# ALLELOPATHY IN SOME ETHIOPIAN GRASSES

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A Thesis

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BY

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## ABSTRACT

Investigation for possible chemical interactions among some of the common grass species that grow in and around Addis Ababa was undertaken. The species used were the grasses Andropogon abyssinicus R. Br. ex Fresen, Hyparrhenia arrhenobasis (Hochst. ex. Steud.) Stapf, Pennisetum glabrum Steud., Snowdenia polystachya (Fresen) Pilger, Eleusine jaegeri Pilger, Eragrostis tenuifolia (A. Rich) Steud. and a legume, Medicago polymorpha L.

The effects of the extracts of the seven species on the seed germination and plumule and radicle growth of the same seven species showed that A. abyssinicus and S. polystachya were the most inhibitory followed by H. arrhenobasis and E. jaegeri in that order. Extracts from E. tenuifolia, M. polymorpha and P. glabrum showed less inhibitory effects than the above species.

Seed germination inhibition effect was greatest on S. polystachya and P. glabrum and that on E. jaegeri and H. arrhenobasis was the least.

Auto-inhibition was found to be as high as allo-inhibition. Extracts from all the species except E. tenuifolia showed auto-inhibitory effects on germination and plumule growth and/or radicle growth.

Different experiments were carried out to detect the way of release of the inhibitory chemical(s) in A. abyssinicus. The results obtained from these experiments indicate that A. abyssinicus inhibits other species when decomposition of its dead remains takes place and that the live plant does not release any allelopathic substance into the soil medium.

# 1. INTRODUCTION

Ethiopia is an agricultural and pastoral country. The preservation of the grass constituents in a vigorous state of productivity is of fundamental importance for countries like Ethiopiawhich rely on their natural vegetation to provide year long sustenance for livestock whether in the form of grazing or harvested and stored hay or silage.

Due to its rugged topography, most of Ethiopia is threatened by hazards of erosion. Grasses are known to be good soil builders and effective soil stabilizers. In both agricultural and pastoral areas over utilization and abuse have resulted in the loss of vast quantities of top soil by the action of wind and water. It is known that a perennial grass cover provides the best means of checking surface soil loss and rebuilding depleted soil.

From the ecological point of view, grasslands develop as a direct expression of climate or other enviromental conditions when these conditions are unfavorable to the growth of trees. A secondary or derived grassland may also develop as a result of biotic influences (McIlory, 1962).

Grasslands often contain a number of communities some of which may have resulted from edaphic variations or from differences in aspect, while others may represent various stages in the succession as a result of biotic influences ( Rattray, 1962).

The rate of succession and the actual species of plant found depend naturally upon a large number of factors one being allelopathy.

Simple observations on grass communities growing in the University Campus and in and around Addis Ababa show that some of the commonest

species, e.g. Andropogon abyssinicus R. Br ex Fresen , Hyparrhenia arrhenobasis (Hochst. ex Steud) Stapf andSnowdenia polystachya (Fresen) Pilger are found in patches of more or less pure stands. The presence of these species in more or less pure stands may not be only due to competitive and edaphic factors but may also be due to chemical interactions among the members of the communities.

These conditions lead to the suspicion that A. abyssinicus and those grasses that behave like it may exude certain chemical substances that stunt or reduce the growth of certain plants or prevent their establishment. Unravelling such phenomena would lead to better understanding of plant communities and indirectly to conservation of vegetation and soil.

## 2. LITERATURE REVIEW

### 2.1. Allelopathy

The question of the existence of substances, secreted by plants, that inhibited the growth of other plants was first raised by De Candolle. He believed that such substances exist and that they are important factors in plant ecology. His theories were based largely on field observations (De Candolle cited in Bonner, 1950). Molisch was the first to use the term allelopathy to refer to biochemical interactions between all types of plants including micro-organisms. His discussion indicated that he meant the term to cover both detrimental and beneficial reciprocal biochemical interactions (Molisch cited in Rice, 1974).

Several investigators have used the term allelopathy to refer to the deleterious effect that one higher plant has on another through the production of chemicals that escape into the enviroment. Accordingly Borner (1960) has classified the influence of plants on one another into four categories, the action of micro-organisms upon micro-organisms by antibiotics (antibiosis), the action of higher plants upon micro-organisms by phytoncides, the action of micro-organisms upon higher plants by marasmines, and the action of higher plants upon higher plants by allelopathica (allelopathy).

But Rice (1974) referring to Molisch feels that the term allelopathy should include any direct or indirect harmful effect by one plant (including micro-organisms) on another through the production of chemical compounds that escape into the enviroment.

A very important point concerning allelopathy is that its

effect depends on a chemical compound added to the enviroment. It is thus separated from competition which involves the removal or reduction from the enviroment of some factor which is required by some other plant sharing the habitat. Factors that may be reduced include water, minerals, food and light. To avoid complications, the term interference is used to refer to the overall influence of one plant on another. Interference would thus encompass both allelopathy and competition (Rice 1979).

## 2.2. Allelopathy in Higher Plants

Allelopathy, the inhibition of growth of one plant by chemicals released from another, occurs widely in plant communities and may regulate the density and distribution of species (Putman and Duke, 1974). Many plant families have a member that is known or suspected to produce allelopathic substance (Wood, 1960).

Allelopathic effects have been reported for agricultural and wild species of most varied growth forms and kinds of communities from rainforest trees to desert shrubs (Whittaker and Feeny, 1971).

Many plants have been shown to produce substances inhibitory to seed germination and growth of other plants and these substances have been found in all plant parts (Garb, 1961). They are found in stems, leaves, roots, flowers, fruits and seeds. Leaves seem to be the most consistent sources of inhibitors, and most investigators have tested them at least in combination with some other parts. Roots have generally been found to contain fewer and generally less potent or at least smaller amounts of inhibitors than leaves, but this is sometimes reversed (Rice, 1974).

Substancespotentially involved in allelopathy are released in four different ways: 1. by rain wash or by condensation during mists causing drips from leaf surface and glands, 2. by excretion or exudation from roots 3. by volatilization from leaves and 4. by decay of above ground or below ground plant parts, or both (Tukey, 1969; Whittaker and Feeny, 1971).

Allelopathy occuring widely, may consequently be of widespread significance in plant communities. In plant succession a dominant species may, by allelopathic suppression, spread its invasion of a preceeding community and delay its replacement by other species. In both successional and climax communities strongly dominated by a single species, chemical effects of that species on the soil may limit the number of other species able to occur with it (Whittaker and Feeny, 1971).

Auto-toxicity or self inhibition has been reported for a number of successional species (McNaughton, 1968; Rice, 1974) and agricultural plants (Borner, 1960), for Eucalyptus (Florence andCrocker, 1962) and for one climax rain forest tree (Web cited in Whittaker and Feeny, 1971). Self toxicity is an evolutionary paradox. One supposes that some selective advantage from production of toxic compounds outweighs the disadvantage of self-inhibition (Whittaker and Feeny 1971).

The known agents of allelopathy belong to a few major groups of compounds among the secondary plant substances,including phenolic acids, flavonoids and other aromatic compounds and organic cyanides. In general allelopathic compounds (and other secondary substances) occur in plants in ways that protect the plant against their effects.

Many of these compounds occur as glycosides. Other secondary substances occur as polymers (tannins, lignins, resins and rubbers) or as crystals (calcium oxalate raphides) (Whittaker and Feeny, 1971).

Many of the substances are deposited outside living cells in the dead heart wood, in dead cells or spaces between cells, in ducts or in glandular hairs found on the surfaces of many plants. Some substances are finally discharged from the living plant by leaching from the leaf surface, exudation from the roots or volatilization. The secondary substances are thus treated like toxic wastes to be inactivated in, or excreted from, the plant or both (Whittaker and Feeny, 1971).

## 2.3. Allelopathy In Grasses

Allelopathy undoutedly exists as a function in the grassland ecosystem and may well have caused many results reported in literature as being due to competition (Risser, 1969). A number of studies have dealt with grassland species and have supplied sufficient evidence that the production of inhibitory substances is quite widespread. There is also strong evidence that these inhibitory substances play a part in vegetational pattern, species diversity and succession in grassland ecosystems.

### 2.3.1. Patterning and species diversity due to allelopathic effects of grasses

In his review, Rice (1979) has intensively discussed that many grasses produce allelopathic substances that have patterning effects on the vegetation. Imperata cylindrica (L.) Beauv. is a perennial grass which is a pernicious weed in many parts of the world. It was found that water extracts of the leaves contained scolopin, scopoletin, chlorogenic acid and isochlorogenic acid , all of which are known phytotoxins.

Miscanthus floridulus (Labill) Warb., a dominant grass in the mountains of Taiwan, shows a unique pattern of herb exclusion from its stands. It was found that leaf leachates resulting from artificial rain or foliar crowns of Miscanthus significantly inhibited seed germination and radicle growth of lettuce. Seven phytotoxins, all phenolic acids, were isolated and identified from leaf extracts. It was concluded, therefore, that allelopathy is important in the exclusion of herbs from Miscanthus stands. (Chou and Chung, cited in Rice, 1979).

A survey of 12 species of subtropical grasses by Chou and Young for the presence of phytotoxins showed that aqueous extracts of the leaves of each of the species inhibited seed germination and radicle growth of lettuce. Acroceras macrum Stapf., Chloris gayana Kunth., Digitaria decumbens Stent and Panicum maximum Jacq. were the most inhibitory and Cortaderia selloana (Schult.) Ashers and Graben. extract was the least. Six phenolic acids were identified in ether extracts of the 12 species, and they were differentially distributed in the grasses. (Chou and Young cited in Rice 1979).

Newman and Rovira (1975) selected eight species from a permanent neutral British grassland which gave no particular indication from field observations that they were involved in allelopathic interactions. Four were grasses - Anthoxanthum odoratum L., Cynosurus cristatus L., Holcus lanatus L., and Lolium perenne L. and four weed forbs, Hypochoeris radicata L., Plantago lanceolata L., Rumex acetosa L., and Trifolium repensL. Leachates of donor pots of each species were tested against each of the eight species in receiver pots. Four of the species, L. perenne, H. radicata, P. lanceolata

and T. repens were inhibited more by pot leachates of their own species than leachates of other species. All the other species, except R. acetosa showed the opposite response. R. acetosa showed an intermediate response to its own leachate. Subsequent field observations indicated that the most auto-inhibited species were normally found as isolated individuals, or as a few individuals in a group, not as pure stand. The three species which were allo-inhibited are all capable of dominating a permanent grassland. The authors concluded that the effects of auto-inhibitory exudates may turn out to be a key process in controlling species diversity in grassland.

Bokhari (1978) investigated the allelopathic effects of four kinds of short grass prairie litter and three kinds of extracts from living plants of Bouteloua gracilis (H.B.K.) Lag and Agropyron smithii Rydb. on the seed germination of B. gracilis, A. smithii and Buchloe dactyloides (Nutr.) Englem. The extracts were made from three distinct phenological stages of growth. The extracts made at the earlier phenological stages were found to be more inhibitory than those made at the advanced stage. Both B. gracilis and A. smithii exhibited autotoxicity and Bokhari reported that both appear to grow better in a mixture with other species.

Sometimes poor correlation between bioassay results and field distribution or succession have been found. Stowe (1979) investigated the influence of the seven most abundant species in an Illiois old field upon each other. the tests were done in four qualitatively different bioassays and the results of these bioassays were compared with the spatial distribution of species in the field.

The seven most abundant species were the grasses Agropyron repens (L.) Beauv., Bromus inermis Leyss., Dactylis glomerataL., Festuca elator L., Phleum pratense L., Poa compressa L., and the legume Coronilla varia L., Though the species had shown allelopathic effects towards each other, statistical tests comapring the germination and growth of plants with indices of association in the field were not significant. It was then concluded that bioassay results may not represent the actual chemical interactions in the field.

2.3.2. Roles of Allelopathy in Old-field Succession

The role of inhibitors in old-field succession has been fairly well studied. In some areas succession does not occur as rapidly as might be expected and this is evidence that some species of the early stages persist by excluding later species or by maintaining unfavourable conditions for species belonging to later successional stages (Risser, 1969).

Booth has described old field succession in Central Oklahoma and South East Kansas as proceeding through four stages:

1. weed stage - lasting 2-3 years including Helianthus annuus, Erigeron canadensis, Digitaria sanguinalis and Croton glandulosis;
2. The annual grass stage lasting for 9-13 years dominated by Aristida oligantha;
3. The perennial bunch grass stage lasting an undetermined length of time dominated by Andropogon scoparius;
4. The climax prairie dominated by A. scoparius, A. geradi and Panicum virgatum (Booth cited in Risser, 1969).

Experimental evidences gathered by different workers suggests that the rapid disappearance of the pioneer weed stage in infertile revegetating old fields in central Oklahoma is due to the allelopathic interaction of the pioneer weeds. In other words they eliminate themselvesthrough the production of toxins. Aristida oligantha, the dominant of the second stage, is generally not inhibited by the same toxins and is able to grow in still infertile soils that would not support species that invade in the later stages of succession. Therefore, A. oligantha invades the pioneer community and starts the second of the seral successions (Rice, 1974).

Rice (1964) found that certain species of the first and second stages produce phenolic compounds that inhibit nitrogen fixing bacteria, nitrifying bacteria and nodulation of legumes. Consequently, the soils that are very low in nitrogen at the time of abandonment remain low in nitrogen for a prolonged period. Therefore, those plants that have higher nitrogen requirements are not able to compete in the infertile soils with the low-nitrogen requiring early invaders. This results in the slowing of succession during the intermediate stages. Eventually, conditions improve for later invaders, and, once they are able to invade, A. oligantha is not able to compete with the more robust subclimax and climax species and is thus eliminated (Rice, 1974).

2.3.3. Inhibition of Nitrification in Climax Grasslands

Many workers have reported that in grassland soils the level of ammonium nitrogen is several times greater than the level of nitrate

Nye et al, in reviewing many African areas and vegetation types reported that irrespective of the C/N ratio of the soil, its pH and moisture regime, very little, if any, nitrate nitrogen is found in the soil while the dominant vegetative cover is a grass (Nye cited in Rice, 1974).

Numerous investigators have reported that nitrification under several species of grasses in Africa is inhibited by phytotoxins produced by the grasses. Boughey reported that two species of Hyparrhenia grasses abundant in the Rhodesian high-veld savana, secrete a toxin that suppresses the growth of nitrifying bacteria (Boughey cited in Rice, 1974). Root extracts from several climax species from the Rhodesian high-veld were found to be more inhibitory to nitrification than seral species investigated (Munro cited in Rice, 1974)

In a series of experiments using numrous grass species important in old-field succession and a climax ecosystem, Rice and Pancholy (1972, 1973 and 1974) found that inhibition of nitrification increases with the progress of succession towards the climax and is particularly strong in climax ecosystems. They found that the amount of ammonium nitrogen was lowest in the first successional stage, intermediate in the second successional stage and highest in the climax stage. The opposite was found for the amount of nitrate in the respective stages.

The ammonium ion being positively charged is adsorbed by the negatively charge colloidal micelles and is thus hardly leached by percolating water. On the other hand the negatively charged nitrate ions are repelled by the colloidal micelles in the soil and thus are easily leached. It would appear from these facts that inhibition

of nitrification would help to conserve nitrogen (Rice 1974).

It also appears likely that the greater inhibition of nitrification in the later stages of old-field succession aids in the build up of available nitrogen in the form of ammonium nitrogen, which finally enables the higher nitrogen-requiring climax species to invade (Rice, 1979).

## 3. MATERIALS AND METHODS

Plant parts (shoots and roots) were gathered from the field in June 1981 for seven of the most common species that grow in and around Addis Ababa. Their seeds were collected partly in June and partly in September 1981.

The species used in the experiment were Andropogon abyssinicus R. Br ex Fresen, Hyparrhenia arrhenobasis (Hochst. ex Steud.) Stapf, Pennisetum glabrum Steud., Snowdenia polystachya (Fresen) Pilger, Eleusine jaegeri Pilger, Eragrostis tenuifolia (A. Rich) Steud . and Medicago polymorpha L.

Some common grasses, e.g. Cynodon dactylon (L.) Pers. and Sporobolus africanus (Poir) Robyns and Tourny, were not included because of difficulties in seed germination. Germination problem with seeds of M. polymorpha was overcomed by scarifying the seeds with sand.

The experiments carried out can be divided into two categories:

1. Extract treatment experiment - This experiment tested the effects of extracts from each of the seven species on the germination, plumule growth and radicle growth of all the seven species.
2. Experiments with A. abyssinicus - In this, different experiments were carried out to detect ways by which A. abyssinicus influences other plants.

### 3.1. Extract Treatment Experiment

The collected plant parts were dried at room temperature and then ground. The ground material was soaked in distilled water for 48 hr at 2 to 3°C. A ratio of 10 gram of dried palnt material to 100 ml of distilled water was used. After soaking the solution was filtered through Whatman No. 1 filter paper and the filtrate was kept

refrigerated until use.

Twenty five seeds of each test species except for E. tenuifolia, for which 100 seeds were used, were spread in petri dishes containing filter paper . The filter paper was moistened with 5 ml of an extract or distilled water in the case of the control. Each treatment was replicated twice and the same was done for the control. At the end of a 10 day period the frequency of germination was determined and the plumule and radicle lengths of the germinated seeds were measured and recorded. In cases where the germination frequency was more than 10, mean plumule and radicle lengths were measured for the longest ten only. If the germination frequency was ten or less, the mean plumule and radicle lengths were taken from all of the germinated seeds.

## 3.2. Experiments with A. abyssinicus

Different experiments were designed to detect ways by which A. abyssinicus may release chemical substances into the surrounding.

### 3.2.1. Shoot and Root Extract Treatments

Shoots and roots of A. abyssinicus were obtained from plants that had been grown in pots in the green house for six months. The shoots and roots were dried at room temperature. They were then ground seperately and 10 gm of each shoot and root powder were soaked in 100 ml of distilled water each for 48 hours at 2 to 3°C. Extracts were then made by filtration and used to treat seeds of three test species in petri dishes containing filter paper . The test species used were A. abyssinicus itself, S. polystachya and p. glabrum. These species were the ones most inhibited by extract from A. abyssinicus in the first experiment.

After 10 days, the number of seeds which germinated was counted and plumule and radicle lengths measured.

3.2.2. Leaf Leachate Experiment

The possibility that rain can leach phytotoxins from live intact shoots was tested in this experiment. Fourty A. abyssinicus plants grown in the green house for four months were sprayed with a fine mist of distilled water. The amount of water used for spraying was two liters. The same water was sprayed 30 times i.e. 10 times in the morning,,10 times at mid-day and 10 times in the evening. The amount of water or leachate collected at the end was about 800 ml. The leachate was then filtered and tested in petri dishes containing filter papers for its effects on the germination and plumule and radicle elongation of the test species.

3.2.3. Growth Performance of Test Species Grown with A. abyssinicus

Five seedlings of A. abyssinicus were planted with five seedlings of each test species in pots containing 4 kgs of quartz sand which had previously been thoroughly washed with tap water. For control the test plants were grown in the absence of A. abyssinicus. The pots were of 19 cm depth, 19 cm top and 4.5 cm bottom diameter. All the pots were provided with draining holes at the bottom. Both control and test pots were replicated three times and all were randomized.

Each pot received an initial watering of 100 ml of half strength Hoaglands nutrient solution but this was increased as the plants grew larger finally reaching 150 ml per day. The plants were grown for 40 days from January 23, to March 4, 1982, after which

height measurements were taken and the plants harvested. Dry weights were obtained after oven drying at 60°C for five days.

3.2.4. Living Root Leachate Experiment

Five seedlings of the three test species were grown separately in pots containing quartz sand. Leachate from pots having A. abyssinicus plants was applied to these. The A. abyssinicus plants were grown in pots each with a hole drilled in the bottom to which a glass tube was fixed to drain leachate to a beaker placed underneath. The sand in the pot held about 900 ml of water and a further 300-400 ml was added which run through the hole at the bottom into the beaker. The leachates collected from the 9 pots were pooled and equally applied to the pots containing test species. Pots used as controls were supplied with nutrient solution only. Controls and treatments were replicated three times. The pots were randomized within blocks.

The plants were grown for 40 days from January 23 to March 4, 1982, and finally height measurements were taken after which the plants were clipped to be oven dried and weighed.

This experiment and the growth performance experiment were carried out in the green house with natural day-light length and average temperature ranging from 28 to 32°C. The nutrient solution used in experiments was Hoagland's nutrient solution No. 1 as described in Hewitt (1966).

3.2.5. Experiments with Decomposing A. abyssinicus Plant Material

One possible means by which one plant could influence the growth of another is by decomposition of its dead remains. Therefore, in order

to find out the effect of A. abyssinicus residues on the test species air dried plant parts were crushed and incorporated into the soil.

Determination of A. abyssinicus dry weight per kilogram of soil was done as follows. An area of one meter by one meter was randomly chosen from a place where A. abyssinicus plants were growing. The area was protected until the A. abyssinicus plants were fully grown. All the A. abyssinicus plants were then uprooted, dried and weighed. The weight was found to be 680 grams.

Using the accepted figure of 224 $kg/m^2$ (2,000,000 lb/acre) as the weight of soil to the depth of plowing, (Rice 1972) this amounted to 3.035 gm of A. abyssinicus dry plant material per kilogram of soil. Pots were filled with 3 kg of soil into which dried plant material of A. abyssinicus was incorporated at the calculated rate of 3.035 gm/kg of soil.

For each of the seven test species 4 pots were assigned out of which two contained soils with the A. abyssinicus straw incorporated, and the other two contained only soil. The pots were allowed to stay for 15 days in the green house for the decomposition of the A. abyssinicus to start. In the, meanwhile, water was being added at intervals of 3 days. Seeds of test plants were then sown in slight excess. In some cases seedlings were transplanted. Seedlings of test plants grown in the pots containing soil free from A. abyssinicus straw were used as control. The pots were randomized within blocks. After 10 days the seedlings were thinned to five per pot and were allowed to grow for 60 days from December 22, 1981 to February 20, 1982.

They were grown in the green house with conditions similar to those of the preceding experiments. Finally height measurements were taken after which the plants were clipped to be oven dried and weighed.

3.3. Statistical Treatment of Data

1. The chi-square test was used to detect significant differences in germination frequency between controls and treatments.
2. The least significant difference (L.S.D.) (Snedecor and Cochran 1968) was used for testing significant differences in plumule and radicle elongations. A pooled variance was claculated for each of the test species. This allowed a least significant difference to be calculated. Any mean which deviated from the control by an amount greater than the L.S.D. was taken to be significantly different from the control.
3. The "t" test was used to test the significance of differences for height and dry weight measurements from the experiments with A. abyssinicus.

# 4. RESULTS

## 4.1. Extract Treatment Experiment

Extracts from all the species used in the experiment were each found to inhibit seed germination, plumule growth and/or radicle growth of the test species.

### 4.1.1. The Effect of Extracts On Seed Germination of Test Species (Table 1)

A. abyssinicus was inhibited by extracts of H. arrhenobasis and itself at 0.5% level of significance.

H. arrhenobasis was inhibited by the extract of S. polystachya at 5% level of significance.

P. glabrum was inhibited by the extracts of A. abyssinicus, H. arrhenobasis, S.polystachya, E. jaegeri and itself at 0.5% level of significance.

S. polystachya was inhibited by all extracts including that of its own at 0.5% level of significance.

E. jaegeri was not inhibited by any of the extracts.

E. tenuifolia was significantly inhibited by extracts of A. abyssinicus and S. polystachya at 1% and 0.5% levels of significance respectively but was stimulated by extracts of H. arrhenobasis and M. polymorpha at 5% level of significance.

M. polymorpha was inhibited by extracts of A. abyssinicus, S. polystachya, E. jaegeri and itself at 0,5% level of significance.

**TABLE 1:** Germination frequency and percentage of control of seven species treated with extracts from the same seven species. Key for species (A) = A. abyssinicus, (H) = H. arrhenobasis, (P) = P. glabrum, (S) = S. polystachya, (Er) = E. tenuifolia, (El) = E. jaegeri, (M) = M. polymorpha

| Test species | No. of seeds used | Seeds Germinated | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | control | Treatments using extract from | | | | | | | |
| | | | A | | | H | | | P | |
| | | No 1 2 | No 1 2 | | % of control | No 1 2 | | % of control | No 1 2 | % of control |
| A. abyssinicus | 25 | 12 15 | 7 | 6 | 46.4*** | 4 | 3 | 25.0*** | 19 17 | 128.6 |
| H. arrhenobasis | 25 | 18 19 | 17 | 18 | 94.6 | 18 | 16 | 91.9 | 22 21 | 116.2 |
| P. glabrum | 25 | 18 18 | 5 | 6 | 30.6*** | 4 | 4 | 22.2*** | 10 10 | 55.6*** |
| S. polystachya | 25 | 20 23 | 3 | 2 | 11.6*** | 9 | 7 | 37.2*** | 6 7 | 32.6*** |
| E. jaegeri | 25 | 11 10 | 7 | 7 | 66.7 | 14 | 12 | 123.8 | 7 6 | 61.9 |
| E. tenuifolia | 100 | 9 11 | 5 | 2 | 35.0** | 18 | 15 | 165.0* | 6 8 | 70.0 |
| M. polymorpha | 25 | 23 20 | 13 | 11 | 55.8*** | 20 | 19 | 90.7 | 16 19 | 81.4 |

* significantly different from control (P=0.05) using Chisquare test
** " " " " " (P=0.01) " " "
*** " " " " " (P=0.005) " " "

TABLE 1: (Cont'd)

| Test species | Seeds germinated | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Treatments using extracts from | | | | | | | | | |
| | S | | | El | | | Er | | M | |
| | No 1 | No 2 | % of control | No 1 | No 2 | % of control | No 1 | No 2 | % of control | No 1 | No 2 | % of control |
| A. abyssinicus | 10 | 12 | 78.6 | 12 | 13 | 89.3 | 17 | 15 | 114.0 | 16 | 15 | 110.7 |
| H. arrhenobasis | 12 | 13 | 67.6* | 17 | 15 | 86.5 | 18 | 17 | 94.6 | 18 | 18 | 97.3 |
| P. glabrum | 7 | 5 | 33.3*** | 9 | 7 | 44.4*** | 15 | 16 | 86.1 | 15 | 17 | 88.9 |
| S. polystachya | 4 | 3 | 16.3*** | 10 | 11 | 48.8*** | 14 | 15 | 67.4*** | 10 | 14 | 55.8*** |
| E. jaegeri | 6 | 7 | 61.9 | 9 | 11 | 95.2 | 10 | 9 | 90.5 | 9 | 11 | 95.2 |
| E. tenuifolia | 2 | 3 | 25.0*** | 10 | 11 | 105.0 | 10 | 12 | 110 | 16 | 20 | 180* |
| M. polymorpha | 3 | 3 | 13.9*** | 13 | 14 | 62.8*** | 13 | 15 | 65.1*** | 12 | 12 | 55.8*** |

* significantly different from control (P=0.05) using Chisquare test
** " " " " (P=0.01) " " "
*** " " " " (P=0.005) " " "

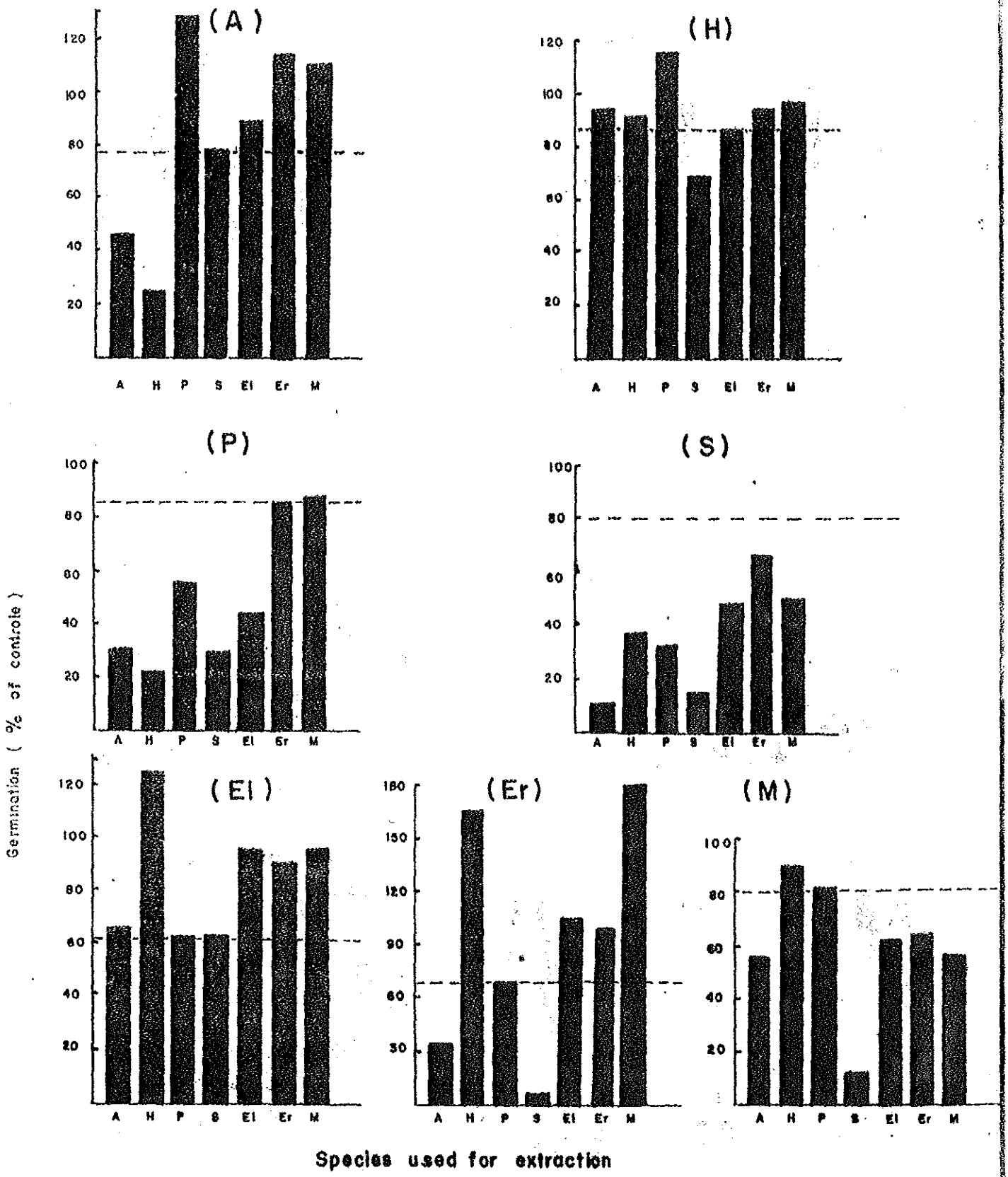


Fig 1. Germination of each of seven species treated with extracts of the same seven species is shown as percentage germination of that in distilled water. Key to species the same as in table 1.
Bars not reaching the dashed line represent significant inhibition P(0.05)

4.1.2. The Effect of Extracts on Plumule Growth of Test Species (Table 2 and 2.1)

A. abyssinicus was inhibited by extracts of S. polystachya and itself at 1% level of significance.

H. arrhenobasis was inhibited by extracts of S. polystachya and itself at 1% level of significance and was significantly stimulated by the extracts of P. glabrum and M. polymorpha at 5% and 1% levels of significance respectively.

P. glabrum was inhibited by extracts of A. abyssinicus, H. arrhenobasis, S. polystachya and itself at 1% level of significance.

S. polystachya was inhibited by extracts of A. abyssinicus and itself at 1% level of significance and by extract of P. glabrum at 5% level of significance.

E. jaegeri was not inhibited by any of the extracts.

E. tenuifolia was inhibited by A. abyssinicus and S. polystachya at 5% and 1% levels of significance respectively.

M. polymorpha was inhibited by A. abyssinicus, E. jaegeri and itself at 5% level of significance and by extracts of S. polystachya at 1% level of significance.

TABLE 2: Mean plumule lengths for each replicate in mm ± standard error (L±SE) of each of seven species treated with extracts from the same seven species. (n) = No. of seedlings measured. For abbrevations refer to table 1.

| Test species | | Control | | Treatment using extracts from | | | |
|---|---|---|---|---|---|---|---|
| | | | | A | | H | |
| | | 1 | 2 | 1 | 2 | 1 | 2 |
| A. abyssinicus | L±SE | 39.9±7.2 | 42.0±8.1 | 27.3±5.3 | 25.0±4.9 | 37.0±6.1 | 42.0±5.4 |
| | n | 10 | 10 | 7 | 6 | 4 | 3 |
| E. arrhenobasis | L±SE | 30.4±4.3 | 32.0±3.8 | 31.9±4.1 | 30.4±4.4 | 20.8±3.9 | 20.4±2.8 |
| | n | 10 | 10 | 10 | 10 | 10 | 10 |
| P. glabrum | L±SE | 20.7±3.3 | 22.0±2.9 | 11.2±1.8 | 11.5±2.1 | 19.6±2.7 | 17.9±2.4 |
| | n | 10 | 10 | 5 | 6 | 4 | 4 |
| S. polystachya | L±SE | 26.5±4.1 | 27.1±3.5 | 23.0±3.2 | 24.0±4.3 | 25.3±3.1 | 27.0±3.9 |
| | n | 10 | 10 | 3 | 2 | 9 | 7 |
| E. jaegeri | L±SE | 19.1±2.7 | 20.4±1.6 | 18.6±2.0 | 19.2±1.8 | 20.5±3.6 | 20.1±3.2 |
| | n | 10 | 10 | 7 | 7 | 10 | 10 |
| E. tenuifolia | L±SE | 14.6±1.7 | 15.0±2.0 | 11.4±1.5 | 12.6±1.2 | 14.7±2.1 | 15.2±2.1 |
| | n | 10 | 10 | 5 | 2 | 10 | 10 |
| M. polymorpha | L±SE | 31.3±3.1 | 33.1±4.2 | 28.7±3.7 | 28.8±3.8 | 33.0±2.9 | 34.1±3.2 |
| | n | 10 | 10 | 10 | 10 | 10 | 10 |

Table 2: (cont'd)

| Test species | | Treatments using extracts from | | | | | |
|---|---|---|---|---|---|---|---|
| | | P | | S | | El | |
| | | 1 | 2 | 1 | 2 | 1 | 2 |
| A. abyssinicus | L±SE | 41.9±6.3 | 38.6±5.7 | 11.4±4.1 | 12.3±3.9 | 39.7±7.2 | 33.8±6.8 |
| | n | 10 | 10 | 10 | 10 | 10 | 10 |
| E. arrhenobasis | L±SE | 33.1±4.1 | 35.9±4.5 | 18.4±3.1 | 17.3±2.9 | 31.2±3.7 | 31.9±4.0 |
| | n | 10 | 10 | 10 | 10 | 10 | 10 |
| P. glabrum | L±SE | 18.4±3.1 | 18.8±3.3 | 11.5±2.5 | 11.5±2.1 | 21.6±3.4 | 20.6±6.0 |
| | n | 10 | 10 | 7 | 5 | 9 | 7 |
| S. polystachya | L±SE | 24.9±2.8 | 24.3±3.2 | 23.1±2.9 | 24.7±2.7 | 26.3±3.3 | 26.0±3.8 |
| | n | 6 | 8 | 4 | 3 | 10 | 10 |
| E. jaegeri | L±SE | 19.6±2.1 | 20.6±1.8 | 19.6±3.3 | 20.1±2.9 | 20.9±2.9 | 20.4±3.4 |
| | n | 7 | 6 | 6 | 7 | 9 | 10 |
| E. tenuifolia | L±SE | 13.2±1.8 | 13.6±2.5 | 8.0±1.1 | 5.0±1.5 | 14.1±1.9 | 15.0±2.3 |
| | n | 6 | 8 | 2 | 3 | 10 | 10 |
| M. polymorpha | L±SE | 32.3±4.4 | 29.7±3.7 | 18.2±2.9 | 15.9±3.4 | 29.1±4.2 | 28.6±3.7 |
| | n | 10 | 10 | 3 | 3 | 10 | 10 |

Table 2: (cont'd)

| Test species | | Treatments using extracts from | | | |
|---|---|---|---|---|---|
| | | Er | | M | |
| | | 1 | 2 | 1 | 1 |
| A. abyssinicus | L±SE | 39.8±6.7 | 37.1±7.2 | 40.3±7.4 | 39.2±7.0 |
| | n | 10 | 10 | 10 | 10 |
| H. arrhenobasis | L±SE | 31.2±4.5 | 33.1±4.6 | 40.8±5.1 | 40.7±3.8 |
| | n | 10 | 10 | 10 | 10 |
| P. glabrum | L±SE | 20.9±2.3 | 21.8±3.1 | 20.5±2.1 | 21.3±3.2 |
| | n | 10 | 10 | 10 | 10 |
| S. polystachya | L±SE | 25.8±3.5 | 26.3±4.0 | 26.5±2.7 | 25.8±3.3 |
| | n | 10 | 10 | 10 | 10 |
| E. jaegari | L±SE | 20.1±1.6 | 20.7±3.0 | 20.7±1.7 | 20.5±2.3 |
| | n | 10 | 9 | 9 | 10 |
| E. tenuifolia | L±SE | 14.9±2.1 | 14.6±2.5 | 16.5±3.1 | 16.1±2.8 |
| | n | 10 | 10 | 10 | 10 |
| M. polymorpha | L±SE | 29.7±3.2 | 29.1±3.5 | 29.1±4.3 | 28.3±3.5 |
| | n | 10 | 10 | 10 | 10 |

TABLE 2.1. Mean plumule lengths in mm (from the replicates in table 2).
Abbrevations the same as in table 1.

| Test species | Mean plumule length in mm. | | | | | | | | L.S.D. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Treatments using extracts from | | | | | | | P(0.05) | P(0.01) |
| | | A | H | P | S | El | Er | M | | |
| A. abyssinicus | 40.45 | 26.15** | 39.50 | 40.25 | 11.85** | 35.85 | 38.45 | 41.10 | 5.44 | 8.62 |
| H. arrhenobasis | 31.20 | 31.15 | 20.60** | 34.50 | 17.85* | 31.55 | 32.15 | 40.75** | 2.44 | 3.53 |
| P. glabrum | 21.35 | 11.35** | 18.75** | 18.60** | 11.50** | 21.40 | 21.35 | 20.90 | 1.53 | 2.23 |
| S. polystachya | 26.80 | 23.50** | 26.15 | 24.60** | 23.50** | 26.15 | 26.05 | 26.15 | 1.71 | 2.49 |
| E. jaegeri | 19.75 | 18.90 | 20.30 | 19.90 | 19.85 | 20.15 | 20.40 | 20.60 | 1.07 | 1.57 |
| E. tenuifolia | 14.80 | 12.0* | 14.95 | 13.40 | 6.50** | 14.55 | 14.75 | 16.30 | 1.99 | 2.90 |
| M. polymorpha | 32.20 | 28.75* | 33.55 | 30.95 | 17.05** | 28.85* | 29.40 | 28.70* | 2.67 | 3.88 |

* singnificantly different from the control at 5% level
** " " " " " " 1% "

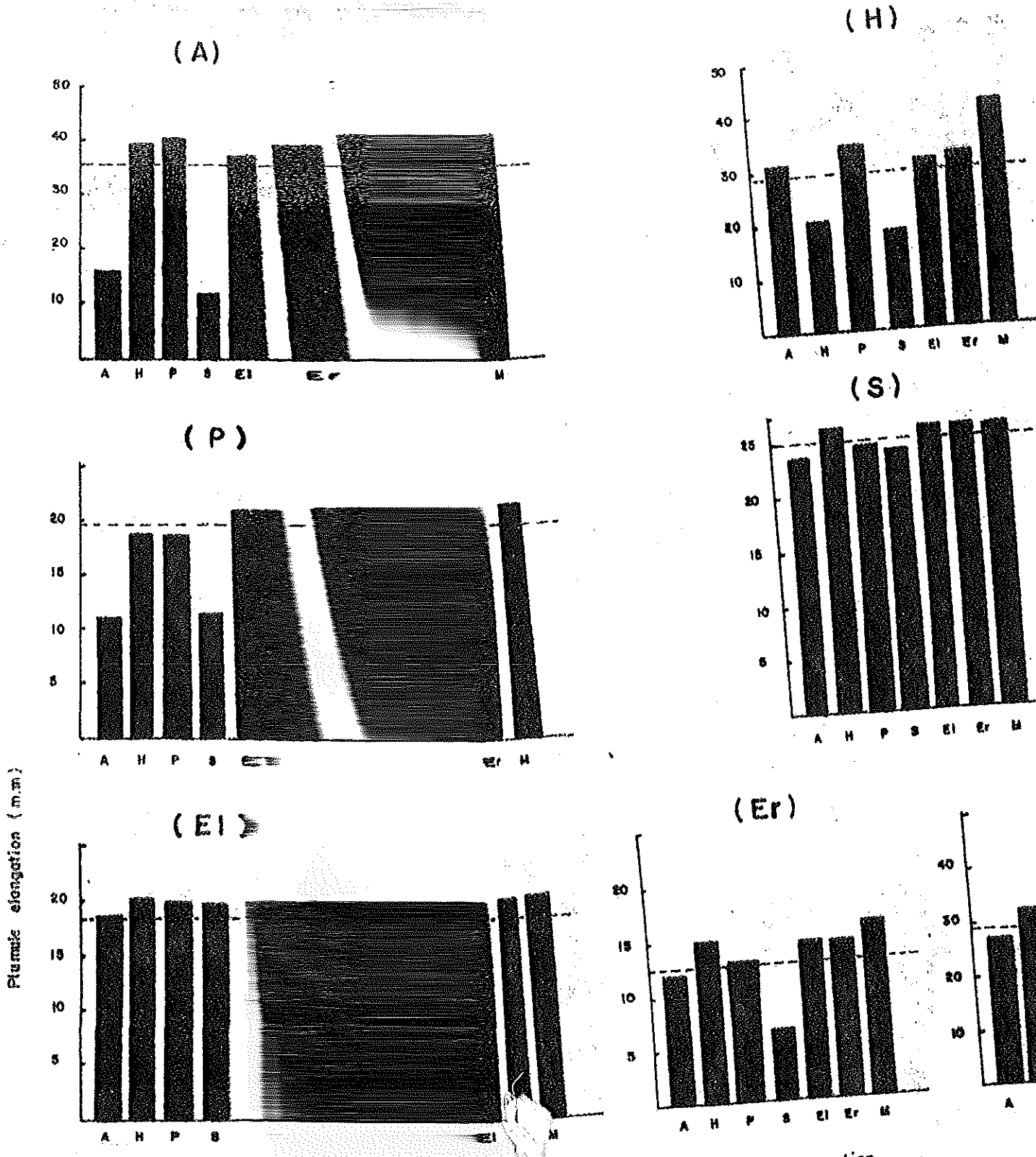


Fig 2. Plumule length in m.m of each of seven species treated with extracts of the s
Bars not reaching the dashed line represent significant inhibition P(0.05)
Key the same as in table 1.

4.1.3. The Effect of extracts on radicle growth of test species (Tables 3 and 3.1)

A. abyssinicus was inhibited by extracts of H. arrhenobasis, P. glabrum, S. polystachya, and itself at 1% level of significance.

H. arrhenobasis was inhibitedby extracts of S. polystachya and itself at 1% level of significnace and was significantly stimulated ($p=0.01$) by the extracts of P. glabrum and M. polymorpha.

P. glabrum was inhibited by extracts of A. abyssinicus, H. arrhenobasis, S. polystachya, E. jaegeri and itself at 1% level of significance and was significantly stimulated ($P=0.05$) by the extract of M. polymorpha.

S. polystachya was inhibited by the extract of each test species at 1% level of significance..

E. jaegeri was inhibited by extracts of A. abyssinicus, P. glabrum, S. polystachya and itself at 1% level of significance.

E. tenuifolia was inhibited by extracts of A. abyssinicus and S. polystachya at 5% and 1% levels of significance respectively.

M. polymorpha was inhibited by extracts of S. polystachya, E. jaegeri, E. tenuifolia and itself at 1% level of significance.

TABLE 3: Mean radicle lengths for each replicate in mm ± standard error (L+SE) of each of seven species treated with extracts of the same seven species. (n) = No. of seedlings measured. For abbreviations refer to table 1.

| Test species | | Control | | Treatments using extracts from A 1 | A 2 | H 1 | H 2 |
|---|---|---|---|---|---|---|---|
| A. abyssinicus | L±SE | 28.9±5.3 | 26.1±4.3 | 13.3±4.5 | 12.7±3.3 | 16.5±2.7 | 15.0±3.1 |
| | n | 10 | 10 | 7 | 6 | 4 | 3 |
| H. arrhenobasis | L±SE | 23.2±3.4 | 23.5±3.2 | 22.6±3.2 | 22.1±2.8 | 10.4±2.1 | 11.8±2.4 |
| | n | 10 | 10 | 10 | 10 | 10 | 10 |
| P. glabrum | L±SE | 13.1±2.2 | 14.2±3.2 | 10.4±1.1 | 10.6±1.4 | 10.3±2.0 | 10.0±1.9 |
| | n | 10 | 10 | 5 | 6 | 4 | 4 |
| S. polystachya | L±SE | 25.0±3.5 | 24.7±4.1 | 10.5±2.3 | 11.6±1.8 | 18.0±3.1 | 18.2±2.1 |
| | n | 10 | 10 | 3 | 2 | 9 | 7 |
| E. jaegeri | L±SE | 24.6±4.1 | 23.3±3.1 | 18.7±2.3 | 20.3±2.0 | 22.4±3.1 | 24.5±2.9 |
| | n | 10 | 10 | 7 | 7 | 10 | 10 |
| E. tenuifolia | L±SE | 8.4±1.7 | 9.1±1.5 | 6.4±0.9 | 7.0±1.3 | 11.7±1.6 | 10.1±2.0 |
| | n | 9 | 10 | 5 | 2 | 10 | 10 |
| M. polymorpha | L±SE | 31.1±6.7 | 30.0±5.1 | 21.7±4.2 | 20.3±4.4 | 31.6±4.8 | 32.0±4.3 |
| | n | 10 | 10 | 10 | 10 | 10 | 10 |

Table 3: (cont'd)

| Test species | | Treatments using extracts from | | | | | |
|---|---|---|---|---|---|---|---|
| | | P | | S | | El | |
| | | 1 | 2 | 1 | 2 | 1 | 2 |
| A. abyssinicus | L±SE | 34.2±5.8 | 35.3±4.9 | 12.7±3.7 | 12.2±2.9 | 26.2±3.5 | 25.4±3.3 |
| | n | 10 | 10 | 10 | 10 | 10 | 10 |
| H. arrhenobasis | L±SE | 37.1±3.1 | 38.2±3.5 | 12.5±2.5 | 12.7±2.0 | 24.5±3.3 | 23.3±2.9 |
| | n | 10 | 10 | 10 | 10 | 10 | 10 |
| P. glabrum | L±SE | 11.6±2.1 | 11.3±1.8 | 10.6±3.0 | 10.9±2.7 | 11.0±1.4 | 11.3±1.9 |
| | n | 10 | 10 | 7 | 5 | 9 | 7 |
| S. polystachya | L±SE | 19.0±2.7 | 18.1±3.1 | 20.4±2.0 | 20.8±2.1 | 13.3±1.1 | 15.4±1.8 |
| | n | 6 | 8 | 4 | 3 | 10 | 10 |
| E. jaegeri | L±SE | 19.3±2.0 | 19.7±2.3 | 19.4±1.9 | 20.1±2.3 | 19.5±3.1 | 19.1±2.8 |
| | n | 7 | 6 | 6 | 7 | 9 | 10 |
| E. tenuifolia | L±SE | 9.5±1.8 | 8.3±1.2 | 3.4±0.7 | 4.1±0.9 | 8.7±1.8 | 9.3±2.1 |
| | n | 6 | 8 | 2 | 3 | 10 | 10 |
| M. polymorpha | L±SE | 24.6±3.7 | 23.0±3.3 | 8.6±1.9 | 10.6±2.1 | 23.2±3.4 | 19.6±2.3 |
| | n | 10 | 10 | 3 | 3 | 10 | 10 |

Table 3: (cont'd)

| Test species | | Treatments using extracts from | | | |
|---|---|---|---|---|---|
| | | Er | | M | |
| | | 1 | 2 | 1 | 2 |
| A. abyssinicus | L±SE | 28.7±4.3 | 27.2±3.9 | 28.1±2.8 | 26.4±3.1 |
| | n | 10 | 10 | 10 | 10 |
| H. arrhenobasis | L±SE | 22.6±1.9 | 22.0±2.2 | 31.1±3.4 | 31.5±2.8 |
| | n | 10 | 10 | 10 | 10 |
| P. glabrum | L±SE | 13.7±3.1 | 12.5±2.4 | 15.5±3.3 | 14.6±2.6 |
| | n | 10 | 10 | 10 | 10 |
| S. polystachya | L±SE | 20.9±2.7 | 21.5±2.3 | 18.7±2.6 | 20.1±2.1 |
| | n | 10 | 10 | 10 | 10 |
| E. jaegeri | L±SE | 23.1±3.8 | 23.3±3.2 | 23.1±3.5 | 23.3±3.3 |
| | n | 10 | 9 | 9 | 10 |
| E. tenuifolia | L±SE | 9.0±1.5 | 9.4±1.8 | 11.1±2.0 | 11.8±2.3 |
| | n | 10 | 10 | 10 | 10 |
| M. polymorpha | L±SE | 22.0±4.1 | 19.9±3.8 | 17.1±2.9 | 16.5±2.4 |
| | n | 10 | 10 | 10 | 10 |

TABLE 3.1. Mean radicle lengths in mm (from the replicates in table 3).
Abbreviations the same as in table 1.

| Test species | Mean radicle length in mm | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | control | treatments using extracts from | | | | | | | L.S.D. | |
| | | A | H | P | S | El | Er | M | P(0.05) | P(0.01) |
| A. abyssinicus | 27.50 | 13.0** | 15.75** | 34.75** | 12.45** | 25.80 | 27.95 | 27.25 | 2.27 | 3.31 |
| H. arrhenobasis | 23.35 | 22.35 | 11.10** | 37.65** | 12.60** | 23.90 | 22.30 | 31.30** | 1.35 | 5.72 |
| P. glabrum | 13.65 | 10.50** | 10.15** | 11.45** | 10.75** | 11.15** | 13.10 | 15.05* | 1.09 | 1.60 |
| S. polystachya | 24.85 | 11.05** | 18.10** | 18.55** | 20.60** | 14.35 | 21.20** | 19.40** | 1.71 | 2.49 |
| E. jaegeri | 23.95 | 19.50** | 23.45 | 19.50** | 19.75** | 19.30** | 23.20 | 23.45 | 2.00 | 2.91 |
| E. tenuifolia | 8.75 | 6.70* | 10.90* | 8.90 | 3.75** | 9.0 | 9.20 | 11.45* | 1.67 | 2.43 |
| M. polymorpha | 30.55 | 21.0** | 31.8 | 24.20** | 9.60** | 21.40** | 20.95** | 16.80** | 2.92 | 4.25 |

* significantly different from the control at 5% level
** " " " " " " 1% "

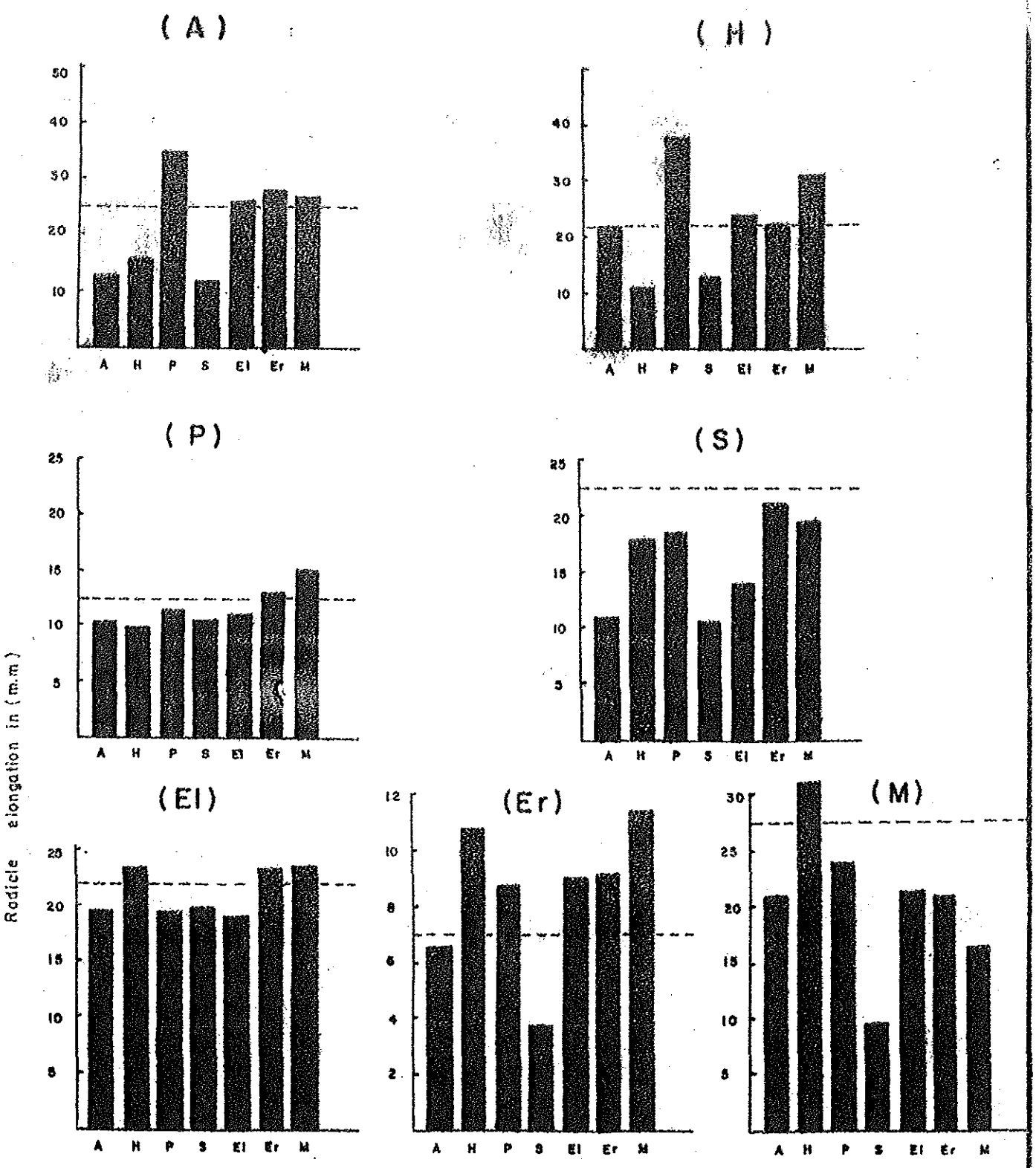


Fig.3 Radicle length of each of seven species treated with extracts of the same seven species. Bars not reaching upto the dashed line represent significant inhibition P(0.05)

Key the same as in table.1

## 4.2. Experiments with A. abyssinicus

### 4.2.1. Effects of A. abyssinicus Shoot and Root Extracts

Both shoot and root extracts of A. abyssinicus significantly inhibited ($P \leq 0.005$) the germination of the three test species used in the experiment, (Table 4).

Plumule growth of each test species was significantly inhibited by the shoot extract but was not affected by root extract (Table 4.1.).

Both shoot and root extracts have significantly inhibited the radicle growth of each of the test species (Table 4.2.). Radicle lengths of A. abyssinicus and P. glabrum in the treatments were significantly different from those in the control at 1% level of significance. The radicle length of S. polystachya in the treatments was significantly different from that in the control at 5% level of significance.

### 4.2.2. Leaf Leachate Experiment

The live leaf leachate of A. abyssinicus was found to have no significant inhibiting or stimulating effect on any of the germination, plumule growth or radicle growth of the test species (Table 5 to 5.2.)

TABLE 4: Germination frequency and percentage of control of three test species treated with *A. abyssinicus* shoot and root extracts.

| Test species | Control | | Shoot extract treatment | | | Root extract treatment | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 1 | 2 | % of control | 1 | 2 | % of control |
| *A. abyssinicus* | 19 | 19 | 7 | 6 | 34.2 | 9 | 10 | 50.0 |
| *S. polystachya* | 18 | 17 | 2 | 3 | 14.3 | 7 | 9 | 45.7 |
| *P. glabrum* | 15 | 17 | 6 | 4 | 31.3 | 6 | 7 | 40.6 |

All treatment were found to be significantly different from the control ($P<0.005$) using Chi-square test.

TABLE 4.1. Mean plumule lengths (mm) of three test species treated with A. abyssinicus shoot and root extracts. (n) = No. of seedlings measured.

| Test species | | Control | | treatment | | | |
|---|---|---|---|---|---|---|---|
| | | | | Shoot extract | | Root extract | |
| | | 1 | 2 | 1 | 2 | 1 | 2 |
| A. abyssinicus | L±SE | 38.2±6.5 | 40.2±8.3 | 26.8±5.3 | 29.1±6.3 | 34.1±5.1 | 37.6±7.4 |
| | n | 10 | 10 | 7 | 6 | 9 | 10 |
| S. polystachya | L±SE | 28.7±3.6 | 28.0±3.1 | 26.9±2.8 | 25.7±1.8 | 27.5±4.1 | 28.1±3.4 |
| | n | 10 | 10 | 2 | 3 | 7 | 9 |
| P. glabrum | L±SE | 22.2±2.3 | 20.2±2.3 | 16.3±3.8 | 15.1±1.9 | 23.0±2.8 | 20.6±2.4 |
| | n | 10 | 10 | 6 | 4 | 6 | 7 |

| Test species | Mean plumule length (mm) of replicates | | | L.S.D. | |
|---|---|---|---|---|---|
| | control | treatments | | | |
| | | Shoot extract | Root extract | P(0.05) | P(0.01) |
| A. abyssinicus | 39.20 | 27.95** | 35.85 | 6.0 | 11.02 |
| S. polystachya | 28.35 | 26.25* | 27.80 | 1.88 | 3.47 |
| P. glabrum | 21.20 | 15.70* | 21.65 | 4.36 | 7.99 |

*Significantly different from control at 5% level
** " " " " " 1% "

Table 4.2. Mean radicle lengths (mm) of three test species treated with *A. abyssinicus* shoot and root extracts. (n) = No of seedlings measured

| Test species | | control 1 | control 2 | treatment: Shoot extract 1 | treatment: Shoot extract 2 | treatment: Root extract 1 | treatment: Root extract 2 |
|---|---|---|---|---|---|---|---|
| *A. abyssinicus* | 1±SE | 27.9±4.1 | 26.5±3.8 | 14.7±3.2 | 15.0±3.5 | 21.0±4.2 | 20.2±2.9 |
| | n | 10 | 10 | 7 | 6 | 9 | 10 |
| *S. polystacha* | L±SE | 25.0±3.7 | 23.1±2.8 | 29.0±1.4 | 19.0±3.5 | 20.5±3.3 | 21.4±4.2 |
| | n | 10 | 10 | 2 | 3 | 7 | 9 |
| *P. glabrum* | L±SE | 14.0±2.4 | 15.2±2.9 | 8.7±1.6 | 9.5±1.4 | 14.6±2.1 | 15.4±3.2 |
| | n | 10 | 10 | 6 | 4 | 6 | 7 |

| Test species | Mean radicle length (mm) of replicates: control | treatment: Shoot extract | treatment: Root extract | L.S.D. P(0.05) | L.S.D. P(0.01) |
|---|---|---|---|---|---|
| *A. abyssinicus* | 27.20 | 14.85** | 20.60** | 1.77 | 3.24 |
| *S. polystachya* | 24.05 | 19.0* | 20.78* | 2.86 | 5.25 |
| *P. glabrum* | 14.60 | 9.1** | 15.0** | 2.14 | 3.93 |

* significantly different from control at 5% level
** " " " " " 1% "

Table 5 - Germination frequency of test species treated with *A. abyssinicus* leaf leachate

| Test species | No. of seeds used | No. of seeds germinated | | | | Germination % of control |
|---|---|---|---|---|---|---|
| | | Control | | Treatment | | |
| | | 1 | 2 | 1 | 2 | |
| *A. abyssinicus* | 25 | 13 | 14 | 15 | 14 | 107.4 |
| *H. arrhenobasis* | 25 | 20 | 20 | 20 | 20 | 100.0 |
| *P. glabrum* | 25 | 15 | 16 | 17 | 16 | 106.5 |
| *S. polystachya* | 25 | 19 | 20 | 20 | 20 | 102.6 |
| *E. jaegeri* | 25 | 11 | 10 | 10 | 10 | 95.2 |
| *E. tenuifolia* | 100 | 11 | 10 | 10 | 12 | 104.8 |
| *M. polymorpha* | 25 | 23 | 24 | 23 | 24 | 100.0 |

No significant difference was found using chi-square test.

TABLE 5.1. Plumule lengths (mm) of test species treated with *A. abyssinicus*, leaf leachate

| Test species | control | | | treatment | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | Mean ± SE | 1 | 2 | Mean ± SE |
| *A. abyssinicus* | 38.6 | 37.3 | 37.95±0.92 | 38.3 | 38.2 | 38.25±0.07 |
| *H. arrhenobasis* | 31.2 | 30.0 | 30.6±0.85 | 31.2 | 30.1 | 30.65±0.78 |
| *P. glabrum* | 20.7 | 20.1 | 20.4±0.42 | 20.5 | 20.8 | 20.65±0.21 |
| *S. polystachya* | 28.7 | 28.1 | 28.4±0.42 | 29.4 | 28.0 | 28.70±0.98 |
| *E. jaegeri* | 17.9 | 16.9 | 17.4±0.71 | 16.3 | 18.8 | 17.55±1.77 |
| *E. tenuifolia* | 14.5 | 13.5 | 14.0±0.71 | 13.6 | 13.9 | 13.75±0.21 |
| *M. polymorpha* | 33.1 | 34.4 | 33.75±0.92 | 34.2 | 34.3 | 34.25±0.07 |

Each figure in the replicates represent a mean from 10 seedlings.

No significant difference was found using "t" test comparisons of means

TABLE 5.2. Radicle lengths (mm) of test species treated with *A. abyssinicus*, leaf leachate.

| Test species | control | | | treatment | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | Mean ± SE | 1 | 2 | Mean ± SE |
| *A. abyssinicus* | 26.5 | 26.0 | 26.25±0.35 | 26.3 | 28.3 | 27.30±1.41 |
| *H. arrhenobasis* | 23.0 | 24.0 | 23.50±0.71 | 25.2 | 23.2 | 24.20±1.41 |
| *P. glabrum* | 14.5 | 13.2 | 13.85±0.92 | 15.0 | 14.4 | 14.70±0.42 |
| *S. polystachya* | 23.9 | 24.1 | 24.0±0.14 | 24.6 | 23.5 | 24.05±0.78 |
| *E. jaegeri* | 23.2 | 23.5 | 23.35±0.21 | 23.3 | 28.5 | 25.50±3.67 |
| *E. tenuifolia* | 5.0 | 7.0 | 6.0±0.14 | 7.6 | 4.7 | 6.15±2.05 |
| *M. polymorpha* | 39.2 | 40.4 | 39.8±0.85 | 39.6 | 41.9 | 40.75±1.63 |

- Each figure in the replicates represents a mean from 10 seedlings.
- No significant difference was found using "t" test comparisons of means.

4.2.3. Growth Performance of Test Species Grown with A. abyssinicus

Shoot heights and dry weights of test species grown with A. abyssinicus were not significantly different from those of control (Tables 6 and 7). Neither was any significant difference found among the heights and dry weights of A. abyssinicus grown with the different test species (Table 8).

4.2.4. Root Leachate Experiment

The root leachate of A. abyssinicus had no significant effect on the shoot heights and dry weights of the test species (Tables 9 and 10).

4.2.5. Experiment with Decomposing A. abyssinicus Plant Material

Shoot height differences between controls and treatments were found to be significant at 5% level for P. glabrum and E. tenuifolia and at 1% level for S. polystachya and E. jaegeri (Table 11).

Dry weight differences were also found to be significant at 5% level for S. polystachya, at 1% level for E. jaegeri and E. tenuifolia and at 0.1% for P. glabrum (Table 12).

Table 6: Shoot heights in cm of test species grown with A. abyssinicus in sand culture

| | height measurements in cm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | control | | | | treatment | | | |
| | 1 | 2 | 3 | Mean ± SE | 1 | 2 | 3 | Mean ± SE |
| H. arrhenobasis | 27.8 | 28.86 | 25.18 | 27.28±1.89 | 25.78 | 27.18 | 28.70 | 27.22±1.46 |
| P. glabrum | 25.82 | 26.80 | 27.07 | 26.56±0.66 | 25.06 | 27.74 | 25.98 | 26.26±1.36 |
| S. polystachya | 36.61 | 36.10 | 35.04 | 35.92±0.80 | 36.30 | 34.20 | 36.80 | 35.77±1.38 |
| E. jaegeri | 16.58 | 17.22 | 16.56 | 16.79±0.38 | 17.53 | 16.80 | 15.88 | 16.74±0.83 |
| E. tenuifolia | 13.46 | 13.17 | 14.30 | 13.64±0.59 | 13.95 | 14.54 | 13.10 | 13.86±0.72 |
| M. polymorpha | 9.6 | 11.08 | 12.00 | 10.89±1.21 | 13.44 | 11.08 | 9.66 | 11.39±1.91 |

No significant differences were found using "t" test comparisons of means

Table 7: Dry weights in grams of test species grown with A. abyssinicus in sand culture

| Test species | Dry weight in grams | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | control | | | | treatment | | | |
| | 1 | 2 | 3 | Mean ± SE | 1 | 2 | 3 | Mean ± SE |
| H. arrhenobasis | 0.832 | 0.835 | 0.885 | 0.851±0.029 | 0.882 | 0.820 | 0.848 | 0.848±0.031 |
| P. glabrum | 0.785 | 0.780 | 0.768 | 0.778±0.009 | 0.858 | 0.782 | 0.757 | 0.757±0.117 |
| S. polystachya | 1.887 | 1.662 | 1.860 | 1.803±0.123 | 1.662 | 1.926 | 1.775 | 1.775±0.136 |
| E. jaegeri | 0.801 | 0.979 | 0.917 | 0.899±0.09 | 0.841 | 0.907 | 0.893 | 0.893±0.047 |
| E. tenuifolia | 0.633 | 0.614 | 0.571 | 0.606±0.032 | 0.668 | 0.592 | 0.592 | 0.611±0.05 |
| M. polymorpha | 0.815 | 0.817 | 0.819 | 0.817±0.002 | 0.816 | 0.827 | 0.827 | 0.827±0.014 |

No significant differences were found using "t" test comparisons of means.

Table 8: Shoot heights and dry weights of A. abyssinicus grown with six test species in sand culture. Key to species the same as in table 1.

| A. abyssinicus + test species | height in cm | | | | dry weight in grams | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | Mean ± SE | 1 | 2 | 3 | Mean ± SE |
| (A) control | 28.6 | 29.7 | 27.5 | 28.6±1.1 | 0.784 | 0.982 | 0.683 | 0.816±0.152 |
| A + H | 30.1 | 27.0 | 26.1 | 27.7±2.1 | 0.967 | 0.739 | 0.718 | 0.808±0.138 |
| A + P | 29.7 | 28.4 | 25.8 | 27.9±1.9 | 0.860 | 0.828 | 0.688 | 0.792±0.091 |
| A.+ S | 28.1 | 26.3 | 27.4 | 27.3±0.9 | 0.788 | 0.765 | 0.778 | 0.777±0.012 |
| A + El | 28.5 | 29.1 | 27.9 | 28.5±0.6 | 0.878 | 0.913 | 0.673 | 0.821±0.130 |
| A + Er | 27.2 | 29.5 | 27.6 | 28.1±1.2 | 0.774 | 0.869 | 0.785 | 0.809±0.052 |
| A + M | 29.6 | 29.4 | 28.3 | 29.1±0.7 | 0.994 | 0.987 | 0.859 | 0.947±0.076 |

No significant differences were found using "t" test comparisons of means.

Table 9: Shoot heights in cm of three test species treated with *A. abyssinicus* root leachate.

| Test species | height measurements in cm. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | control | | | | treatment | | | |
| | 1 | 2 | 3 | Mean ± SE | 1 | 2 | 3 | Mean ± SE |
| *P. glabrum* | 24.20 | 23.50 | 24.10 | 23.90±0.38 | 24.44 | 25.40 | 23.40 | 24.41±1.0 |
| *S. polystachya* | 37.50 | 36.76 | 35.20 | 36.49±1.17 | 36.0 | 38.70 | 36.04 | 36.91±1.55 |
| *E. jaegeri* | 16.30 | 16.18 | 15.84 | 16.11±0.24 | 14.50 | 17.22 | 18.50 | 16.74±2.04 |

No significant differences were found using "t" test comparisons of means.

Table 10: Dry weights in grams of three test species treated with *A. abyssinicus* root leachate.

| Test species | Dry weight in grams | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | control | | | | treatment | | | |
| | 1 | 2 | 3 | Mean ± SE | 1 | 2 | 3 | Mean ± SE |
| *P. glabrum* | 0.729 | 0.782 | 0.777 | 0.763±0.029 | 0.777 | 0.701 | 0.739 | 0.739±0.039 |
| *S. polystachya* | 1.894 | 1.873 | 1.839 | 1.869±0.028 | 1.816 | 1.663 | 1.988 | 1.837±0.164 |
| *E. jaegeri* | 0.862 | 0.877 | 0.826 | 0.855±0.026 | 0.846 | 0.884 | 0.799 | 0.843±0.043 |

No significant differences were found using "t" test comparisons of means.

TABLE 11: Shoot heights in cm of test species grown in soils containing decomposing *A. abyssinicus* plant material.

| Test species | Height measurements in cm. | | | | | |
|---|---|---|---|---|---|---|
| | control | | | treatment | | |
| | 1 | 2 | Mean ± SE | 1 | 2 | Mean ± SE |
| *A. abyssinicus* | 37.20 | 36.50 | 36.85±0.49 | 35.70 | 32.50 | 34.10±2.3 |
| *H. arrhenobasis* | 31.36 | 29.82 | 30.59±1.08 | 29.30 | 33.50 | 31.40±2.96 |
| *P. glabrum* | 31.56 | 29.82 | 30.65±1.23 | 22.30 | 22.50 | 22.40±0.14* |
| *S. polystachya* | 27.82 | 26.90 | 27.36±0.65 | 22.30 | 22.50 | 22.40±0.14** |
| *E. jaegeri* | 50.96 | 48.86 | 49.90±1.48 | 31.14 | 32.30 | 31.72±0.81** |
| *E. tenuifolia* | 37.04 | 38.92 | 37.98±1.33 | 28.90 | 28.58 | 28.74±0.23* |
| *M. polymorpha* | 24.60 | 23.64 | 24.12±0.68 | 24.41 | 22.74 | 23.57±1.17 |

"t" test, * significantly different from control at 5% level

** " " " " " 1% "

TABLE 12: Dry weights in grams of test species grown in soils containing decomposing A. abyssinicus plant materials.

| Test species | Dry weight in grams | | | | | |
|---|---|---|---|---|---|---|
| | control | | | treatment | | |
| | 1 | 2 | Mean ± SE | 1 | 2 | Mean ± SE |
| A. abyssinicus | 2.2 | 2.4 | 2.30±0.14 | 2.1 | 1.8 | 1.95±0.21 |
| H. arrhenobasis | 3.8 | 3.7 | 3.75±0.07 | 3.7 | 3.9 | 3.80±0.14 |
| P. glabrum | 3.8 | 3.7 | 3.75±0.07 | 2.1 | 2.1 | 2.1±0*** |
| S. polystachya | 1.9 | 1.8 | 1.85±0.07 | 1.1 | 1.2 | 1.15±0.07* |
| E. jaegeri | 3.6 | 3.6 | 3.60±0 | 1.3 | 1.5 | 1.40±0.14** |
| E. tenuifolia | 2.5 | 2.5 | 2.50±0 | 1.1 | 1.0 | 1.05±0.14** |
| M. polymorpha | 3.2 | 3.1 | 3.15±0.07 | 3.3 | 3.2 | 3.25±0.14 |

"t" test, * significantly different from control at 5% level
** " " " " " " 1% "
*** " " " " " " 0.1% "

## 5. DISCUSSION AND CONCLUSION

Allelopathy is a widely distributed phenomenon among plant communities (Evenari, 1949; Putman and Duke, 1974; Woods, 1960). This fact can be seen clearly from the results of the extract treatments. The extract from each test species was found to be inhibitory in at least one case (Tables 1 to 3.1).

Autotoxicity was as high as allotoxicity. All, except H. arrhenobasis, E. jaegeri, and E. tenuifolia significantly inhibited their own seed germination. The extract of each of the species except E. tenuifolia significantly inhibited radicle growth of their own seedlings. The only species that did not exihibit autotoxicity for either germination or radicle growth was E. tenuifolia.

Extracts of A. abyssinicus and S. polystachya were found to be the most inhibitory followed by those of H, arrhenobasis and E. jaegeri in that order. The extracts of E. tenuifolia, M. polymorpha and P. glabrum were relatively less inhibitory. The extract of A. abyssinicus was found to inhibit seed germination of P. glabrum, S. polystachya, E. tenuifolia, M. polymorpha and itself, significantly at 1% level or less (Table 1). It significantly inhibited radicle growth of P. glabrum, S. polystachya, E. jaegeri, M. polymorpha and that of itself at 1% level and that of E. tenuifolia at 5% level (Table 3.1)

The extract of S. polystachya was found to inhibit significantly seed germination of P. glabrum, E. tenuifolia, M. polymorpha and itself at 0.5% level and that of H. arrhenobasis at 5% level.

Radicle elongation of all test species was also significantly inhibited ($P < 0.001$) (Tables 1 and 3.1)

Of all test species, S. polystachya and P. glabrum were the most susceptible to inhibition. Seed germination and radicle growth of S. polstachya were significantly inhibited by extracts of all the species at either 0.5% or 1% levels of significance. Extracts from all test species, except those of E. tenuifolia and M. polymorpha, significantly inhibited seed germination of P. glabrum (Fig. 1 to 3).

The demosntration of allelopathy in the laboratory does not prove that it operates in field conditions. In the field, the activities of the allelopathic substances are influenced by many factors such as soil dynamics, soil temperature, soil moisture, soil microorganisms etc. (Newman and Rovira, 1975; Stowe, 1979). This does not mean that allelopathy is not operating in the field. Laboratory results can have many correlations with the field distribution of plants in a given community.

One of the striking results of the extract treatment in this experiment is that of S. polystachya. The seed germination and radicle growth of S. polystachya was found to be severely inhibited by extracts from all test species including itself. On the other hand, its extracts have shown significant inhibition on the germination of five and radicle elongation of all test species. Naturally two species which are inhibitory to each other might be expected to avoid each other.

Simple observations in the field show that S. polystachya is hardly ever seen in association with the test species and the other grasses that grow with them. It is observed to grow in pure stands, in soils that seem to have high humus incorporated, with animal dung and organic debris. The exclusion of S. polystachya from the grass community that include the test species, and the presence of S. polystachya in pure stands may be attributed to the inhibitory effect of all test species on S. polystachya and S. polystachya on the other species.

It is also known that S. polystachya does not occupy the same place for a long time, it is soon replaced by other grasses. The humus content in the area can not be easily depleted because S. polystachya would, itself, change to humus. So the cause for its disappearance would seem to be the inhibitory effect of its own residue on its seed germination.

S. polystachya is known to be a serious weed of arable land (Froman and Persson, 1974). This may also be attributed to its allelopathic effects on cultivated crops.

Another species that was found to be severely inhibited by the extracts of the majority of the species was P. glabrum. P. glabrum is known to thrive under water-logged conditions (Alemayehu, 1979; Froman and Persson, 1974). A. abyssinicus, H. arrhenobasis and S. polystachya, which have severely inhibited seed germination and radicle growth of P. glabrum do not grow well in water-logged conditions (Froman and Persson, 1974). Therefore, adaptation to

water-logged condition may thus help P. glabrum in avoiding allelopathic species that do not grow well in such condition.

The ability of an organism to maintain itself and to reproduce in a specific habitat is a measure of the relative success of that species. A further indication of that success is its ability to invade areas containing established communities and to become a viable member of that community structure (Gant and Clebsch, 1975). Invasion and perpetuation of a species in an established community require either the more efficient use of one or more of the resources essential for survival or the production of chemicals that would hinder potential competitors (Gant and Clebsch, 1975).

A. abyssincus, H. arrhenobasis and E. jaegeri are among the most common species observed in grass communities growing in and around Addis Ababa. Rattray (1960) has also cited that H. arrhenobasis and A. abyssinicus are common species in both Hyparrhenia and Pennisetum types of grass cover in Ethiopia. The success of these species may partly be attributed to their allelopathic effects. Of all extracts tested, those of A. abyssinicus and S. polystachya were found to be the most inhibitory. The extracts of H. arrhenobasis and E. jaegeri have shown inhibitory effect on the germination of others to some extent but their germination was the least to be inhibited by extracts from the other test species. No significant inhibition was found by any of the extracts on the germination of E. jaegeri. The germination of H. arrhenobasis was inhibited only by the extract of S. polystachya. Since S. polystachya eliminates itself soon, it can not hinder the establishment of H. arrhenobasis for long. Thus

success at the establishment stage may contribure to their overall success. Once they are established, they are known to be robust and can invade a community. E. jaegeri being unpalatable (Froman and Persson, 1974) and resistant to trampling is capable of persisting in over-grazed areas.

Allelopathy has been reported to play a significant role in species diversity and vegetational pattern in plant communities (Bokhari, 1978; Lodhi, 1975; McPherson, 1969).

In all the treatments tried there was high specificity in the species response to the phytotoxins. For example, the extract from A. abyssinicus was inhibitory to the radicle growth of all test species except H. arrhenobasis. The extract from P. glabrum was inhbitory to radicle growths of S. polystachya, E. jaegeri and M. polymorpha but radicle growths of A. abyssinicus and H. arrhenobasis were promoted by it.

Allelopathic substances have been reported to be highly specific in their action (Garb, 1961; Overland, 1966). The extract of H. arrhenobasis severely inhibited the germination of A. abyssinicus, P. glabrum and S. polystachya but had no effect on that of the rest of the species.

The extract of S. polystachya was highly inhibitory to the germination of all test species except that of A. abyssinicus and E. jaegeri. The extract of M. polymorpha was inhibitory to the germination of S. polystachya and itself but stimulated that of E. tenuifolia.

Species diversity and vegetational pattern in plant communities is partly caused by selective inhibition at the germination stage (Muller, 1964; Lodhi, 1975). The overall inhibition (allo- and auto-inhibition) at the germination stage is also of primary importance in population control in plant communities (Went, cited in Overland, 1966).

In an ecological study of grassland condition in Chilalo (Alemayehu, 1979) A. abyssinicus was reported to be common in young grasslands after cultivation and is later said to be replaced by A. pratensis Hochst. ex Hack. Many species such as Andropogon virginicus (Rice, 1972), Digitaria sanguinalis (Parenti, cited in Rice, 1974), Sorghum halepense (Abdul-Wahab, cited in Rice, 1974), Agropyron repens (Stowe, 1979) etc. that appear in the succession of abandoned old-fields were found to be allelopathic.

In the abandoned old-fields (Rice, 1964, 1965, 1971) many plants in successional stages 1 and 2 are inhibitory to nitrogen fixing bacteria, to nodulation of legumes and tonitrogen fixing blue green algae. Consequently, the soils that are very low in nitrogen at the time of abandonment remain low in nitrogen for prolonged periods. Therefore, those plants that have higher nitrogen requirements are not able to compete in the infertile soils with low nitrogen tolerating invaders. This results in a slowing down of succession in the intermediate stages.

Though there is no evidence to support a similar interpretation as yet, further studies may reveal that such a phenomenon could be true for A. abyssinicus. And indication from this study is pointed out

by the significant inhibition of the germination and/or radicle growth of M. polymorpha.

Many species of legumes, Trifolium repens (Newman and Rovira, 1975) Medicago sativa (Nielson, cited in Rice, 1974), etc. have been reported to be allelopathic and are known to exhibit autotoxicity. T. repens dominates local patches in grasslands but these have been reported to migrate from year to year so that on any one spot, after a short period of dominance, T. repens declines and is replaced by other species (Leith cited in Newman, 1975). This may be also true with M. polymorpha which has shown auto-inhibition and the promotion of growth of some test species. Its extract was found to promote the radicle elongation of H. arrhenobasis, P. glabrum and E. tenuifolia and to have no significant effect on A. abyssinicus and E. jaegeri. Those grasses which are promoted or are not affected by extract of M. polymorpha could grow well in spots where M. polymorpha was growing.

Assuming all enviromental factors to be controlled and considering the results of the extract treatment (the effect of extracts on germination) to be true in the field, one can expect the following results.

| Species | Replaced by | Excluded from |
|---|---|---|
| P | A,H,El | S |
| M | A,El,Er | S |
| Er | A | S |
| S | A,El | P,M,Er,H |
| A | H | - |
| H | - | S |
| El | - | - |

(A) = A. abyssinicus (S) = S. polystachya (Er) = E. tenuifolia

(M) = M. polymorpha (P) = P. glabrum (El) = E. jaegeri

(H) = H. arrhenobasis

Taking the above assumption, A. abyssinicus, P. glabrum, S. polystachya and M. polymorpha showing auto-inhibition will be checked or eliminated by themselves. A. abyssinicus replacing the majority of the species will in turn be replaced by H. arrhenobasis. E. jaegeri far from being inhibited by any of the species will establish unchecked. Therefore, in the long run the species in the community will be completely dominated or replaced by H. arrhenobasis and E. jaegeri.

Allelopathic materials are variously released: by leaching from leaf surfaces, by excretion or exudation from roots and by the decay of plant material (Tukey, 1969). In this, work different experiments were carried out to detect the way of release of chemicals in A. abyssinicus. The results obtained from these experiments indicate that A. abyssinicus inhibits other species when decomposition of its dead remains takes place. Dead shoot and root extracts of A. abyssinicus have shown

inhibitory effects on the germination and radicle growth of P. glabrum, S. polystachya and itself (Tables 4 and 4.2). The living shoot and root leachates failed to inhibit the test species and do not seem to contain inhibitors. From this it can be concluded that A. abyssinicus may naturally not produce inhibitors that are leached from its leaves or exuded from its roots.

The test species treated with living root leachate and those that were grown with A. abyssinicus in sand culture have shown slight reduction in dry weight compared with their respective controls. But these differences were not found to be statistically significant.

The absence of any strong inhibition may reflect that at the beginning the plants were quite small and were probably not releasing substantial amount of root exudates. Another reason may be that in the experiment plants were growing in sand with ample supplies of nutrients in a glass house. In the different enviroment of the field, the exudates produced by the plant might be different quantitatively. Lehman et al have shown that nutrient deficiency can increase the amount of toxic substances in a plant (Lehman, cited in Newman, 1975).

In the field slight inhibition by allelopathy can be accentuated by competition and plants will probably be competing for light or mineral nutrients or both. Under such conditions a relatively small effect due to allelopathy might be swamped by greater effects of direct competition, but a synergistic effect is equally possible whereby small alterations of the species balance by allelopathy give a further advantage to a given species in direct competition (Newmanet al, 1975; 1977).

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