COMPARATIVE BIOLOGY AND GROWTH BEHAVIOUR OF *Pennisetum polystachyon* (L.) Shult. AND *P. pedicellatum* Trin.

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled "**Comparative biology and growth behaviour of *Pennisetum polystachyon* (L.) Shult. and *P. pedicellatum* Trin.**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled "**Comparative biology and growth behaviour of *Pennisetum polystachyon* (L.) Shult. and *P. pedicellatum* Trin.**" is a record of research work done independently by **Mr.A. KARTHIK,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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We, the undersigned members of the Advisory Committee of **Mr.A.Karthik,** a candidate for the degree of **Master of Science in Agriculture** with major in **Agronomy**, agree that the thesis entitled "**Comparative biology and growth behaviour of *Pennisetum polystachyon* (L.) Shult. and *P. pedicellatum* Trin.**" may be submitted by Mr.A.Karthik, in partial fulfilment of the requirements for the degree.

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In memory of my beloved sister

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

INTRODUCTION

Humid tropics are rich in biodiversity. This is equally true of weeds. Because of the favourable climate, a variety of weeds are seen in abundance in Kerala, which lies in the humid tropical region. *Pennisetum polystachyon* (L.) Shult. and *P. pedicellatum* Trin. are two major grass weeds of the tropics and subtropics having good competing ability and persistence. They usually dominate in situations where frequent tillage is not practised. These weeds are widespread in Kerala in young plantation crops such as rubber, coconut and cashew and non-arable areas (Sreekumar and Nair, 1991; KAU, 1991). They also dominate in highlands and edges of forests.

P. polystachyon is very common along the secondary forests, roadsides, waste places, scrub jungles and in cleared forest patches. The occurrence of this grass in a forest is an indication of secondary formation (Sreekumar and Nair, 1991). Widespread occurrence of *P. pedicellatum* is, however, not reported from Kerala except Thrissur district. The menace is more felt in the coconut plantations. It is believed that the widespread occurrence of *P. pedicellatum* in Thrissur district is due to the subsequent escape of *P. pedicellatum* introduced as a fodder crop. *Pennisetum* spp. have the remarkable ability to persist and spread rapidly. They produce seeds abundantly, which are covered by fluff and hence distributed by wind over large areas (Noda *et al.*, 1985). Under natural conditions, the plants are self propagated by air borne seeds from mature plants. It was also reported that these grasses have the capacity to propagate through seeds, slips and stem cuttings (KAU, 1996, 1997). All these make *Pennisetum* spp., highly persistent and successful weeds.

Growth, development and competition of weeds may vary considerably due to the differences in the time of emergence, plant height, tillering capacity, leaf area or growing periods. As Ghersa and Holt (1995) commented, the success of a weed management strategy based on ecological principles and weed biology will

depend on a better understanding of the effects of environment on life history strategies, growth and competition of weeds and crops and particularly upon the ability to predict weed and crop phenology.

Many perennial weeds were found to exhibit allelopathy. In general perennial plants are reported to be more active in developing allelopathic reactions than annual plants (Alstrom, 1990). Aspects of seed production, dissemination, dormancy, germination and plant allelopathy are considered as mechanisms to increase weed persistence and competitiveness. Knowledge of these processes will be useful to maximize weed control and management practices.

Though *P. polystachyon* and *P. pedicellatum* are persistent weeds, they are good source of fodder for cattle. *P. pedicellatum* is reported as a species which has the potential to meet the fodder demands of an ever increasing live stock population (Abraham *et al.*, 1980; Krishnakumar, 1996; KAU, 1998). Several research findings pertaining to the use of *P. pedicellatum* for forage have been presented by Chatterjee and Das (1989). However, information on *P. polystachyon*, which is more widely distributed in the state is scarce. The behaviour of *P. pedicellatum* as a weed is also not fully known. Finding ways of utilization of weeds is one of the strategies to manage them in cropped and non-cropped situations. In view of all these, an investigation on the comparative biology and growth behaviour of *Pennisetum polystachyon* (L.) Shult. and *P. pedicellatum* Trin. has been undertaken.

The objectives of the study were:

1. To compare the seed dormancy, phenology, growth, development and regeneration ability of *Pennisetum polystachyon* and *P. pedicellatum.*
2. To study the presence and distribution, if any, of the allelopathic substances in *Pennisetum* spp.and
3. To assess the fodder production potential of the two species.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

According to Sreekumar and Nair, (1991) fifteen species of *Pennisetum* are present in India and five in Kerala. These are *P. polystachyon* (Mission grass,thin napier grass) *P. pedicellatum* (Kyasuwa grass, deenanath grass), *P. purpureum* (Napier grass), *P. hohenackeri* and *P. orientale*. An early work on the distribution of *Pennisetum* in South India is that of Gamble (1928). He mentioned five species of *Pennisetum* occurring in South India and listed *Pennisetum typhoides*, *P. pedicellatum*, *P. polystachyon*, *P. hohenackeri* and *P. villosum*. Among the above, three species - *P. pedicellatum, P. polystachyon* and *P. purpureum* have been known as serious weeds widely distributed in the tropical and sub-tropical areas of the world (Holm *et al.*, 1977). In Kerala, *P. polystachyon* and *P. pedicellatum* were reported as very serious grass weeds in the plantation crop areas (KAU, 1991).

Literature on various aspects of *P. polystachyon* and *P. pedicellatum* such as seed dormancy, phenology, allelopathy, regeneration ability, fodder production potential, growth behaviour and nutritional aspects are reviewed in this chapter.

2.1 Distribution and characteristics

P. polystachyon is a short-lived tufted perennial. Culms are 50-200cm high, densely tufted, erect, nodes glabrous, leaves lanceolate, panicles spiciform, 8-20 cm long, cream yellow or purplish (Fig.1a). It shows much variation in the habit and also in the colour of panicles. It differs from other species of *Pennisetum* by having an angular rachis with shape decurrent wings below the scars of the fallen involucres (Sreekumar and Nair, 1991). It can easily establish with seeds. It is distributed throughout Africa, India, Sri Lanka, Fiji and South America (Chatterjee and Das, 1989). The grass is very common along the secondary forests, roadsides, waste places, scrub jungles and in cleared forest patches. The

Fig.1a. Flowering head of *P. polystachyon*

occurrence of this grass in a forest is an indication of secondary formation. It is used locally as a very good fodder (Sreekumar and Nair, 1991). Problems due to the presence of *P. polystachyon* and *P. pedicellatum* have been reported from many tropical countries. *P. polystachyon* has become a problem in tea plantations of Sri Lanka (Watson, 1986). The occurrence of *P. pedicellatum* and *P. pupureum* was reported from Nepal recently (Siwakoti and Varma, 1997). Symanand (1971) reported that *P. polystachyon* and *P. pedicellatum* widely dominate in farm lands, high lands and forests of the North-East Thailand and gave several kinds of weedy problems. *P. pedicellatum* was reported to be abundant in Northern Thailand and moderately abundant in other regions; While *P. polystachyon* was abundant in N, NE and Central regions and moderately abundant elsewhere (Harada *et al.*, 1991). Hills (1991) reported that *P. polystachyon* was present in the region of Northern territory of Australia. According to him, *P. polystachyon* and *P. setosum* arrived from Thailand in the early and late 1980's respectively. *P. polystachyon* is now widely distributed in Malaya peninsula region, infesting atleast 10 km^2 of roadsides in 1988 (Bakar *et al.*, 1990).

P. pedicellatum has come into prominence in recent years. It is a native of tropical and sub-tropical Africa and India and found to be a promising forage grass in Nigeria, Sierra Leone and India (Whyte *et al.*, 1975). Its fodder value was first recognized in Africa and Australia. In 1950's, some seeds from Australia were received for trial in India and the work was first initiated at Sabour in Bihar(Mandal and Chatterjee, 1953,cited by Chatterjee and Das, 1989). In India *P. pedicellatum* is known under various names, such as *Deenanath, Deenabandhu, Deena* and *Dina* grass, meaning friend of the poor as it is capable of growing under poor management and low fertility conditions. In Africa the name given is Kyasuwa. Sreekumar and Nair (1991), describes it as an annual. However, according to Chatterjee and Das (1989), both annual and perennial types are present. The culms are 30-150 cm high, tufted, erect, tinged reddish-purple at their base and nodes glabrous. Plant reaches a height of about 2m and often produces 30 to 60 tillers per plant. The

inflorescence is a spike like panicle, 15 to 20 cm long, purplish when young but turns darkish and whitish on maturity (Fig.1b). *P. pedicellatum* is adapted to wide climatic and soil conditions. It is a fairly nutritious and highly succulent fodder that can be fitted in crop rotations (Selvi and Subramanian, 1993). *P. pedicellatum* out yielded other widely cultivated fodder crops such as sorghum, maize and pearl millet in India (Chatterjee and Singh, 1967; Singh and Arora, 1970).

2.2 Seed dormancy

Dormancy is a state in which viable seed fails to germinate even under conditions of moisture, temperature and oxygen favourable for plant growth. Seeds of weed species of Boraginaceae, Convolvulaceae, Cucurbitaceae, Leguminaceae and Gramineae have long dormancy periods often running into several years (Sen and Bansal, 1978).

Mott (1980) reported that the seed dormancy of *P. pedicellatum* vanished after finishing a dry season. Premadasa and Amarasinghe (1982) reported that initial and maximum seed germination of *P. polystachyon* occur in March and April respectively. As reported by Noda *et al.* (1985), the dormancy of the seeds of *P. purpureum* almost end in four months and that of *P. polystachyon* and *P. pedicellatum* in six months. He also reported that the *Pennisetum* seeds are light favourite types in germination, though response to light in *P. purpureum* is very low compared with that of *P. pedicellatum* and *P. polystachyon.*

According to Kiatsoonthorn (1991),the percentage germination of *P. polystachyon* seeds after one month of storage was low (27.2%) but after two to four months, it was more than 90 per cent. Germination declined after four months storage to 28 per cent. Seeds collected in December had higher germination rate than those collected in November or January. Hull imposed dormancy was evident in *P. pedicellatum* and removal of husks facilitated germination (Parihar and Shanker, 1997).

Fig.1b. Flowering head of *P. pedicellatum*

Seed dormancy has been reported in many other weeds. Seeds of *Scirpus articulatus* possess internal dormancy and require an after ripening period of four months to germinate (Datta and Roy, 1973). Mani and Singh (1977) observed that 25 species of weeds exhibited definite periodicity in germination in a particular season and at a particular point of time. Even under optimal conditions, only a part of the seeds germinated at one time while the rest remained in earth's seed bank (Elgey and Duke, 1985). It has also been found that in the field, weed seeds alternatively lost and acquired dormancy and displayed seasonal rhythmic germinability during their periods of persistence in the soil.

Santa-Pau and Guerenu (1995) reported that *E. crusgalli* had dormant seeds, which could be removed by dehulling and wounding. Summer dormancy induction and its winter termination in *E. crusgalli* were probably due to variation of weather conditions (Honek *et al.*, 1999). They also found that the minimum germination of *E. crusgalli* (0 to 4%) was in September-November and maximum germination (88 to 92%) was in May. *E. crusgalli,* with peak germination in the spring, seed dormancy termination by chilling and secondary dormancy induction in summer, is a typical example of the annual seed dormancy/non-dormancy cycle of summer annuals (Baskin and Baskin, 1987).

Pickett (1993) suggested that environmental factors including temperature, moisture and plant residues influence the expression of dormancy. Most weed species have a single temperature optimum for germination. Temperature strongly influences the breaking of both primary and secondary dormancy especially the onset and breaking of secondary dormancy (Elgey and Duke, 1985). Honek and Martinkova (1992) reported that at 25°C, secondary dormancy was induced in *E. crusgalli* seeds exposed for 100 days to oxygen deficiency. Oxygen deficiency may increase the proportion of dormant seeds in the soil and affect the dynamics of the *E. crusgalli* soil seed bank. All species of *Avena* have a relatively long dormant period. The development of dormancy is influenced by the temperature during maturation. At harvest, dormancy may be very high up

to 90 per cent, but it decreases with time, being about 50 to 25 per cent, four to six months later, during its natural period of germination (Torres, 1994).

Germination of seeds varied with depth of burial. In fact, secondary dormancy is induced by burial. Emergence of seeds of *Commelina benghalensis* were 19.5, 9.8, 2.5, 1.0 and 0.5 per cent for seeds buried at 0, 2, 4, 6 and 8 cm depth respectively (Budd *et al.*, 1979). In general, weed seeds buried near soil surface lost viability more rapidly than seeds buried in depth (Toole, 1946). Seeds of *Stellaria media* lost dormancy slowly on the ground surface but quickly when buried in soil. (Miura *et al.*, 1995).

Light is a principal requirement by which seed germination is restricted to the proximity of soil surface (Woolley and Stoller, 1978; Karssen, 1980). Seeds of *Setaria pallede-fusca* and *P. pedicellatum* germinated well under various light conditions. Ismail *et al.* (1994) reported that light was required for germination of *P. polystachyon* and observed that 59 per cent of the seeds germinated in sunlight and 24 per cent in the dark. Afolayan and Olugbami (1993) found that the seeds of *P. pedicellatum* showed 94 per cent viability and maximum seedling emergence occurred at the soil surface; there was a progressive decrease in emergence as the weeds were sown at greater depth. Maximum sowing depths for emergence were 7 cm for *P. pedicellatum.*

2.3 Phenology

The structure of a plant community changes with the season. There are certain events in the life cycle of a plant, for instance, germination, flowering, fruit set and finally death. The timings of these phases in the life cycle are dependent on environmental conditions, especially temperature and day length. Phenological behaviour of weeds is of great significance for designing any control measure (Kumar and Singh, 1994).

Weeds in general exhibit early germination, rapid growth, deeper and more spreading roots, more tillers, longer leaves, numerous flowers and seeds (Donald, 1963). Most of the weeds belonging to Poaceae and Cyperaceae complete their life cycle along with crops and most weed seeds exhibit 30-35 per cent germination even after two years (Saraswat, 1977).

According to Parihar and Shanker (1997) initial head emergence of *P. pedicellatum* started in the first week of November after the commencement of pasture growth at the onset of monsoon during July and head density packed during mid December. They got a total spikelet yield of 665 and 848 kg ha^{-1} during the two years of their study, with 17.5 and 12 per cent germination of seeds respectively. Kiatsoonthorn (1991) observed that fertile seed production in spikes gradually decreased from 62.4 per cent in the early part of January to 3.4 per cent in the middle of April. The number of spikelets gradually decreased from approximately 175 per culm in the early part of January to 150 per culm in the middle of February and then increased again to 225 per culm in the middle of April.

Kumar and Singh (1994) studied the phenology of *P. typhoides* and found that its germination started during the month of July and the vegetative period continued up to mid September. The flowering and fruiting occured during the period of October and late October respectively. From late October onwards disappearance started. Most of the grasses (*Dactyloctenium aegyptium, Digitaria sanguinalis, Eleusine aegyptia, Eragrostis* spp. and *Echinochloa colona*) started germination during the month of July and flowering and fruiting occurred between August-September and September-October respectively (Kumar and Singh, 1994).

Weeds often shows high reproductive capacity such as large quantity of seed production, short life span, capacity for vegetative regeneration etc. *Cyperus difformis, C. iria* and *Fimbristylis* sp. produced 50,000, 5,000 and 10,000 seeds per plant respectively (Reissig *et al.*, 1985). Wild oats, generally in the absence of

competition grows to very large plants with a high reproductive capacity (from 5 to 12 culms and from 400 to 800 seeds per plant) (Torres, 1994).

The highest emergence level of the *Sorghum halepense* grass weed reached when the rhizomes were planted at a depth of 5 cm in soil. The beginning of the different physiological phases of the weed, as well as its cycle up to complete panicle ripeness was more accelerated during the dry season. Intensive production of rhizomes was observed 45 days after planting (Lao *et al.*, 1994). Seed production, dissemination, dormancy and germination and plant allelopathy of turf grass are considered as mechanisms to increase weed persistence and competitiveness (Watschke and Engel, 1994).

Viggiani (1995) reported that flowering and fruiting period were longest in *Galinsoga ciliata* whilst,*Abutilon theophrasti* and *Datura stramonium* flowered in June to October and fruited in August to November. *Knoxia wightiana* and *Cleome burmanni* completed their life cycle before intercultivation was carried out in cassava, indicating that control measures must be carried out before seed setting in both species (Srinivasan and Maheswarappa, 1995).

The success of weed management based on ecological principles and weed biology will depend on a better understanding of the effect of environment on life history strategies, growth and competition of weeds and crops and particularly upon the ability to predict weed and crop phenology (Ghersa and Holt, 1995).

2.4 Regeneration ability

Perennial weeds live for three or more years. The potential for survival is influenced by life span, depth of propagule penetration, depth from which regeneration occurs, the age at which the seedlings assume perennial characteristics, the potential for seed production and the resistance of the plant and its organs for control measures. Perennial grasses like *Imperata cylindrica* and

Agropyron repens, which propagate through rhizomes, have the ability to regenerate even from a small piece of rhizome tissue (Rao, 1986).

Regrowth rate is the ability of the sward to regenerate. New photosynthetic tissues are high in earlier cuttings and low in the later cuttings which according to Kamidi and Wanjala (1988) may be due to the maximum meristematic activity and efficient translocation of photosynthates to the growing apex.

Noda *et al.*(1985) found no regrowth in *P. pedicellatum* and *P. polystachyon,* but observed vigorous regrowth in *P. purpureum.*

Cutting height in kikuya grass affected extension from the centre, linear plant frequency and plant biomass. The lowest height of cut, 2.5 cm, had the least extension and frequency. The higher cut at 5 cm was intermediate (Wilen and Holt, 1996).

The grasses (*Brachiaria* spp. and *Panicum maximum*) were cut after every 3, 6, 9 or 12 weeks of regrowth during the dry, rainy and cold seasons for three years. The grasses reached their highest dry matter yield and development during rainy season. The highest forage yield was at 12 weeks of regrowth (4.4 Mg DM ha^{-1}) (Rio and Reyes, 1998). Regrowth in the second harvest was compared in *Phalaris arundinacea, Dactylis glomerata* and *Festuca arundinacea.* During early and mid regrowth, herbage dry weight was in the order of *Dactylis* > *Festuca* > *Phalaris.* While in late regrowth in summer, the dry weight was greatest in *Phalaris* which had a higher proportion of stem and less senescent material (Watanabe *et al.*, 1998).

In an experiment, *P. pedicellatum* was cut every 45, 75 or 120 days (5, 3 and 2 cuts in 1992 and 3, 2 and 1 cut in 1993 respectively). The harvest interval of 45 days in early growth phases and 75 days in later phases in combination with 75

kg N ha^{-1} was superior for regrowth in terms of efficiency index (Ramamurthy and Shankar, 1996).

2.5 Allelopathy

Plants release various compounds to their surroundings that have either deleterious or beneficial effects on others in the vicinity. This naturally occurring direct or indirect interaction between plants through the production of chemicals that escape in to the environment is called allelopathy and the chemicals responsible for these are called allelochemicals (Rice, 1984). Both positive allelopathy and negative allelopathy can be utilized in crop production. Negative allelopathy of a particular weed on other weeds can be utilized as "natural or green herbicide". Similarly, positive allelopathic effect of any weed on crops can be utilized for achieving many objectives viz., to promote efficient rooting in dry land crops, to enhance germination of crops, to produce smothering effect of crops on weeds for reducing early crop-weed competition etc. (Oudhia and Tripathi, 1997). Allelochemicals are believed to be released into the environment mainly by root exudation, leaching of the above ground parts, volatilization and release from litter or decomposed tissues. As the allelochemicals move through the crop-weed environment, their quantity, the degree of potential activity and biological activity fluctuate widely (Einhellig, 1987). The allelopathic compounds produced by higher plants are often affected by environment, light intensity, soil moisture, nutrient and soil organisms (Chou, 1986).

E. crusgalli, an annual weed is very harmful for crops such as maize, soybean, wheat and gram (Singh *et al.*, 1988; Angiras *et al.*, 1988). *E. crusgalli* cuttings and extracts reduced rice plant height, leaf area, total dry matter production and finally yield (Velu and Rajagopal, 1996). Singh *et al.* (1988) found that the boiled and unboiled extracts of *E. crusgalli* inhibit the shoot length significantly. Lopes *et al.* (1987) found that root and shoot aqueous extracts of *Echinochloa* sp. and *Cyperus* sp. did not affect the germination of rice but reduced

radicle and coleoptile growth. Extract from *Echinochloa* sp. shoot was more inhibitory to rice. The decrease in root growth may be attributed to blockage of mitotic phases by the inhibitor alkaloides (Bukolova, 1971).

Purple nutsedge (*Cyperus rotundus*) extracts significantly decreased root nodule formation, growth and yield of soybean (Wibowo, 1996). Aqueous extracts (boiled and unboiled) of fresh root and shoot of purple nutsedge (*C. rotundus*) and barn yard grass at the concentration of 1:5 and 1:10 did not influence germination of paddy and blackgram (Porwal and Mundra, 1996). Madhu *et al.* (1995), however, reported that certain crops such as french bean and soybean are comparatively resistant to the allelopathic effects of *Parthenium* and *Cyperus rotundus.* In chickpea, *Cyperus rotundus* extracts did not influence seed germination but had differential effect on seedling growth (Saxena and Varshney, 1995). It also inhibit the germination and growth of pearl millet, cowpea, maize and blackgram (Singh, 1968). Root and foliage extracts of *C. rotundus* are potent sources of toxic metabolites, however, toxicity is species specific (Bhowmik and Doll, 1982).

Boiled extract of *Sorghum halepense* had promotory effect on shoot length, which was significantly more than the control. However, this effect was reverse when its unboiled extract was used (Singh *et al.*, 1988). Aqueous extracts, rain leachates and litter from *Imperata cylindrica* shoots and rhizomes suppressed either germination, seedling growth or both of *Brassica campestris, Pennisetum americanum* and lettuce (Hussain *et al.*, 1994). Shoot and root extracts of *Amaranthus* spp. inhibited barley germination and seedling growth with fresh extracts more potent than dried ones and shoot extracts more effective than root extracts (Qasem, 1994).

Chenopodium album contains allelochemicals which may inhibit the seed germination and growth of cucumber. The growth inhibition was around 68 per cent (Reinhardt *et al.*, 1994). Decaying leaves of *C. album* were more

inhibitory than root and leaf leachates, but the effect was species specific (Goel *et al.*, 1994).

Oudhia (1999) reported that different parts of *Lantana* produced significant effect on germination of soybean. Leaf and stem + leaf extracts lowered the germination to 30.1 per cent and 40.1 per cent respectively. Different parts of *Ageratum conyzoides* have potentiality to produce different allelopathic effects on paddy (Oudhia *et al.*, 1996). The extracts of many dominant plants such as *Delonix regia, Digitaria decumbens* contains allelopathic compounds (Chou, 1995). The leaf leachates of *Tectona grandis* significantly decreased the germination of rice and cowpea (Jadhav and Gaynar, 1994).

Narwal (1994) suggested that allelopathy can be used to control weeds and may offer substitutes for the chemical control or may reduce the dose of herbicides. Bhan and Sushilkumar (1998) suggested that because of the allelopathic effects of *Cassia tora* on the germination of *Parthenium* it could be included in the Integrated Weed Management of *Parthenium.* Kohli and Rani (1988) (cited by Bhan and Sushilkumar, 1998) observed that the herbicide action of glyphosate increased considerably when mixed with allelochemicals. Allelopathy may be beneficial to crops in some other ways too. Different parts of *Calotropis gigantea* failed to produce any detrimental effect on targeted weeds but the extract increased seed germination and vigour of soybean, mustard and kodo millet (*Paspalum scrobiculatum*) (Oudhia and Tripathi, 1997).

2.6 Fodder production

The rate of green fodder production is a function of tiller production and leaf growth (Ryle, 1970). The plant height, tiller number and leaf number directly influence the yield of green fodder (Selvi and Subramanian, 1993).

Tripathi and Gill (1990) observed that *P. pedicellatum* produced significantly higher forage yield as compared to cowpea and cluster bean.

Sequential cropping of deenanath grass-oat and cowpea-oat produced maximum forage and crude protein yield respectively. According to them higher forage yield of deenanath grass was due to its profuse tillering habit which provided more number of shoots per unit area at harvest. High herbage yield from deenanath grass had also been reported by Relwani and Bagga (1968); Rathore and Vijayakumar (1977).

Deenanath grass sown by the end of March gave fresh fodder of 65, 81 and 55.7 Mg ha^{-1} for the cultivars T_3, T_{10} and T_{15} when harvested 82 days after sowing (DAS) and 82.1, 128.5 and 92.8 Mg ha^{-1} when harvested 100 DAS (Mandal and Vamadevan, 1978).

In general, the green fodder yield showed a diminishing trend with the progressive increase in the number of cuttings (Ramasamy *et al.*, 1993). Higher the cutting frequency, the higher the yield (yearly accumulated biomass) of forages (Nemoto *et al.*, 1977). However, forage quality in *P. pedicellatum* improved with the increase in cutting frequency but the trend was reversed for dry matter yield and dry matter content (Tyagi and Singh, 1986).

P. *pedicellatum* was cut at 110 or 110-180 days after transplanting and dry matter yield increased up to 90 kg N ha^{-1} in the single and double cut crops; and it ranged from 81.7 to 145.6 Mg ha^{-1} with one cut and from 90 to 167.2 Mg ha^{-1} with two cuts (Pandey and Dwivedi, 1992). Total fresh herbage yield and average yield of *P. polystachyon* was 133.8 and 16.7 Mg ha^{-1} when grown under eight year old coconut palms (Gowda *et al.*, 1985).

In Jabalpur, work done on deenanath grass varieties showed tremendous response up to 200 kg N ha^{-1} (ICAR, 1972). Application of N @ 120 kg ha^{-1} increased the green fodder production of deenanath grass by 60 per cent over control at Rahuri (MPKV, 1979). An increase in the yield of this grass with N application up to 150 kg ha^{-1} has been recorded at Vellayani (KAU, 1979).

Deenanath grass produced highest yields of green fodder (182.7 Mg ha^{-1}), dry matter (21.0 Mg ha^{-1}) and crude protein (121.8 kg ha^{-1}) when fertilized at 150 kg N + 60 kg P_2O_5 ha^{-1} (Bhagat *et al.*, 1986b). Increase in N rates from 0 to 200 kg and or P_2O_5 rates from 0 to 60 kg ha^{-1} increased the fresh fodder and dry matter yield of *P. pedicellatum* (Sharma *et al.*, 1985).

Cross-sowing of two species (*P. pedicellatum* and maize) gave higher green forage yield (when cut at 50 per cent flowering) than sowing the crops in lines (Prasad and Singh, 1997). Deenanath grass in the Kharif season followed by an oats/sarson mixture in the Rabi season and jowar/cowpeas mixture in summer season was the best rotation with total fresh fodder yield of 139.9 Mg ha^{-1} (Bhagat *et al.*, 1986a). Yields of fodder crops, *P. pedicellatum,* Pillipesara, *Vigna acontifolia,* stylosantus, fodder chloam and fodder cowpea were decreased as fruit tree (mango, custard apple and guava) growth increased during the second year. Among the fodder crops, stylosanthes and deenanath grass showed greatest compatability with the above fruit tress (Sekar *et al.*, 1998).

Inter crop of thin napier (*P. polystachyon*) in coconut garden gave significantly higher forage yield (17.72 Mg ha^{-1} cut^{-1}) which was followed by hybrid napier var. BH-18 (16.64 Mg ha^{-1} cut^{-1}) (Gowda *et al.*, 1985). Shade levels of 35 and 70 per cent reduced dry matter (DM) of *P. polystachyon* by 25 and 48 per cent respectively compared to plants grown in full sunlight (Ismail *et al.*, 1994).

2.7 Nutritional aspects

Crude protein (CP) content of *P. pedicellatum* is comparable with that of many other fodder crops. *P. pedicellatum* in Niger was reported to contain 12.5 per cent crude protein and 35.2 per cent crude fibre (CF) at mid–bloom stage (Gohl, 1981). However, in Nigeria, reports suggest that the CP and CF value of fresh mature plants are 5.5 and 33.0 per cent respectively. Reports from India indicated that it contained 6.5 per cent CP and 35.8 per cent CF at flowering stage

(Chatterjee and Das, 1989). According to Upadhyay *et al.* (1978), *P. pedicellatum* at the flowering stage showed 19.2 per cent drymatter, 87.5 per cent organic matter and 5 per cent CP, 42.7 per cent CF, 37.8 per cent NFE, 10.5 per cent ash, 0.4 per cent Ca, 0.1 per cent phosphorus, 2.9 per cent DCP and 58.6 per cent TDN in the drymatter.

The CP and CF values of *P. polystachyon* were reported to be higher than that of *P. pedicellatum.* The values of CP and CF were 17.4 per cent and 23.0 per cent for fresh first cutting and 12.3 and 31.4 for fresh second cutting (Gohl, 1981).

Experiments on deenanath grass revealed a linear increase in crude protein content of the fodder with successive application of N up to 150 kg ha^{-1} (HPAU, 1977). Phosphorus content of deenanath grass remained unchanged with N application although the yield increased significantly (Acharya, 1973). Abraham *et al.* (1980) found an increase in K content due to the application of N in *P. pedicellatum.*

Cutting frequency may affect the nutrient content. Almar *et al.* (1997) reported that the crude protein content of Italian rye grass was decreased with delay in cutting. Botha and Rethman (1994) reported that the moisture, crude protein and P content of *P. glaucum* decreased with decreasing cutting frequency while Ca content was unaffected. Acunha and Coelho (1997) reported that the Ca, P, K and Mg contents of elephant grass were not significantly affected by cutting height, but generally decreased with increasing cutting interval.

Reduction in crude fibre content with enhanced N application was also reported by Abraham *et al.* (1980) in deenanath grass. Studies by Johnson *et al.* (1967) in guinea grass revealed that crude fibre content of the forage was reduced by N application. Thomas (1978) found that crude fibre content in guinea grass and hybrid napier was significantly reduced with increased N application up to 250 kg ha^{-1}.

Mukherjee *et al.* (1981) obtained a decrease in ash content in a trial of deenanath grass under three levels of P (0, 30 and 60 kg P_2O_5 ha^{-1}) at Kalyani. Trials on fodder types of *Avena sativa* with 0, 100 and 200 kg N ha^{-1} revealed that ash content was reduced with each successive increase in the level of N (HPAU 1977). Almost similar results were reported with *P. pedicellatum* at Vellayani (KAU, 1978).

2.8 Growth analysis

Weeds in general exhibit early germination, rapid growth, deeper roots, more spreading roots, more tillers, longer leaves, numerous flowers and seeds (Donald, 1963). Most of the perenicious weeds have C_4 photosynthetic pathway capable of thriving in tropics with high light, temperature and limited moisture (Patterson, 1985).

Trials conducted under the AICRP on forage crops at Vellayani on deenanath grass (*P. pedicellatum*) with 0, 50 and 150 kg N ha^{-1} recorded a linear increase in plant height in course of time (KAU, 1978). Similar results were reported by Abraham *et al.* (1980). Rathore and Vijayakumar (1977) recorded increased tiller production with increase in N fertilization in deenanath grass and fodder sorghum.

Ludlowu *et al.* (1974) reported higher LAI values in full sunlight and lower values with decrease in light in grasses. At ear emergence, the LAI of *P. pedicellatum* may be as high as 20. In grass legume mixed cropping sown 30 cm apart in alternate rows, the critical LAI of the grass was 7.5 and that of legume 3 (Chatterjee and Das, 1989).

Leaf:stem ratio indicates the general succulence of the herbage. The leaf:stem ratio of *P. pedicellatum* herbage varies between 1:0.2 and 1:1.22 as against 1:2 in sorghum (Chatterjee and Das,1989).

Rathore and Vijayakumar (1977) got a significant decrease in leaf stem ratio due to N application in fodder sorghum and deenanath grass. The leaf stem ratio was not significantly affected by N fertilization in deenanath grass eventhough a decreasing trend was obtained (Abraham *et al.*, 1980).

Singh *et al.* (1997) reported that the shoot and root weight of *P. pedicellatum* in different tree stands for each of three locations (below canopy, canopy edge and open location) were significantly different and were related to each other.

P. pedicellatum rooted slips were given 75 kg N ha^{-1} at transplanting and the crop was cut every 45, 75 or 120 days and growth analysis such as leaf area index, net assimilation rate, relative growth rate, crop growth rate and leaf area ratio were carried out. Application of 75 kg N ha^{-1} was superior in terms of growth indices and dry matter yield (Ramamurthy and Shankar, 1996). Seed yield of *P. pedicellatum* increaed linearly with N rate and produced yield of 1.2 Mg ha^{-1} with 75 kg N ha^{-1} (Ramamurthy *et al.*, 1998).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Field experiments were conducted during the year 1999 to study the comparative biology and growth behaviour of *Pennisetum polystachyon* (L.) Shult. and *P. pedicellatum* Trin. The details of the materials and methods adopted for the study are reported in this chapter.

3.1 General details

Experimental site: The experiments were conducted at the Research Farm of College of Horticulture, Kerala Agricultural University. Geographically the area is situated at 10°31' N latitude and 76°13' E longtitude and at an altitude of 40.3 M above mean sea level.

Soil

The soil of the experiment site was sandy clay loam in texture (Order: Ultisols). The physico-chemical properties of the soil are given in Table.1

Climate

The weather data recorded during the cropping period (July to December) are given in Appendix I and graphically presented in Fig.2a and 2b.

Field operations

The selected area was ploughed, stubbles removed, levelled and laid out into plots as per the layout plan.

Sowing

The seeds of *P. polystachyon* and *P. pedicellatum* were collected during November – December, 1998 and stored in airtight containers. Stored seeds were used for sowing during July 1999. The spacing followed was 20 x 20 cm.

Fig. 2a Weekly weather data during crop period (July 2 to Dec. 2) 1999 at Vellanikkara, Thrissur

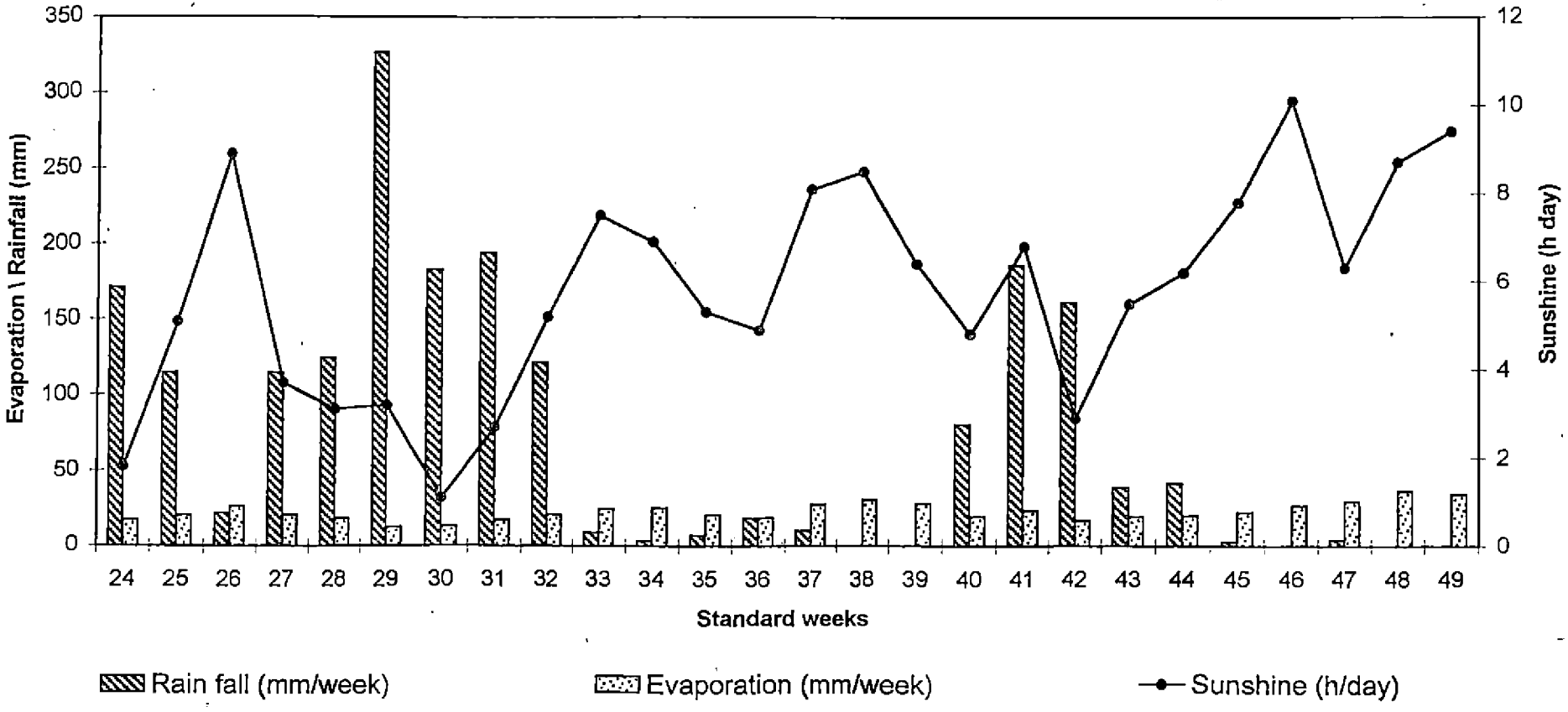


Fig. 2b Weekly weather data during crop period (July 2 to Dec. 2) 1999 at Vellanikkara, Thrissur

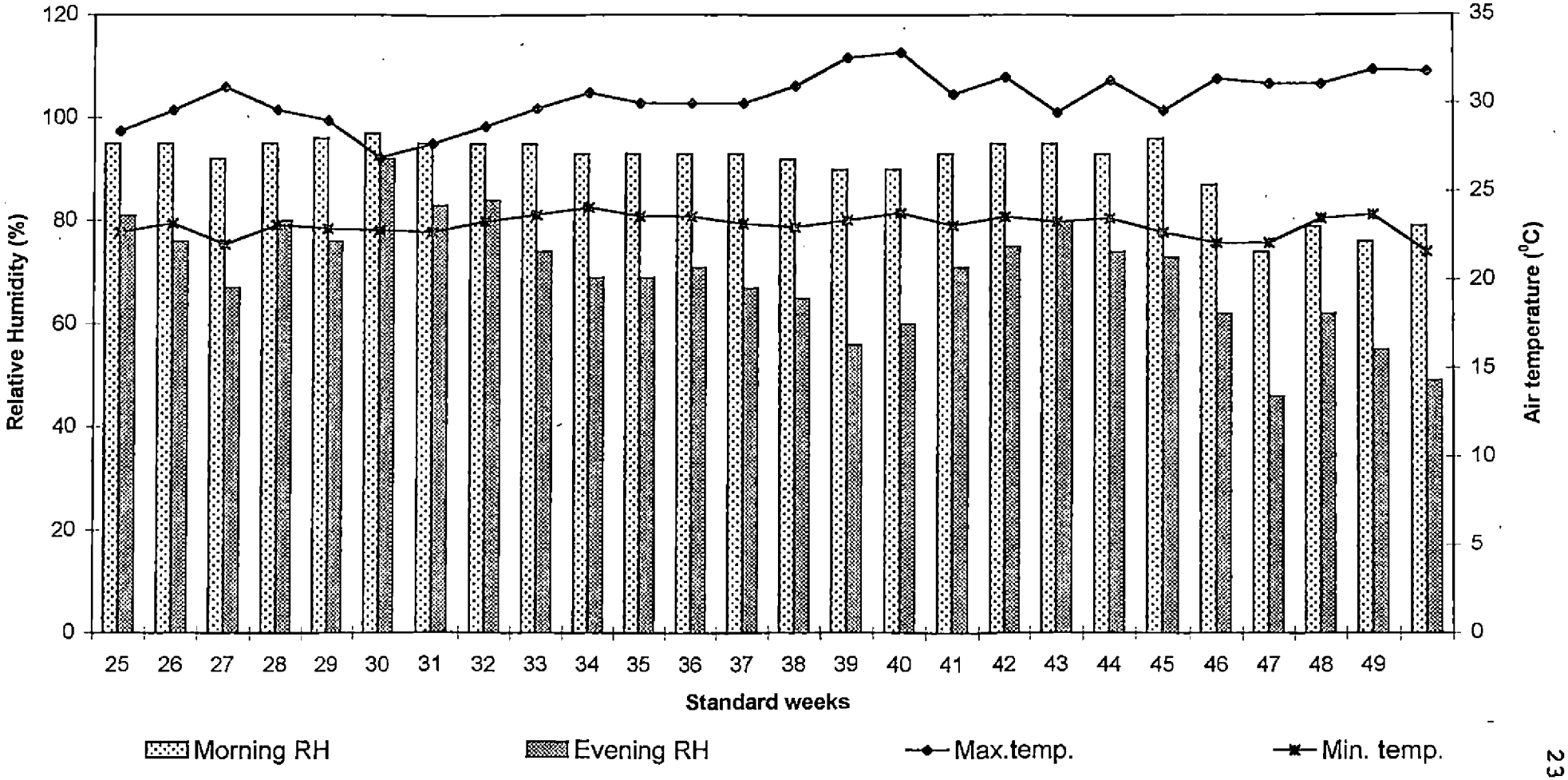


Table 1. Physico-chemical properties of the soil

Particulars	Content	Method used
A. Mechanical composition		
Coarse sand (%)	27.20	Robinson International Pipette method (Piper, 1942)
Fine sand (%)	23.70	
Silt (%)	22.20	
Clay (%)	26.90	
B. Chemical composition		
Organic C (%)	0.36	Walkley and black method (Jackson, 1958)
Available N (kg ha^{-1})	213.45	Alkaline permanganate method (Subbiah & Asija, 1956)
Available P (kg ha^{-1})	20.83	Ascorbic acid reduced molybdophosphoric blue colour method (Watnabe and Olsen, 1965)
Available K (kg ha^{-1})	98.45	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1958)

Plate 1. A general view of *Pennisetum* infestation. Both *P. polystachyon* and *P. pedicellatum* occur as a mixed population

Fifteen days after sowing, gap filling and one hand weeding were done. Since the idea was to simulate natural conditions, the crops were grown without applying any fertilizer, irrigation, plant protection measures etc.

3.2 Experimental Details

The investigation involved five experiments. The details of each experiment are given below:

Experiment 1: Studies on seed dormancy

Fresh seeds of *P. polystachyon* and *P. pedicellatum* were collected during the month of December-January (1999-2000). Germination tests were conducted at monthly intervals until more than 80 per cent germination was obtained. First lot of seeds were put on germination test on 27th December 1999. Subsequent tests were conducted on 7th February, 25th February, 25th March and 25th April.

Twenty five seeds of each species in five replication were placed in petridishes. Ordinary (Whatman No.1) filter paper was used as a substratum. The petridishes were kept at room temperature. It was moistened daily and continued until a constant germination percentage was obtained. Germinated seedlings were counted daily and it was expressed as percentage of total seeds.

Experiment 2: Life cycle and seed characters of *Pennisetum* spp.

Major phenological events were noted from a natural population of the two *Pennisetum* spp. The following phenological events were noted from 15 randomly selected plants.

1. Time of germination
2. Vegetative growth
3. Flowering
4. Seed formation

5. Seed maturation

6. Senescence

Other characters noted at maturity were

(i) Plant height

(ii) No. of main tillers per plant

(iii) No. of panicles per plant

(iv) No. of spikelets per plant

(v) No. of seeds per panicle

(vi) No. of seeds per plant

(vii) Reproductive capacity per plant
(Mean seed out put x maximum germination percentage)

Based on the above observations phenograms of *P. polystachyon* and *P. pedicellatum* were prepared.

Experiment 3: Studies on regeneration ability of *Pennisetum* spp.

The plants were retained as such in one treatment and cut at different heights in another two treatments at maturity. Regenerated plants were noted after one month of receipt of rainfall. After the harvest, fresh and dry weight of sprouts were recorded. The experiment was laid as a factorial experiment as detailed below:

Factor A. *Pennisetum* spp. - 2

P_1 – *P. polystachyon*

P_2 - *P. pedicellatum*

Factor B. Cutting levels – 3

T_1 - Plants retained as such after maturity

T_2 - Plants cut at 5 cm above ground level (at maturity)

T_3 - Plants cut at 10 cm above ground level (at maturity)

Design and layout of the experiment (Fig.3a)

No. of replications	- 5
Plot size	- 1 x 1 m
Spacing	- 20 x 20 cm
Design	- 2 x 3 factorial RBD

Experiment 4: Allelopathic effects of *Pennisetum* spp.

The leachates (both cold and boiled extracts) of leaf, roots and seeds of *Pennisetum* spp. were prepared. The cold extract was prepared by soaking chopped leaves, roots and seeds in distilled water for 24 h. The ratio used was 1:3 for leaves and roots, 1:5 for seeds i.e. one part of sample, and three and five parts of water (Porwal and Mundra, 1996). After 24 hours, the leachates were collected and filtered. The boiled extract was prepared in the same ratio by boiling 15 min. Both these leachates were used for conducting germination test.

Germination tests using cowpea, bhindi and cucumber were done using the extract in petridishes with filter paper and an absolute control of distilled H_2O. Observation on germination percentage, root length and shoot length were recorded after 10 days.

Experiment 5: Comparative growth analysis and fodder production potential of *Pennisetum* spp.

This experiment was conducted to compare the growth indices and fodder production potential of *Pennisetum* spp. The experiment was laid out in 2x3 factorial RBD with five replications. The plot size was 3 x 3m and the seeds were sown at a spacing of 20 x 20cm. Field layout was presented in Fig.3b.

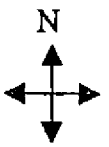
Treatments:

Factor A. *Pennisetum* spp. - 2

P_1 – *P. polystachyon*

P_2 - *P. pedicellatum*

Fig. 3a. Layout of the experiment Regeneration ability of *Pennisetum* spp.



1m

R_1 1m	P_2T_3	P_1T_1	P_1T_2	P_2T_1	P_1T_3	P_2T_2
R_2	P_1T_3	P_2T_3	P_1T_2	P_2T_2	P_2T_1	P_1T_1
R_3	P_2T_3	P_2T_1	P_2T_2	P_1T_1	P_1T_2	P_1T_3
R_4	P_2T_1	P_1T_3	P_1T_1	P_2T_3	P_1T_2	P_2T_2
R_5	P_1T_1	P_2T_2	P_1T_3	P_2T_1	P_1T_2	P_2T_3

P_1 - *P. polystachyon*

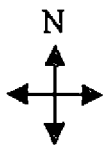
P_2 - *P. pedicellatum*

T_1 - Plants retained as such after maturity

T_2 - Plants cut at 5 cm above ground level (at maturity)

T_3 - Plants cut at 10 cm above ground level (at maturity)

Fig. 3b. Layout of the experiment Comparative growth analysis and fodder production potential of *Pennisetum* spp.



3m

R_1 3m	P_1T_3	P_2T_3	P_1T_2	P_1T_1	P_2T_2	P_2T_1
R_2	P_2T_3	P_2T_1	P_2T_2	P_1T_2	P_1T_3	P_1T_1
R_3	P_2T_2	P_2T_3	P_2T_1	P_1T_1	P_1T_3	P_1T_2
R_4	P_2T_1	P_2T_2	P_2T_3	P_1T_2	P_1T_3	P_1T_1
R_5	P_1T_3	P_1T_2	P_2T_1	P_2T_3	P_2T_2	P_1T_1

P_1 - *P. polystachyon*

P_2 - *P. pedicellatum*

T_1 - Cutting of fodder at 30 day interval

T_2 - Cutting of fodder at 45 day interval

T_3 - One cutting just before flowering

Factor B. Cutting intervals

T_1 - Cutting at 30 days interval

T_2 - Cutting at 45 days interval

T_3 - One cutting just before flowering

The experimental results were analysed in two parts – (I) growth analysis and (II) fodder production potential

I. Growth analysis

At monthly intervals, observations on growth characters were taken. Three plants were uprooted randomly from each plot. These plants were used to take observation and also for chemical analysis. Based on the observations, derived variables such as Relative Growth Rate (RGR), Net Assimilation Rate (NAR), Absolute Growth Rate (AGR), Leaf Weight Ratio (LWR), Specific Leaf Area (SLA), Leaf Area Ratio (LAR), Leaf Area Duration (LAD) as detailed by Gardner et *al.* (1985) and Dhopte and Livera (1989) were calculated. The following growth analysis characters were noted/calculated.

(i) Plant height

Plant height in cm was recorded from the base of the plant to the tip of the top most leaf during vegetative growth stage and from the base to the tip of inflorescence at maturity stage.

(ii) Number of leaves per plant

Number of leaves were counted at different stages of observation and the mean was worked out.

(iii) Leaf area per plant

The maximum length and breadth of all leaves of the middle tiller was recorded from three plants and leaf area in cm^2 was worked out using the formula length x breadth x factor (Gardner *et al.*, 1985). The factor was found out using leaf area meter.

(iv) Dry matter production

The pulled out plants were initially sun dried, then oven dried at 80°±5°C and above ground weight was recorded. The mean weight of the plant was expressed in g.

(v) Stem and leaf weight per plant

Stems, leaves and roots were separated from whole plant. Fresh weight and dry weight of different parts were recorded separately. Leaf:stem ratio was also worked out.

(vi) Derived growth variables

Different growth indices were worked out by using the following formula

(a) Leaf Area Ratio $= \frac{(La_2 - La_1)}{(\ln La_2 - \ln La_1)} \times \frac{(\ln W_2 - \ln W_1)}{(W_2 - W_1)}$ $g^{-1}\ cm^2\ day^{-1}$

(b) Leaf Weight Ratio = LW/W

LW - total leaf weight in g

W - whole plant dry weight in g

(c) Specific Leaf Area = La/Lw $cm^2\ g^{-1}$

La – Leaf area in cm^2

Lw – Leaf weight in g

(d) Leaf Area Duration $= \frac{(La_2 - La_1)}{(\ln La_2 - \ln La_1)} \times (t_2 - t_1)\ dm^2\ days$

where, La_1 and La_2 are total leaf area at time t_1 and t_2

(e) Absolute Growth Rate $= \frac{(W_2 - W_1)}{(t_2 - t_1)}$ $g\ day^{-1}$

where, w_1 and w_2 are the total dry weight at times t_1 and t_2.

$$\text{(f) Relative Growth Rate} = \frac{(\ln w_2 - \ln w_1)}{(t_2 - t_1)} \quad g\, g^{-1}\, day^{-1}$$

where, w_1 and w_2 are the total dry weight at times t_1 and t_2.

$$\text{(g) Net Assimilation Rate} = \frac{(w_2 - w_1)(\ln La_2 - \ln La_1)}{(t_2 - t_1)(La_2 - La_1)} \quad g^{-1}\, m^2\, day^{-1}$$

where, La_1 and La_2 are total leaf area at time t_1 and t_2 and w_1 and w_2 are total dry weight during the same period.

Quality characters

Nutrient accumulation per plant was calculated by different methods of chemical analysis.

(i) Nitrogen

Total nitrogen in the plant sample was determined by the microkjeldahl digestion and distillation method (Jackson, 1958).

(ii) Phosphorus

Plant samples were digested in the diacid mixture and the P content was determined by Vanodomolybdo phosphoric yellow colour method (Jackson, 1958). Intensity of colour was read using Spectronic 20 spectrophotometer at 420 nm.

(iii) Potassium

Potassium present in the diacid mixture was estimated using EEL Flame photometer (Jackson, 1958).

(iv) Calcium and magnesium

By using diacid mixture, Ca and Mg present in plant sample was read by AAS (Atomic Absorption Spectrometer) (Jackson, 1958).

Fodder production potential

Seventy days after sowing, the plants were uniformly cut at above ground level in all the treatments by leaving stubbles for its regrowth. Fresh and dry weight of fodder were recorded. After, the first cut different treatments were allotted to different plots. Fresh weight and dry weight of fodder were recorded from different treatments and expressed in Mg ha^{-1}.

Plant samples collected from different stages were analysed to determine the quality of fodder as shown below.

(i) Crude fibre

The crude fibre content of the forage was estimated using the acid-alkali digestion method (Sadasivam and Manickam, 1996).

(ii) Crude protein

Plant nitrogen content was obtained by microkjeldahl digestion and distillation method (Jackson, 1958). This content was multiplied by 6.25 to obtain crude protein content of plant sample.

(iii) Ash content

Ash content was determined by igniting known quantity of plant sample at 500°C for 1 h.

3.3 Data analysis

Analysis of variance was performed on the data collected in the field by using the statistical package 'MSTAT' (Freed, 1986). Data that showed wide variations were subjected to square root transformation to make analysis of variance valid (Gomez and Gomez, 1984).

4. RESULTS

Field and laboratory experiments on various aspects of seed dormancy, regeneration ability, phenology, allelopathic effects, comparative biology and fodder production potential were conducted during the period 1998-2000 at College of Horticulture, Vellanikkara. The results obtained from various trials are presented here after tabulation and data analysis.

4.1 Studies on seed dormancy

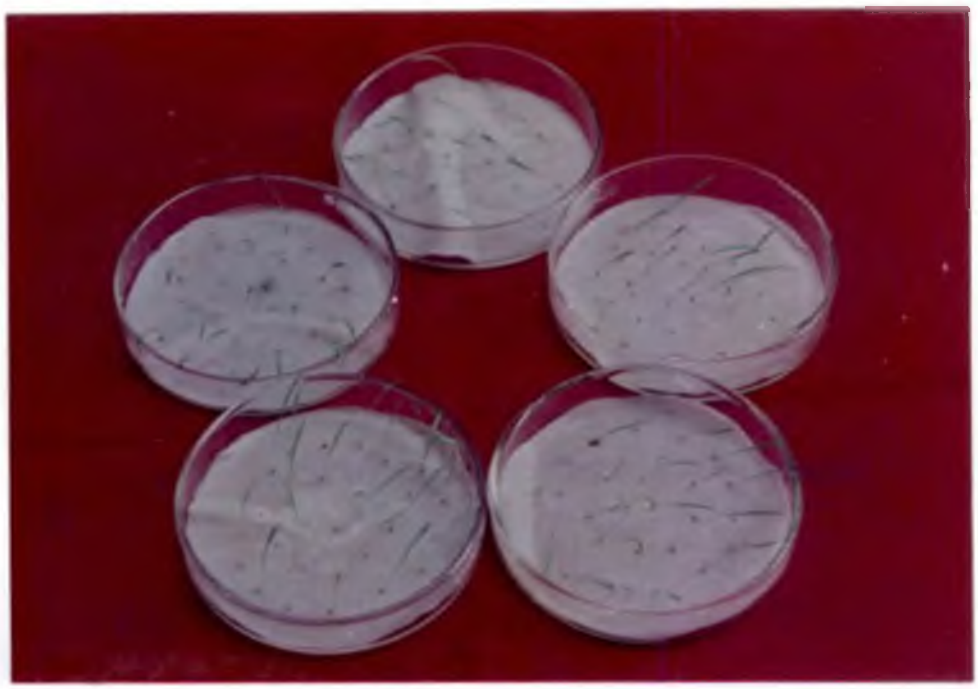
Germination ability of the freshly harvested seeds of *Pennisetum* spp was investigated at monthly intervals starting from December 1999 to April 2000 and the data are presented in Table 2.

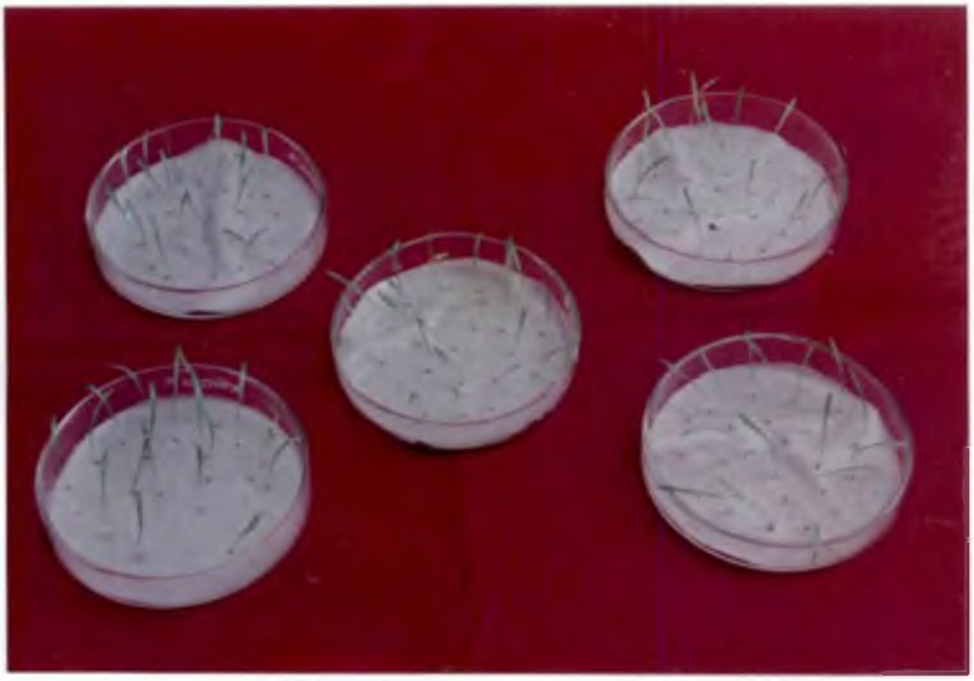
First germination test was done during the last week of December (27/12/99). Only *P. polystachyon* seeds showed germination in this test. The germination was 17.6 per cent on the second day and the maximum germination was 42.4 per cent. *P. pedicellatum* began to germinate in the test conducted during the first week of February. During the test conducted on 7/2/2000, the maximum germination was 59.0 per cent in *P. polystachyon* and 58.0 per cent in *P. pedicellatum*. In the test conducted at the end of February, both the species had similar germination percentage. The maximum germination obtained was 54.7 percent in *P. polystachyon* and 52.0 per cent in *P. pedicellatum*. *P. polystachyon* had 85.0 per cent and *P. pedicellatum* 88.0 per cent germination in the test done on 25/3/2000. The germination percentage recorded during the last week of April was 78.0 per cent and 93.0 per cent in *P. polystachyon* and *P. pedicellatum* respectively. Germination percentage started declining in *P. polystachyon*. However, *P. pedicellatum* continued to germinate with the same vigour. As both species recorded more than 80 per cent germination by March end and a declining trend was noticed in *P. polystachyon* by April end, the experiment was discontinued at this stage.

Table 2. Percentage seed germination of *P. polystachyon* and *P. pedicellatum* at different intervals

Pennisetum spp.	Date of test									
	27th December		7th February		25th February		25th March		25th April	
	Second day	Maximum germination	Second day	Maximum germination	Second day	Maximum germination	Second day	Maximum germination	Second day	Maximum germination
P. polystachyon	17.6	42.4	28.0	59.0	38.7	54.7	35.0	85.0	54.0	78.0
P. pedicellatum	0.0	0.0	11.0	58.0	36.0	52.0	67.0	88.0	85.0	93.0
SEm	5.5	17.7	11.4	13.7	17.6	5.3	11.8	5.0	9.4	4.9
LSD (0.05)	12.6	40.9	NS	NS	NS	NS	28.8	NS	22.9	11.9

Plate 2. Seeds of *P. polystachyon* and *P. pedicellatum* showing more than 80 per cent germination by March





4.2 Life cycle and seed characters of *Pennisetum* spp.

Phenological charaters

Phenological charaters of both species were noted from natural population during the year 1999 and the data are presented in the Table 3. Phenograms drawn using the above observations are shown in Fig 4.

Time of germination

Pennisetum spp. seeds were found to germinate soon after the receipt of monsoon showers during the month of April. First rainfall was on 21.4.99. However, maximum percentage of germination occurred during the first week of May for *P. polystachyon* and during the second week of May for *P. pedicellatum.* Germination continued in June also.

Vegetative growth

Vegetative growth period starts from seed germination and end by flowering. In the case of *P. polystachyon* it was from the first week of May which continued upto the first week of September. In the case of *P. pedicellatum* it started during the second week of May and extended upto late September.

Flowering

Flowering period was from the month of early September to early October in *P. polystachyon* and mid September to mid October in *P. pedicellatum.*

Seed formation and maturation

In *P. polystachyon*, seed formation occurred between the period of late September to mid October. Seed maturation began in mid October in *P. polystachyon*. However, in *P. pedicellatum*, seed formation and maturity period were between the first week of October to late October and late October to mid November respectively.

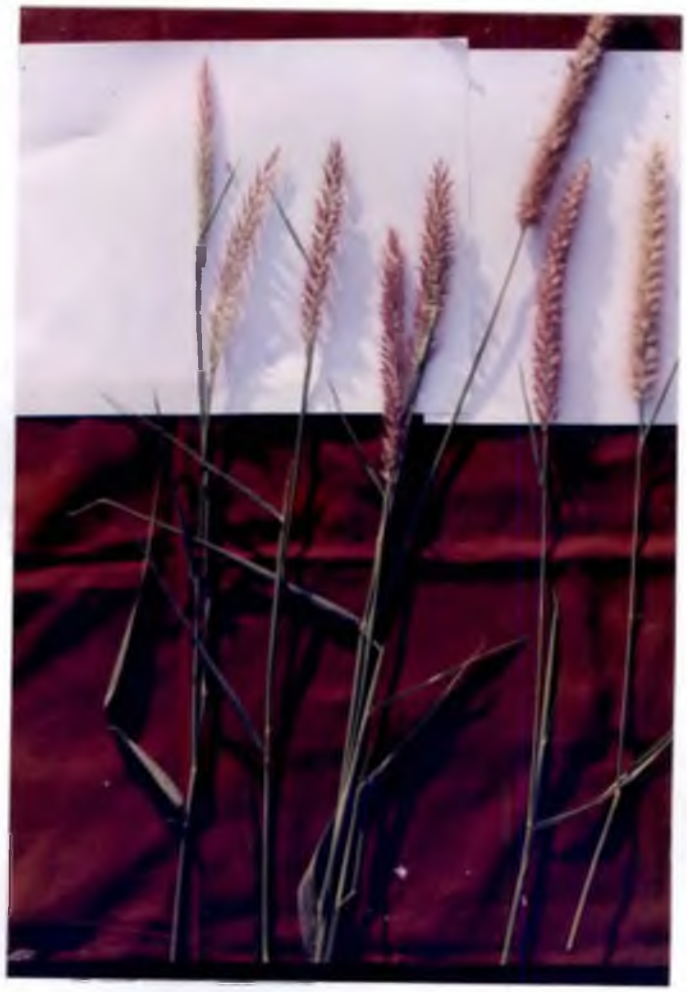
Table 3. Life cycle of *Pennisetum* spp.

Characters	*P. polystachyon*	*P. pedicellatum*
Time of germination	Late April - June	May - mid July
Vegetative growth	Early May - early Sep	Mid May - late Sep
Flowering	Early Sep - early Oct	Mid Sep - mid Oct
Seed formation	Late Sep - mid Oct	Early Oct - late Oct
Seed maturation	Mid Oct - early Nov	Late Oct – mid Nov
Senescence	Mid December	Mid November
Plant height at maturity	2.29 (1.95-2.6)* m	2.12 (1.73-2.4) m
No. of main tillers/plant	8 (6-12)	9 (8-13)
No. of panicles/plant	15 (10-18)	21 (14-25)
No. of spikelets/plant	7520 (6701-8483)	2248 (1802-2862)
No. of seeds/panicle	357 (280-421)	84 (60-110)
No. of seeds/plant	5439 (4264-6411)	1787 (1272-2332)
1000 seed weight	0.38 g	0.64 g
Reproductive capacity per plant	4623	1679

* Range values are given in the parenthesis

Plate 3. *Pennisetum polystachyon* showing mature panicles

Plate 4. *Pennisetum pedicellatum* showing mature panicles



Senescence

The culms and leaves started drying by mid December and mid November in *P. polystachyon* and *P. pedicellatum* respectively.

Vegetative and seed characters at maturity

At maturity stage the plant height recorded was 2.29 m in *P. polystachyon* and 2.12 m in *P. pedicellatum*. *P. pedicellatum* produced more tillers than *P. polystachyon*. *P. polystachyon* produced an average of 15 panicles per plant. A single panicle had around 493 spikelets; thus yielding 7520 spikelets per plant. Mean seeds per panicle was 357 and mean total number of seeds per plant was 5439. One thousand seeds weighed 0.38 g.

P. pedicellatum on the other hand produced an average of 21 panicles per plant. Mean spikelets per panicle was 106 and mean total number of spikelets per plant were 2248. Each spike produced 84 seeds and the mean total number seeds per plant was 1787 seeds. One thousand seeds weighed 0.64 g. The reproductive capacity of *P. polystachyon* (4623) was more than *P. pedicellatum* (1679).

4.3 Regeneration ability of *Pennisetum* spp.

Percentage of plants regenerated

The mean percentage of plants regenerated from 1 m^2 area after one month of receipt of rainfall are presented in the Table 4. Percentage of plants regenerated from 1m^2 area was not significantly different. Cutting heights also did not influence the regeneration ability. Interaction effect was also not significant.

Fresh weight of sprouts

The data on fresh weight of sprouts are given in Table 4. There was no significant difference in fresh weight of sprouts of both species, but significant differences were observed in cutting heights. The plants which were cut above 10

Table 4. Effect of different cutting heights on the percentage of plants regenerated and fresh and dry weight of sprouts in Mg ha^{-1}

Treatments	Fresh weight	Dry weight	Percentage of plants regenerated
A. *Pennisetum* spp.			
1. *P. polystachyon*	3.07 (9.64)*	1.07	65.08
2. *P. pedicellatum*	2.78 (8.05)	1.09	64.28
SEm	0.16	0.09	5.33
LSD (0.05)	NS	NS	NS
B. Cutting height			
1. Plant retained as such	3.08 (9.7)	1.14	61.60
2. Cut at 5 cm level	2.50 (6.43)	1.00	66.80
3. Cut at 10 cm level	3.20 (10.41)	1.14	65.60
SEm	0.20	0.11	6.53
LSD (0.05)	0.42	NS	NS
Interaction			
SEm	0.28	0.16	9.23
LSD (0.05)	NS	NS	NS

* Original values given in parenthesis

Plate 5. Regenerated *P. polystachyon* from stubbles cut at 10 cm height

Plate 6. Regenerated *P. pedicellatum* from stubbles cut at 10 cm height

cm ground level and plants retained as such recorded maximum fresh weight of fodder and were on par. Lowest fresh weight was obtained from cut at 5 cm level. The interaction between cutting height and grass species were absent.

Dry weight of sprouts

The data on the dry weight of regrowth sprouts are presented in Table 4. Mean total dry weight of sprouts of both *Pennisetum* spp. were almost similar. Dry weight of sprouts were unaffected between cutting treatments and were not significant.

4.4 Allelopathic effects

Allelopathic effects on germination

Leaf extracts

The effect of leaf extracts on germination percentage of bhindi, cucumber and cowpea are presented in Table 5. It seems leaf extracts have no influence on the germination percentages in any of the crops. All the treatment showed non-significant variation in germination percentages.

Root extracts

The effect of different root extracts on germination percentage of bhindi, cucumber and cowpea are presented in Table 6. In bhindi, the germination percentage noted after 48 hours showed significant variations. Highest germination percentage was in control. However, the germination percentage in boiled extracts were on par with control. The lowest germination was recorded in cold water extracts of *Pennisetum* spp. which were on par. The germination percentage was not significantly different in cucumber and cowpea. In the case of bhindi, observation on sixth day also recorded significant difference in germination percentage. Control and boiled root extract of *P. pedicellatum* recorded 100 per cent germination. The least value was recorded in *P. pedicellatum* cold root

Table 5. Allelopathic effect of *P. polystachyon* and *P.pedicellatum* leaf extracts (unboiled and boiled) on germination of bhindi, cucumber and cowpea

Treatments	Germination percentage					
	Bhindi		Cucumber		Cowpea	
	2/7/2000	5/7/2000	2/7/2000	5/7/2000	2/7/2000	5/7/2000
P_1CL	70.0	96.7	90.0	100.0	13.3	100.0
P_2CL	56.7	96.7	93.3	100.0	3.3	93.3
P_1BL	80.0	96.7	93.3	96.7	3.3	100.0
P_2BL	83.3	93.3	86.7	93.3	3.3	90.0
Control	63.3	100.0	100.0	100.0	10.0	100.0
SEm	11.83	3.94	5.77	3.33	5.37	3.94
LSD (0.05)	NS	NS	NS	NS	NS	NS

P_1CL - *P. polystachyon* cold leaf extract
P_2CL - *P.pedicellatum* cold leaf extract
P_1BL - *P. polystachyon* boiled leaf extract
P_2BL - *P.pedicellatum* boiled leaf extract

Table 6. Allelopathic effect of *P. polystachyon* and *P.pedicellatum* root extracts (unboiled and boiled) on germination of bhindi, cucumber and cowpea

Treatments	Germination Percentage					
	Bhindi		Cucumber		Cowpea	
	3/8/2000	6/8/2000	3/8/2000	6/8/2000	3/8/2000	6/8/2000
P_1CR	43.3	76.7	96.7	100.0	96.7	100.0
P_2CR	46.7	60.0	80.0	100.0	73.3	100.0
P_1BR	63.3	86.7	96.7	100.0	66.7	100.0
P_2BR	60.0	100.0	96.7	100.0	93.3	100.0
Control	66.7	100.0	96.7	100.0	100.0	100.0
SEm	5.37	4.47	14.05	-	15.35	-
LSD (0.05)	11.96	9.96	NS	-	NS	-

P_1CR - *P. polystachyon* cold root extract
P_2CR - *P.pedicellatum* cold root extract
P_1BR - *P. polystachyon* boiled root extract
P_2BR - *P.pedicellatum* boiled root extract

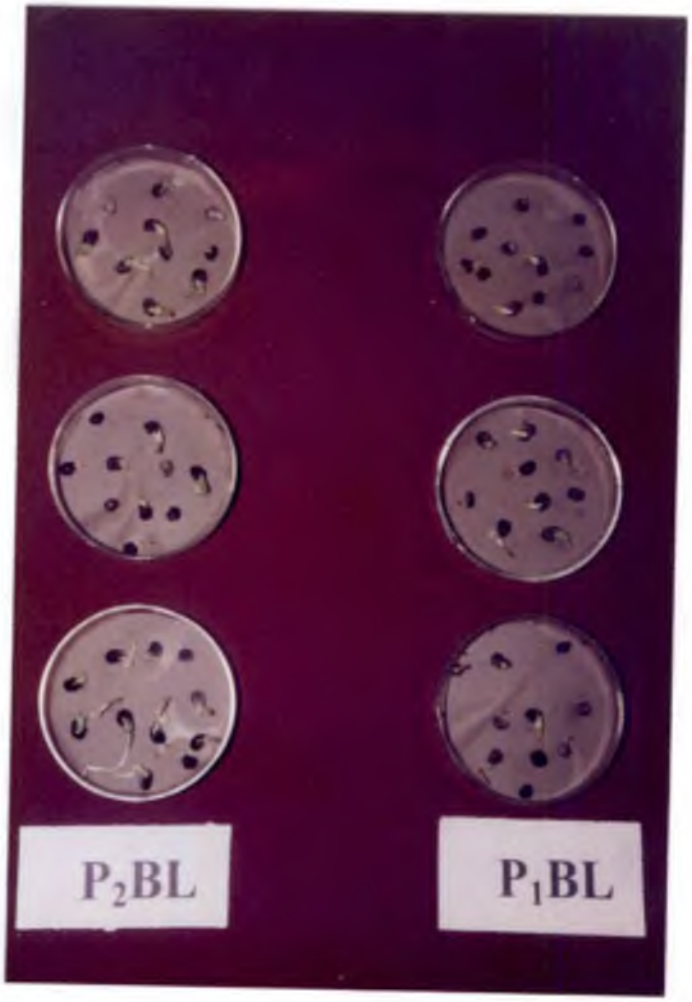
Plate 7. Allelopathic influence on shoot and root growth of Bhindi

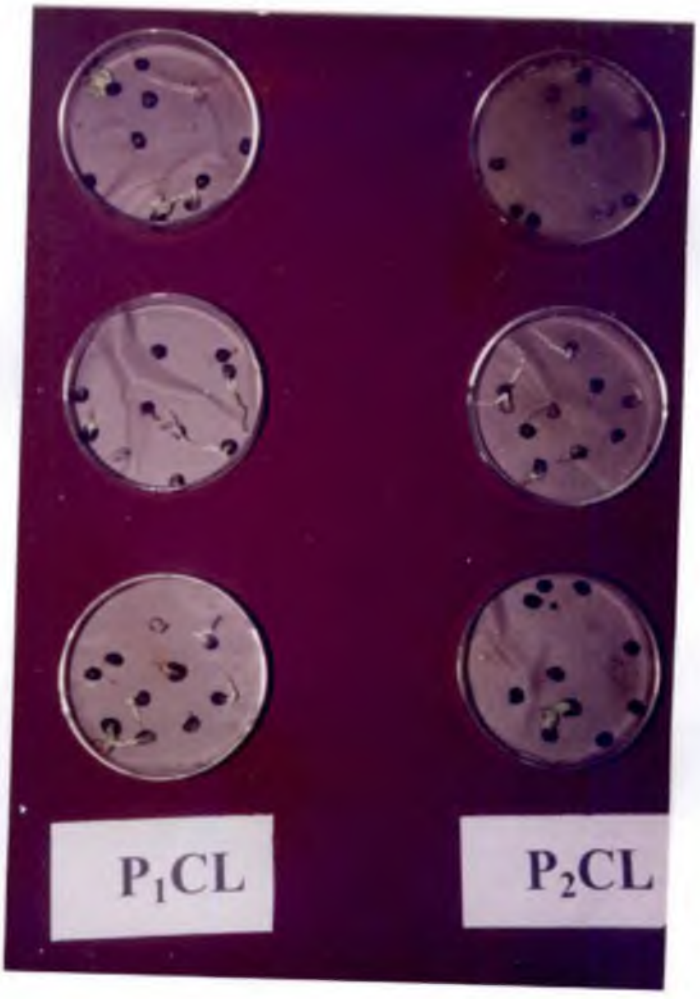
P1BL – *P. polystachyon* boiled leaf extract

P2BL – *P. pedicellatum* boiled leaf extract

P1CL – *P. polystachyon* cold leaf extract

P2CL – *P. pedicellatum* cold leaf extract


P_2BL
P_1BL


P_1CL
P_2CL

extract. In the case of cucumber and cowpea no significant differences were observed between the treatments.

Seed extracts

The effect of seed extracts on germination percentage of bhindi, cucumber and cowpea are presented in Table 7.

The germination percentage which were recorded after 48 hours showed significant differences among treatments. In bhindi, highest germination was recorded in control. Lowest germination was recorded in *P. pedicellatum* cold seed extract. In cucumber, control recorded more germination percentage which was followed by *P. pedicellatum* boiled seed extract and *P. polystachyon* cold seed extract. The germination percentage was less in *P. polystachyon* boiled seed extract. Control had higher percentage of germination in cowpea. Lowest germination was observed in *P. polystachyon* and *P. pedicellatum* cold seed extracts treated seeds. There was no germination in the boiled seed extracts of these two species.

Observation on the sixth day did not show any significant difference on germination of bhindi and cucumber. More than 90 per cent germination was observed in all the treatments. In cowpea, however, germination percentage was significantly different among treatments. Control recorded highest germination followed by *P. polystachyon* cold water seed extract. Lowest germination percentage was in *P. pedicellatum* cold water seed extract.

Allelopathic effect on shoot and root length

Leaf extracts

The effect of leaf extracts on shoot and root length of bhindi, cowpea and cucumber are presented in Table 8. Different treatments had significant effects on bhindi shoot and root growth in *P. polystachyon* cold and boiled leaf extracts treated seeds. The other extracts also had significant influence

Plate 8. Allelopathic influence on shoot and root growth of Cucumber

P1BL – *P. polystachyon* boiled leaf extract

P2BL – *P. pedicellatum* boiled leaf extract

P1CL – *P. polystachyon* cold leaf extract

P2CL – *P. pedicellatum* cold leaf extract


P2BL
P1BL

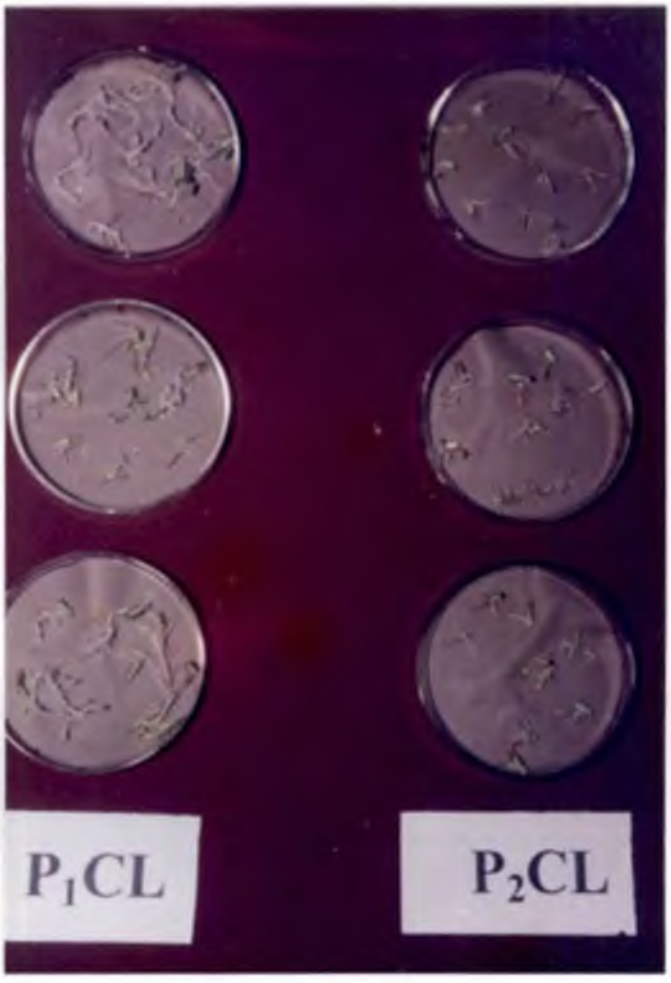

P1CL
P2CL

Table 7. Allelopathic effect of *P. polystachyon* and *P.pedicellatum* seed extracts (unboiled and boiled) on germination of bhindi, cucumber and cowpea

Treatments	Germination percentage					
	Bhindi		Cucumber		Cowpea	
	15/2/2000	19/2/2000	15/2/2000	19/2/2000	15/2/2000	19/2/2000
P_1CS	45.2	91.7	63.3	93.3	30.0	86.7
P_2CS	26.7	90.0	50.0	83.3	3.3	56.7
P_1BS	43.3	93.3	16.7	93.3	0.0	73.3
P_2BS	66.7	100.0	70.0	90.0	0.0	73.3
Control	95.0	100.0	100.0	100.0	86.7	100.0
SEm	9.43	3.33	6.67	6.83	6.15	8.69
LSD (0.05)	21.01	NS	14.90	NS	13.70	19.36

P_1CS - *P. polystachyon* cold seed extract
P_2CS - *P.pedicellatum* cold seed extract
P_1BS - *P. polystachyon* boiled seed extract
P_2BS - *P.pedicellatum* boiled seed extract

Table 8. Allelopathic effect of *P. polystachyon* and *P.pedicellatum* leaf extracts (unboiled and boiled) on shoot and root length (cm) of bhindi, cucumber and cowpea

Treatments	Bhindi		Cucumber		Cowpea	
	Shoot length	Root length	Shoot length	Root length	Shoot length	Root length
P_1CL	0.0	0.0	4.0	2.7	2.1	1.6
P_2CL	2.7	0.9	6.0	3.1	2.5	2.3
P_1BL	0.0	0.0	6.2	4.5	5.7	5.2
P_2BL	0.9	0.6	4.3	1.7	2.2	3.1
Control	5.0	5.2	7.9	7.6	10.0	7.6
SEm	0.75	0.47	0.79	0.58	0.38	0.41
LSD (0.05)	1.70	1.05	1.76	1.30	0.85	0.91

P_1CL - *P. polystachyon* cold leaf extract
P_2CL - *P.pedicellatum* cold leaf extract
P_1BL - *P. polystachyon* boiled leaf extract
P_2BL - *P.pedicellatum* boiled leaf extract

on shoot and root length. In cucumber also, there was a significant difference in shoot and root length. It was high in control. *P. polystachyon* cold leaf and *P. pedicellatum* boiled leaf extracts had more inhibitory effect on shoot length of cucumber followed by *P. pedicellatum* cold leaf and *P. polystachyon* boiled leaf extracts. In the case of root length, the lowest length was recorded in *P. pedicellatum* boiled leaf extract followed by *P. polystachyon* cold leaf and *P. pedicellatum* cold leaf extracts. Slight inhibitory effect was also found in *P. polystachyon* boiled leaf extract. Control recorded maximum root length.

Different treatments had significant effects on cowpea shoot and root length. Maximum shoot length was in control. Shoot length was very much reduced in *P. polystachyon* cold leaf, *P. pedicellatum* cold leaf and *P. pedicellatum* boiled leaf extracts. In the case of root length of cowpea, the least root length was recorded in *P. polystachyon* cold leaf extract followed by *P. pedicellatum* cold leaf extract. Both the species of boiled extract also inhibited the root growth. Control recorded more root length.

Root extracts

The effect of root extracts on shoot and root length of bhindi, cowpea and cucumber are presented in Table 9. The shoot and root length of bhindi differed significantly among the treatments. There was no shoot and root growth in *P. pedicellatum* boiled root extract treated seeds. The seeds completely died. The lowest length of root and shoot was recorded in *P. polystachyon* boiled root extract followed by *P. pedicellatum* cold root extract. Control recorded more shoot length. In cucumber, though the treatments had no effect on shoot length, there were significant differences in root length. Root length was maximum in control. The lowest length was recorded in *P. pedicellatum* boiled root extract. Shoot length of cowpea was highest in *P. polystachyon* and *P. pedicellatum* cold root extracts followed by control. Lesser values were recorded in boiled extracts of both species.

However, the root length recorded in different treatments did not differ significantly.

Seed extracts

The effect of different seed extracts on bhindi, cowpea and cucumber are presented in Table 10. Different seed extracts had significant influences on shoot and root length of bhindi, cucumber and cowpea. In bhindi, the effect of inhibition on shoot length was more in *P. polystachyon* boiled seed extract followed by *P. pedicellatum* boiled seed extract. Highest shoot length recorded in control. In case of root length, it was less in cold extract of both the species. In cucumber, the lowest length was recorded in *p. polystachyon* boiled seed extract followed by *P. pedicellatum* boiled seed extract. Control recorded more shoot and root length. The length recorded in *P. polystachyon* and *P. pedicellatum* cold seed extracts were less compared to control. In cowpea, control recorded more shoot and root length. The least value observed in *P. polystachyon* boiled seed extract followed by *P. pedicellatum* boiled seed extract. Cold extracts also recorded less value compared to control.

4.5 Comparative growth analysis

Plant height

The plant height at different stages are presented in Table 11. The height of *P. polystachyon* and *P. pedicellatum* at 30, 60 and 90 days after sowing were significantly different. *P. pedicellatum* recorded more heights in the above mentioned stages and there was rapid elongation from 30 to 90 DAS. However, from 60 DAS to 90 DAS, the elongation was slow whereas from 90 to 120 DAS it was rapid in *P. polystachyon.* At 120 DAS and later both the *Pennisetum* spp. showed almost similar heights.

Table 9. Allelopathic effect of *P. polystachyon* and *P.pedicellatum* root extracts (unboiled and boiled) on shoot and root length (cm) of bhindi, cucumber and cowpea

Treatments	Bhindi		Cucumber		Cowpea	
	Shoot length	Root length	Shoot length	Root length	Shoot length	Root length
P_1CR	3.7	4.2	8.7	5.2	15.1	9.1
P_2CR	4.3	4.4	8.8	5.5	14.3	9.3
P_1BR	3.5	4.5	8.9	7.1	7.5	5.3
P_2BR	0	0	7.6	4.0	6.8	8.5
Control	4.8	5.4	7.6	7.5	10.0	8.3
SEm	0.58	0.29	0.67	0.49	0.92	1.16
LSD (0.05)	1.29	0.65	NS	1.09	2.05	NS

P_1CR - *P. polystachyon* cold root extract
P_2CR - *P.pedicellatum* cold root extract
P_1BR - *P. polystachyon* boiled root extract
P_2BR - *P.pedicellatum* boiled root extract

Table 10. Allelopathic effect of *P. polystachyon* and *P.pedicellatum* seed extracts (unboiled and boiled) on shoot and root length (cm) of bhindi, cucumber and cowpea

Treatments	Bhindi		Cucumber		Cowpea	
	Shoot length	Root length	Shoot length	Root length	Shoot length	Root length
P_1CS	2.4	1.7	5.6	5.4	4.2	3.5
P_2CS	2.7	2.1	5.2	3.8	2.8	2.1
P_1BS	1.5	2.4	2.5	2.6	1.5	1.8
P_2BS	2.0	3.3	3.5	3.1	2.0	2.7
Control	4.8	4.6	7.6	6.7	9.8	7.2
SEm	0.25	0.27	0.32	0.26	0.23	0.25
LSD (0.05)	0.56	0.60	0.71	0.58	0.51	0.56

P_1CS - *P. polystachyon* cold seed extract
P_2CS - *P.pedicellatum* cold seed extract
P_1BS - *P. polystachyon* boiled seed extract
P_2BS - *P.pedicellatum* boiled seed extract

Number of leaves per plant

The mean number of leaves per plant at different months are given in Table 12. Significant differences were observed between species in leaf number at 30 DAS and 90 DAS. *P. pedicellatum* produced more number of leaves than *P. polystachyon* at 30 DAS. At 60 DAS, there was no significant differences between the species. Both species had equal number of leaves. However, at 90 DAS, *P. polystachyon* produced more number of leaves than *P. pedicellatum.* During the later stages of maturing phase, i.e., at 120 and 150 DAS, mean number of leaves per plant were similar in both species.

Leaf length

The length of leaf at different periods is presented in Table 13. The leaf length at 30, 60, 90 and 120 DAS differed significantly. Leaf length in the above mentioned stages were higher in *P. pedicellatum.* At maturing stage, there was no significant difference in leaf length between the species.

Leaf breadth

The data on the breadth of leaves at different periods are given in Table 14. Significant differences were observed in leaf breadth at 30, 60 and 90 DAS. *P. pedicellatum* recorded more breadth than *P. polystachyon.* However, at 120 and 150 days after sowing, both species had similar values.

Fresh and dry weight of stem per plant

The fresh and dry weight of stem per plant are presented in Table 15. There was significant difference in stem fresh weight at 60 DAS. *P. pedicellatum* produced more fresh weight than the other one. However, at 90 DAS and later stages, there was no difference in fresh weight. Dry weight was significant at 60 and 90 DAS. *P. pedicellatum* recorded higher dry weight than *P. polystachyon.*

Table 11. Height of *P. polystachyon* and *P.pedicellatum* at different growth stages

Pennisetum spp.	Plant height (cm)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	15.96	52.60	73.94	186.60	233.80
P. pedicellatum	19.56	68.46	140.20	200.80	222.20
SEm	1.05	2.03	8.06	15.73	4.86
LSD(0.05)	2.91	5.63	22.37	NS	NS

Table 12. Number of leaves of *P. polystachyon* and *P. pedicellatum* at different growth stages

Pennisetum spp.	Number of leaves per plant				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	4.95	22.01	26.78	11.55	8.32
P. pedicellatum	5.85	25.77	19.23	10.36	7.85
SEm	0.19	1.59	2.01	0.86	1.07
LSD(0.05)	0.53	NS	5.59	NS	NS

Table 13. Leaf length of *P. polystachyon* and *P. pedicellatum* at different growth stages

Pennisetum spp.	Leaf length (cm)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	9.39	32.73	38.76	49.02	40.40
P. pedicellatum	11.47	41.98	47.84	44.22	39.44
SEm	0.58	1.42	1.66	1.33	1.27
LSD(0.05)	1.62	3.93	4.60	3.70	NS

Table 14. Leaf breadth of *P. polystachyon* and *P. pedicellatum* at different growth stages

Pennisetum spp.	Leaf breadth (cm)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	0.77	1.27	1.36	1.38	1.21
P. pedicellatum	1.05	1.56	1.55	1.39	1.22
SEm	0.05	0.05	0.05	0.04	0.53
LSD(0.05)	0.14	0.12	0.12	NS	NS

Fresh weight and dry weight of leaves per plant

The mean fresh weight and dry weight of leaves are presented in Table 16. At 60 DAS, the leaf fresh weight was more in the case of *P. pedicellatum* than *P. polystachyon*. However, by 90 DAS, *P. polystachyon* by passed *P. pedicellatum* in leaf fresh weight and had a higher value, though they are not significantly different. At 120 and 150 DAS differences were observed. During these stages *P. polystachyon* recorded more fresh weight than *P. pedicellatum*. Leaf dry weight at 60 and 90 DAS behaved similar to the fashion of fresh leaf weight. However, at 120 DAS though *P. polystachyon* had higher leaf dry weight, it was not significantly different from that of *P. pedicellatum*. At 150 DAS, *P. polystachyon* was superior in terms of leaf dry weight than *P. pedicellatum*.

Total fresh and dry weight of plant

The data on total biomass, both in terms of fresh and dry weight, are given in Table 17. Species differences were evident in the total plant fresh weight at 30 and 60 DAS. At these stages, *P. pedicellatum* recorded the highest total plant weight. At 90 DAS, *P. pedicellatum* recorded more fresh weight. However, at 120 DAS, *P. polystachyon* had more fresh weight than *P. pedicellatum*. No significant differences were observed at 150 DAS.

Significant differences in total plant dry weight was observed at 30, 60 and 90 DAS. *P. pedicellatum* produced more total plant dry weight in the above mentioned stages. At 120 and 150 DAS, both the *Pennisetum* spp. behaved similarly and recorded similar dry weight.

Leaf area per plant

The leaf area per plant recorded at different growth stages are given in Table 18. *P. pedicellatum* had a higher leaf area at 30 and 60 DAS. No significant differences were, however, observed in leaf area at 90 DAS though the leaf area was more in *P. pedicellatum*. At 120 DAS, *P. polystachyon* had more leaf area

Table 15. Fresh and dry weight (g) of stems in *P. polystachyon* and *P. pedicellatum* at different growth periods

Pennisetum spp.	60 DAS		90 DAS		120 DAS		150 DAS	
	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
P. Polystachyon	6.89	0.94	18.35	2.24	26.00	6.52	30.36	13.03
P. pedicellatum	15.02	1.98	29.24	5.51	26.60	6.77	30.06	14.08
SEm	1.95	0.21	4.58	0.69	0.90	1.32	2.51	1.04
LSD (0.05)	5.41	0.57	NS	1.92	NS	NS	NS	NS

Table 16. Fresh and dry weight (g) of leaves in *P. polystachyon* and *P. pedicellatum* at different growth periods

Pennisetum spp.	60 DAS		90 DAS		120 DAS		150 DAS	
	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
P. Polystachyon	8.89	1.55	16.44	3.49	9.56	2.09	2.45	1.34
P. pedicellatum	17.10	2.79	12.97	3.09	6.80	1.88	1.68	1.02
SEm	1.69	0.29	1.73	0.24	0.43	0.17	0.18	0.08
LSD (0.05)	4.69	0.80	NS	NS	1.20	NS	0.49	0.22

Table 17. Total plant weight (g) at different stages

Pennisetum spp.	30 DAS		60 DAS		90 DAS		120 DAS		150 DAS	
	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
P. polystachyon	0.26	0.14	18.58	3.71	45.89	8.30	42.57	10.47	40.83	18.59
P. Pedicellatum	0.58	0.26	40.99	6.56	53.42	11.35	38.22	10.48	40.17	18.85
SEm	0.05	0.02	3.26	0.64	5.01	0.78	1.27	1.51	2.13	1.32
LSD (0.05)	0.15	0.06	9.05	1.79	NS	2.16	3.52	NS	NS	NS

than *P. pedicellatum*. At 150 DAS, differences narrowed and the values were non significant.

Leaf:stem ratio

The data on leaf:stem ratio are presented in Table 19. Significant differences were observed between the species. *P. polystachyon* had higher leaf:stem ratio. The differences were also significant between the species. Leaf:stem ratio value was maximum at earlier stages and it decreased gradually showing the lowest value at 150 DAS. Interaction was significant. *P. polystachyon* had higher leaf:stem ratio at 60 and 90 DAS. Both species were similar in leaf:stem ratio at all other stages.

Leaf Area Ratio (LAR)

The data recorded on LAR are presented in Table 20. There were not much differences in LAR among the two *Pennisetum* spp. at all the stages. However, the stage of observation was significant and maximum LAR was at 30-60 DAS, followed by 60-90 DAS. Least LAR was at 120-150 DAS.

Leaf Weight Ratio (LWR)

Data on LWR of *Pennisetum* spp. at various stages are given in Table 21. No significant difference were observed between species mean. However, LWR differed between the stages of observation, maximum being at 60 DAS and minimum at 150 DAS. Interaction effect was also significant. At 90 DAS, *P. polystachyon* had higher LWR. *P. pedicellatum* and *P. polystachyon* recorded similar LWR at 60 DAS.

Specific Leaf Area (SLA)

The data on SLA recorded at various stages are presented in Table 22. The value of SLA recorded on *Pennisetum* spp. differed significantly. Between the

Table 18. Leaf area of *P. polystachyon* and *P. pedicellatum* at different growth stages

Pennisetum spp.	Leaf area (cm^2)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	25.14	622.59	944.62	539.31	306.27
P. pedicellatum	50.25	1183.96	994.26	434.95	277.33
SEm	4.75	87.69	141.02	22.31	32.02
LSD(0.05)	13.19	243.45	NS	61.93	NS

Table 19. Leaf:stem ratio of *P. polystachyon* and *P.pedicellatum* at different growth stages

Pennisetum spp.	Leaf:stem ratio				Species mean
	60 DAS	90 DAS	120 DAS	150 DAS	
P. polystachyon	1.68	1.56	0.35	0.10	0.93
P. pedicellatum	1.44	0.59	0.28	0.07	0.60
Stages mean	1.56	1.09	0.32	0.09	

SEm for species = 0.05 LSD (0.05) = 0.11
SEm for stages = 0.06 LSD (0.05) = 0.11
SEm for interaction = 0.08 LSD (0.05) = 0.16

Table 20. Leaf area ratio of *P.polystachyon* and *P.pedicellatum* at different stages of growth

Pennisetum spp.	LAR ($g^{-1}cm^2day^{-1}$)				Species mean
	30 – 60 DAS	60 – 90 DAS	90 – 120 DAS	120 – 150 DAS	
P. polystachyon	180.50	141.95	77.50	28.48	107.11
P. pedicellatum	184.28	131.16	59.62	22.82	99.47
Stages mean	182.39	136.55	68.56	25.65	

SEm for species = 5.69 LSD (0.05): NS
SEm for stages = 5.53 LSD (0.05): 11.47
SEm for interaction = 7.82 LSD (0.05): NS

Table 21. Leaf weight ratio of *P. polystachyon* and *P.pedicellatum* at different growth stages

Pennisetum spp.	Leaf weight ratio (g)				Species mean
	60 DAS	90 DAS	120 DAS	150 DAS	
P. polystachyon	0.43	0.45	0.19	0.07	0.29
P. pedicellatum	0.43	0.34	0.16	0.06	0.25
Stages mean	0.43	0.40	0.17	0.07	

SEm for species = 0.02 LSD (0.05) = NS
SEm for stages = 0.02 LSD (0.05) = 0.04
SEm for interaction = 0.03 LSD (0.05) = 0.06

species, mean SLA values were high for *P. pedicellatum*. Mean SLA values during various stages of observation were also different. There was a gradual decline in SLA from 60 to 120 DAS. SLA value at 120 DAS and 150 DAS were on par.

Leaf Area Duration (LAD)

The data on LAD of *Pennisetum* spp. at various stages are given in Table 23. The mean LAD values differed significantly between the species. *P. pedicellatum* recorded more LAD values. Stages of observation also differed significantly. There was a gradual increase in LAD upto 60-90 DAS, thereafter decreasing trend was observed. LAD was maximum at 60-90 DAS followed by 90-120 DAS. Interaction was significant. *P. pedicellatum* had higher LAD values at 30-60 and 60-90 DAS than *P. polystachyon*. At all other stages, LAD were similar in both species.

Absolute Growth Rate (AGR)

The AGR recorded at different stages are presented in Table 24. The AGR values of both the *Pennisetum* spp. were similar at all the stages. However, there were significant differences between the stages. Maximum AGR was during 120-150 DAS followed by 30-60 DAS. Least AGR values were observed during the period of 90-120 DAS.

Relative Growth Rate (RGR)

The RGR value recorded at different growth stages are presented in Table 25. Both the *Pennisetum* spp. had similar RGR values at all the stages of observation. Between the stages, maximum RGR was recorded during 0-30 DAS followed by 30-60 DAS. Subsequently the RGR declined. However, RGR values during 90-120 and 120-150 DAS were almost same.

Table 22. Specific leaf area of *P. polystachyon* and *P.pedicellatum* at different growth stages

Pennisetum spp.	Specific leaf area ($cm^2 g^{-1}$)				Species mean
	60 DAS	90 DAS	120 DAS	150 DAS	
P. polystachyon	416.90	274.02	265.70	235.02	297.91
P. pedicellatum	449.02	317.38	243.95	276.35	321.67
Stages mean	432.96	295.70	254.83	255.69	

SEm for species = 8.07 LSD (0.05) = 16.65
SEm for stages = 34.15 LSD (0.05) = 70.49
SEm for interaction = 48.30 LSD (0.05) = NS

Table 23. Leaf area duration of *P. polystachyon* and *P. pedicellatum* at different growth stages

Pennisetum spp.	Leaf area duration (d m^2 days)					Species mean
	0-30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	
P. polystachyon	1.52 (2.33)*	7.42 (55.61)	15.14 (231.24)	14.65 (216.46)	11.03 (122.57)	9.95 (125.64)
P. pedicellatum	1.94 (3.83)	10.29 (106.59)	17.90 (325.01)	14.12 (202.24)	10.11 (103.77)	10.87 (148.29)
Stages mean	1.73 (3.08)	8.86 (81.10)	16.52 (278.13)	14.38 (209.35)	10.57 (113.17)	

*Original values in parenthesis
SEm for species = 0.31 LSD (0.05) = 0.63
SEm for stages = 0.50 LSD (0.05) = 1.02
SEm for interaction = 0.70 LSD (0.05) = 1.45

Table 24. Absolute growth rate of *P. polystachyon* and *P.pedicellatum* at different growth stages

Pennisetum spp.	Absolute growth rate (g day^{-1})				Species mean
	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	
P. polystachyon	0.34 (0.12)*	0.37 (0.14)	0.31 (0.10)	0.49 (0.25)	0.38 (0.15)
P. pedicellatum	0.46 (0.21)	0.34 (0.12)	0.27 (0.08)	0.46 (0.22)	0.38 (0.16)
Stages mean	0.39 (0.17)	0.35 (0.13)	0.29 (0.09)	0.48 (0.24)	

*Original values in parenthesis
SEm for species = 0.01 LSD = NS
SEm for stages = 0.04 LSD = 0.08
SEm for interaction = 0.06 LSD = NS

Table 25. Relative growth rate of *P. polystachyon* and *P.pedicellatum* at different growth stages

Pennisetum spp.	Relative growth rate (g g^{-1} day^{-1})					Species mean
	0-30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	
P. polystachyon	0.487 (0.237)*	0.334 (0.112)	0.158 (0.026)	0.110 (0.013)	0.123 (0.016)	0.243 (0.081)
P. pedicellatum	0.511 (0.261)	0.328 (0.108)	0.190 (0.060)	0.081 (0.007)	0.117 (0.014)	0.246 (0.090)
Stages mean	0.499 (0.249)	0.331 (0.110)	0.174 (0.043)	0.096 (0.010)	0.120 (0.015)	

*Original values in parenthesis
SEm for species = 0.015 LSD (0.05) = NS
SEm for stages = 0.028 LSD (0.05) = 0.057
SEm for interaction = 0.040 LSD (0.05) = NS

Net Assimilation Rate (NAR)

The data on NAR are presented in Table 26. Species differences were non significant with respect to NAR at all the stages. However, the NAR at different stages of plant growth differed significantly. NAR was maximum at later stages (120-150 DAS) of growth. The least values were observed during 90-120 DAS.

4.6 Nutrient composition and uptake

The data on Nitrogen content in the plants at different stages are presented in Table 27. There was no significant difference in N content at 30,60 and 90 DAS. Numerically, maximum N content was at 60 DAS and started declining thereafter. Nitrogen content was the least at 150 DAS. In terms of N content, *P. polystachyon* and *P. pedicellatum* had similar values at 30, 60 and 90 DAS. However, at 120 and 150 DAS, *P. polystachyon* showed higher nitrogen content than *P. pedicellatum.*

Phosphorus content

The data on Phosphorus content in the plants at different stages are presented in Table 28. Between the species, the P content recorded at 30, 60 and 150 DAS were not significantly different. At 90 and 120 DAS significantly higher P values were recorded in *P. polystachyon* than *P. pedicellatum.*

Potassium content

The data on Potassium content in the plants at different stages are presented in Table 29. Both the *Pennisetum* spp. had similar potassium content at 30, 60 and 120 DAS. However, K content was significantly higher at 90 and 150 DAS in *P. polystachyon.* However, at 60 DAS, *P. pedicellatum* recorded higher value.

Table 26. Net assimilation rate of *P. polystachyon* and *P.pedicellatum* at different growth stages

Pennisetum spp.	Net assimilation rate (g^{-1} m^{-2} day^{-1})					Species mean
	0-30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	
P. polystachyon	2.53 (6.44)*	2.52 (6.38)	1.44 (2.10)	1.19 (1.48)	2.48 (6.40)	2.03 (4.56)
P. pedicellatum	2.58 (6.68)	2.44 (5.98)	1.26 (1.62)	1.11 (1.32)	2.58 (7.06)	1.99 (4.53)
Stages mean	2.56 (6.56)	2.48 (6.18)	1.35 (1.86)	1.15 (1.40)	2.53 (6.73)	

*Original values in parenthesis

SEm for species = 0.07 LSD (0.05) = NS
SEm for stages = 0.17 LSD (0.05) = 0.34
SEm for interaction = 0.23 LSD (0.05) = NS

Table 27. Nitrogen content in *P. polystachyon* and *P. pedicellatum* at different stages

Pennisetum spp.	Nitrogen (%)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	2.43	2.83	2.07	1.50	1.07
P. pedicellatum	2.45	2.74	1.88	1.43	0.95
SEm	0.05	0.22	0.16	0.02	0.05
LSD (0.05)	NS	NS	NS	0.06	0.14

Calcium and magnesium content

The data on Ca and Mg content in the plants are presented in Table 30 and 31. There was no significant difference in Ca and Mg content at 30 DAS between the species. At all other remaining stages, Ca and Mg values differed significantly. At these stages, *P. polystachyon* recorded higher Ca and Mg value than *P. pedicellatum*. *P. polystachyon* was superior in terms of Ca and Mg content.

Nitrogen uptake

The data on N uptake by the plants at different stages of growth are presented in Table 32. The species differed significantly only at 30 DAS. *P. pedicellatum* had more N uptake at this stage. It was almost equal in both the species at later stages of crop growth.

Phosphorus uptake

The data on P uptake are given in Table 33. The uptake was more in *P. pedicellatum* at 30 and 60 DAS. However, 90, 120 and 150 DAS P uptake did not differ significantly.

Potassium uptake

The data on K uptake are presented in Table 34. Potassium uptake was more in the case of *P. pedicellatum* at early stages of 30 and 60 DAS. However, between the species the uptake was not significant at 90, 120 and 150 DAS.

4.7 Fodder production potential

Fresh and dry weight of fodder at 70 DAS

The data on fresh and dry weight of fodder which were cut at 70 DAS are presented in Table 35. *P. pedicellatum* recorded more fresh weight than *P. polystachyon*. *P. pedicellatum* was superior in terms of fresh weight and dry weight. It produced a fresh fodder yield of 24.56 Mg ha^{-1} while *P. polystachyon*

Table 28. Phosphorus content in *P. polystachyon* and *P. pedicellatum* at different stages

Pennisetum spp.	Phosphorus (%)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	0.12	0.15	0.16	0.15	0.07
P. pedicellatum	0.13	0.15	0.12	0.11	0.06
SEm	0.002	0.002	0.002	0.002	-
LSD (0.05)	NS	NS	0.006	0.006	NS

Table 29. Potassium content in *P. polystachyon* and *P. pedicellatum* at different stages

Pennisetum spp.	Potassium (%)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	1.91	1.79	1.68	1.42	1.10
P. pedicellatum	1.86	1.81	1.38	1.29	1.00
SEm	0.02	0.04	0.06	0.06	0.03
LSD (0.05)	NS	NS	0.17	NS	0.08

Table 30. Calcium content in *P. polystachyon* and *P.pedicellatum* at different stages

Pennisetum spp.	Calcium (%)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	1.00	1.20	1.07	0.92	0.80
P. pedicellatum	0.86	0.98	0.93	0.74	0.60
SEm	0.07	0.05	0.04	0.02	0.01
LSD (0.05)	NS	0.12	0.10	0.06	0.02

Table 31. Magnesium content in *P. polystachyon* and *P.pedicellatum* at different stages

Pennisetum spp.	Magnesium (%)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	0.67	0.76	0.69	0.60	0.57
P. pedicellatum	0.62	0.67	0.60	0.83	0.50
SEm	0.02	0.02	0.01	0.02	0.02
LSD (0.05)	NS	0.06	0.02	0.06	0.06

Table 32. Nitrogen uptake by *P. polystachyon* and *P.pedicellatum* at different growth period

Pennisetum spp.	Nitrogen uptake (kg ha^{-1})				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	0.84	5.08 (26.71)*	6.35 (41.02)	44.95	49.64
P. pedicellatum	1.60	6.74 (46.92)	6.88 (48.29)	44.23	45.28
SEm	0.20	0.64	0.44	4.80	1.96
LSD (0.05)	0.54	NS	NS	NS	NS

*Original values in parenthesis

Table 33. Phosphorus uptake by *P. polystachyon* and *P.pedicellatum* at different growth period

Pennisetum spp.	Phosphorus uptake (kg ha^{-1})				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	0.04 (0.2)*	1.33	3.12	4.32	2.72
P. pedicellatum	0.08 (0.29)	2.37	3.03	3.32	2.59
SEm	0.02	0.18	0.32	0.61	0.28
LSD (0.05)	0.06	0.49	NS	NS	NS

*Original values in parenthesis

Table 34. Potassium uptake by *P. polystachyon* and *P.pedicellatum* at different growth period

Pennisetum spp.	Potassium uptake (kg ha^{-1})				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
P. polystachyon	0.67	16.54	32.66	40.7	50.61
P. pedicellatum	1.23	29.79	34.15	36.90	46.08
SEm	0.16	3.12	1.94	3.78	2.85
LSD (0.05)	0.45	8.66	NS	NS	NS

Table 35. Fresh and dry weight of fodder in *P. polystachyon* and *P.pedicellatum* at 70 DAS

Pennisetum spp.	Fresh weight (Mg ha^{-1})	Dry weight (Mg ha^{-1})
P. polystachyon	11.76	2.51
P. Pedicellatum	24.56	4.94
SEm	1.23	0.23
LSD (0.05)	2.56	0.49

produced 11.76 Mg ha^{-1} only. Dry weight behaved in the manner similar to fresh weight.

Fresh weight and dry weight of fodder after the first cut

The data on fresh weight and dry weight of fodder got after 70 DAS are presented in Table 36. Fresh weight of fodder in both *Pennisetum* spp. did not differ significantly. *P. pedicellatum* produced a fodder yield of 19.20 Mg ha^{-1} and *P. polystachyon* 18.57 Mg ha^{-1}. Cutting intervals had significant effect on fodder yield. Single cut just before flowering (51 days after the first cut) recorded maximum fresh weight of fodder followed by cutting at 45 days interval. The lowest value was recorded in cutting at 30 days interval. Interaction effect was not significant. Dry weight of fodder followed the same trend as that of fresh weight.

Total fresh and dry weight of fodder

The data on total fresh and dry weight of fodder are presented in Table 37. In terms of total fresh fodder yield, *Pennisetum* spp. differed significantly. *P. pedicellatum* yielded more fresh weight of fodder (45.06 Mg ha^{-1}) than *P. polystachyon* which recorded only 32.4 Mg ha^{-1}. Among cutting intervals, single cut recorded more fresh weight followed by cutting at 45 days interval. The lowest fodder yield was recorded when cuttings were given at 30 days interval, though this was on par with cutting at 45 days interval. The interaction effect was not significant.

P. pedicellatum recorded higher total plant dry weight (8.55 Mg ha^{-1}) than *P. polystachyon* (5.97 Mg ha^{-1}). Cutting intervals also differed significantly. Single cut recorded the highest dry weight followed by cutting at 45 days interval. The lowest total plant dry weight was observed when cuttings were given at 30 days interval. Interaction effect was not significant.

Table 36. Fresh and dry weight of fodder in *P. polystachyon* and *P. pedicellatum* after the first cut

Pennisetum spp.	Fresh weight (Mg ha^{-1})				Dry weight (Mg ha^{-1})			
	30 days	45 days	Single cut	Species Mean	30 days	45 days	Single cut	Species Mean
P. polystachyon	13.22	20.30	22.20	18.57	1.93	3.12	4.30	3.1
P. pedicellatum	13.93	21.10	22.60	19.20	1.98	3.58	4.70	3.4
Intervals Mean	13.58	20.68	22.37		1.96	3.35	4.50	

SEm for species	- 0.89	LSD (0.05)	- NS		SEm for species	- 0.30	LSD (0.05)	- NS
SEm for intervals	- 1.10	LSD (0.05)	- 2.82		SEm for intervals	- 0.37	LSD (0.05)	- 0.77
SEm for interaction	- 1.55	LSD (0.05)	- NS		SEm for interaction	- 0.52	LSD (0.05)	- NS

Table 37. Total fresh weight and dry weight of fodder in *P. polystachyon* and *P. pedicellaum*

Pennisetum spp.	Fresh weight (Mg ha^{-1})				Dry weight (Mg ha^{-1})			
	30 days	45 days	Single cut	Species Mean	30 days	45 days	Single cut	Species Mean
P. polystachyon	31.64	31.82	33.72	32.40	5.54	5.60	6.80	5.97
P. pedicellatum	42.45	45.62	47.10	45.06	7.46	8.53	9.66	8.55
Intervals Mean	37.05	38.72	40.41		6.50	7.07	8.22	

SEm for species	- 0.99	LSD (0.05)	- 2.06	SEm for species	- 0.29	LSD (0.05)	- 0.61	
SEm for intervals	- 1.21	LSD (0.05)	- 2.53	SEm for intervals	- 0.36	LSD (0.05)	- 0.74	
SEm for interaction	- 1.71	LSD (0.05)	- NS	SEm for interaction	- 0.50	LSD (0.05)	- NS	

Quality of fodder

Nutrient composition such as crude protein, crude fibre and ash content of fodder harvested at 70 days after sowing are presented in Table 38. The data for subsequent harvests according to different cutting intervals are presented in Table 39.

Crude protein

The crude protein content of fodder harvested at 70 DAS did not differ significantly among *Pennisetum* spp. *P. polystachyon* had 14.56 per cent and *P. pedicellatum* 13.37 per cent crude protein. Crude protein content of fodder from subsequent cuts was not significantly different between species. *P. pedicellatum* had 11.41 per cent and *P. polystachyon* had 10.93 per cent crude protein. Cutting intervals influenced the crude protein content. Cutting the fodder at 30 days interval recorded the highest crude protein content. The least value was observed in single cut followed by cut at 45 days interval. Interaction was not significant.

Crude fibre

The species differed significantly in terms of crude fibre content at 70 DAS. *P. pedicellatum* had a higher crude fibre content (34.29%) than *P. polystachyon* (29.38%). Crude fibre content of fodder from subsequent cuts differed significantly. *P. pedicellatum* contained (34.09%) more crude fibre than *P. polystachyon* (32.51%). Cutting intervals also significantly influenced crude fibre content. Cutting at 45 days interval recorded more crude fibre content followed by single cut. The lowest value was observed in cutting at 30 days interval. Interaction effect was not significant.

Ash content

Both the species recorded similar ash content when analysed at 70 DAS. *P. polystachyon* had 9.38 per cent and *P. pedicellatum* had 9.39 per cent ash content. In the later harvests also ash content was not significantly different.

Table 38. Fodder quality of *P. polystachyon* and *P.pedicellatum* at 70 DAS

Pennisetum spp.	Crude protein (%)	Crude fibre (%)	Ash content (%)
P. polystachyon	14.56	29.38	9.38
P. Pedicellatum	13.37	34.29	9.39
SEm	0.80	0.61	0.56
LSD (0.05)	NS	1.28	NS

Table 39. Effect of cutting intervals on fodder quality of *P. polystachyon* and *P.pedicellatum*

Treatments	Crude protein (%)	Crude fibre (%)	Ash content (%)
A. *Pennisetum* spp.			
I. *P. polystachyon*	10.93	32.51	10.74
2. *P. Pedicellatum*	11.41	34.09	10.57
SEm	0.85	0.62	0.90
LSD (0.05)	NS	1.29	NS
B. Cutting intervals			
30 days	12.83	31.06	12.45
45 days	10.43	35.69	11.43
Single cut	10.21	33.15	8.09
SEm	1.04	0.76	1.11
LSD (0.05)	2.18	1.58	2.30
Interaction			
SEm	1.48	1.07	1.56
LSD (0.05)	NS	NS	NS

P. polystachyon had 10.74 per cent and *P. pedicellatum* 10.57 per cent ash. Cutting intervals affected the ash content. The highest ash value was noted in cutting at 30 days interval and the lowest value in single cut. Interaction effect was not significant.

DISCUSSION

5. DISCUSSION

The results of various trials conducted on the Comparative biology and growth behaviour of *P. polystachyon* (L.) Shult. and *P. pedicellatum* Trin. are discussed in this chapter.

5.1 Studies on seed dormancy

The results suggest that seed dormancy exist in *Pennisetum polystachyon* and *P. pedicellatum* (Table 2). The dormancy seems to be season oriented. Seasonal changes in the percentage of germinating seeds appear fairly common in weeds (Baskin and Baskin, 1980). *P. polystachyon* recorded 42 per cent germination in December end and 85 per cent germination in March end. In this species, dormancy seems to be over by this month. It seems, *P. pedicellatum* seeds remain dormant for a longer period than *P. polystachyon*. Seeds of *P. pedicellatum* kept for germination in December did not germinate at all. However, those kept for germination in February beginning, had 58.0 per cent germination. However, both species showed above 80 per cent germination in late March. Since the germination percentage is less in the succeeding month, it could be assumed that its viability is getting lost after March-April. Premadasa and Amarasinghe (1982) reported that initial and maximum time of seed germination of *P. polystachyon* were in March and April. Kiatsoonthorn (1991) reported 90 per cent germination in 2-4 months time. He also reported that germination declined after four months to 28 per cent. Under natural conditions, seeds of any origin become germinable in spring. The increase in germination percentage can be ascribed to a favourable season. Maximum percentage of germination was obtained in both the species during March and April. The dormancy present in *P. polystachyon* and *P. pedicellatum* suggests its ecological significance in its survival. Maximum germination in these two species almost coincide with the receipt of pre-monsoon showers in April-May.

5.2 Life cycle and seed characters of *Pennisetum* spp.

Germination in both *Pennisetum* species started after the receipt of pre-monsoon showers during the last week of April. First rainfall of the season was received on 21.4.99. The process of germination is mainly dependant on the receipt of rainfall (Appendix-I). Seeds of *Pennisetum* spp. were found to overcome dormancy by this period (Table 2). However, maximum germination was observed during May. By this time, good amount of rains were received. In the sample plants vegetative growth took place from May and continued up to late September (Table 3). Flowering started after the sessation of heavy rains in September. The other phases such as seed formation and maturation were completed by the month of November (Fig. 4). The plants started drying mid November in *P. pedicellatum* and by mid December in *P. polystachyon*. *P. polystachyon* took more time for completing the phases and drying, may be due to its high persistence and perennial nature. A single plant of *P. polystachyon* could produce 15 panicles per plant yielding 7520 spikelets per plant. The mean seed output per plant was 5439. That means, some of the spikelets contain immature or no seeds. The thousand seed weight of *P. polystachyon* was 0.38 g. Compared to *P. polystachyon*, *P. pedicellatum* produced more panicles than *P. polystachyon*. Mean number of panicles per plant was 21 in *P. pedicellatum*, while it was only 15 in *P. polystachyon*. *P. pedicellatum* produced 2248 spikelets per plant and produced 1787 seeds per plant. Seed weight of *P. pedicellatum* was almost double that of *P. polystachyon*, thousand seed weight being 0.64 g. The reproductive capacity, which was calculated by multiplying mean seed output with percentage germination was high in the case of *P. polystachyon* than that of *P. pedicellatum*.

5.3 Regeneration ability

P. polystachyon and *P. pedicellatum* behaved similarly with respect to the mean percentage of plants regenerated per m^2 (Table 4) after one month of receipt of rainfall. This indicates that both the *Pennisetum* spp. have remarkable regeneration ability. Cutting at different heights did not influence the number of

1. Time of germination
2. Vegetative growth
3. Flowering
4. Seed formation
5. Seed maturation
6. Senescence

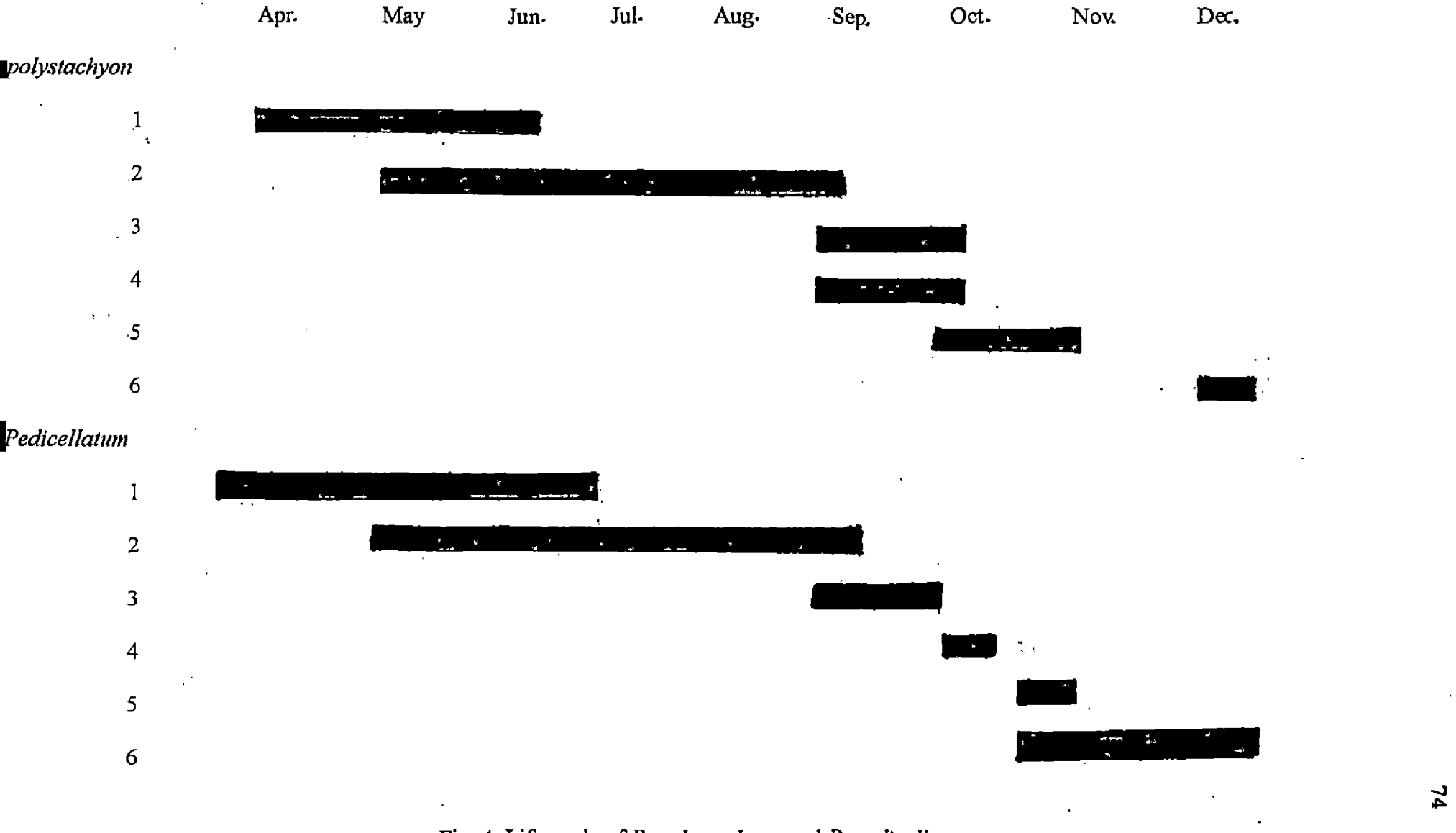
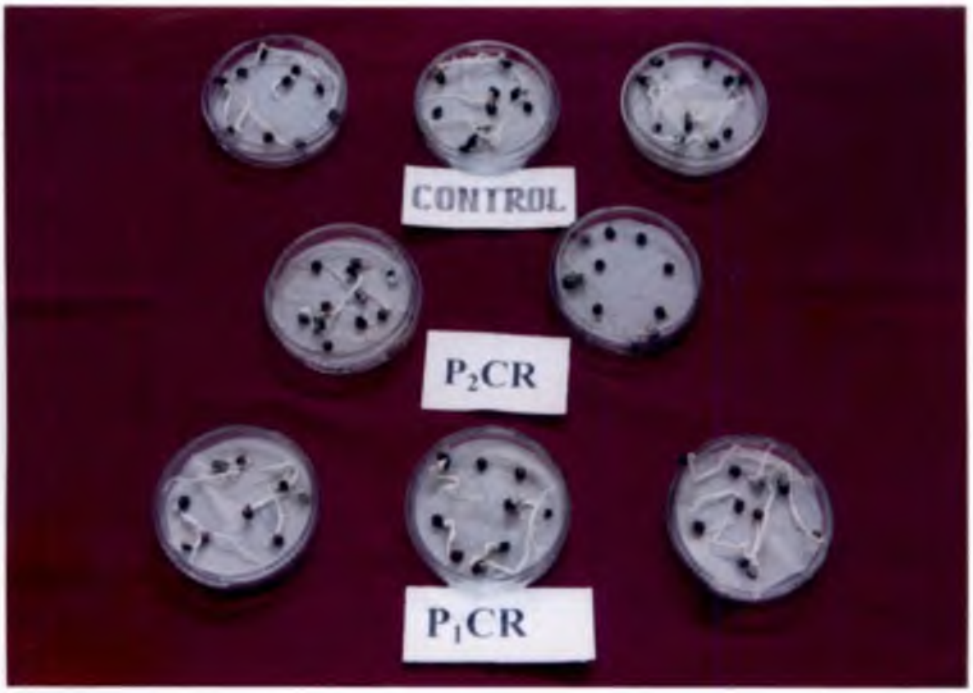


Fig. 4. Life cycle of *P. polystachyon* and *P. pedicellatum*

Plate 9. Allelopathic influence on germination of Bhindi

P1CR – *P. polystachyon* cold root extract

P2CR – *P. pedicellatum* cold root extract


CONTROL
P2CR
P1CR

plants regenerated. Perennial grasses like *Imperata cylindrica* and *Agropyron repens*, which propagate through rhizomes have the ability to regenerate even from a small piece of rhizome tissue (Rao, 1986). However, cutting height did influence fresh weight of the grass. The plants, which were cut at 10 cm above ground level, and plants retained as such, recorded maximum fresh weight of sprouts and were on par (Table 4). The fresh weight of the regenerated sprouts from cut given at 5 cm level was the lowest. This may be due to the availability of more food materials from retained portions which encourages early regeneration and early growth. As Chattrjee and Das (1989) explained, the energy for regrowth is provided by substances stored in the reserve organs to which photosynthates have been transferred. The growing points began to develop using the energy supplied by these reserves. *Cirsium arvense* uses carbohydrate reserves in its roots for early above ground growth (Hodgson, 1968).

5.4 Allelopathic effects

Leaf extracts

The cold and boiled leaf extracts of both species did not have any influence on germination of bhindi, cucumber and cowpea (Table 5 and Fig. 5). Cowpea showed very low germination on the second day in all the treatments compared to other crops. However, after five days, it also showed good germination in all the treatments. It seems two days are not enough to get consistent values of germination for the cowpea. It seems leaf extracts have no influence on the germination percentages in any of the crops. However, all the extracts inhibited root and shoot growth of test crops (Table 8 and Fig. 8). Saxena and Varshney (1995) reported almost similar results from *Cyperus* extract on chickpea germination and shoot and root lengths. Singh *et al.* (1988) reported that boiled and unboiled extracts of *E. crusgalli* inhibit the shoot length of rice. The depressing effect noted in the present experiments can be ascribed to the presence of allelopathic chemicals in the leaf extracts.

Root extracts

Germination percentage of bhindi noted after 48 hours and 120 hours showed significant differences (Table 6 and Fig. 6). Germination percentage was lower in the case of seeds treated with cold root extract of *P. polystachyon* and

Fig. 5 Allelopathic effect of *Pennisetum* spp. leaf extracts on germination of bhindi, cucumber and cowpea

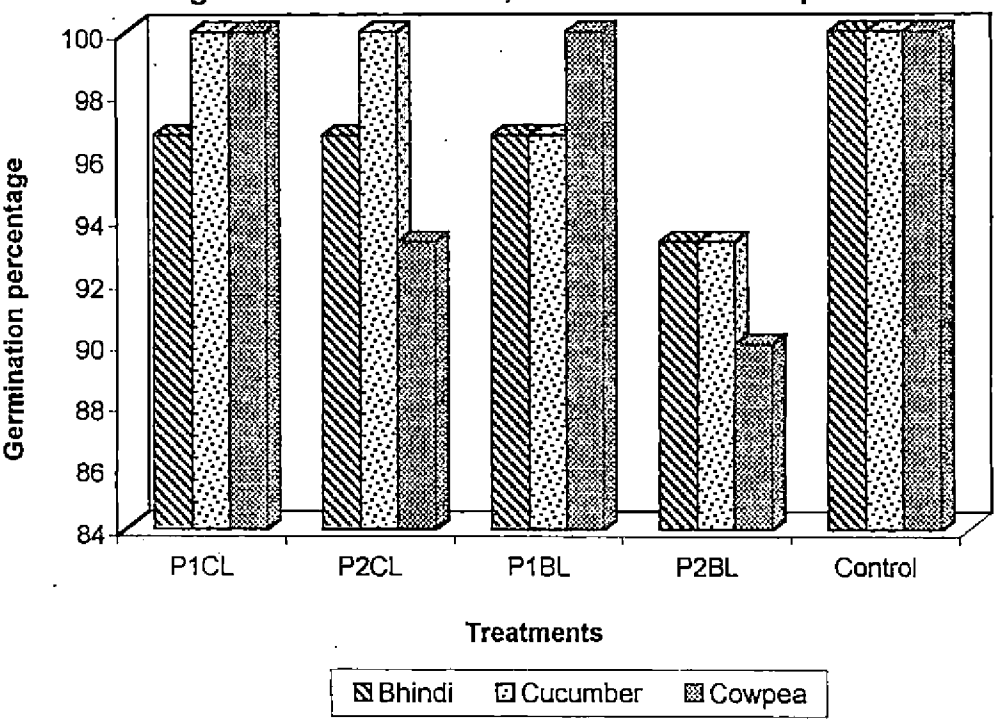


Fig. 6 Allelopathic effect of *Pennisetum* spp. root extracts on germination of bhindi, cucumber and cowpea

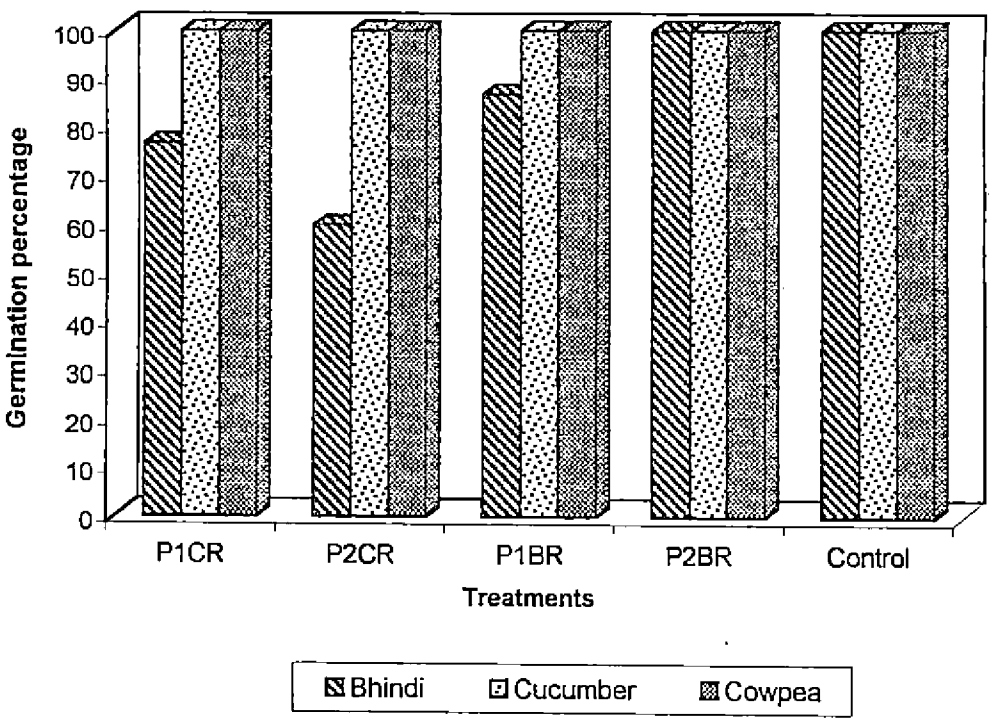


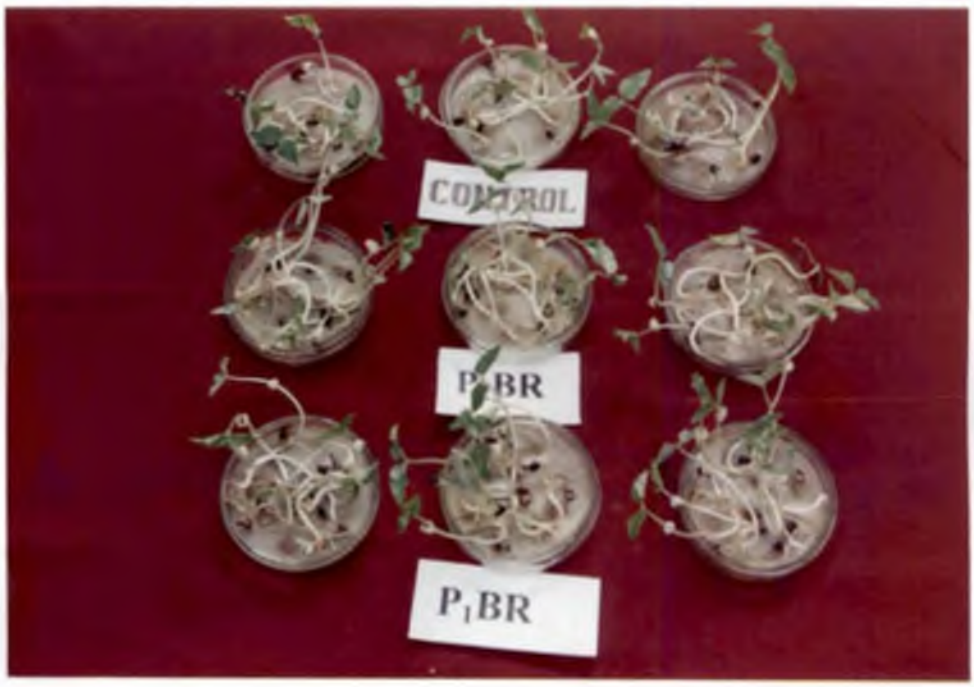
Plate 10. Allelopathic influence on shoot and root growth of Cowpea

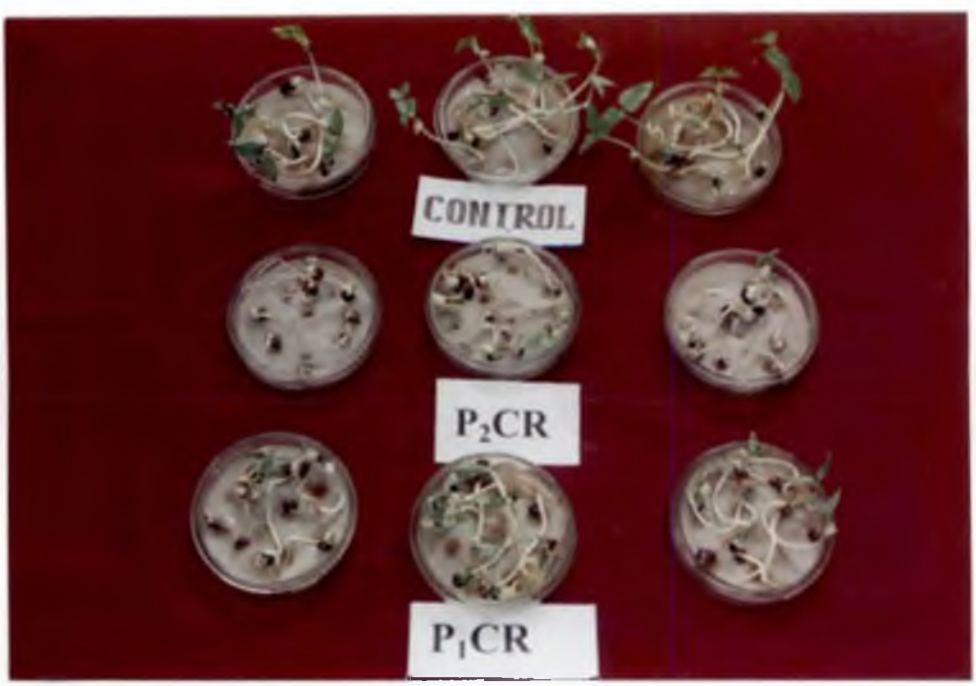
P1BR – *P. polystachyon* boiled root extract

P2BR – *P. pedicellatum* boiled root extract

P1CR – *P. polystachyon* cold root extract

P2CR – *P. pedicellatum* cold root extract


CONTROL
P2BR
P1BR


CONTROL
P2CR
P1CR

P. pedicellatum. However, the boiled root extract of *P. pedicellatum* completely inhibited the shoot and root length of bhindi (Table 9 and Fig. 9). Other extracts also showed inhibitory effect. Though root extracts did not have any influence on the germination percentage of cowpea and cucumber, shoot length was more in cowpea treated with cold root extracts of *P. polystachyon* and *P. pedicellatum*. At the same time, boiled root extracts of both species had inhibitory effect. It seems cold root extracts of *Pennisetum* spp. had some growth promotery effect on shoot length of cowpea. This kind of differences in behaviour are aplenty in literature Singh *et al.* (1988) found promotery effect on shoot length of wheat due to boiled extract of *Sorghum halepense* and inhibitory effect when unboiled extract was used. Oudhia and Tripathi (1997) reported promotery effect on germination and root length of soybean due to root extracts of *Calotropis gigantia*. In cucumber, though all the extracts did not show any effect on shoot length, root length was reduced.

Seed extracts

Germination percentages of bhindi, cucumber and cowpea showed significant difference after 48 hours and found to be reduced by all the extracts. However, after six days, germination percentage was almost similar in all the treatments in bhindi and cucumber (Table 7 Fig. 7.). In cowpea, significant differences were observed in germination percentage. It seems seed extracts are having some inhibitory effect on cowpea germination. Seed extracts of *Pennisetum* spp. had significant influence on shoot and root length of all the test crops and it was reduced in both cold and boiled extracts (Table 10 and Fig. 10).

It is evident from the above, that different crops respond differently to the same allelochemical. Some may even have a promotery role. In this respect extracts from different parts of *Pennisetum* spp.-leaf, root and seed, behaved differently; which means, the real worth of an allelochemical can be considered taking in to consideration the totality of its effects.

Fig. 7 Allelopathic effect of *Pennisetum* spp. seed extract on germination of bhindi, cucumber and cowpea

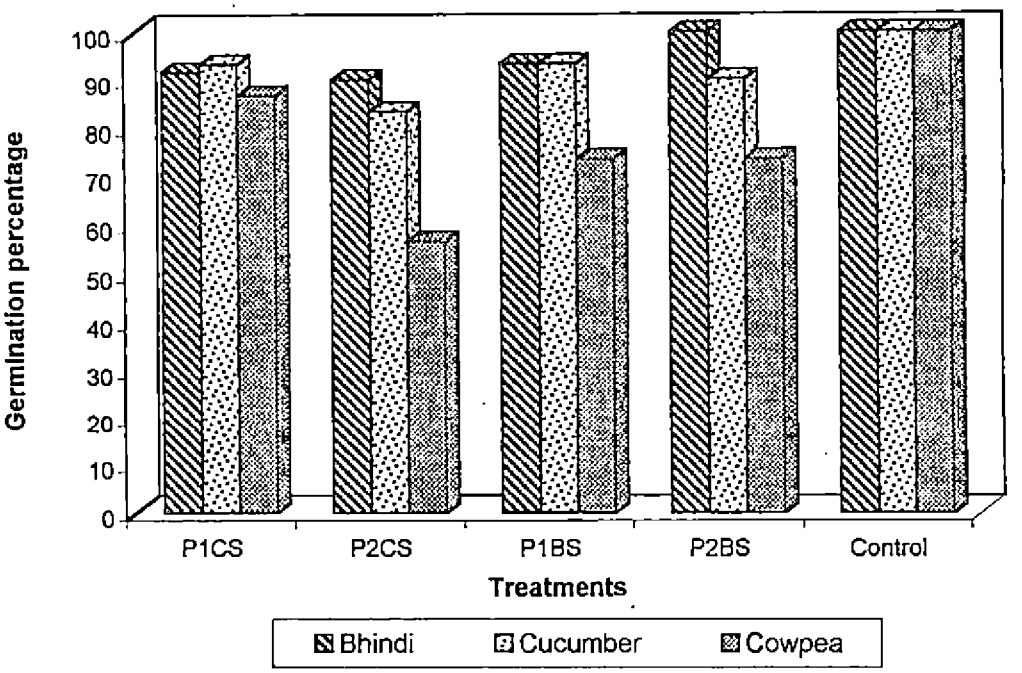


Fig. 8 Allelopathic effect of *Pennisetum* spp. leaf extracts on shoot and root length of test crops

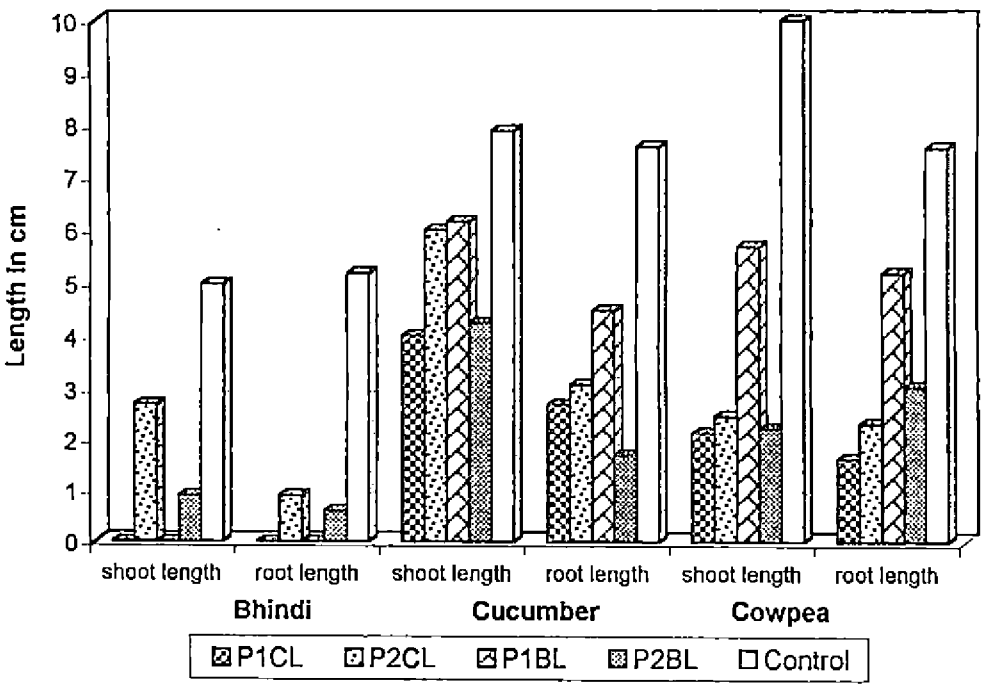


Fig. 9 Allelopathic effect of *Pennisetum* spp. root extracts on sooht and root length of test crops

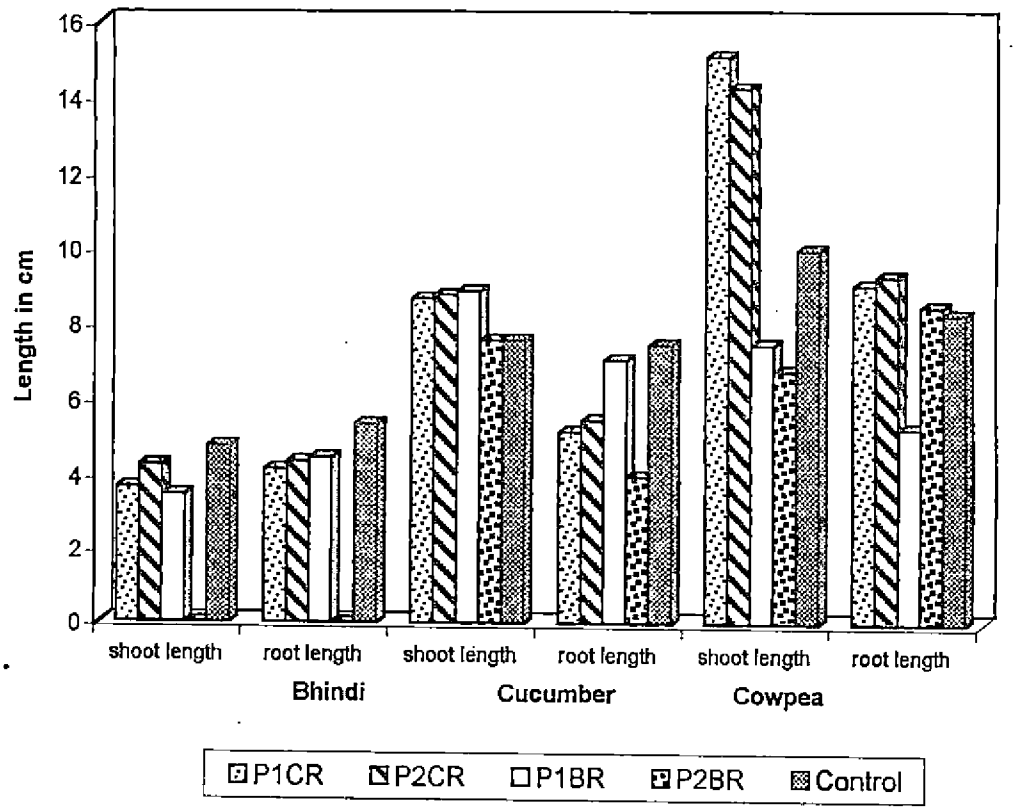
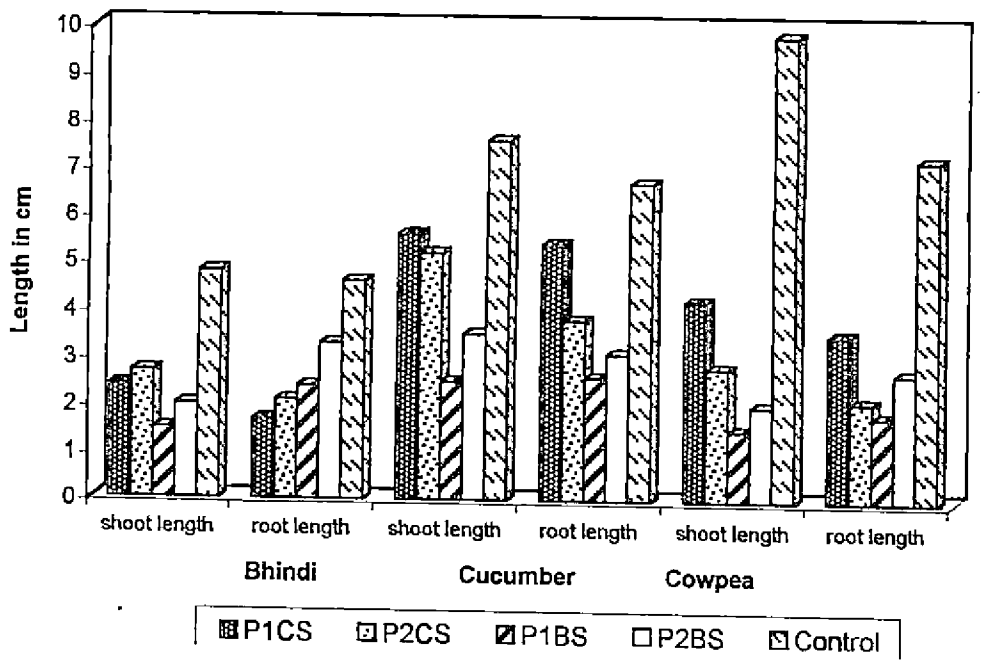


Fig.10 Allelopathic effect of *Pennisetum* spp. seed extract on shoot and root length of test crops



5.5 Comparative growth analysis

Compared to *P. polystachyon*, growth in *P. pedicellatum* was more rapid in the early stages. *P. pedicellatum* recorded more height up to 120 DAS (Fig 11). However, by the end of the experiment (150 DAS), both were having similar heights. Increase in height from 60 to 90 and 90 to 120 DAS followed almost separate patterns in both species. In *P. polystachyon*, the increase from 60 to 90 DAS was 40.6 per cent and from 90 to 120 DAS it was 152 per cent; while it was 104.8 and 43.2 per cent respectively for *P. pedicellatum*. This might be because the floral primordia elongation taking place at different time for the species. *P. pedicellatum* come to flower earlier than *P. polystachyon* under field condition.

In the case of leaf number, higher number of leaves were produced by *P. pedicellatum* up to 60 DAS; by 90 DAS, *P. polystachyon* was having more number of leaves and later, leaf numbers were non-significant (Fig 12). In the case of leaf length, a higher value was shown by *P. pedicellatum* up to 90 DAS; by 120 DAS, *P. polystachyon* had longer leaves and by 150 DAS, leaf lengths were similar (Table 13). *P. pedicellatum* had its peak leaf length at 90 DAS (47.84 cm) and *P. polystachyon* had its peak leaf length at 120 DAS (49.02 cm). In the case of leaf breadth also, it was more up to 90 DAS in *P. pedicellatum* (Table 14). Thereafer, leaf breadths in both species were similar. Maximum leaf breadth for *P. pedicellatum* was at 60 DAS (1.56 cm) and for *P. polystachyon* it was at 120 DAS (1.38 cm). Leaf length and breadth began to decline by 90 DAS in the case of *P. pedicellatum* and by 120 DAS in the case of *P. polystachyon*. The declining values of length and breadth can be ascribed to the senescence of earlier produced leaves and the fact that later producing leaves are smaller in size.

Regarding total plant fresh weight, *P. pedicellatum* had higher values up to 90 DAS and thereafter *P. polystachyon* recorded higher values (Table 17). Both species recorded peak fresh weight values at 90 DAS and thereafter declined. Dry

Fig. 11 Height of *P. polystachyon* and *P. pedicellatum* during the growth period

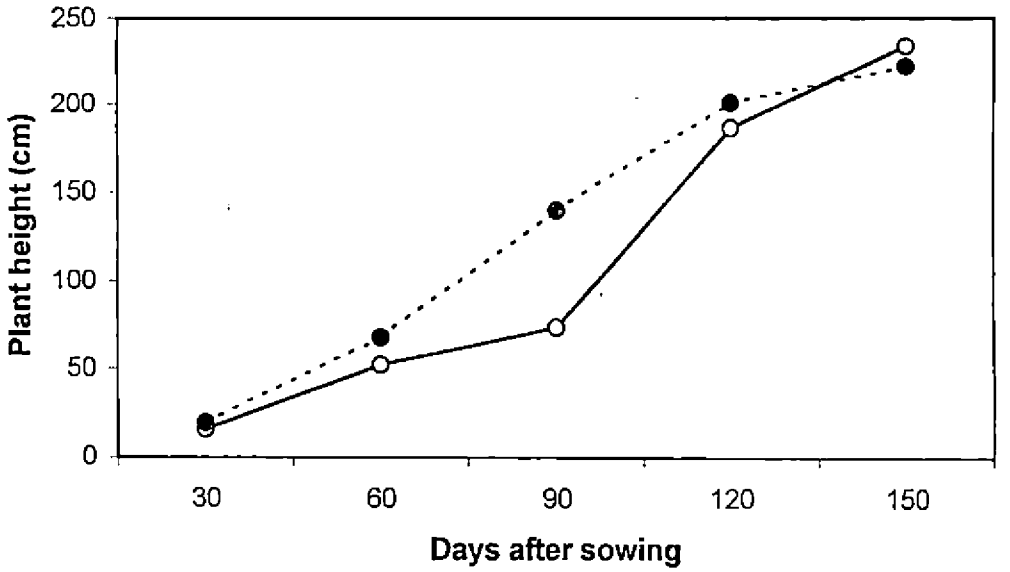
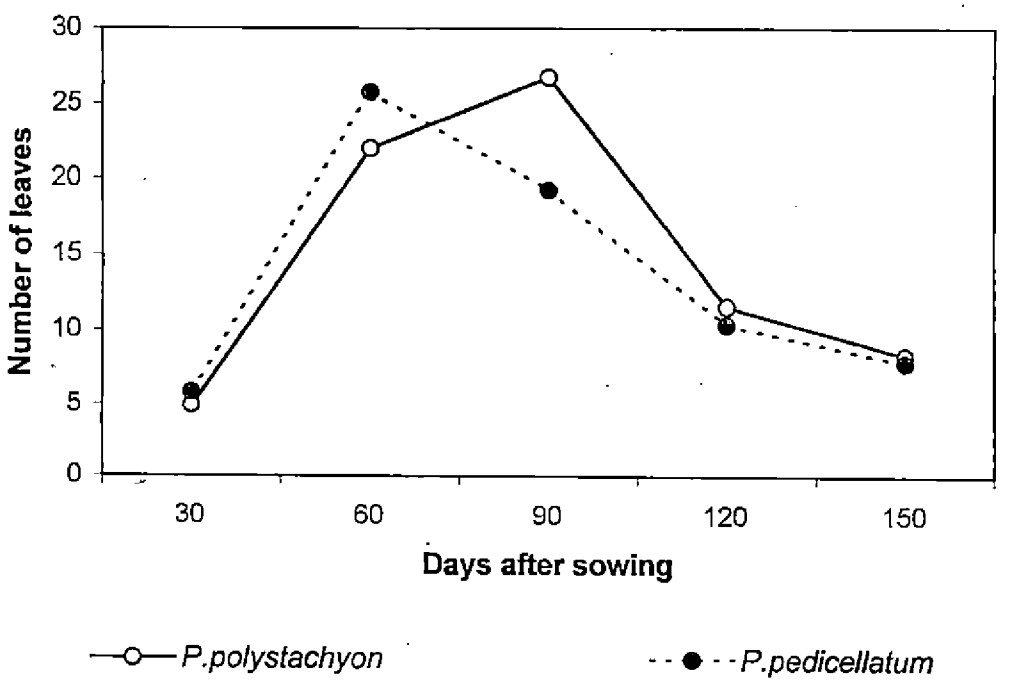


Fig. 12 Number of leaves of *P. polystachyon* and *P. pedicellatum* at different stages



weight values, however, showed a gradual increase in both species until the last observation. However, up to 90 DAS, *P. pedicellatum* showed higher dry weight. Later, they behaved similarly. Stem fresh weight showed an increasing trend until last observation in both species. However, *P. pedicellatum* had more stem weight at 60 DAS and non-significant values at 90, 120 and 150 DAS. In the case of leaf weight at 60 DAS, it was more in *P. pedicellatum* and at 90 DAS, the trend reversed and it was more in *P. polystachyon*. In all the later stages, though the differences were non-significant at 90 DAS. Leaf dry weight followed the same trend as that of leaf fresh weight (Fig 13). *P. pedicellatum* had higher leaf area up to 60 DAS. At 90 DAS, it was equal in both species. *P. polystachyon* recorded higher value at 120 DAS. During later stages, both the species recorded similar leaf area (Fig 14).

In general *P. polystachyon* is showing a slow initial growth compared to *P. pedicellatum*. This is evident from the values of LAD and RGR (Tables 23 and 25).

P. polystachyon recorded a higher leaf:stem ratio than *P. pedicellatum* at all the stages (Fig 15). Both species had the maximum leaf:stem ratio at 60 DAS, which declined thereafter. The decline in the leaf:stem ratio was steep in the case of *P. pedicellatum*, which dropped from 1.44 at 60 DAS to 0.59 at 90 DAS. However, *P. polystachyon* remained leafy at 60 and 90 DAS and then only the ratio declined. Later stages recorded less leaf:stem ratio due to the senescence of leaves. Leaf:stem ratio indicates the succulence of the herbage. A high leaf:stem ratio means better palatability by animals (Jayanthi *et al.*, 1996). Rathore and Vijayakumar (1977) reported significant decrease in leaf:stem ratio due to more N uptake in fodder sorghum and deenanath grass.

Leaf area ratio is a measure of relative leafiness of a plant. The ratio of photosynthesising tissues to the total respiring tissues give an indication how a system is efficient in growth. Both *Pennisetum* spp. were similar in LAR (Fig 16).

Fig. 13 Distribution pattern of stem and leaf dry weight of *P. polystachyon* and *P. pedicellatum* at different stages

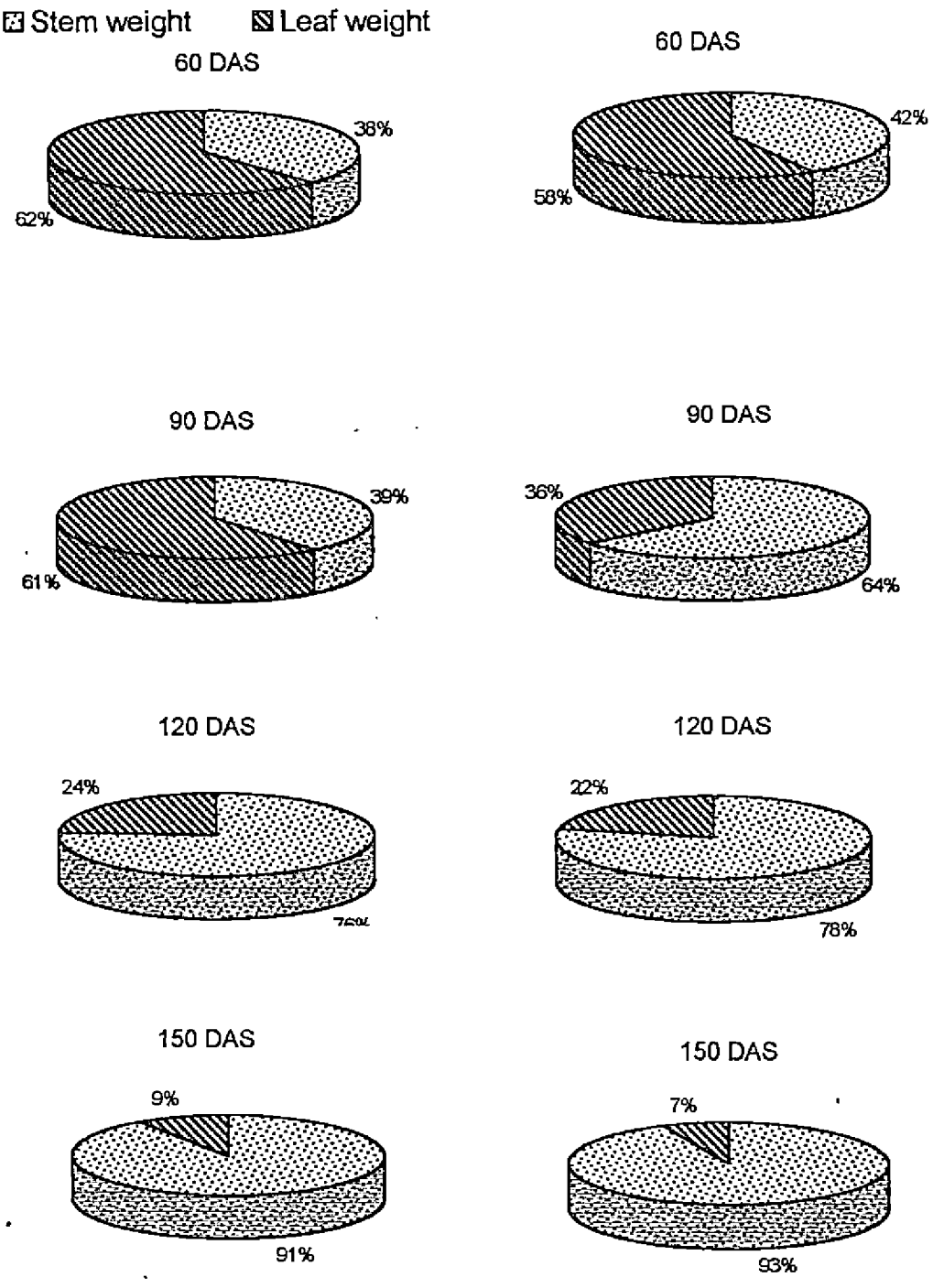


Fig.14 Leaf area per plant of *P. polystachyon* and *P. pedicellatum* at different growth stages

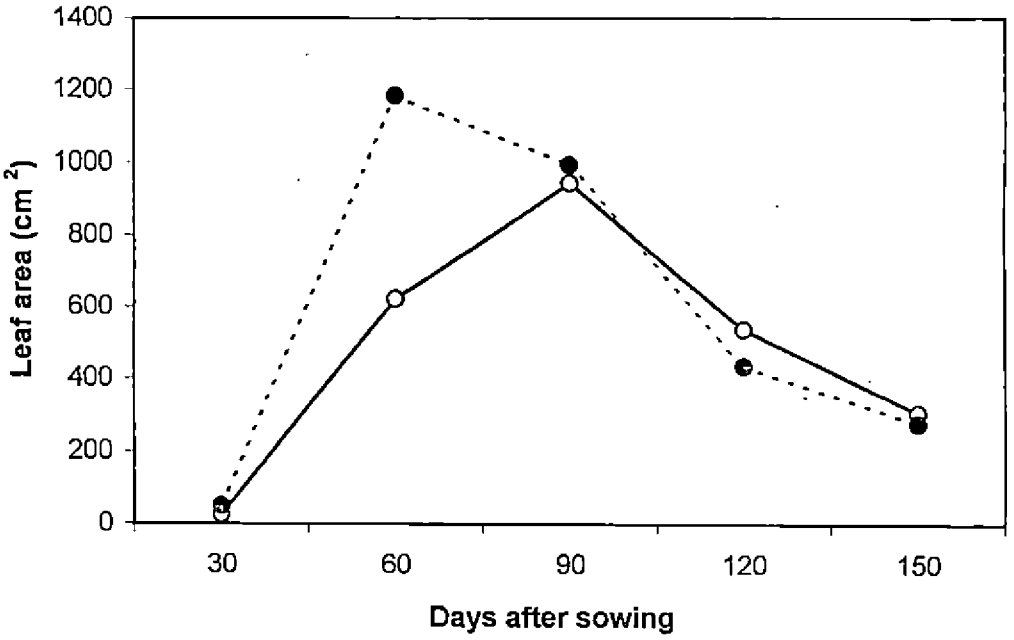
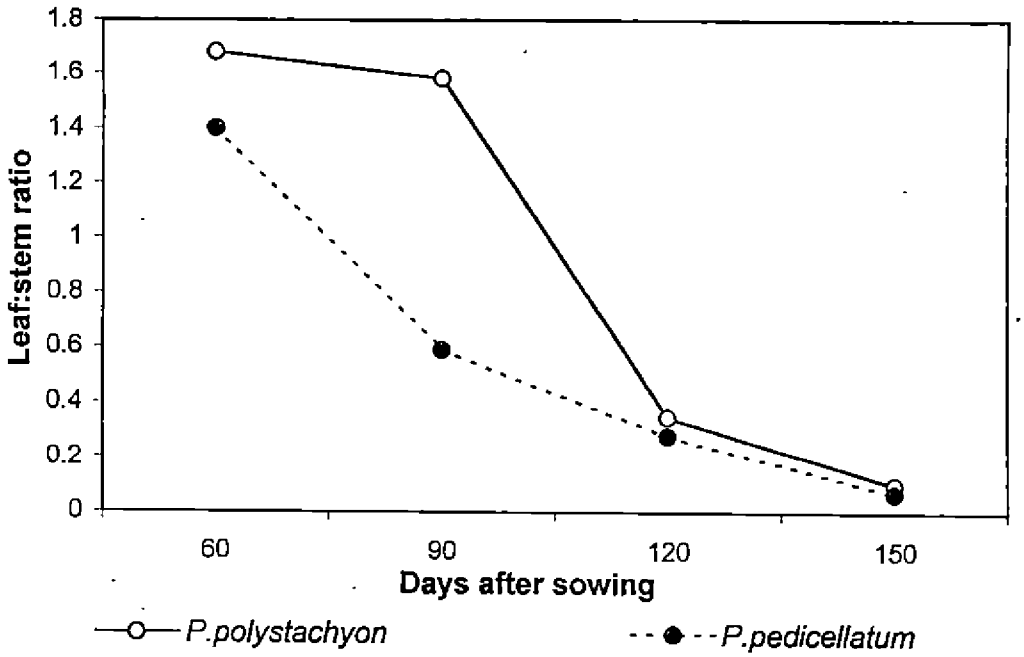


Fig.15 Leaf:stem ratio of *P. polystachyon* and *P. pedicellatum* at different growth stages



However, LAR values declined with time. Maximum LAR was at 30-60 DAS and minimum at 120-150 DAS. As plants grow, the proportion of purely structural material increases and hence a decline in LAR.

Leaf weight reflects the thickness of a leaf. Thickness of leaf is an important character in relation to the boundary layer and aerodynamic resistances (Dhopte and Livera, 1989). These are important in the adaptation of a species to an environment such as temperature tolerance, drought resistance etc. LWR, which is the ratio of leaf weight per unit total plant dry weight was higher in *P. polystachyon* than *P. pedicellatum* only at 90 DAS. In both species, LWR (Table 21 and Fig. 17) was higher in the early stages and declined gradually. However, specific leaf area which is the leaf area per unit leaf dry weight differed between the species at all the stages. *P. pedicellatum* is having high mean SLA (Table 22). There was also a gradual decline in SLA from early stages to later stages (Fig. 18). From this, it could be concluded that leaf thickness is high in *P. polystachyon* than *P. pedicellatum*. Similarly, leaf thickness increases upon ageing.

Leaf area duration (LAD) expresses the magnitude and persistence of leaf area during the period of plant growth. It takes into account both the duration and extent of photosynthetic tissues of the plant canopy. As Gardner *et al.* (1985) stated LAD is correlated to dry matter yield and gives an indication of plant productivity. Mean LAD was higher in *P. pedicellatum* indicating a higher productivity than *P. polystachyon*. Though it was superior to *P. polystachyon* only at 30-60 and 60-90 DAS, it is reflected on the final yield, as these periods are crucial vegetative and reproductive phases. LAD varied between stages. It was low in the beginning, topped by 60-90 DAS and then declined (Fig.19).

Absolute growth rate is a simple measure of rate of increase in dry weight of a plant per unit time. With respect to AGR, *Pennisetum* spp. behaved similarly at all the stages (Table 24 and Fig 20). However, both species were

Fig. 16 Leaf Area Ratio of *P. polystachyon* and *P. pedicellatum* at different growth stages

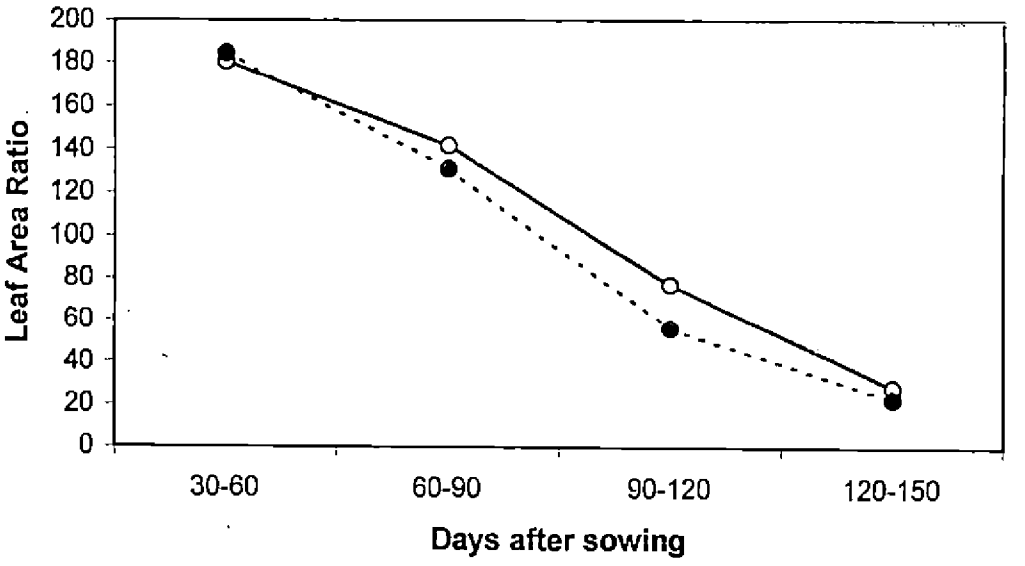


Fig. 17 Leaf Weight Ratio of *P. polystachyon* and *P. pedicellatum* at different growth stages

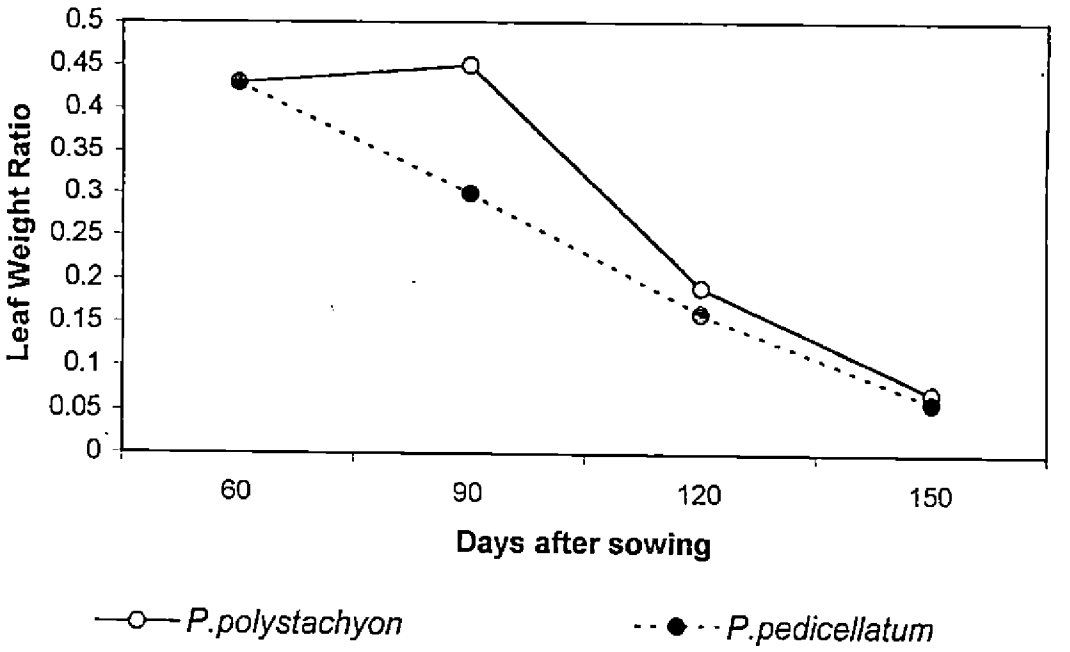


Fig. 18 Specific Leaf Area of *P. polystachyon* and *P. pedicellatum* at different growth stages

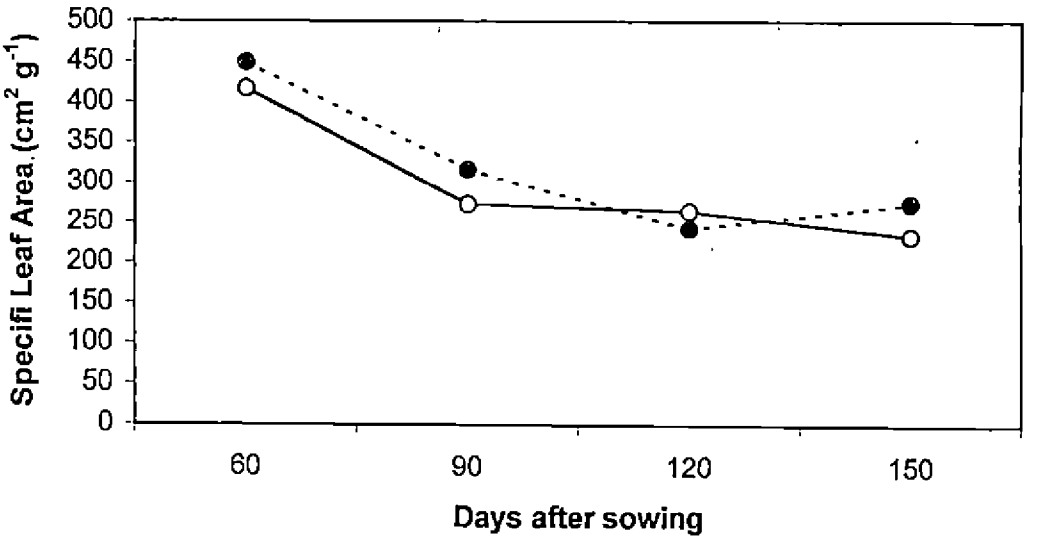
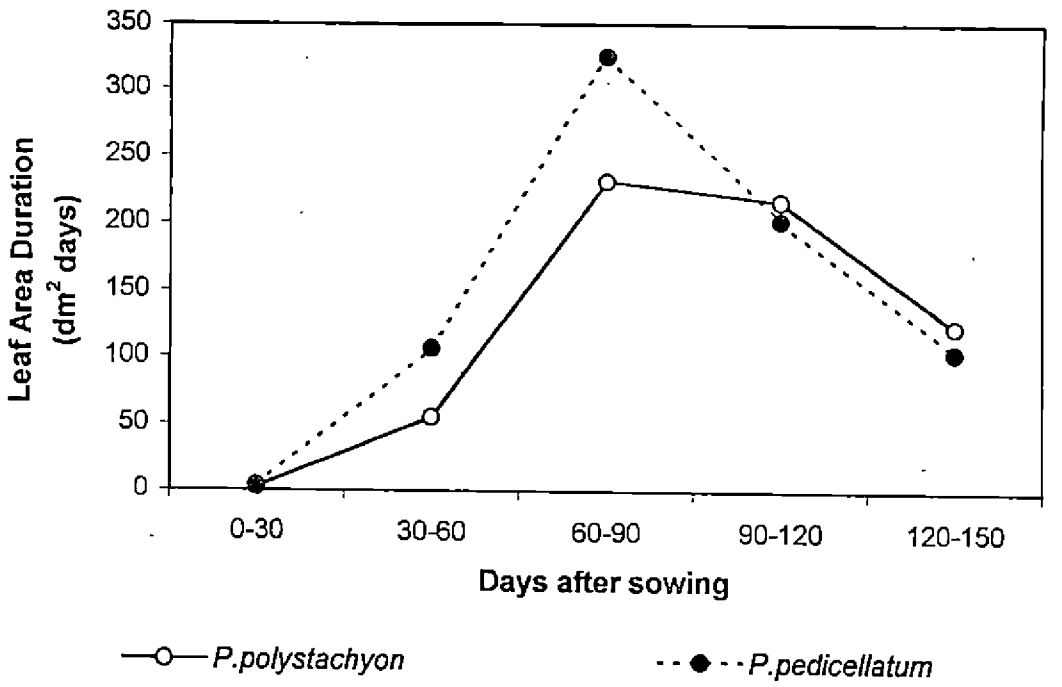


Fig. 19 Leaf Area Duration of *P. polystachyon* and *P. pedicellatum* at different growth stages



having maximum AGR during 120-150 DAS and 30-60 DAS. These two stages coincide with reproductive growth and vegetative growth which witnessed rapid increase in dry weight (Table 17).

Relative growth rate is the dry weight increase in a time interval in relation to its initial weight. The mean RGR values of both *Pennisetum* spp. were similar in all the stages of observation (Table 25). RGR was high in the early stages, declined in the middle stages and then again increased (Fig 21). According to Gardner *et al.* (1985), RGR of crop plants begins slowly just after germination, peaks rapidly soon afterwards and then falls off. Wall (1995) in the case of wild, ball and dog mustard observed that RGR was greatest shortly after seedling emergence and declined throughout plant growth. However, in the case of *Pennisetum* spp., there was a rapid increase in stem weight (Table 15), and total plant dry weight (Table 20) between the stages of 120 DAS and 150 DAS, which reflected in a high RGR.

Net assimilation rate is a measure of the average photosynthetic efficiency of leaves. It is the net gain of assimilate or dry matter accumulation per unit leaf area per unit time. Gardner *et al.* (1985) suggested that as the plant grows and LAI increases, more and more leaves become shaded, causing a decrease in NAR as the growing season progresses. In the present experiment, *P. pedicellatum* and *P. polystachyon* had similar NAR values throughout its growth period (Fig. 22). NAR between 0-30, 30-60 and 120-150 were almost same and showed higher value than other stages similar to RGR. Between 120 and 150 DAS, there was rapid increase in total dry weight (Table 17) coupled with a decrease in leaf weight per plant (Table 16) and LAR (Table 20) mainly because of senescence of leaves.

5.6 Nutrient composition and uptake

Nitrogen, phosphorus and potassium content during different growth stages were almost similar in both the species. However, nutrient content was high

Fig. 20 Absolute Growth Rate of *P. polystachyon* and *P. pedicellatum* at different growth stages

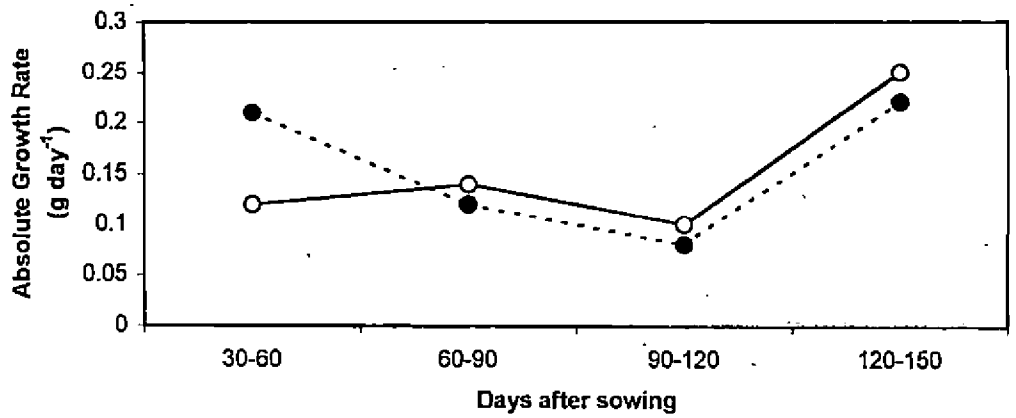


Fig. 21 Relative Growth Rate of *P. polystachyon* and *P. pedicellatum* at different growth stages

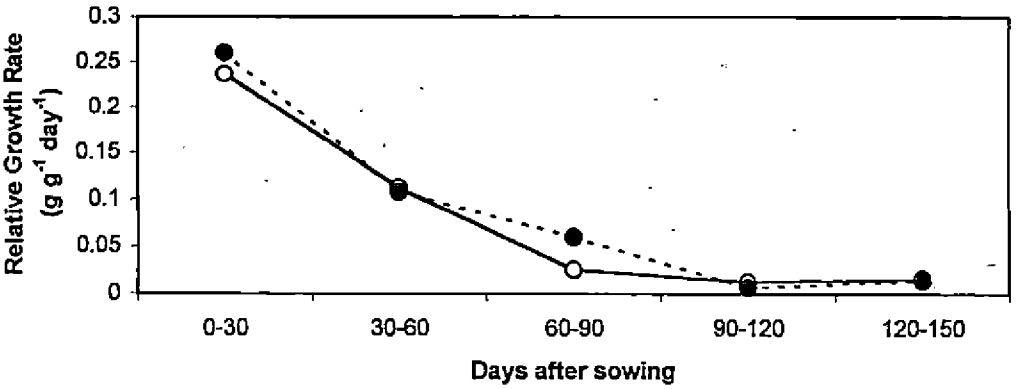
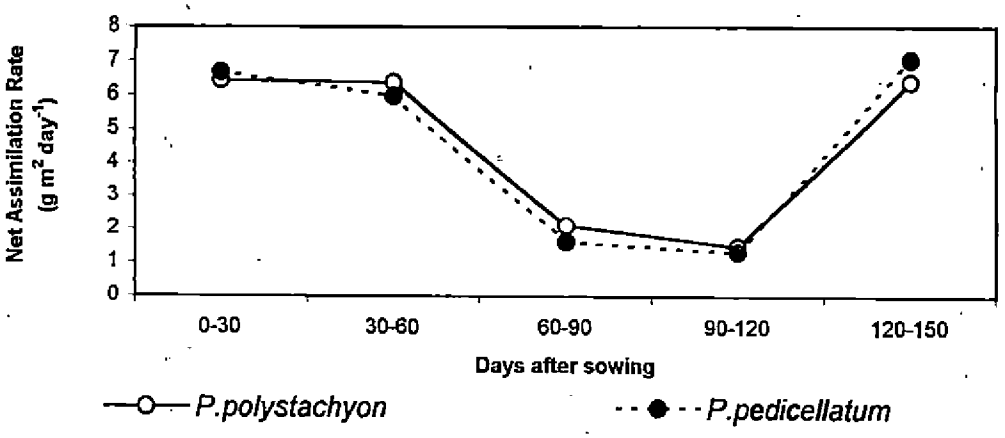


Fig. 22 Net Assimilation Rate of *P. polystachyon* and *P. pedicellatum* at different growth stages



during early vegetative growth stages and less at maturity stages (Figs. 23, 24 and 25).

With increasing age, the proportion of potentially digestible components comprising of soluble carbohydrates, proteins and other cell contents tend to decline (Whiteman, 1980). Wilson (1976), from studies on green panic (*Panicum maximum* var. *trichoglume*), observed that the upper leaves produced by the physiologically older plant appear to be of lower nutritive value than earlier produced leaves. Increase in cutting intervals of fodder grasses, in general, reduces crude protein and mineral contents (Botha and Rethman, 1994; Almar *et al.*, 1997; Acunha and Coelho, 1997).

Species differences in nutrient uptake was evident only in certain stages. In the case of N, P and K uptake, *P. pedicellatum* had higher values in the early stages (Figs. 26, 27 and 28). However, in the later stages both species had similar uptake values. Nutrient uptake almost followed the trends of nutrient content and total dry matter production since it is a function of dry matter yield and nutrient content. Nutrient uptake increased with age. However, in the later stages, though dry matter was high, nutrient uptake was almost static. This was due to the decline in nutrient content as discussed earlier.

5.7 Fodder production potential

P. pedicellatum was superior in terms of fresh weight at the first cut uniformly done after 70 days after sowing (Table 35). It produced a fodder yield of 24.66 Mg ha^{-1} while *P. polystachyon* produced 11.76 Mg ha^{-1} only. There was one fold increase in fresh weight of fodder in *P. pedicellatum* compared to *P. polystachyon*. Higher forage yield can occur due to the production of more leaves, higher plant height, more number of tillers and high photosynthetic activity at the earlier stages of crop growth (Gowda *et al.*, 1985; Tripathi and Gill, 1990). In the present experiment also, the factors such as height, dry weight per plant, number of leaves and leaf area per plant observed at 60 DAS were higher in

Fig. 23 Nitrogen content in *P. polystachyon* and *P. pedicellatum* at different stages

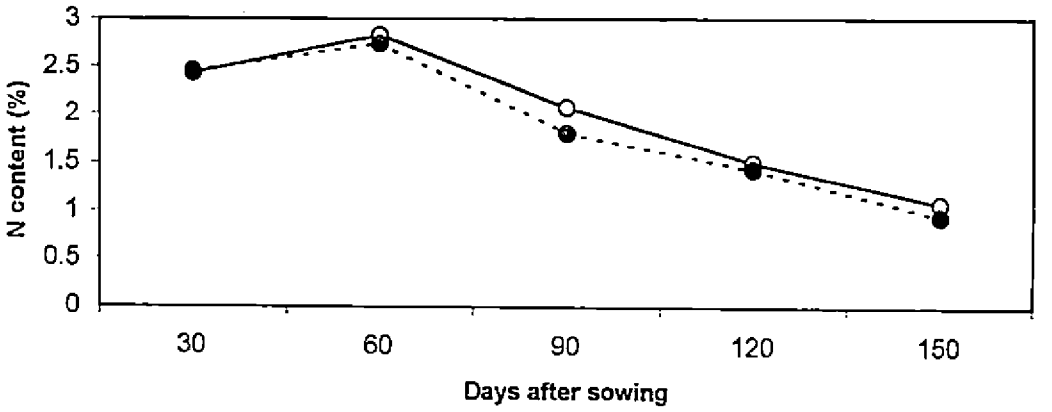


Fig. 24 Phosphorus content in *P. polystachyon* and *P. pedicellatum* at different stages

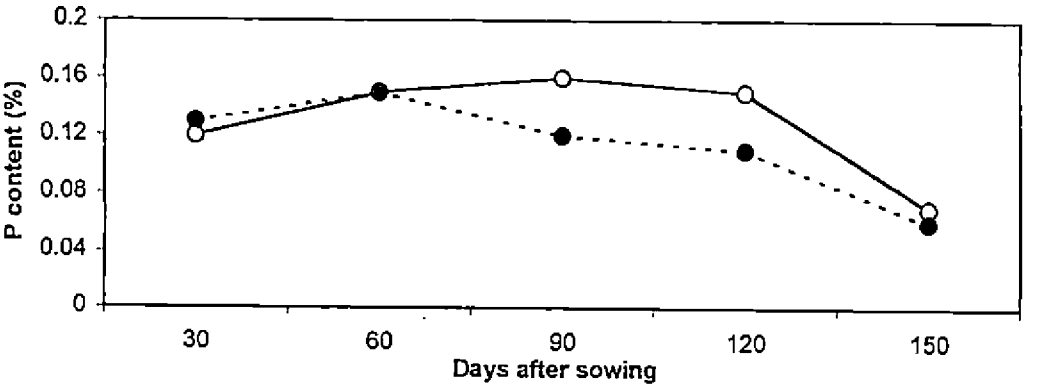


Fig. 25 Potassium content in *P. polystachyon* and *P. pedicellatum* at different stages

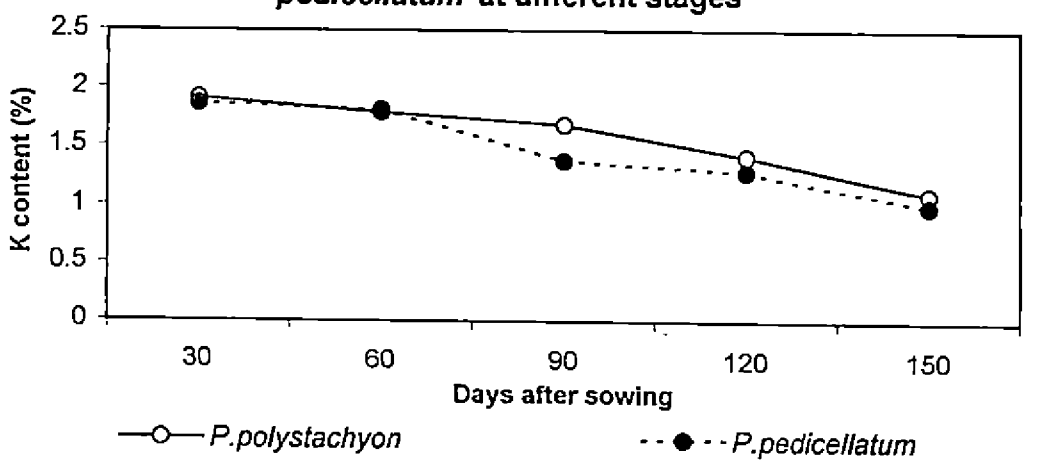


Fig. 26 Nitrogen uptake by *P. polystachyon* and *P. pedicellatum* at different stages

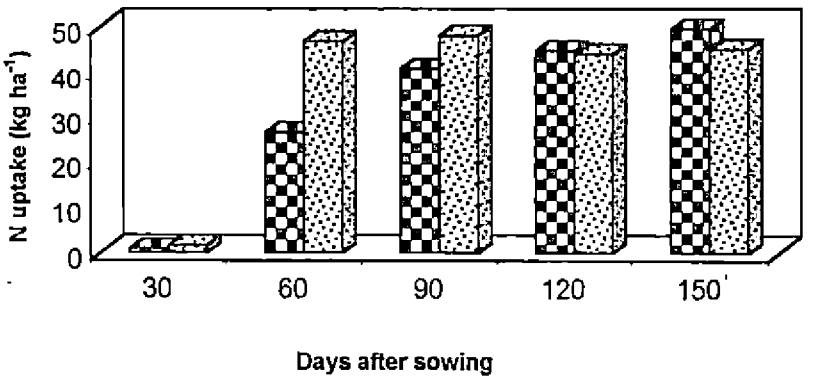


Fig. 27 Phosphrous uptake by *P.polystachyon* and *P. pedicellatum* at different stages

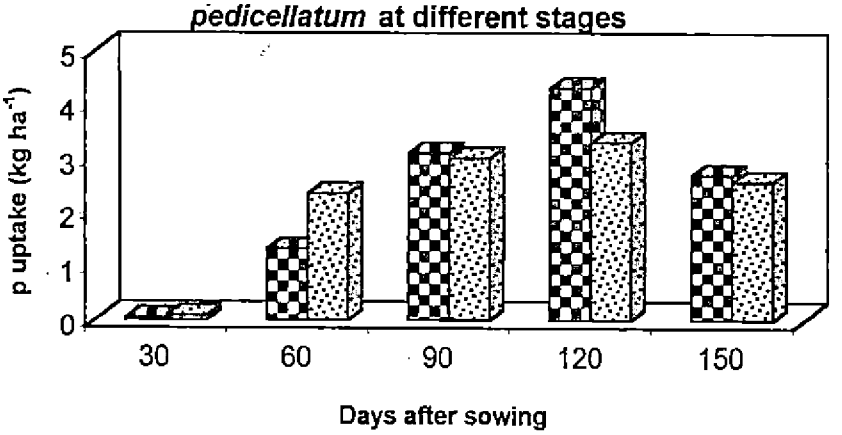
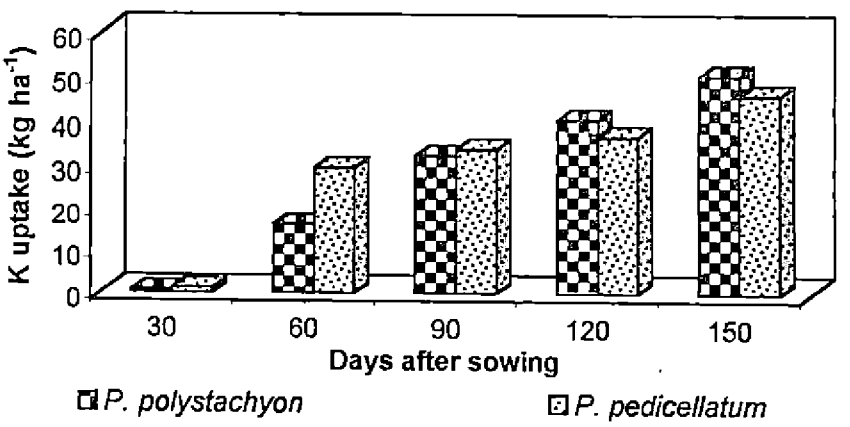


Fig.28 Potassium uptake by *P. polystachyon* and *P. pedicellatum* at different stages



P. pedicellatum than *P. polystachyon* (Tables 11, 17, 12 and 18). Significant differences were observed between cutting intervals also.

Apart from the uniform harvest at 70 DAS, two more cuttings were possible from harvest at 30 days interval and only one more harvest from that at 45 days interval. Total green fodder production was high in the case of *P. pedicellatum* than *P. polystachyon* (Fig. 29). Relwani and Bagga (1968) and Rathore and Vijayakumar (1977) reported high yield from deenanath grass. The total green fodder yield obtained in *P. pedicellatum* without adding any fertilizer (45.06 Mg ha^{-1}) was almost equal to the yields obtained by Bhagat *et al.* (1986b) by applying 100 kg of 'N' and 30 kg of 'P'. Among the cutting intervals, single cut at the time of flowering was significantly superior to cutting at 30 days interval.

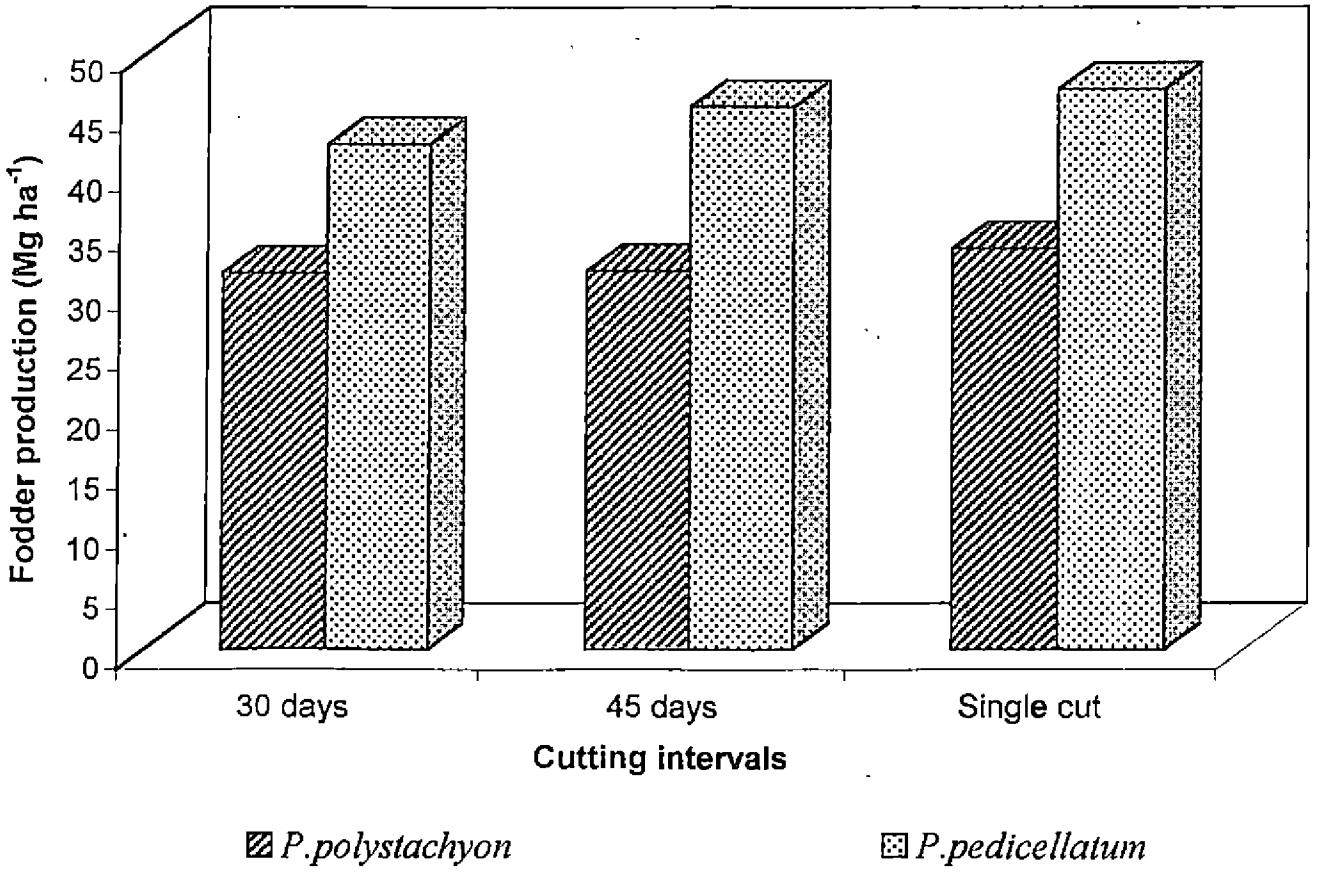
Dry weight of fodder at 70 DAS behaved in the manner similar to fresh weight of fodder (Table 35). Dry weights from different cutting intervals also differed significantly. Single cut just before flowering recorded maximum dry matter. The main reserve substances the non-structural carbohydrates are reported to be maximum before flowering (Chatterjee and Das, 1989).

Fodder quality

Crude protein content of fodder at 70 days harvest and that of different cutting intervals were similar in both the species (Table 38). A decrease in crude protein content was observed at later stages. Between cutting intervals, 30 days interval recorded more crude protein compared to other cutting intervals. During earlier stages, increased nitrogen availability and increased nitrogen absorption was reported by many workers (Amrutkar *et al.*, 1985; Manohar *et al.*, 1991; Singh *et al.*, 1997).

Cutting at 30 days interval also recorded more ash content followed by 45 days interval. Crude fibre content differed significantly between the species. *P. pedicellatum* had higher crude fibre content (34.29%) than *P. polystachyon*

Fig. 29 Total green fodder production by *P. polystachyon* and *P. pedicelatum* at different cutting intervals



(29.38%). Cutting intervals also affected crude fibre content (Table 39). Cutting at 45 days interval recorded more crude fibre content and the lowest value was recorded at 30 days interval. Frequent cutting of fodder naturally increases the crude protein content; at the same time crude fibre content showed a decreasing trend (Tyagi and Singh, 1986). The effect of cutting intervals in reducing crude protein content and mineral contents of fodder grasses were reported by many workers (Botha and Rethman, 1994; Almar *et al.*, 1997; Acunha and Coelho, 1997).

SUMMARY

6. SUMMARY

Pennisetum polystachyon (L.) Shult. and *P. pedicellatum* Trin. are two major grass weeds of the tropics and subtropics. These grass weeds are widespread in Kerala in young plantation crops and non-arable areas. The present experiment was undertaken to have an understanding on the biology, growth behaviour and fodder production potential of the two *Pennisetum* spp. at the Research Farm, College of Horticulture, Vellanikkara during 1998-2000. The main objectives were to compare the seed dormancy, growth and development and regeneration ability of *P. polystachyon* and *P. pedicellatum*. The presence and distribution, if any, of the allelopathic substances and the fodder production potential of these grass weeds were also investigated.

The study involved five experiments to achieve the objectives.

Experiment 1: Studies on seed dormancy

Fresh seeds of *P. polystachyon* and *P. pedicellatum* were collected during the month of December-January (1999-2000). Germination tests were conducted at monthly intervals by keeping 25 seeds in each petridish. *P. polystachyon* did not show any dormancy and started germination in December itself. It showed minimum germination in December and maximum germination in late March. *P. pedicellatum* seeds remained dormant during December and January and it was broken by February. Both species showed above 80 per cent germination in late March. Germination percentage started declining in *P. polystachyon* after April.

Experiment 2. Life cycle and seed characters of *Pennisetum* spp.

Phenological characters of both species were noted from a natural population during the year 1999. Seeds of *Pennisetum* spp. started germination soon after the receipt of monsoon showers by the end of April. Flowering started

after the sessation of heavy rains in September. Plants started drying by mid December in *P. polystachyon* and mid November in *P. pedicellatum*. The mean seed output per plant was 5439 in *P. polystachyon* and 1787 in *P. pedicellatum*. Reproductive capacity per plant was high in the case of *P. polystachyon*. However, the test seed weight was high in *P. pedicellatum*.

Experiment 3: Regeneration ability of *Pennisetum* spp.

The plants were retained as such in one treatment and cut at 5 and 10 cm heights in another two treatments at maturity. Regenerated plants were noted after one month of receipt of rainfall. *P. polystachyon* and *P. pedicellatum* behaved similarly with respect to percentage of new plants regenerated. Both species showed remarkable regeneration ability from different cutting heights. However, fresh weight of sprouts were more when cutting was given at 10 cm level and in plants retained as such after maturity without any cutting.

Experiment 4: Allelopathic effects of *Pennisetum* spp.

The leachates (both cold and boiled extracts) of leaf, roots and seeds of *Pennisetum* spp. were prepared. Germination tests using cowpea, bhindi and cucumber were done using the extracts in petridishes. The cold and boiled leaf extracts of both species did not show any effect on germination of test crops. However, all the extracts inhibited root and shoot growth. In the case of root extract, cold extracts of both *Pennisetum* spp. reduced the germination percentage of bhindi. Shoot and root length of bhindi was completely inhibited by boiled root extract of *P. pedicellatum*. In cowpea, some promotery effect on shoot length was noticed in cold root extract of *Pennisetum* spp. Seed extracts showed some inhibitory effect only on cowpea germination. Shoot and root length was considerably reduced in the test crops by both cold and boiled seed extracts.

Experiment 5: Comparative growth analysis and fodder production potential of *Pennisetum* spp

Seeds of *P. polystachyon* and *P. pedicellatum* were sown at a spacing of 20 x 20 cm during July. At monthly intervals, observations on growth characters were taken. The experimental results were analysed in two parts - growth analysis and fodder production potential.

Growth was comparatively fast in *P. pedicellatum* during its early stages than *P. polystachyon*. Plant height, number of leaves, fresh weight and dry weight were more in *P. pedicellatum* during its initial stages of growth. *P. polystachyon* showed higher leaf:stem ratio than *P. pedicellatum*. Growth indices like LAR, LWR, RGR, AGR and NAR were similar in both *Pennisetum* spp. The values of LAR and LWR showed a decreasing trend with time. RGR was high in the early stages, declined in the middle stages and then again increased. The plants had maximum AGR and NAR values during its vegetative and maturity phases. In the case of SLA and LAD, it was higher in *P. pedicellatum*. SLA values showed a gradual decline from early stages to later stages. LAD was low in the beginning, topped by 60-90 DAS and then declined.

Nutrient composition and nutrient uptake especially N, P, K, Ca and Mg were determined at monthly intervals. Nutrient contents during different growth stages were almost similar in both species. All the nutrients tested were high during early vegetative stages and less at maturity stages. In the case of N, P and K uptake, *P. pedicellatum* had a higher uptake in the early stages. At maturity both species showed similar uptakes.

Fodder production

In terms of total green fodder production, *P. pedicellatum* was superior to *P. polystachyon*. Cutting intervals also affected the fodder yield among *Pennisetum* spp. Two cuttings, one at 70 days after sowing and the other just

before flowering, recorded maximum fresh weight of fodder compared to other treatments. In terms of quality, both species recorded substantial amounts of crude protein, crude fibre and ash content. Crude protein content was affected by cutting frequencies and early cutting recorded higher percentage. Crude fibre content was, however, significantly higher in *P. pedicellatum* than in *P. polystachyon.*

Conclusion

Dormancy studies indicated that *P. polystachyon* is non-dormant and *P. pedicellatum* had a brief period of dormancy. Both showed more than 80 per cent germination by the end of March. *P. polystachyon* produced more number of seeds and had higher reproductive capacity when compared to *P. pedicellatum. P. polystachyon* produces lighter seeds than *P. pedicellatum* facilitating easy aerial dissemination to a vast area.

It was found that both the species had remarkable regenerating ability. However, more fresh weight after regeneration was found at the 10 cm cutting level and with plants retained as such without any cutting. Cutting of these grasses leaving the basal clumps or retaining them in the field may lead to persistence and rapid spread as indicated by the high regeneration capacity of these grasses.

Allelopathic studies conducted with cold root extracts of both the *Pennisetum* spp. recorded inhibitory effects on the germination of bhindi seeds. The seed extracts (both cold and boiled) of *P. pedicelltum* and *P. polystachyon* also showed inhibition on cowpea germination. But the test with cold root extract of both *Pennisetum* spp. highlighted a promotery effect on shoot length of cowpea. However, more tests are needed to have definite conclusions.

In terms of total green fodder production, *P. pedicellatum* outyielded *P. polystachyon.* Maximum fresh weight was recorded at cuttings given at 70 days interval and just before flowering. It seems *P. pedicellatum* has more potential to be used as a fodder crop than *P. polystachyon.* However, *P. polystachyon* has

shown a higher leaf:stem ratio and low crude fibre content indicating better palatability. Fodder quality, in terms of crude protein and ash content, of the two species were similar. The results indicate that as the fodder quality is good, utilizing these grasses as cattle feed can be one of the strategies for managing them. However, cultivation of these grasses for fodder purposes involves some risks because of their high reproductive capacity and persistence.

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* Originals not seen

APPENDIX

Weekly rainfall (mm), evaporation (mm), surface air temperature (°C), relative humidity (%) and sunshine hours (h/day) at CoH, Vellanikkara From January to December 1999
(Latitude 10°31'N, Longitude 76°13' and Altitude 40.29 MSL)

Week No.	Rainfall		Evaporation (mm)	Surface air temperature (°C)			Relative Humidity (%)		Sunshine Hours (h/day)
	Amount (mm)	NRD		Max.	Min.	Mean	Morning	Evening	
1	0.0	0	39.5	31.9	21.8	26.9	75	45	9.4
2	0.0	0	34.8	32.5	21.9	27.2	79	43	9.5
3	0.0	0	48.2	32.2	22.8	27.5	70	40	10.0
4	0.0	0	41.2	32.5	19.5	26.0	74	32	7.9
5	0.0	0	31.5	33.9	22.1	28.0	83	39	10.1
6	22.8	1	35.8	34.0	23.4	57.4	80	44	9.2
7	0.0	0	43.9	34.7	23.2	29.0	79	39	10.0
8	0.0	0	53.0	34.2	24.5	29.4	70	33	6.9
9	0.0	0	53.4	36.4	22.2	29.3	74	33	10.4
10	0.0	0	40.6	36.5	23.8	30.2	92	34	9.9
11	0.0	0	34.2	35.2	25.0	30.1	89	54	8.4
12	0.0	0	31.7	34.8	25.0	29.9	91	55	8.4
13	0.0	0	34.3	34.9	25.1	30.0	89	54	7.5
14	26.2	2	39.6	34.9	24.5	29.7	90	55	7.8
15	0.0	0	32.3	33.2	25.8	29.5	86	59	7.4
16	7.6	1	27.0	33.1	26.2	29.6	89	62	4.6
17	5.2	1	25.1	32.0	25.9	29.0	90	59	4.2
18	35.0	1	30.7	33.6	25.8	29.7	89	59	6.3
19	37.0	3	21.6	31.0	25.2	28.1	90	66	6.4
20	51.6	4	22.6	30.4	25.1	27.8	88	74	5.5
21	221.2	6	20.1	29.0	23.8	26.4	95	85	2.6
22	143.2	7	21.5	29.8	23.5	26.7	96	75	5.0
23	134.7	6	22.7	29.1	22.8	26.0	94	81	4.8
24	170.9	7	17.3	28.4	22.7	25.5	95	81	1.8
*25	114.8	6	20.6	29.6	23.2	26.4	95	76	5.1
*26	21.6	1	26.4	30.9	23.0	27.0	92	67	8.9
*27	114.7	6	20.5	29.6	23.1	26.4	95	80	3.7
*28	124.6	7	18.0	29.0	22.9	26.0	96	76	3.1
*29	326.5	7	12.6	26.9	22.8	24.9	97	92	3.2
*30	182.8	7	13.0	27.7	22.7	25.2	95	83	1.1
*31	194.1	6	17.1	28.7	23.3	26.0	95	84	2.7
*32	121.5	5	20.8	29.5	23.7	26.6	95	74	5.2
*33	8.9	1	24.7	30.6	24.1	27.4	93	69	7.5
*34	3.2	1	25.1	30.0	23.6	26.8	93	69	6.9
*35	7.1	0	20.6	30.0	23.6	26.8	93	71	5.3
*36	18.3	1	18.7	30.0	23.2	26.6	93	67	4.9
*37	10.1	1	27.6	31.0	23.0	27.0	92	65	8.1
*38	0.0	0	31.0	32.6	23.4	28.0	90	56	8.5
*39	0.0	0	28.2	32.9	23.8	28.4	90	60	6.4
*40	80.5	4	19.6	30.5	23.1	26.8	93	71	4.8
*41	185.7	2	23.8	31.5	23.6	27.6	95	75	6.8
*42	161.6	5	16.8	29.5	23.3	26.4	95	80	2.9
*43	38.8	1	19.6	31.3	23.5	27.4	93	74	5.5
*44	41.9	3	20.3	29.6	22.7	26.2	96	73	6.2
*45	2.8	1	22.4	31.4	22.1	26.8	87	62	7.8
*46	0	0	26.6	31.1	22.1	26.6	74	46	10.1
*47	4	0	29.4	31.1	23.5	27.3	79	62	6.3
*48	0	0	36.4	31.9	23.7	27.8	76	55	8.7
*49	0	0	34.3	31.8	21.6	26.7	79	49	9.4
50	0	0	31.5	31.8	22.6	27.2	78	50	8.1
51	0	0	44.8	31.4	22.6	27.0	72	47	8.7
52	0	0	49.0	31.4	23.4	27.4	68	43	8.8
Total/ Mean	**2618.9**	**104**	**1502**	**31.57**	**23.44**	**28.07**	**87.23**	**61.09**	**6.71**

* Crop period

COMPARATIVE BIOLOGY AND GROWTH BEHAVIOUR OF *Pennisetum polystachyon* (L.) Shult. AND *P. pedicellatum* Trin.

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Pennisetum polystachyon (L.) Shult. and *P. pedicellatum* Trin. are two major grass weeds that are widespread in young plantation crops and non-arable areas of the tropics. The present investigation was undertaken to have an understanding on the biology, growth behaviour and fodder production potential of these two *Pennisetum* spp. at the Research Farm, College of Horticulture, Vellanikkara during 1998-2000.

Germination tests were conducted at monthly intervals. *P. polystachyon* did not show any dormancy and started germination as soon as the seeds are collected (December). *P. pedicellatum* seeds remained dormant during December and January and it started germination by February only. Both species showed above 80 per cent germination by late March. Germination percentage started to decline in *P. polystachyon* after April.

Phenological characters of both species were noted from a natural population during the year 1999. Seeds of *Pennisetum* spp. started germination soon after the receipt of monsoon showers by the end of April. Flowering started after the completion of the rainy period in September. Plants started senescence by mid December in *P. polystachyon* and mid November in *P. pedicellatum.*

Both *Pennisetum* species studied showed remarkable regeneration ability from different cutting heights. The percentage of plants regenerated was similar in both species. Allelopathic reactions of roots, leaves and seeds were also studied. Boiled and unboiled extracts were prepared and germination test were conducted using cowpea, bhindi and cucumber as test crops. The cold and boiled leaf extracts of both species did not show any effect on germination of test crops. However, cold root extract of both *Pennisetum* spp. reduced the germination percentge of bhindi. Cold root extract of both species also showed some promotery

effect on shoot length in cowpea. Seed extracts showed inhibitory effects only on cowpea germination.

Growth was comparatively fast in *P. pedicellatum* than *P. polystachyon* during its early stages. *P. polystachyon* showed higher leaf : stem ratio than *P. pedicellatum*. Growth indices like LAR, LWR, RGR, AGR and NAR were similar in both *Pennisetum* spp.

In terms of total green fodder production, *P. pedicellatum* was superior to *P. polystachyon*. Two cuttings, one at 70 days after sowing and the other just before flowering recorded maximum fresh weight of fodder. Though crude protein content was similar in both the species, *P. pedicellatum* showed a higher crude fibre content than *P. polystachyon*. The results indicate that as the fodder quality is good, utilizing these grasses as cattle feed can be one of the strategies for managing them. However, cultivation of these grasses for fodder purposes involves some risks because of their high reproductive capacity and persistence.