below the middle. Spikelets 4 mm long, usually solitary. It differs from *P. setosum* in having the inner bristles of the involucre densely villous while in *P. setosum* the inner bristles are laxly ciliate with long silky hairs.

**Season of growth**: Summer and rainy.

**Optimum temperature for growth**: 30-35°C.

**Frost tolerance**: It has little frost tolerance.

**Latitudinal limits**: 20° N and S.

**Rainfall requirements**: In Bihar, India, it grows on a rainfall of 1270 mm between June to September, from which it can produce seeds. The usual rainfall range is 500-650 mm.

**Drought tolerance**: It has good drought tolerance. It persists well in northern Nigeria with a dry season of seven months.

**Soil requirement**: It does best on fertile, loamy soils but with manuring, can grow in sandy soils. It can tolerate both acidic and alkaline soils (Narayanan and Dabadghao, 1972).

**Fertilizer requirement**: It responds well to added nitrogen.

**Ability to spread naturally**: It spreads rapidly by self sown seed.

**Land preparation for establishment**: It needs a well prepared moist seedbed.

**Sowing methods**: The seed is broadcasted or drilled in rows at 45 cm apart in India.

**Sowing depth and cover**: It is either surface sown or drilled at 1 cm.

**Sowing time and rate**: Just before the rainy season (May-July in India) at 1-2.2 kg/ha.

**Compatibility with other grasses and legumes**: It grows well in mixtures with *Stylos*, *Phaseolus mungo* and *Melilotus alba* in India.

**Response of defoliation**: It can stands several cuts a year for green fodder.
Grazing management: It is generally used as a cut and carry green forage in India at ear emergence (80-90 days).

Genetics and reproduction: 2n = 36, 48, 54. There is a wide range of growth forms. It is strongly apomorphic (Whyte, 1964).

Dry and green matter yields: At the Punjab Agricultural University, Ludhiana, India, four cultivars of *P. pedicellatum* yielded from 9.6 to 11.0 t/ha green matter compared with 5.7 t/ha from sweet Sudan grass and 3.6 t/ha from Sorghum. It is cut two or three times a season, first 80 days after germination and subsequently at 60 days intervals. It has also yielded good hay in Nigeria and Sierra Leone (Whyte, 1964). The dry forage yield of this grass can be enhanced upto 9.2 t/ha with improved variety like IGFRI-S-2808 as well as introduction of legumes (Dwivedi, et al., 1982).

Suitability for hay and silage: It has been made into silage in Nigeria, Sierra Leone and India and also into hay.

Palatability: It is very palatable to cattle in India. It has a high leaf/stem ratio.

Seed production and harvesting: It seeds abundantly and matures very quickly in India.

Seed yields: Up to 2 t/ha (Whyte, 1964).

Value for erosion control: It is a valuable soil stabilizer in India.

Economics: In India it is a valuable grazing grass for sheep, goat and cattle (Bor, 1960). It is also good as a short term hay and soil stabilizer. In northern Australia it is a weed.

Main attributes: Its early flowering, high tiller number, high leaf/stem ratio, low oxalic acid content, and palatability.

Main deficiencies: Being an annual it provides only short term grazing, can become a weed of cultivation.
REVIEW OF LITERATURE
REVIEW OF LITERATURE

History of Allelopathy:

Allelopathy (root words: allelon and pathos) is derived from the Greek allelon, 'of each other' and pathos, 'to suffer': hence it means: the injurious effect of one upon another. The term denotes that body of scientific knowledge which concerns the production of biomolecules by one plant, mostly secondary metabolites, that can induce suffering in, or give benefit to another plant. The phenomenon could also be considered as a biochemical in erection among plants. The concept suggests that biomolecules (specially termed allelochemicals) produced by a plant escape into the environment and subsequently influence the growth and development of other neighbouring plants. The subject not only deals with the grass biochemical interactions and their effect on physiological process but also with the mechanism of action of allelochemicals at specific sites of action at the molecular level (Rizvi et al., 1992).

The term 'allelopathy' was coined by Molisch in 1937 and his definition referred to both the detrimental and beneficial interactions among all class of plants, including micro-organisms. This has led Rice (1984) to give the following definition of allelopathy: 'any direct or indirect harmful or beneficial effect by one plant (including micro-organisms) on another through production of chemical compounds that escape into the environment'.

Harper (1970) used the term interference to describe changes in the environment. Interference, thus includes the accepted competition which occurs for environmental resources, together with any allelopathic effect which may occur.

The recent upsurge of interest in allelopathy, with major volumes of collected papers
regularly published (Rice, 1984; Thompson, 1985; Putnam and Tang, 1986 a,b; Waller 1987; Chou and Waller, 1983) has established the topic as one of biological significance, although the ecological impact of allelopathy remains a subject of debate.

Trans-disciplinary studies suggest that the significance of allelopathy may be extended even further. Entomologists, for example, write of ‘allelochemicals’ in a context much wider than plant scientists concerned with allelopathy. Thus, Reese (1979) defines allelochemicals as ‘non nutritional chemicals produced by one organism that affect the growth, health, behaviour or population biology of other species’. Behaviour-controlling chemicals semi-chemicals are beginning to find a place in integrated pest management systems (Pickett, 1988), realizing a potential which has frequently been discussed in the literature.

We perceive allelopathy as one of the many stresses with which plants must cope in their environment. Recent data suggest that the responses to other stress factors, for example, invasion by viruses (Bassi et al., 1986), or stress by heavy metals (Wierzbicka, 1987) are similar. To extend this concept further, there is evidence that chemicals identified with allelopathy may also affect other organisms, and that the responses of these organisms follow a common pattern (Lovett et al., 1989).

It seems likely, giving the present state of knowledge, that allelopathy might best be regarded as a part of a complex network of chemical communication between organisms (Harborne, 1987) in which groups of chemicals compounds elicit similar, quantifiable, responses from disparate organisms (Lovett, 1982).
Allelopathic Phenomena:

Secondary effects:

Reports of allelopathic phenomena most frequently identify effects which are readily observed in the field or under controlled conditions. Delayed or inhibited germination and the stimulation or inhibition of root and shoot growth are often reported. Yet, the visible effects of allelopathy are merely secondary expressions of primary effects upon metabolic processes (Winter, 1961).

Primary effect:

Many possible primary effects on plant metabolism, affecting the majority of vital processes, have been suggested (Rice, 1984) but few have been rigorously investigated. Most attention has probably been paid to effects of allelochemicals on cell elongation and ultrastructure of root tips; for example, Lorber and Muller (1976). Koch and Wilson (1977) reported on the effects of allelochemicals on mitochondria but the total volume of work on primary effects remains small. Thus, in the five recent collection of papers previously cited, few focus mainly on this topic, although Waller (1989) notes that studies of allelopathy are moving 'quite rapidly' from practical considerations to molecular biology. Among recent contributions are a hypothetical sequence of action for the effects of phenolics. One of the most frequently reported groups of allelochemicals, proposed by Einhellig (1986). Membrane function and interaction with hormones are included. However, supporting evidence is not abundant and there is a paucity of data on the primary effects of other important groups of allelochemicals, for example, alkaloids. An examination of mono- and sesqui-terpenes as plant germination and growth regulators, again, points to the lack of evidence for elucidating primary effects (Fischer, 1986).
Most studies of primary effects have focused on early plant growth, a time of high metabolic activity but great susceptibility to environmental stress. Some weeds, for example, *Datura stramonium* L. (thornapple) (Lovett et al., 1981) release from the seed coat, compounds which have the ability to inhibit early growth of competing seedlings in their vicinity. Some crop plants, for example, *Hordeum vulgare* L. (Liu and Lovett, 1990), have a similar facility.

The chemicals involved in both these examples are alkaloids, compounds widely used in medicine and veterinary science and highly active, biologically. In thornapple and barley they appear to contribute to plant defence by causing disruption at the level of the cell (the primary effect) which is observed as impaired germination or reduced early seedling growth (the secondary effects).

The concept of germination inhibitors is due to Molisch (1922) and their presence in reproductive structures of plants such as fruits, seeds etc. has been a subject of discussion since then. According to Mayer and Poljakoff-myber (1982), Wieshner (1897), was the first worker to suggest that the seeds of *Viscum* sp. contain a germination inhibitor. Oppenheimer (1922) was among the first to study the problem experimentally. He tested among many other things the juices of tomato to determine whether they contain a germination inhibitor or not and concluded that they did indeed contain such an inhibitory substance. Later on Akkerman and Veldstra (1947) showed that caffeic, ferulic acids are the compounds responsible for inhibition of germination of seeds within the tomato fruit. Kockemann (1934) termed these natural germination inhibitors as ‘Blastocholines’.

Molisch (1937), the originator of the term allelopathy, was very much aware of the biochemical interactions between plants and animals, and between one animal and other
in addition to interactions between plants. As research progressed it became increasingly
evident that there are many close relationships between various types of chemical
interactions. Many of the same or related compounds are involved in interactions between
plants and animals as pointed out by Whittaker (1970, 71). Whittaker and Feeny (1971)
suggested that all interspecific chemical agents, other than used as food be called
allelochemics or allelochemicals and the phenomenon as ‘Chemical Ecology’. Harborne
(1972, 1977 a) termed these chemical interactions as ‘Phytochemical Ecology’ or

In addition to setting limits of growth by inhibiting germination of other species,
allelopathic substances are also important in self inhibition (Evenari, 1961; Went and Sheps,
1969). This phenomenon has also been termed as auto-allelopathy. According to Went
and Sheps (1969), this is a factor of major importance in the survival of many temperate
annuals by preventing the germination under adverse climatic conditions. Same is the case
of desert plants when water supply is a limiting factor. It has been found that seeds of
many desert annuals must be adequately leached by the rain before germination can
occur. This not only serve to remove the seed coat inhibitors, but at the same time also
assures growth only in the presence of an adequate water supply of soil moisture which
permits the survival of the plants. The result is that once desert annuals germinate, they
usually survive and form seeds. In other words competition is eliminated by germination
control mechanism. Self inhibition also plays a role in population control. By preventing
the germination of its own propagules under the already established plant, adequate
spacing as well as more water availability is assured for the existing plants (Went, 1948,
49, 57, 74; Went and Sheps, 1969).
According to Beck and Reese (1976), allelopathy, production of phytotoxins, attractants, repellents, deterrents, antifeedents, germination inhibitors and toxicants are examples of allelochemical interactions.

Only organic compounds involved in allelopathic reactions have been considered as allelopathic agents and has been termed allelochemicals. According to Swain (1977) more than ten thousands such organic compounds are known to exist in plants. They have been termed 'secondary compound 'by Fraenkel (1959) and Whittaker and Feeny (1971), because they are produced and byproducts of primary metabolic pathways and have no recognised role in the maintenance of fundamental life processes in the organisms that synthesize them. Swain (1977) considered that the function of such secondary compounds are as chemical signals in ecosystem and there are documented example of the significance of such chemicals in communication between plants and other organisms, including the performance of defensive and even offensive function for the plant which produces them. Levin (1976) considered resistance to fungi, bacteria, viruses etc. as a basis for the presence of secondary compounds, particularly the phenolics. According to Lovett and Levitt (1981) allelochemicals are part of checks and balances that maintain relative stability and many responses to allelo-chemicals are, therefore, subtle having developed during evolution of the community.

Evanari (1949) gave a list of 121 species which produce inhibitor of germination of their own seeds or other test seeds. The same author in his summary has further stated "The presence of germination inhibiting substances in plants seems to be a wide spread phenomenon. They occur in all parts of the plant e.g. fruit pulp, fruit coat, endosperm,
seed coat, embryo, leaves, bulbs and roots". Since Evanari's review a considerable number of additional publications have appeared further extending the list of plants and plant parts containing inhibitors. Important contributions have been made in the identification of compounds involved in allelopathy with the advancement of scientific knowledge especially in chromatography and absorption spectroscopy (UV and NMR).

Germination inhibitors are also of wide occurrence in the juice of many other fruits viz., orange, lemon, straw berries, apricots etc. and has been identified as coumarins are derivatives of cinnamic acid, benzoic acid and other organic acids by Varga (1957 a, b,c,d,1958). He suggested that inhibitory activity was the result of the additive effect of a number of such compounds.


It is a well known phenomenon that barley (Hordeum vulgare L.) and oats (Avena sativa L.) exhibit dormancy when freshly harvested. The removal of hull permits the germination of the isolated caryopsis, so that evidently the hull exerts an inhibitory effect. It is also known that the hull contain water soluble inhibitory substances (Elliot and Leopold, 1953; Cook and Pollock, 1954) though Black (1959) provided evidences that in Avena fatua Linn. the inhibitory effect of hull is not primarily due to these substances, but to the fact that they prevent the leaching out of other inhibitors from the caryopsis. Khan
et. al. (1964) reported germination inhibitors from barley while Van Sumere et. al. (1958) isolated coumarins, hydroxy cinnamic acid and their derivatives as well as vanillic acid from barley husk.

Phenolic compounds reported from seeds and fruits includes simple phenol such as catechol and hydroxyquinone, phenolic acids such as p-hydroxy benzoic acid, salicylic acid, vanillic acid, protocatechuic, syringic, gentisic, gallic, ellagic acids, hydroxy cinnamic acid such as caffeic, ferulic, p-coumaric, sinapic, glycosides of hydroxy cinnamic acids, flavonoids and their glycosides such as anthocyanins, flavones, flavanols, flavanones, isoflavones etc. and tannins (Harborne, 1967; Bate-Smith and Metcalfe, 1957).

Varga and Koves (1959) identified several phenolic acids and gallotannins in dried fruit of 24 species of plants. Compounds involved in allelopathic activities have been reviewed from time to time (Rice, 1974, 84; Bhakuni and Silva, 1974; Robinson, 1974; Strobel, 1974; Gross, 1975; Thompson, 1985).

Mikkelsen and Sinha (1961) demonstrated the presence of a number of water soluble inhibitory substances in the hull of rice (Oryza sativa Linn.) e.g. vanillic acid, ferulic acid, p-hydroxy benzoic acid, p-coumaric acid and indole-acetic acids, which delayed the germination.

The possible ecological significance of germination inhibitors has been discussed by Evanari (1949, 57), who pointed out that the occurrence of germination inhibitors in the seed or fruit tends to result in sporadic germination over a period of time. According to Went (1949) in some desert species germination occur only after a certain quantity of rain has fallen and it appears that this requirement for a minimum rainfall is determined by the rain required to leach out the inhibitors.
According to Oppenheimer (1960), presence of germination inhibitors is an adaptation to drought xerophytism.

Many types of phenolic compounds occur in fruits and seeds both as aglycones and glycosides (Feenstra, 1960, Harborne, 1964, 65 a, 67, 73 b, 79, 80; Harborne and Simmonds, 1964; Henis et al., 1964; Harris and Burns, 1972). Phenolic compounds rarely occur in free state in living tissue. They are practically present in conjugated form, as water soluble glycoside (Harborne, 1979; Wollenweber and Dietz, 1981).

Regarding the possible role of germination inhibitors in seed dormancy, Wareing (1965) concluded "when we come to consider the possible role of inhibitors in seed dormancy phenomenon, the situation is more complex". While reviewing the relationship between seed dormancy and germination inhibitors in cereals, Roberts (1965) is also of the opinion that in some species there is good evidence that dormancy is largely controlled by germination inhibitors, however, in some other cases, the role of germination inhibitors in dormancy is obscure.

According to Van Sumere et al. (1972) phenolics and coumarins and their derivatives are often reported as almost universally present inhibitors, which also act as germination inhibitors in seed husk, coats, fruits etc.

Germination inhibitors in fruit juices ensure that germination will only occur if the seeds are some way dispersed and this will occur if the fruit is decomposed or broken or if it is eaten by animals and the seeds subsequently excreted (Mayer and Poljakoff-Mayber, 1982).

Mayer and Poljakoff-Mayber (1982) has reviewed the role of germination inhibitors in fruits, seeds etc. and stated "It must, however, be remembered that these resumed
function of inhibitors in fruits are by no means finally proven and in fact they are very difficult to prove unequivocally. It is possible to interpret the observed fact differently (as already discussed). It is to be hoped that different approaches will lead to new lines of research into the probable biological and ecological function of inhibitors.

According to Rice (1984), inhibitors of preharvest seed germination may play an important role in preventing the germination of seeds before harvest or subsequent to cutting or stocking. Harris and Burns (1970) investigated the relationship between tannin content of the seed of hybrids of *Sorghum bicolor* and the preharvest germination of these hybrids. They found a strong negative correlation, indicating that tannins were good inhibitors of preharvest seed germination. Tannins like many other phenolic compounds are strong inhibitors of growth as well as germination. These are potent microbial inhibitors also.

However, in view of researches carried out especially since 1970 in the diverse field of chemical ecology, it has become increasingly evident that secondary compounds present in the seeds constitute the defensive mechanism and protect the seeds against the micro-organisms as well as from herbivorous predators. For example, according to Rice (1984) these secondary compounds act as preservatives: prevent the seeds from decaying after dispersal in a natural ecosystem and further stated (Chapter 8, Rice, 1984).“Probably one of the most critical points in the life cycle of many plants is seed germination. It seems surprising, therefore, that a little research has been done (allelopathy and prevention of seed delaying germination) in the past decade in this important area”. Tang and Zang (1986) has also stated “seeds and fruits often contain pre-existing secondary metabolites
which inhibit microbial activity and seed germination”.

Recent work carried out on the occurrence of secondary compounds in seeds has also revealed that secondary metabolites also act as feeding deterrent, repellent or anti-feedents for a variety of phytophagous insects as well as herbivores and therefore, protect the seed from predators (Feeny 1975, 76; Bell, 1978, 81; Swain, 1977,79; Harborne 1979, 80; Bell and Charlwood, 1980; Mckey, 1979; Fox, 1981; Wilson, 1983; Janzen, 1983; Price et. al. 1984a and many others).

Recently it has been reported that secondary compounds present in the seeds also act as stimulators of germination and growth (Rice, 1986) as well as forms an allelochemic sphere around the germinating seedling, which (allelochemic sphere) adversely effect the germination and growth of co-germinating seeds resulting in the successful establishment in favour of the former.

The studies of secondary plant metabolites has become an exciting area of research (Krebs, 1985) and Price et. al. (1984 b). While discussing, “Is there a New Ecology” rightly stated “Ecology has moved from a strongly descriptive discipline to an experimental science”. Descriptive studies of vegetation types, animal distribution have been replaced by studies of mechanisms. The transition from description to mechanisms, however, has not been accompanied by a whole sale move to a more rigorous application of the scientific method. Answers has been largely speculative at best. Had the scientific methods come into play adequately as the interpretive phase developed in ecology description would have provided the first link in erecting hypothesis about ecological mechanisms. Test of these hypothesis would have provided with some concrete information on the viability of some mechanisms and interpretations".
Parihar (1983); Parihar and Patil (1984, 86); Parihar (1985, 86b); Parihar and Kanodia (19f 6, 83) has also discussed the possible ecological significance of these phenolics present in the dispersal units of Cenchrus ciliaris, C. setigerus, Dichanthium annulatum and other range grasses.

Li, et al. (1993) reported the lettuce seeds and eliolated seedlings (with hypocotyls about 3 mm long and roots about 5 mm long) were exposed to various concentration of trans-cinnamic acid, caffeic acid, ferulic acid, chlorogenic acid, abscisic acid (ABA), o-coumaric acid, m-coumaric acid, p-coumaric acid or coumarin. The growth of eliolated seedlings was inhibited by trans-cinnamic acid and o-, m- and p-coumaric acid at concentrations > 10^{-4} M and seed germination was inhibited by those >10^{-3} M. Coumarin inhibited seedling growth and seed germination at 10^{-5} M or above. Chlorogenic acid inhibited seedling growth at > 10^{-4} M but did not inhibit germination at 10^{-5} to 5x10^{-3} M. Low concentrations (<10^{-3} M) of caffeic acid and ferulic acids promoted hypocotyle elongation, but higher ones (>10^{-3} M) inhibited seedling growth and germination. These phenolic compounds and ABA had additive inhibitory effects both on seedling growth and germination. Inhibition (except that of coumarin on germination) could be reversed by applying caffeic acid or ferulic acid at concentration < 10^{-3} M.

Bioassay, in the context of allelopathy, have been reviewed by Einhellig (1986). Probably the simplest forms of bioassay used in studies of allelopathy have been to quantify germination and/or emergence of seedlings, and to measure the length of the radicle or its equivalent. As defined by Winter (1961), although useful, such gross morphological data define only the secondary readily observable effects of allelopathy.

The main tool used in the small number of critical investigations of primary effects
of allelochemicals has also been the bioassay, but in more refined forms. Thus, the inhibition of mineral uptake in excised plant roots treated with phenolic acids are reported as being a consequence of the alteration of cellular membrane function (Balke, 1985), while phenolic acids, coumarins and flavonoids inhibit carbon dioxide dependent oxygen evolution in intact chloroplasts of spinach (Spinacia oleracea L.) and inhibit electron transport with mitochondria prepared from mung bean (Vigna radiata Roxb.) hypocotyls. Few published reports have combined bioassay with microscopy to elucidate primary allelopathic effects.

A bioassay has been developed capable of reliably assessing reduction in germination percentage and seedling length of small seeded plant species caused by exposure to minute quantities of these compounds. The germination and growth of lucerne (Medicago sativa) cv. vernal, annual rye grass (Lolium multiflorum) and velvet leaf (Abutilon theophrasti) were evaluated against plumbagin, (benzylisothiocyanate), cinnamaldehyde, coumarin, junglone and nigericin. Cinmethylin was selected as a comparison standard. Each phytotoxin, dissolved in a suitable organic solvent, was placed on water, agar in small tissue culture wells. After the solvent evaporated, imbibed seeds were placed on the agar, after 3 days, germination percentages and seedling lengths were measured. Compared to a commonly used filter paper procedure, this modified agar bioassay required smaller quantities of seed for comparable results. This bioassay also readily permitted the measurement of seedling length, a more sensitive indicator of phytotoxicity then germination seedling length decreased sigmoidally as toxin concentration increased logarithmically. Phytotoxicity was a function of both compound rye grass seedling by 90-100%, where as that of alfalfa and velvet leaf as inhibited only slightly. The
agar bioassay facilitated the rapid and reliable testing of slightly water soluble compound, requiring only minute quantities of each compound to give reproducible results (Dornbos and Spencer, 1990).

The occurrence of germination inhibitors in the propagative bodies (dispersal unit) of grasses is a common phenomenon. Therefore, inhibitors removal by soaking the seeds in water or placing them in activated charcoal beads before sowing has been recommended by various workers viz., Ballard (1964), Chippindale (1933) showed that soaking and redrying improve the germination in Dactylis glomerate. Linn. and this effect was evident in hulled grains and not in dehulled ones. Aqueous extract from the hull of dormant crab grass (Digitaria sanguinalis (L) Scop.) inhibited the germination of non-dormant seeds (Delouche, 1956). The inhibitory property was not destroyed by boiling the extract for 30 minutes. Similarly extracts prepared from non dormant seeds were not inhibitory. Kollar and Negbi (1959) showed that the dispersal unit of Oryzopsis miliacea contained germination inhibitor which was essential to be leached before the germination.

Ching and Foote (1961) also found water and ethanol soluble growth inhibitors in the extract of dormant seeds of wheat (Triticum vulgare) and it was postulated that loss of dormancy was due to the oxidation of these inhibitors. Miayamoto et al. (1961) also isolated four types of water soluble inhibitors from the seed coat of wheat, which possibly inhibited the germination of isolated wheat emryos. After three weeks of harvest it was seen that there was a loss of inhibitors since the dormancy decreased with the period of storage. It may be possible that these germination inhibitors play a role in dormancy mechanism.

In grasses also like some cereals, removal of glumes facilitates germinations which
has been attributed to the removal of germination inhibitors present in caryopsis enclosing glumes etc. Though some authors attribute the effectiveness of this treatment to the removal of structures constituting a barrier to oxygen diffusion to embryo (Carr, 1965). Many workers viz., Lahiri and Kharbanda (1962,63); Ahring (1963); Mott, (1974); Martin (1975); Hagon (1976); Pandeya and Jayan (1978); Parihar et al. (1984, a,b) also observed enhanced germination of caryopsis as compared to diaspores. Lahiri and Kharbanda, 1962 and 63; Pandeya and Jayan, 1978 and Parihar and Kanodia, 1984 also recorded inhibition of germination by glume extract/spikelet leachate confirming inhibition of germination due to inhibitors. Lahiri and Kharbanda (1962) believed these inhibitors to be coumarins in Cenchrus ciliaris, C. setigerus and Lasiurus sindicus. However, subsequent work by Parihar and Patil (1984); Parihar and Kanodia (1984 and 86), demonstrated the presence of phenolic onium-ions, cyanidin glycoside and cinnamic acid derivatives in the caryopsis enclosing glumes of Cenchrus ciliaris, C. setigerus and Dichanthium annulatum. Parihar and Patil (1986) also demonstrated in inhibition of germination and inhibition of root and shoot growth of grasses in isolated phytotoxins by bioassay studies.

Panicum virgatum establishment from seed was limited by current years growth of Cenchrus longispinus in the Nebraska sand hills. Stand reduction was greater than in other warm-season grasses sown at the same time, indicating possible allelopathy. Fresh C. longispinus plant material was extracted with distilled water for 24 h. Root, shoot and whole plant leachate collected between the vegetation and culm elongation stage and whole plant leachate from vegetative or mature plants was used, P. virgatum germination was not influenced by root, shoot or whole plant leachate. However, leachate reduced the length of the primary root and increased shoot length. Generally, the response was greater
with vegetative *C. longispinus*, compared with mature and at the higher leachates concentration. Whole plant leachate from vegetative *C. longispinus* reduced *P. virgatum* germination compared with mature plant leachates (Roder, et. al, 1988).

According to Takahashi, et. al. (1988) 6 grass and 3 legume species were grown in sand and the leachate, including the root exudate, from each species was applied to the 9 species grown in separate pots. The growth of all species was reduced by the addition of leachate, *Lolium perenne* causing the greatest inhibition and in *Medicago sativa* the least. The growth of most of the species, particularly *M. sativa* and *Trifolium repens*, was inhibited more by grass species leachate than by legume species leachate. The growth of *Trifolium hybridum*, *T. repens* and *L. perenne* was inhibited more by their own leachate than that of other species. All the other species showed the opposite response.

In germination studies with seeds of the lettuce, namely white Bostan and aqueous extract of *V. sativa*, obtained from the aerial parts, was applied to filter paper at concentrations of 100, 75, 50, or 25%. Control was treated with water. The effects on seed germination, length of the primary root and seedling dry weight were determined over 96 h. At 75 and 100% concentrations, the seeds did not germinate and decomposed rapidly. The more dilute extracts delayed germination and checked root growth (Medeiros and Lucchesi, 1993).

Laboratory and greenhouse studies were conducted by Chung and Miller (1995a), to determine the allelopathic potential of nine grasses to alfalfa (*Medicago sativa*) on germination and seedling growth. Alfalfa seeds were germinated in aqueous extracts of
nine grasses, using distilled water as a control. Measurement were taken to determine the
effect of extracts on germination, seedling length, and weight. Alfalfa germination ranged
from 64% for Festuca arundinacea extracts to 91% for the control. Total alfalfa seedling
length was reduced by 39% for grain sorghum extracts. Dry weights of alfalfa cotyledons,
hypocotyls and radicles were reduced significantly by several grass extracts. Bromus
inermis, Dactylis glomerata and grain sorghum extracts were more inhibitory than other
grass extracts. Alfalfa seedling emergence and survival percentage was affected by
various grass root residues. Phleum pratense extracts caused the lowest survival
percentage of 59% compared with the control of 88%. Agrostis giganta and Phalaris
arundinacea extract has no effect on alfalfa seedling emergence and survival.

Green house and laboratory studies were conducted by Chung and Miller (1995
b) to investigate the allelopathy potential of Chenopodium album, Setaria faberii,
Amaranthus retroflexus, Abutilon theophrasti, Digitaria sanguinalis, Crisium areense and
Polygonium aviculare on germination and seedling growth of lucerne. The weeds were
collected at their vegetative stage, and the shoots and roots were dried at room
temperature. Extracts were prepared in distilled water and germination trials were
conducted with lucerne seeds. Results showed that extracts obtained from shoots and
leaves resulted in a greater allelopathic effect on lucerne germination than root extracts.
Shoot and root extracts of all the weed species resulted significant inhibition of
germination, seedling weight, vigour and germination rate of lucerne. A. theophrasti
resulted in the greatest inhibitory effect, whilst D. sanguinalis had the least effect. Further
germination trials were conducted using 0.0, 0.5 10.0, 15.0 and 20% concentration of A.
theophrasti. Results showed that lucerne seed germination, seedling weight and seedling
length were inversely proportional to the A. theophrasti extract concentration. Dried extracts were more inhibitive than fresh extracts. Trials were conducted to assess the allelopathic effects of dried lucerne residues mixed into vermiculite on the germination, shoot length and root length of the crops such as *Perilla frutescens*, *Sehima nervosum* and *Platycodon grandiflorum* and the weeds *Digitaria sanguinalis*, *Setaria viridis*, *Sigesbeckia pubescens*, *Amaranthus lividus* and *Solanum nigrum*. Lucerne residues were added at concentrations of 0.1, 1.0, 5.0, 10.0 and 20.0%. The above crop and weed species were significantly inhibited as the concentration of lucerne residues increased; concentration 10.0% resulted in 80.0% inhibition of germination and growth in the test species (Yu, et al., 1995).

According to Chung and Miller (1995 c), then allelopathic effects of various alfalfa (*Medicago sativa*) plant parts the soil in which alfalfa was grown, on alfalfa germination and seedling growth were investigated. Aqueous extracts of alfalfa leaf, stem, flower, seed and root parts were made to determined there effects on germination and dry weights of hypocotyl, radicle and total length of 5 days old alfalfa seedlings over a range of extract concentration. Soil samples from around alfalfa plants at the vegetative and reproductive stages were compared with sterilized and non sterilized soil formerly sown with alfalfa, hairy vetch (*Vicia villosa*) and winter rye. Increasing the aqueous extracts concentrations of separated alfalfa plant parts significantly inhibited alfalfa germination, seedling length and weight. Radicle length was more sensitive to extract source than seed germination or hypocotyl length. Based on 5 days old alfalfa radicle length growth and averaged across all extract concentrations, the degree of toxicity of different alfalfa plant parts and soil from around alfalfa was classified in order of decreasing inhibition as follows: leaf, seed,
complete plant mixture, soil, root, flower and stem. Leaf extract caused a 48% decrease in water uptake by alfalfa seed. Soil in which alfalfa had previously grown was the most inhibitory to alfalfa growth after 25 days of growth compared with soil where winter rye or hairy vetch had previously grown. Inhibitory effects were greater for soil collected around alfalfa grown at the reproductive than the vegetative growth stage. It is suggested that alfalfa autotoxicity may result from a release of one or more water soluble compounds from alfalfa leaf tissue.

Studies on long term storage of grass seeds were conducted by Ackignoz and Knowles (1983) reported that seed of crested wheat grass, intermediate wheat grass and smooth brome were stored for 20 years, under various conditions. Temperature was a major factor affecting success with viability inversely related to storage temperature. At -7°C and -18°C, viability of 80-90% were shown after 20 year storage. Drying seed for 7-5 h at 60°C prior to storage gave little improvement over undried seed stored with 8% m.c. Plastic bags were as good as glass jars with screw top lids although plastic bags were less effective in excluding moisture. It was conducted that adequate germination could be obtained after 2-30 yrs of storage.

Parihar, et al. (1984 b) studied the effect of age (storage) and removal of glumes on germination of Cenchrus ciliaris Linn. He reported that spikelets and dehulled seeds of 10 C. ciliaris cv. (cultivar) were stored for up to 4 years and their germination was tested at 1 year intervals. The germination percentage of seeds in spikelets was highest (average 38.8-39.1%) after 1 and 2 years of storage. Germination percentage of the dehulled seeds was markedly higher than that of seeds in spikelet and was highest (75.5%) after 1 year of storage.
The effect of seed storage on germination of different tropical grasses conducted by Matias and Bilbao (1985) revealed that all cultivars P. maximum had different reactions to storage. Si4-127 and the local ecotype showed highest germination after 2 months (12.54 and 9.6%, respectively), after this germination percentage dropped. Likoni and Australian showed highest germination at harvest (15.91 and 9.05%, respectively). Makueni showed highest germination at 6 months (25.89%) storage had a significant effect on C. gayana, with highest germination at 4 months (13.46%) where as in C. ciliaris germination was always low (1.5%) with no significant difference between different storage periods. Germination in S. bicolor decreased significantly from 66.53% at harvest to approximately 40% after a year.

Seed of C. ciliaris clones were started in butter paper bags under ambient conditions (Mean max. temp. 29.4-34.9°C, 77-90% RH) for 21 months and their germination was tested at 3 month intervals. Seeds of introduced clones, Anjan, FC 3108 and FS339 gave the highest germination (89, 73 and 68%, respectively) after 12 months storage and these of a local cultivar (cv.) (40%) after 18 months storage (Selvaraj and Ramaswamy, 1986).

Germination of the salt-tolerant grass Diplachne fusca was tested by Morgan and Myers (1989). They collected fresh seed of D. fusca at 2 locations over several years of dormant. Dormancy was not broken by scarification, but gradually broke down during air-dry storage, indicating an after-ripening period of at least 1 year. Bract removal increased germination percentage and rate and significantly interacted with pre soaking to increase germination percentages. When seeds were pre-soaked but to decrease them when soaked at 10°C, subsequent drying increased germinability. The germination of germinable stored seed at various temperature. Regimes (Combinations of day and night
temperature between 11 and 31°C) was assessed on a therogradient plate. The germination after 21 day was greatest (40-49%) at high temperature when both day and night temperature were between 24 and 31°C, either constant or alternating). Germination was completely inhibited when both day and night temperature were \( \leq 18.5°C \). Germination percentage was more strongly correlated with night than with day temperature. Seeds for which dormancy has been broken by scarification were capable of germinating at lower temperature (19% germination at 11°C) than stored seeds. From the observed temperature dependence of germination and the mean daily maximum and minimum temperature recorded at Tatura and Deniliquin, (latitudes 36° 26' S and 35° 32' S respectively), it was suggested that germination in the field, in the Riverain plain of SE Australia, would be limited to the summer months (Dec.-Feb.).

Scarified and non-scarified *Fragostis lehmanniana* seeds from 7 seed lots were germinated over a water potential range of 0 to -1.16 M Pa. Six of the seed lots were harvested \( \leq 1 \) year before the germination tests. Results showed that mechanical scarification increased total germination and germination rate. Mechanical scarification reduced variability among seed lots for germination rate but increased variability for total germination. Total percentage germination was least in the most recently harvested seeds in all treatments. It is concluded that rapid germination hypothesis may be valid for *F. lehmanniana* as long as seed numbers are not limiting. Of the scarified seed that germination above a water potential of -0.4 M Pa, at least 10% did so between days 1 and 2 of the study (Hardegree and Emmerich, 1991).

The effect of mechanical scarification on germination and seedling emergence of neoteric (1 to 18 month old) switch grass was studied by Nancy and Boe (1991).
Scarification for 15 or 30 second in a Forsberg cylinder scarifier significantly increased 14 day germination percentage for 1 to 5 month old seed of 5 cultivars. The magnitude of increase in seedling emergence due to scarification varied across cultivars. Four month and eighteen month old seed lots of ‘Sun brust’ and a North Dakota ecotype (NDE) exhibited significant increase in germination and seedling emergence after scarification. Scarification increased overall mean germination percentage for 3 lots of ‘Sun brust’ and 2 lots of NDE by 73%. Field studies are needed to determine the usefulness of mechanical scarification as a preplant treatment for neoteric.

Dormancy factors that contributed to slow germination and poor stand performance in Paspalum notatum were studied. Several dormancy releasing treatments were ineffective. The importance of the lemma was established by excising parts of the seed covers. Removing the second glue and sterile lemma did not reduce dormancy. Removing pales resulted in significantly improved germination but still not as rapid nor as complete as removing the lemma. Germination was observed to occur by the coleorhiza protruding through an opening in the lemma caused by the separation of fibres immediately above the embryo. Aging the seed increased germination and the number of seed with visible separated fibres. A dormancy mechanism is proposed in which water uptake and the expansion of the embryo are restricted until an opening occur in the lemma (West and Marcusky, 1989).

Weaver and Jordan (1985) reported the effects of various treatments on germination rates of Eragrostis lehmanniana, E. trichophora, E. curvula variety conferta, Panicum antidotale and Atriplex canescens seeds. Rates were approximation of time of 50% germination and seed treatments included application of KNO₃, Ammonium nitrate, GA₃.
and heat desiccation. Germination rates could be increased, but treatment effects were not uniform between seed lots within a species or amongst species. Desiccation at 70°C for 24h was very effective in increasing germination rates of E. lehmanniana and E. curvula variety Conferta seeds.

Studies on dormancy of seeds of Melanocenchrus jacquemontii showed dormancy for one month. A water soluble inhibitors also develops in hot months which becomes deactivated in July by rains or if the narrow range of temperature is available. Seeds lose viability after 18 months of dry storage (Pathak et al., 1976).

The effect of five growth regulators and three chemicals was studied on the germination in behaviour of Parthenium hysterophorus seed by Dagar et al. (1977). He reported an inhibitory effect at all the five concentrations of IPA and NAA and four higher concentrations of 2, 4-D and interaction of GA\textsubscript{3} with IPA and 2, 4-D at 100 and 200 ppm was observed. 10 and 25 ppm of IAA also showed retardation in germination. Higher concentrations of IAA showed normal effects while in rest of the cases the effects were more or less promoting.

Seed germination studies were performed in petridishes lined with filter paper with distilled water in continuous light with many arid zone species. Treatment of acid scarification, continuous washing for 1-5 days and seed coat removal were used to enhance germination. Most of the seed possessed hard coat dormancy and some contained germination inhibitors. Germination ranged from 0-100% and variety of dormancy mechanism adaptive to the arid environment were found. Alysscarpus monilifer, A. vaginalis, Aristida adscensionis, Eragrostis ciliaris, showed 1%-20% germination, Dactyloctenium acgpticum, Digitaria adscendens, Eragrostis tremula, Tragus biflorus
showed 20-50% germination and *Chloris virgata*, *Cynoglossum tetragenoloba* showed 100% germination (Bansal and Sen, 1981).

Germination of *Brachiaria decumbens* was shown to be controlled by two dormancy mechanisms. Primary dormancy was variably expressed in freshly harvested seed and over come by "after ripening" during storage of up to three months. Long term dormancy may be due to mechanical restriction imposed by the seed coat and to inhibition of O₂ diffusion due to the closely appressed, hard shiny Palea and Lemma structure enclosing the caryopsis. Removal of these structure by hand allowed germination percentage up to 100 in naked caryopsis. Impermeability of the seed coat declined with time in storage up to one year. Germination of intact stored seed reached 40% to 55%. Further storage at 10°C and 29% RH up to 4 & 1/2 years did not result in increased germination in intact caryopsis, although viability was maintained at 80% to 90%. Scarification in concentrated H₂SO₄ for 20 minutes increased germination of stored seed to 72% (Whiteman and Mendra, 1982).

Fulbright, *et al.* (1983) studied in a green house and found that germination of seed of *Stipa viridula* was highest (50%) when temperature was at constant 20° or 20/15°C (16/8 hr periods), in darkness, prechilled or treated with GA and the lemma and palea were clipped with a razor blade.

Gonzalez and Torriente (1983) reported that stored Guinea grass seeds were treated with 0, 0.1, 0.2 or 0.3% KNO₃ after 0, 1, 2, 3, 4 or 6 months. There was a significant interaction between KNO₃ and storage time on percent germination, germination energy percentage, dormancy and death. The highest germination of 46.09% occurred after 2 months storage with 0.2% KNO₃ compared with 37.9% without KNO₃ and 2.88% at the start of the experiment, germination energy (40.64%) was also greatest with this
treatment. Percentage dead seeds and abnormal germination increased with storage while germination energy decreased.

Effect of substrates and scarification methods on seed germination in buffel grass (*Cenchrus ciliaris* cv. Biloela) was studied by Vieira Neto and Aragao (1984). Authors used sterilized sand or filter paper, the germination percentage of *C. ciliaris* cv. *Biloela* stored for 7 months was not significantly affected by 24 M. Sulphuric acid treatment for 30 minute. Treatment with ethanol for 10, 20 or 30 minute or with boiling water after freezing for 2-5 or 1-25 hr reduced percentage germination. Germination ranged from 0% in both substrates with boiling water after freezing for 1-25 hr. to 38-63% in sand after acid treatment.

Parihar and Rai (1985) reported that seeds of 9 grasses collected in 1974 and stored in polythene bags at room temperature were studied for viability. The minimum period of seed viability was at least 48 months for *Cenchrus ciliaris* and *Chrysopogon fulvus*, 60 months for *Cenchrus setigerus*, *Heteropogon contortus* and *Sesima nervosum* and 84 months for *Bothriochloa pertusa* and *Bothriochloa intermedia*. Germination of seeds of *Dichanthium annulatum* was consistently good for 4 years of storage and decreased in the 5th years. *Panicum antidotale* gave 19% germination after storage for 6 years.

Rodrigues, et. al. (1986) studied the effects of different methods of breaking seed dormancy of *Brachiaria humidicola* (Rendle) Schweickerdt. Washed and unwashed *B. humidicola* seeds were chemically (KNO₃, GA₃ and H₂SO₄) or mechanically scarified and subjected to a constant (30°C) or alternating (20/35°C, 16 hr/8 hr) temperature regime in the presence or absence of light. None of the dormancy breaking methods were successful
at 30°C. Treating washed seed with gibberellic acid followed by an alternating temperature regime was the most effective dormancy breaking method (51.5% germination). Sulphuric acid and light treatments were ineffective for breaking seed dormancy.

Seeds of 3 important Somali rangeland grasses (Cenchrus ciliaris, Dactyloctenium sindicum and Sorghum arundinaceum) were scarified by rubbing with sand paper and soaking in hot water or sulphuric acid. Seed germination of C. ciliaris was greatest (41%) in the hot water treatment and lowest (10%) in the sulphuric acid treatment. Both D. sindicum and S. arundinaceum germination was highest with the rubbing treatment (41 and 55%) and lowest with the sulphuric acid and hot water treatments (14 and 24% and 22 and 22%), respectively. The scarification treatments had no influence on the mean germination times of the 3 species except for sulphuric acid, which increased D. sindicum mean germination time from 6-2 days in the untreated controls to 10-3 days (Barker and Abdi, 1988).

Dormancy in freshly harvested seeds of Panicum maximum cv. PGG-19 was studied by Basra, et al. (1990) to know the inhibitory influence of husks. Mechanical or acid dehusking markedly increased the germination percentage. Germination was further augmented when the acid dehusking was followed by soaking seeds in KNO₃, GA₃ and or phthalimide. KNO₃ in combination with either GA₃ or phthalimide was the most effective. Phthalimide effectively mimicked the effect of GA₃.

Toledo and Carvalho (1990) studied quantity of KNO₃ solution and the germination of 3 species of Brachiaria seeds. The seeds of B. decumbens, B. brizantha and B. ruziziensis were germinated on 2 sheets of paper wetted with 6, 12 and 20 ml KNO₃ or on
1, 2 or 3 sheets of paper wetted with 6, 12 and 18 ml KNO₃, respectively. Germination of B. decumbens was not affected by substrate treatment. Germination of B. brizantha decreased with 20 ml KNO₃ on 1 sheet on paper and with 16 ml KNO₃ on 3 sheets of paper. B. ruziziensis germination decreased with 16 ml KNO₃ on 1 sheet and with 16 ml on 3 sheets of paper.

Burbano, (1990) studied the effect of chemical scarification and storage on seed quality in Centrosema species. Seeds of C. brasiliunum cv. CIAT 5234, C. acutifolium cv. CIAT 5277 or C. macrocarpum cv. CIAT 5713 were subjected to several scarification treatments with 100 ml H₂SO₄/kg seeds and storage for 1-19 months in laboratory (22°C, 88% RH) or cold room (18°C, 50% RH) conditions. The percentage of normal seedlings was generally greater and the percentage of hard seeds was always lower with than without scarification before storage in all species. After 19 months storage with scarification 30 d before quality evaluation, the percentage of normal seedlings was greater with storage under cold room conditions, the percentage of hard seed decreased with increasing storage duration. After 19 months storage in laboratory conditions, germination and percentage emergence were greater without than with scarification 3 d before showing in C. brasiliunum and C. acutifolium. Germination and emergence of C. macrocarpum after 19 months storage in laboratory conditions and of all species stored in a cold room were greater with than without scarification 3d before sowing. Emergence and germination were greater under cold room than laboratory storage conditions and were generally greatest with scarification every 30 d.

Quantities of KNO₃ solution and the germination of P. maximum Jacq. seeds were
studied Yoledo, et. al. (1994). Recently harvested seeds of 5 cultivars of P. maximum were germinated in the presence of 12, 16, or 20 ml of 0.2% KNO₃ solution either immediately or after storage under ambient condition at intervals of 4 months over a 2 years period. Germination percentage was significantly higher (28.5-78.4% germination) in the presence of 12 ml KNO₃ solution than at higher volumes (cultivar) cv. Centenario was the most sensitive and cv. Tobiata the least sensitive to excessive amount of KNO₃.

In a laboratory experiment Khandelwal and Sen (1994) studied the effect of soaking seeds for 24 h in 50-1000 ppm KNO₃ on germination of fresh and 1 year old seeds of *Eragrostis ciliaris*, *E. tremula* and *E. poaeoides*, (E. minor). No seed germination was recorded for *E. poaeoides*. In *E. ciliaris* germination was highest (36.7%) in 1 year old seeds soaked in 1000 ppm KNO₃ where as in *E. tremula* it was highest (96.7%) in 1 year old seeds soaked in 50 ppm KNO₃.

Toledo, et. al. (1995) studied the seeds of P. maximum cultivars were treated with sulphuric acid and germinated immediately after treatment in August, 1991 or at intervals upto April, 1993 during which time they were stored under ambient conditions. Acid treatment did not improve germination, independent of storage duration.