrapal (1980).
The role of iodine in the stabilization of double bonds of unsaturated fatty acid moieties of lipoprotein biomembranes as a possible reason for viability extension was suggested by Basu and Rudrapal (1980), besides the possibility of iodine acting as a free radical controlling agent (Pryor and Lasswell, 1975). Chlorine (bleaching powder, a source of chlorine) and bromine would also be more or less similar to iodine in their seed protective action. Exposure of freshly harvested egg plant and radish seeds to halogen vapour slowed down deterioration under accelerated and natural ageing conditions, presumably because of stabilization of unsaturated fatty acids in membranes making them less prone to peroxidative attack (Rudrapal and Nakamura, 1988). Mandal and Basu (1986) reported that dry dressing of wheat seed with calcium hypochlorite (@ 2 g/kg of seed) significantly reduce physiological as well as pathological deterioration during storage under accelerated and natural ageing conditions. Vidyadhar and Singh (2000) reported the halogenation of fresh and partially aged maize seeds with KCl showed a concomitant effect in influencing the absolute cob growth rate (ACGR), test weight and seed yield compared to untreated control. The beneficial role of chemicals dry-permeated into the seed on storability was recorded by Basu et al., (1979) in lettuce and Dey and Basu (1985) in Indian mustard. Woodstock et al., (1983) successfully minimized the deterioration of stored parsley (Petroselinum crispum L.) and onion (Allium cepa L.) seeds using the antioxidants vitamin ‘E’ (α-tocopherol) and butylated hydroxytoluene (BHT) which were ineffective in pepper seeds indicating a differential response. Afterwards, Gorecki and Harman (1987) improved the storability of pea seeds by α-tocopherol and BHT and suggested that lipid peroxidation was probably reduced by their application prior to storage.

The chemicals, pharmaceutical products and crude plant materials were selected on the basis of previous studies conducted in the present laboratory with seeds of wheat and other crop plants (Rudrapal and Basu, 1980; Mandal and Basu, 1986; Pal and Basu, 1988, 1993; De et al., 1998; Mandal et al., 1999; 2000; De et al., 2003; Kapri et al., 2003; Biswas et al., 2012; Biswas and Mandal, 2012) for their possible effectiveness in controlling free radical reactions as antioxidants, antioxidant-synergists and radio protective agents (Heckly and Dimmick, 1967; Dertinger and Jung, 1970; Slater, 1972; Demopoulous, 1973b; Milvy, 1973). Demopoulous (1973b) stated that a number of antioxidants played a significant role in controlling free
radical reactions. Heckly and Dimmick (1967) showed that even sodium chloride may act as a free radical controlling agent.

The mode of action of the beneficial effects of crude plant preparations and pharmaceutical formulations on the viability maintenance is yet to be elucidated. Capsaicin, an active ingredient of chilli (*Capsicum frutescens* L.) is an acknowledged inhibitor of lipid peroxidation (Brand *et al*., 1990; Dey and Ghosh, 1993). Mandal and Basu and other coworkers tested a range of crude plant preparations which are generally used traditionally as spices and household preservatives. They found the treatment of high-vigour (harvest-fresh) wheat seed with red chilli powder, turmeric rhizome powder (*Curcuma longa* L.), nisinda (*Vitex negundo*), neem (*Azadirachta indica* L.), bael (*Aegle marmelos*), mango (*Mangifera indica*), vinca (*Catharanthus roseus*) leaf powder significantly slowed down the deterioration of seed in storage (Pal and Basu, 1993, 1994; Mandal *et al*., 1999; Mandal *et al*., 2000, 2010; Kapri *et al*., 2003; De *et al*., 2003; Mishra *et al*., 2008; Biswas *et al*., 2012; Biswas and Mandal, 2012; Guha *et al*., 2012; Layek *et al*., 2012; Guha and Mandal, 2013). They have also reported that acetyl salicylic acid (aspirin), a plant derivative and widely used pharmaceutical formulations (ASPRO), proved very effective even at a very much lower concentration (50-100 mg per kg of seed). Revathi *et al*., (2003) reported that *Phyllanthus amarus* seeds treated with turmeric rhizome powder (@1:20 ratio) and stored in 700 gauge polythene bag under ambient conditions maintained higher vigour and viability upto six months. Umarani *et al*., (1997) also studied the efficacy of leaf powder (*Albizia amara*, *Vitex negundo* and *Azadirachta indica*) treatment for the maintenance of vigour and viability of *Casurina equisetifolia* seeds. Present experimental findings showed most of the plant materials have some positive effect in controlling seed deterioration during storage.

Salicylic acid belongs to an extraordinary diverse group of plant phenolics, usually defined as substances that possess an aromatic ring bearing a hydroxyl group or its functional derivative. Many phenolic compounds play an essential role in the regulation of plant growth, development and interaction with other organisms (Harborne, 1980). Phenolics are essential for the biosynthesis of lignin, an important structural component of plant cell walls. Several phenolics function as allelopathic compounds influencing germination and growth of neighbouring plants (Einhellig,
1986). The effect of salicylic acid on the timing of flower bud initiation and on the total number of floral bud was synergistic to the GA effect and was accompanied by increase in total RNA content, phosphatases and some non-identified protein in the vegetative organs of treated plants (Kumar and Nanda, 1981a, 1981b). Other effects of salicylic acid on plant development include increasing the pod number and yield in mung bean (Singh and Kaur, 1980) and increasing the height and grain number of cheena millet (Datta and Nanda, 1985). It was also suggested that salicylic acid increased nitrate reductase activity indirectly by protecting the enzyme from inactivation (Jain and Srivastava, 1981). Aspirin, nonsteroidal antiinflammatory drugs are related chemically in that they are weak organic acids. They may also decrease the production of free radicals and superoxide may interact with adenyl cyclase to alter the cellular concentration of cAMP (Bertram, 1998). Recently, Takaki and Rosim (2000) have reported that aspirin application to Raphanus sativus L. seed would increase the tolerance to high temperature and synchronize seed germination. Another pharmaceutical product ‘Celin’ containing vitamin ‘C’ (ascorbic acid, used as an antioxidant) also effectively controlled seed deterioration during storage (Pal and Basu, 1993; Mandal et al., 2000, 2010; De et al., 2003; Kapri et al., 2003; Mishra et al., 2008; Biswas et al., 2012; Biswas and Mandal, 2012; Guha et al., 2012; Layek et al., 2012; Guha and Mandal, 2013). Further the present results convincingly demonstrate the seed invigoration effects of aspirin, celin, and bleaching powder.

A very important point which requires further elucidation is the question of entry of the active ingredients of crude plant preparations or pharmaceuticals in the dry state into the dry-stored seed. Surface application of dry powders on the outer surface of a high moisture seed may cause a slow penetration of soluble materials but how the same would happen in a seed with 8-12% moisture (tightly hold water molecules which are not freely available for solubilization and diffusion of the solution) is an interesting but debatable issue. There is no doubt that the treatments significantly improve the seed performance. The seed is not an absolutely sealed living unit, there are cracks and crevices which facilitate gas exchange may serve as entry point of exogenously applied substances that may in hitherto unexplained pathway would invigorate the seed.
Whatever may be the exact mechanism operative in the viability maintenance, pre-storage dry dressing treatments in high-medium vigour sesamum (cv. Rama and B-67) seeds with finely powdered chemicals, pharmaceuticals and crude plant materials especially, aspirin @ 50mg/kg of seed, bleaching powder @ 2g/kg of seed and red chilli powder @ 1g/kg of seed may be suggested for the improvement of germinability and field performance and productivity of the resultant crop. If the seeds are medium vigour in quality then mid-storage soaking-drying treatment (soaking for 2 h in water followed by drying to its original weight) are advocated for the improvement of storability and field performance of stored sesamum seeds. In situation, where the storage conditions are not reasonably good and the germinability of seeds are moderately medium to low vigour in quality then pre-soaking treatment (soaking in water for 6-8 h followed by light air drying of facilitate sowing in the field) may be practiced.