THE EFFECT OF DEPTH OF SEED BURY ON GERMINATION AND EMERGENCE OF WEED SEEDLINGS.

by

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PARENTS

ABSTRACT.

The experiments were conducted at the Sugarcane Research Institute, Udawalawe to study the effect of depth of seed bury on germination and emergence of weed seedlings.

Seeds of five selected weed species were allowed to germinate at different depths (from surface to 20 cm) in wooden boxes filed with sterilized soil. The soil boxes were kept in a green house to provide favourable environment for germination and emergence of seedlings. The temperature within the green house was 30 ± 2°c.

In addition, separate seed batches of same weed species were germinated at 30 ± 2°c under spontaneous change of day and night illumination and complete dark to observe their germination characteristics under various light regims.

There was no relationship of percentage germination, mean germination time and the rate of germination to the 1000 - seed weight. However, weed seeds showed discontinuous germination extending period sometimes more than 40 days for final germination to occur. Also, there was wide difference (0.05 to 0.39 seeds day^{-1}) among the species of their rate of germination. The percentage germination, mean germination time and the rate of germination were always high at the spontaneous change of day and night illumination than that of complete dark. The most of emerged seedlings had come from surface soil. More than 70% - 80% of emerged seedlings of the tested weed species were recorded above 4cm soil depth. Also, seeds at greater soil depth took longer time to emerge their seedlings. In generally, larger seeded weed species could produce seedlings from greater soil depth.

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CONTENTS.

LIST OF TABLES.

Chapter 01

INTRODUCTION.

Problem of weeds in world food production and the losses of yields due to weed competition has been well documented by many authors for various crops (Rao,1983; Mortimer,1989). Apart of the low productivity due to weed competition, weed control practices itself contribute considerable weight to the production cost (Table 1.1). This is more critical under the present system of intensive market oriented commercial crop production, where the reduction of cost of production is important for the products to be competitive under open market situation. Weed control is one of the major area where this can be achieved. Thus, effective and economic weed control programme not only increases yield in absence of crop - weed competition but also reduces weed control cost as well.

Table 1.1. Weed control in some field crops and plantation crops.

Type of crop	Cost of weed control	
1. Field Crops	Rs/ha/season	% Total cost
Rice - Irrigated	630	6.14 (4-8)
Rainfed	570	6.28 (3-9)
Soybean (irrigated)	500-1250	11.18
Chilies (irrigated)	900-1100	7-15
Bombay Onion(irrigated)	3000-3500	10-15
Red Onion (irrigated)	600-1800	4 15
Ground nut	4050	16
Green gram	1370	25
Cowpea	1220	19
2. Plantation Crops		
Coconut	500	5
Rubber(immature period)	3000	30
Sugarcane	4300	10.2
Tea - Young tea	3000-3600	18 20
- Mature tea	3600-4200	18-20

Source: Senanayake, 1992.

At the beginning of the season all individuals of the weed population are represented as seeds or perinnating portions distributed through the top soil (Naylor, 1970; Wilson, 1987). The portion of these propagules which germinate depends on the species and environmental condition. After germination some of the seeds, die before emergence and yet more die before establishment (Grime et al., 1981; Marks and Hawachuku, 1966; Kremer, 1989). Later size of these established weed population will provide a good indication of their likely competitiveness with growing crops.

There are number of factors which regulate germination and emergence of weed seedlings from soil seed bank. The depth of seed buried in soil is intimontely related to its germination and longevity. By cultivation, the soil surface is disturbed and such events as better aeration, stimulation of nitrate production by the soil organism and change in the moisture level, all favour the breaking of seed dormancy and the stimulation of seed germination. Seeds that are light sensitive, including those of many of the grasses are brought up from lower zone to higher light levels by turning the soil.

The process of germination eventually lead to the development of the embryo into a seedling. However physical properties of soil may interfere the amount of light the seed received for germination and may retard the movement of seedlings. Nevertheless, the safety of recrement site of seedlings is determined not only by the necessary elements that is provided for seed germination and seedling establishment but also by the hazards that it exclude. Therefore, the location of seeds in the soil seed bank has direct influence on the germination and emergence of weed seedlings. As such, this study focused on the effect of depth of seed buried on the germination and emergence of weed seedlings.

An increasing awareness of the ecological relationship of weeds as well as difficulties understanding of the systemic interaction among the numerous agronomic, socioeconomic and cultural variable that affect pattern of vegetation management, should aid in developing an emphasize on weed management which is not merely the removing of undesirable vegetations from a cropped land. Thus, investigation of ecological principles on the germination, emergence and establishment of weeds, though it has been given little attention would given useful guidelines in developing effective and economic weed management programme.

Chapter 02

REVIEW OF LITERATURE.

2.1. Weeds and their role in agricultural systems.

2.1.1. Weeds.

Agriculture has been a major force influencing the evolution of weeds. By pushing succession back to early stages, agricultural activities have maintained plant communities at their immature stages. Most of the vegetational components of these communities have wide diversity, and special adaptability and terms "weeds". Therefore, the weeds are not easy to define in general terms on the basis of narrow sets of taxonomic, morphological or phenological properties.

There are number of definitions given to weeds. In ecological term, weeds have been defined as "wild plants that grow in habitat frequently disturbed by human activities" (Baker, 1965). In agricultural term, weeds can be defined as "a natural hazards to the activities of man" (Mortimer, 1989). "A plant growing where it is not wanted" is an another definition given to weeds (Mortimer, 1989). European Weed Research Society has defined "any plant or vegetation interfering with the objectives of people" as weeds. In shorter term, this can be expressed as "a plant out of place". However, the potential threat that weeds pose to crop productivity is indicated in all these definitions.

The world relies on just 12 - 15 major crop species. However, about some 250 plant species are regarded as important weeds, of which only about 75 are thought to be responsible for 90% of crop losses attributable to weeds (Mortimer, 1989). Whatever the weeds in agro - ecosystem it may have common characteristics, notably the ability to persist in the face of repeated habitat disturbance and periodic and near total destruction of above ground biomass. This characteristic may be achieved by a variety of means. Therefore, weeds are an integral component of agro - ecosystems, and thus greatly influence the organization and functioning of these systems. Hence, the examinations of the relationships among weeds, crops, animals, soils and humans in agricultural systems is a meaningful ecological approach to study the role of weeds and their management in farming systems.

2.1.2. Damages caused by weeds.

Weeds are generally more harmful than useful, even after taken their possible beneficial effects into account. The estimated total yield losses in the world due to weed competitions is equivalent to 287.5 millions tons per year (Koch et al., 1982). This total amount of food being lost could be attributed to 25% of potential production in the developing countries, 10% in those with an international level of agricultural technology, and 5% in the developed countries, on an average of 11.5% overall.

Reduction in crop yield has a direct correlation with weed competition. Generally an increase in 1kg of weed growth corresponds to reduction in 1kg of crop growth depending upon the degree of competition. For example, a study conducted in five asian countries showed that proper weed control increased the yield of rice by 45%. In extreme weedy situations, weed control tripled the yield of rice (Rao, 1983).

Weeds compete with crop plants for nutrients, soil moisture, sunlight and space. Weeds remove plant nutrients more efficiently than crop plants. In drought situation, they thrive better than crop plants. When left uncontrolled, some weeds can grow better than crop plants and inhibit tillering and branching. They can curtail sunlight and adversely affect photosynthesis and plant productivity (Rao, 1983).

In a long term trial conducted by Kolbe (1977), it was found that for every 1% increase in yield, weed infestation should be eliminated to the extent of 3% in winter barley, 2% in winter wheat, 0.05% in maize, 1% in potatoes, 3% in tomatoes and, 8% in apples. In a review on yield losses due to weeds, Mani et al., (1968) reported the reduction of yield in different crops due to weed competition (Table 2.1.). This shows that crops differ appreciably in competitive ability with weeds.

Table 2.1. Yield losses in some crops due to weed competition.

Crops	Yield losses (%)
Wheat	6.3 - 34.8
Rice	9.1 - 51.4
Corn	29.5 - 74
Millet	6.2 - 81.9
Peas	25.3 - 35.5
Carrot	70.2 - 78
Groundnut	29.7 - 32.9
Linseed	30.9 - 39.1
Sugarcane	14.1 - 71.7
Cotton	20.7 - 61.0

Source: Mani et al., 1968

In addition to the reduction in crop yield, the following damages could be caused by weeds.

i Reduction in land value.
ii Limited choice of crops.
iii Loss of quality of crop produce.
iv Reduced human efficiency.
v Increased costs of insect and disease control.
vi Problems through aquatic weeds, such as;
(a) flooding.

(b) seepage into adjoining areas.

(c) breaks in canal banks.

(d) inadequate delivery of irrigation water to farms located at a distance from the main water source.

2.1.3. Control of weeds in agricultural systems.

Controlling of weeds is not merely the scope of removing undesirable vegetation in an agricultural system. This implies that weeds have to be controlled to the extent which gives the most economic return for the inputs. However, the farmers choice of control methods can be based on either their own experience or an recommendations by an advisory body. In any case, the farmer has to choose and carry the cost as well as harvest the result. As proposed by Doll (1976) that "the maintenance of weed populations at levels which do not cause economic losses" was an appropriate definition of weed control especially for the traditional farmers. However, any weed control programme should economical and necessarily effective as well to eliminate yield losses due to weed competition.

The challenge in modern agriculture is to produce an economic crop yield while preserving and enhancing local, regional and global environmental sustainability (Poul and Robertson, 1989). This philosophical shift has resulted in the development of the concept referred to as sustainable agriculture. Thus, an initiative was launched to promote the investigation towards the development of an integrated weed management systems. Nevertheless, weed control can not be taken in isolation. It has interrelation with other cultural operations associate with crop husbandry. Therefore, economic and effective weed control can only be achieved through an integrated approach which includes the application of numerous alternative weed control measures. However knowledge on weed ecology would give guidelines to integrate varies mean of weed control strategies towards effective and economic weed management programme.

2.2. Weed seeds and their propagative roles.

2.2.1. Seeds.

A seed represents the end of the flowering process and the beginning of a new plant. It contains the new plant in miniature and everything needed for dispersal, survival, renewal, and germination. In addition, seeds provide the beginning for the harvest of food, but also the beginning of one of the greatest deterrents to crop yield, the weeds.

The size and shape of seeds is extremely variable. It depends on the form of the ovary, the condition under which the parent plant is growing during seed formation and obviously on the species. Other factors which determine the size and shape of seeds are the size of the embryo, the amount of endosperm present and to what extent other tissues participate in the seed structure.

The normal seeds contain materials which its' utilize during the process of germination. These are frequently present in the endosperm. The endosperm may contain a variety of storage material such as starch, oils, proteins or hemicelluloses. Some time, the endosperm is greatly reduced, its formation is entirely suppressed. In these cases, the reserve materials are present elsewhere, for example in the cotyledons of the embryo. In some plants, the storage materials are contained in the perisperm or the seed may contain both endosperm and perisperm. The perisperm originates from the nucellus.

2.2.2. Seed production of weeds.

Weeds produce large number of seeds during its life cycle. This is a mechanism for the survival of species under the environmental hazards. Thus, the production of abundant and small seeds is a common adaptation that ensures a high probability of dispersal and reinfestation.

Annual and biennial weeds depend on seed production as the sole means of propagation and survival while perennial weeds are less dependent on this mechanism. A single plant of an annual weed can produce enough seeds in one season to cover an entire area of one acre with this weed species in the next year. For example, one plant of hedge mustard (*Sisymbrium altissinum*) produces over a half million (511,208 to be exact) seeds, which are enough, if evenly scattered, to sow eleven seeds on every square foot in an acre of land or enough to sow 3,200 seeds on every acre of a 160 acre farm. Similarly, redroot pigweed (*Amarunthus retroflexus*), purslane (*Portulaca oleracea*) and black nightshade (*Solanum nigrum*) produce 196,405, 193,213 and 178,000 seeds per plant, respectively, while black mustard (*Brassica nigra*) produces 58,363 seeds per plant (Muenscher, 1935).

Some weed species have an ability to produce seeds between intervals of normal disturbance associated with a cropping situation. Wild oats (*Avena fatua*) germinate at the same time the crop was sown but shatter their mature seeds before harvest. Many weeds can produce large number of viable seeds even after having been cut off soon after flowering. A few seeds may produce seed through apomixis, i.e. without fertilization. Weeds like ferns reproduce by spores rather than by seed (Rao, 1983).

2.2.3. Seed dissemination of weeds.

Most weeds are good travellers. They use various forces or agents to transport and scatter themselves from place to place. Of all the agents by which weeds are disseminated, wind, water, animals and man play important roles.

Many weeds have modifications or adaptations which aid them in getting scattered by the wind. Seeds or small fruits with tufts or hair or wing - like appendages are carried by the wind over long distances. The lighter seeds may drift for miles. The various modifications of seed structure that equipped them for wind dissemination are termed as saccate, winged comate (hair - covered), parachute, and plumed.

Many weed seeds are light or are covered with an oily film so that they float on the surface of water. Such seeds are frequently washed into the streams by surface run off during heavy rains or they are picked up by overflowing streams and are carried to other fields lower down the valley. Some weeds have air filled membranous seed envelops or corky adjuncts of mature fruits which can float on the surface of water. Flood waters, running streams, and irrigation water are important in the spread of weed seeds. Millions of weed seeds pass a given point of an irrigation canal in a day. In addition, some weed seeds can remain viable even after a long time of storage in water.

Weed seeds are also disseminated by animals. Many seeds pass through the digestive tracts of animals without loss of viability. Birds also consume large quantities of weed seeds and scatter them in droppings. The dispersal of seeds in the form of incompletely digested materials passing through the animals is termed as endozoochory. Seeds also stick to the fur, feathers and the muddy feet of birds and animals, and are carried from place to place.

Seeds of many weed species have specialized structures like hooks, spines, barbs, and awns which tend to cling to man's clothing and foot wear or agricultural implements used by man. They are carried in packing materials and in soil and sand or gravel used in construction. Man often carries weed seeds of interest from one part of the country to the other and from one country to another. It was due to man's indifference or carelessness that many weeds are 'imported' through various means. The movement of commercial seeds and grains is an important means of weed seed dispersal by man.

2.3. Soil seed bank.

2.3.1. Introduction.

Weeds are always present in agronomic systems and most owe their beginning to weed seed in the soil. Therefore, soil acts as a medium for seed storage and the growth of weedy plants. When seeds are present in the soil, it is called as "soil seed bank".

The density of seed bank ranges from 0 in newly developed soils to 4,100 to 137,700 seed per square meter. Seed density is influenced by past farming practices and may vary from field to field and between areas within fields. But seed bank do have a number of similarities. Generally, they are made up of numerous species, although several species may comprise 70% to 90% of the total seed bank (Milton, 1943). This large set may be followed by a second smaller subset of species that may comprise 10% to 20% of the seed reserve (Wilson, 1987).

The species composition of living vegetation is typically a reflection of the species diversity of propagules buried in the soil. Both the magnitude and composition of these banks reflects past and present weed management practices as well as the crops grown (Table 2.2). Comparatively there are between 100 and 1000 seeds m^{2} in forest soils, 100 and 1,000,000 seeds m^{2} in grassland and in arable soils 1,000 and 1,000,000 seeds m^{2} (Mortimer, 1989).

Kelly and Bruns (1975) compared the kind and number of seeds in the soil in grassland and adjacent land that had been cropped for 5 years. Seed density was fourfold greater in the cropped land compared with the grassland.

Thompson and Grime (1979) divided the seed bank into several groups. The first group consists of transient seeds, which are usually from grasses and generally do not persist longer than one year. Grass seeds are produced during late spring and summer,

Table 2.2. Weed seeds in agricultural soils.

Location	Crop history	Soil depth (cm)	Average no. of seeds collected (seeds m^{2})	Total number of species
England	Vegetables	0 - 15	4,100	76
Scotland	Potatoes	0 - 20	16,000	80
Colorado	Barley-corn-sugar beats	0 - 25	137,700	8
Illinois	Corn-soybeans-corn	0 - 18	10,200	25
Nebrasaka	Corn-field beans-sugar beats	0 - 15	20,400	19
Washington	Potatoes-wheat	0 - 30	51,000	23

Source: Wilson, 1987

germinate in the fall, or overwinter and germinate in the early spring. These seeds usually escape burial in the soil and remain at or near the soil surface. The second group consist of the persistent seed bank, which is represented by species from a wide range of habitats. A portion of the seeds remain dormant and becomes incorporated into a persistent seed bank. Seed become buried in the soil, and as long as the cropping pattern remains the same, the seed bank changes little from season to season.

The depth of cultivation has important implications not only for seed survival but also on the vertical distributions of seed in the soil. In grasslands, a majority of the seed bank is located within 2cm of the soil surface and nearly the entire seed population is located in the upper 10cm of soil (Hayashi and Numato, 1971). In cultivated soils the majority of the seeds are in the upper 15cm of soil, and they may be found as deep in the soil as the soil cultivated (Idris and Beshir, 1979). Wicks and Somerhalder (1971) compared the distribution of seeds in the soil profile following different methods of seedbed preparation. The first seedbed method consisted of tandem disking, plowing and planting. This method left weed seed distributed in the upper 30cm of the soil, with 25% of seeds in the upper 0 to 7cm. A second method was a reduced tillage system called ridge planting, which consisted of planting corn along the old corn row. Reduced tillage of the soil left 50% of the weed seeds in the upper 0 to 7cm of the soil, as compared with the extensively tilled soil where seeds were distributed fairly evenly through the upper 30cm of soil.

The popularity of no - or reduced - tillage systems of crop production is increasing, and as the intensity of tillage declines, the seed bank moves closer to the soil surface (Wicks and Somerhalder, 1971). Seeds are then in a better position to germinate and interfere with crop production; while conversely, under good weed management, the seed bank could be more easily reduced. Design of planting and weed control systems that capitalize on the shallow seed bank will undoubtedly improve the effectiveness of reduced - tillage cropping systems (Wilson, 1987).

Seed size and shape, the changing pattern of dormancy within the species and nature of cultivation practices are all important in determining the size of the seed bank. The small seeds of meadow - grasses and dicotyledonous species enter the soil profile readily on dispersal being aided by activities of invertebrates. Behavioral studies have shown that earth worms are selective in taking seeds according to seed shape, size and surface texture (Mortimer, 1989). The seeds of some grass weed species possess trichomes and hygroscopic awns that aid burial but typical undisturbed soil profiles display a concentration of seeds in the upper layers which diminishes with depth (Mortimer, 1989).

Few studies have addressed the rates of decline of buried seeds at differing depths but they are likely to be very different. In blackcurrant plantations the percentage loss of groundsel seed per annum at 7cm was 38% in comparison to 60% in the top 1cm layer (Mortimer, 1989). Rotary cultivation once a year which disturbed but did not invert the soil profile tended to equalize the seed distribution, the difference between the layers being 42% to 30% respectively (Mortimer, 1989). Experiments demonstrate that the soil seed bank can be reduced by applying effective herbicides; however, when herbicide use declines, the seed bank rapidly increases and under optimum conditions can approach the original within one year (Wilson, 1987).

2.3.2. Biology of soil seed bank.

Seeds enter the soil seed bank through several avenues. Most weeds produce large quantities of seeds that, if allowed to mature, are rapidly added to the seed bank. Therefore, if plants are allowed to mature and produce seeds, their seeds remain an integral part of the soil seed bank. Seeds can also enter a field from outside sources. The dissemination of seeds by water, wind, animals, and humans is an important consideration in introducing new species to an area. Once the species has been introduced, if the seeds can germinate and the seedlings develop and mature, the seeds produced will become part of the seed bank.

Seeds are lost from the seed bank as they are eaten by rodents, insects and microbes; as they decay, or as they germinate and either emerge or die. The longevity of dormant seeds varies considerably depending upon the species, depth of seed burial, soil type and tillage (Wilson, 1987).

In a project originated by Duvel (1946), seeds of 107 species were buried and exhumed at various intervals. Seeds from 36 species failed to germinate after one year of burial, seeds from 35 species failed to germinate after 1 to 39 years, while seeds of 36 species were viable after 39 years. A more recent buried seed experiment has further substantiated that certain seeds buried in undisturbed soil have the potential to remain viable for considerable period of time (Burnside et al., 1981).

Some early experiments reveled that there was a tendency for seed to remain viable longer period when buried at 106cm than those buried at 20cm depth (Toole and Brown, 1946)

Dormancy is a state in which viable seed fails to germinate even under conditions of moisture, temperature and oxygen favourable for plant growth. It is also a type of resting stage for the seed. It controls the time of the year that a species germinate or delays germination for years, thus guaranteeing viable seed in the soil for several years. When the conditions for germination are not favourable, seeds can become dormant to survive in the soil. Many annual weeds produce dormant seed that germinate under a narrow range of environmental conditions. Therefore, seed dormancy is a remarkably efficient survival mechanism of weeds. Seeds of weed species of Boraginaceae, Convolvulaceae, Cucurbitaceae, Leguminasae, and Graminae have a long dormancy period often running into several years (Sen and Bansal, 1978).

Metabolic activity in dormant seeds is at a low level and seeds of many species can survive for long periods when buried in the soil.

.4. Weed seeds germination.

The term germination is used to refer to a fairly large number of processes, including the germination of seeds, and of spores of bacteria, fungi and ferns as well as the process occurring in the pollen grain when the pollen tube is produced.

The process of germination involve breaking of seed dormancy and subsequent germination. It is under hormonal control and the naturally occurring hormones, auxins, gibberellins, and cytokinins function as germinate agents via the inhibitor - promoter complexes. Of these, gibberellins are the predominant germination agents early in the germination phase during the food - reserve degradation stage. Cytokinins exert their influence later on the initiation of cell proliferation and expansion (Rao, 1983).

The germination of weed seeds involves the inception of rapid metabolic activity within the seed, resulting in a perceptible growth of the embryo: first the radicle and then the aerial parts appearing from inside the testa. Then there follows an underground elongation of the seedling that relies on the food reserves in the seed, and finally the emergence of the aerial parts from the soil.

2.4.1. Factors affecting germination.

For germination, seeds of both crops and weeds must have their viability, adequate soil moisture, favourable temperature and supply of oxygen. Weed seeds, however, possess a variety of special germination mechanisms adapted to changes in temperature, soil moisture, aeration, exposure to light, depth of burial of seeds, etc. (Rao, 1983). When conditions are unfavourable for germination, they can remain dormant or delay germination.

1.4.1.1. Viability and life span of seeds.

Seeds are fairly resistant to extreme external conditions, provided they are in a state of desiccation. As a result seeds can retain their ability to germinate, or viability, for considerable periods. The length of time for which seeds can remain viable is extremely variable and depends both on the storage conditions and on the type of seed. In general, viability is retained best under conditions in which the metabolic activity of seeds is greatly reduced. The period for which seeds remain viable is determined genetically and by environmental factors (Mayer and Mayber, 1963).

1.4.1.2. Water.

The first process which occurs during germination is the uptake of water by the seeds. This uptake is due to the process of 'imbibition'. The extent to which imbibition occurs is determined by three factors; the composition of the seed, the permeability of the seed coat to water, and the availability of water in liquid or gaseous form in the environment.

An adequate amount of available soil moisture is essential for weed seeds germination. In general, the plants of xeric or halophytic character can germinate at lower moisture levels than plants from more mesic habitats (Peng, 1984). Germination, with adicle emergence may occur under quite dry conditions. The lternate wetting and drying of the soil surface also favours the timulation of weed seed germination (Peng, 1984).

.4.1.3. Gases.

Germination is a process related to living cells and requires n expenditure of energy by these cells. Energy - requiring rocess in living cells are usually sustained by process of xidation, in the presence or absence of oxygen. These process; espiration and fermentation, involve an exchange of gasses, an utput of carbon dioxide in both cases and also the uptake of xygen in the case of respiration. Consequently seed germination s markedly affected by the composition of the ambient atmosphere. lost seeds germination in air (20% of oxygen and 0.03% of carbon lioxide).

Most seeds will show lower germination if the oxygen tension s decreased appreciably below that normally present in the tmosphere. The effect of carbon dioxide is usually the reverse of hat of oxygen. Most seeds fails to germinate if the carbon lioxide tension is greatly increased (Mayer and Mayber, 1963).

Many weeds germinate under aerobic conditions while some equire anaerobic conditions (Rao, 1983). Soil disturbance has a eneficial effect on germination due to greater oxygen availability nd aeration. The quantity of oxygen in the soil is greatly influenced by porosity of the soil, depth of the soil, and nicrobial activities.

2.4.1.4. Temperature.

Different seeds have different temperature ranges within which they germinate. At very low temperatures and very high temperatures the germination of all seeds is prevented. The precise sensitivity is very different according to the species. A rise in temperature does not necessarily cause an increase in either the rate of germination or in its percentage. Germination as a whole is therefore not characterized by a simple temperature coefficient. The germination is a complex process and a change in temperature will affect each constituent step individually, so that the effect of temperature which is observed will merely reflect the overall resultant effect.

In the range of temperatures within which a certain seeds germinate, there is usually an optimal temperature, below and above which germination is delayed but not prevented. The optimal temperature for germination is the temperature at which the highest percentage of germination is attained in the shortest time.

Under field conditions in a temperature zone, the breaking of dormancy by a varying temperature is required initiate seed germination. The temperature alternations also favour the germination and emergence of the non - dormant viable seeds (Peng, 1984). The temperature requirement for the germination of a weed seed range from 5 °c - 22 °c in a north - temperate climate. In subtropical and tropical regions weed germinate all the year round, at temperatures from 20 °c - 35 °c (Peng, 1984).

2.4.1.5. Light.

Among cultivated plants, there is very little evidence for light as a factor influencing germination. The seed of most cultivated plants usually germinate equally well in the dark and in the light. In contrast among other plants much variability in the behaviour toward light is observed (Mayer and Mayber, 1963). Daily illuminations have also been shown to effects being similar to those of photoperiodism in flowering.

Soil turn over during ploughing and other land preparation exposes the seed to light and induces germination (Rao, 1983).

2.5. Emergence and establishment of weed seedlings.

The process of germination eventually leads to the development of the embryo into a seedling. When dormancy ends, the normal sequence of events is emergence of the radicle, which signifies that germination has occurred. Subsequently, the growth of underground primary root, emergence of the soot from the soil, and seedling establishment, accompanied by photosynthesis and independent growth. Emergence in most early successional dicotyledonous plants is epigeal, characterized by protrusion of the cotyledons above the soil surface. This is distinct from hypogeal emergence in which cotyledons remain below ground. Upon emergence, cotyledons quickly become photosynthetic and leaf surface area enlarges rapidly.

In describing seedling establishment, Haper (1977) developed the concept of the "safe site" as a zone in which conditions appropriate for germination and survival are found. The safe site provides stimuli to break dormancy and encourage germination. It also provides resources for germination and establishment and prevents hazards such as predators, competitors, pathogence and toxins. While a seed reaches a safe site by chance, information about safe site requirements could be used to predict occurrence of weed infestations, and also to manipulate the environment to promote or suppress weed germination.

The species composition of emerged seedlings has been shown to vary with the season (Robert et al., 1980). Each spring there was a flush of seedlings associated with rising soil temperature. Subsequent flushes were associated with cultivation and rainfall. Even when temperatures were optimal for germination, the lack of soil moisture prevented emergence (Wilson, 1987).

After, their germination, a rapid growth with early and extensive development of roots, particularly the primary roots, establishes the weed seedlings in the native habitat. The prominent, large primary roots and leaf areas and in some cases, the expansive, foliar - type cotyledons of the small seedlings, contribute much to the establishment of most weed species. In the Gramineae, the multiple shoot development from the auxiliary, buds early in the seedling stage is another feature (Peng, 1984).

A seedling can only reach the surface if the food reserve in the seed is sufficient for respiration and growth until the plants are able to photosynthesis. When ground is cultivated, germination may be promoted in seeds present at depths greater than that from successful emergence can occur and these seedlings will die. In addition, the pre - emergence death and no emergence can be taken place due to the activities of parasites, predators and microbes on the seedlings before they emerge.

The established small seedlings of many different weed species, forming mixed populations of plants, exert competition against each other. Primarily, competition is a physical phenomenon - to interact or compete with each other in striving for light, water and nutrients. The severity of this physical type of competition depends on such factors as differential responses of different species to the environment, the growth habits of the seedlings, soil factors, the botanical composition and standing of the plants. This often results in the emergence of a few dominant species, and in a high seedling mortality of those losers in competition due either to the production of albino seedlings, or to the premature drying up of the cotyledonary leaves, or to the inability to the stand erect or to other unknown physiological causes. The severity of competition increases with the growth and the increasing differentiation of the seedlings. At a certain stage, when the death - rate reaches a maximum, the competition gradually decreases (King, 1966 quoting Verma, 1938).

For the purposes of weed management, it is imperative to recognize weed seedlings as distinct from vegetative sprouts. The seedling represents the most vulnerable stage in the life cycle of a plant, and is generally the easiest stage to disturb mechanically or to control with herbicides. Because the timing of this stage is critical to survival and competitive success. Therefore, weed scientists have devoted major efforts to develop control practices directed at weed seedlings.

2.6. Effect of depth of seed buried on germination and emergence.

The depth of the seed buried in soil is intimately related to its germination. Quoted by King (1966) from Hant's observations, the greater the seed's weight, the greater is its ability to grow through the soil. In loose and sandy soil, emergence is possible with seeds planted at a greater depth than in heavy and clay soil. Weeds which normally emerge from a depth of only a few millimeters, can germinate successfully in deeper layers of soil, providing the temperature is optimal at these levels and the soil is not too compact. The soil pressure seems to have little influence on the retardation of germination occurring under such compact conditions, although the lack of air resulting from the soil pressure is important (Peng, 1984). The optimum depth for the emergence of seeds varies with different species. By compiling data from observations with 31 species, King (1966) showed that it ranges from 0.05cm to 2.5cm and is roughly in proportion to the 1000 - seed weight in grams. By cultivation the soil surface is disturbed, and such events as better aeration, stimulation of nitrate production by the soil organisms and changes in moisture levels all favour the breaking of seed dormancy and the stimulation of seed germination. Seeds that are light - sensitive, including those of many of the grasses, are brought up from lower zones to higher - light levels by turning the soil. Holm and Miller (1972) reported results from a recent experiment where freshly - harvested seeds of several common weeds showed little or no promotion of germination by light. However, after the seeds had been buried 7.5cm deep in soil for a period of six months, germination became entirely dependent on exposure to light. The freshly - harvested seeds were made light - requiring by treating them with certain growth substances (Peng, 1984).

Roberts and feast (1972) examined depth of seed burial in undisturbed and cultivated soils and found seedling emergence was greatest from cultivated soil at shallow depth of burial. Seedling emergence declined with soil depth and was generally higher in cultivated compared to undisturbed soil.

Depth of seed burial affects germination and emergence in several ways. Downybrome seeds germinated and emerged from soil depths of 2.5cm, but did not emerged from a 10cm depth (wicks et al., 1971). In a similar experiment the seeds of 12 weed species were buried and emergence was greater from a 1cm soil depth than from a depth of 20cm (Van, 1969).

The aeration of soil is also important in governing weed seed germination. Even in the most quiescent state, the buried weed seed caries on a feeble, hardly detectable respiration (Peng, 1984). In many seeds, the seed - coats must imbibe water before they permit oxygen to diffuse through them readily, and a few seeds are known to be able to germinate in the total absence of oxygen. The buried seeds readily become fully imbibed and in fact have the capacity to withdraw water from the soil with a force equivalent to some 965atm, as is indicated by the experiments of Shull (1916) with *Xanthium* seeds. One reason for the increased of germination following tillage is improved aeration. Other factors such as light, soil P^H, and soil nitrate levels also, in some ways influenced weed seed germination. Moreover, the seed structures of certain species actually facilitate germination. The spirally twisted awns attached to seeds of some weed species have the function of turning the seeds when moisture is absorbed. This motion helps the seeds to drop into any depression or crevice of soil surface, to be buried further, and germination is facilitated (King, 1966).

Herbicides of various kinds inhibit germination to a greater or lesser extent. Many of the commonly used substances, such as, 2,4-D, affect germination at comparatively low concentrations. The more effective, such herbicides have been used in order to prevent the germination of weed seeds in agricultural crops.

Chapter 03

MATERIALS AND METHODS.

.1. Location.

The experiments were conducted at Sugarcane Reşearch nstitute, Udawalawe during June to October, 1996.

The five selected weed species were examined for seed ermination and emergence of seedlings. These species were both rasses and broad leaves weeds. The selected weed species were,

i *Borreria hispida*

ii *Dactyloctenium aegyptium*

iii *Echinochloa colonum*

iv *Euphorbia heterophylla*

v *Euphorbia hirta*

The seeds were collected from matured panicles of wild opulation of plants growing within the Research farm of SRI and he seeds were gathered from as many different plants of a species. ll seeds had been dried and stored at 4 c in a refrigerator about -9 months period until the experiments were commenced.

.2. Experiment I

The seeds of each weed species were germinated separately in terile soil in wooden boxes measuring 60cm x 20cm x 20cm depth. he bottom of the boxes were fixed to make a gradient from top to ottom in one end to the other as shown in the diagram.

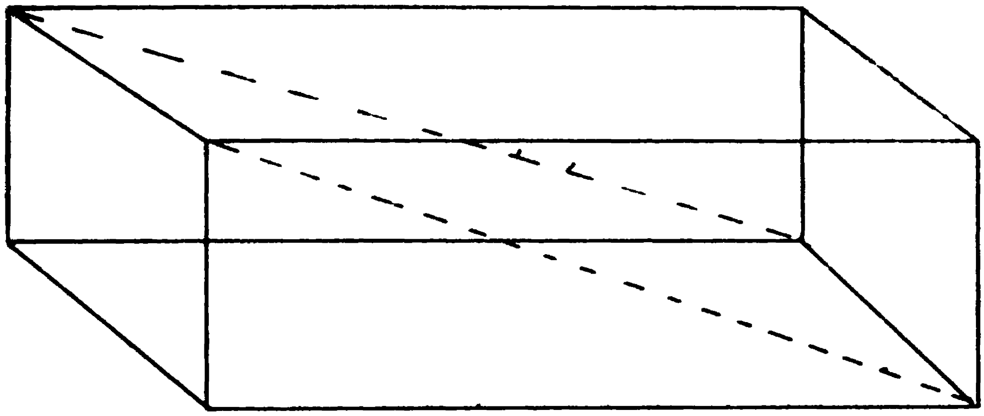


Figure 3.1. The diagram of the box used to germinate weed seeds.

Sterile soil was spreaded on the bottom of the boxes to make cm thick soil layer parallel to the slope. Then the seeds of each weed species were sown uniformly on the soil layer. Then the boxes were filled to the top with sterilized soil. Thus, seeds were allowed to germinate uniformly at different depths. The temperature within the soil boxes were 30 ± 2°c. The soil collected from the field were sieved by 2mm mesh and steam boilled for 48 hours for sterilitzation.

Each boxes were watered regularly as required. Emerged seedlings were counted and removed daily until no emergence was recorded during 14 consecutive days. Also, the distances from '0' depth of the boxes to each emerged seedlings were recorded. Thus depths of each emerged seedling were calculated. Finally, the profiles of soil in each box was examined to find out the fate of remaining seeds.

The soil, used to germinate weed seeds and to fill the wooden boxes, was analyzed to determine the texture by hydrometer method. It was silt loam soil and contained 8.94% of clay, 17.73% of sand and 73.33% of silt. The Surface compaction of soil (soil streanth) in a box was also measured and it was about 60 - 80 KPa at field capasity.

Experiment II

Five representative samples of 100 seed of each weed species weighed separately by an analytical balance to get 1000 - seed ght.

The above five samples of each set of weed seeds were minated separately in between two moist filter papers placed in etridish under normal day and night illumination. Similarly ther three representative seed samples of each weed species were minated in complete dark. Each petridishes were watered larly as required. Germinated seeds in each replicate were nted and removed daily until no further germination is recorded ing 14 consecutive days. Seeds were taken as germinated when re is a visual signs of radical emergence.

These data were used to calculate mean germination time and e of germination of each weed species.

Data analysis.

1. **Thousand seed weight.**

The weight of each 100 seeds samples (five replicate) were ded together and divided it by 5 to get average weight of 100 ds of each species. These values were multiplied by 10 to culate 1000 seed weight as follows.

$$1000 - s.w. = \frac{\Sigma (R_{\ldots}) \times 10}{5}$$

R = weight of a 100 seed sample (g)

.4.2. Percentage germination.

The number of germinated seeds in each replicate (the seed sample) were added together and the values were divided by five to calculate percentage germination of each species as follows.

$$\% \text{ germination} = \frac{\Sigma(\text{No. of germinated seeds } R_i)}{5}$$

.4.3. Mean germination time (t_{50}) and Rate of germination (R_g).

The mean germination time can be defined as "the time taken to 50% of the final fractional germination to occur" and the reciprocal of mean germination time gives the rate of germination.

The mean germination time for each replicate was calculated as follows and the average value of the five replicates was taken as the t_{50} for one species

$$= \frac{\sum \left[\text{No. of germinated seeds in each day}\right] \times \left[\text{Time taken for the germination}\right]}{\text{Total No. of germinated seeds}}$$

The rate of germination for one replicate of one species was calculated by following equation and the average value of five replicates was taken as the R_g for particular species.

$$R_g \text{ of a one replicate} = \frac{1}{t}$$

3.4.4. Standard deviation.

Standard deviation measures the degree to which individual values vary from the mean (average) of all values in the data list. The standard deviation of the sample data was calculated with help of following formula.

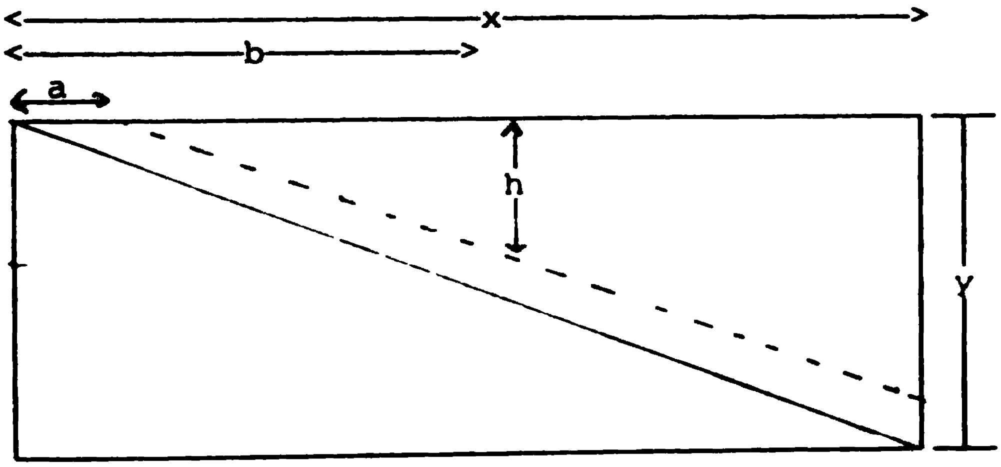
$$\sqrt{\frac{\Sigma (V_i - AVG)^2}{n-1}}$$

Where,

n = number of items in list
V_i = the ith item in list
AVG = average of values in list

3.4.5. Depths of seedlings emerged.

The depths from which the seedlings emerged, were calculated by a geometrical theorem ("Samanupathika niyamaya") as follows.



$$\frac{y}{h} = \frac{x}{b-a}$$

Therefore, the depth; $h = \frac{y(b-a)}{x}$

Chapter 04

RESULTS AND DISCUSSION.

There was a wide difference among the tested weed species in their 1000 - seed weight, percentage germination, mean germination time and the rate of germination (Table 4.1). Seeds had been collected from matured panicles. Therefore, this variation may perhaps be duo to the incomplete physiological maturity of seed, inherent dormancy mechanism associated with seeds, or genetical characteristics of the species.

Also, there was no relationship of percentage germination, mean germination time and the rate of germination to the 1000 - seed weight (1000-sw) of the tested weed species (Table 4.1). Although the percentage germination was less (14%), the species with smaller seeds *Euphorbia hirta* (1000-sw = 0.05g) showed a higher rate of germination (0.38 seeds day^{-1}). The relatively larger seeded *Borreria hispida* (1000-sw = 2.83g) showed a same rate of germination (0.39 seeds day^{-1}), but its percentage germination was high (52.6%). Also, larger seeded *Euphorbia heterophylla* (1000-sw = 5.88g) showed a very slow rate of germination (0.05 seeds day^{-1}), but its percentage germination was high (38.4%). This indicates that there is no apparent relationship of percentage germination and the rate of germination to the 1000 - seed weight. However, some authors (King, 1966; Wilson, 1987) have reported that higher the 1000 - seed weight which is an indication of amount of food reserve available for germinating seeds, the greater the percentage germination and rate of germination.

It also appears in the table (4.1) that the seeds of five tested weed species have germinated under the both natural day and night illumination and also at complete dark. However, the percentage germination, mean germination time and the rate of

Table 4.1. Thousand seed weight, percentage grmination, mean germination time and the rate of germination (with standard deviation) of five selected weed species under complete dark and natural day and night illumination.

Species	1000 s.w.	STD	% germination				t_M (days)				R_t			
			Light	STD	Dark	STD	Light	STD	Dark	STD	Light	STD	Dark	STD
Borreria hispida	2.03	0.022	52.6	7.5	36.5	0.7	2.64	0.66	2.52	0.02	0.39	0.096	0.39	0.004
Dactyloctenium aegyptium	0.23	0.004	0.4	0.8	---	---	2.2	4.91	---	---	0.01	0.04	---	---
Echinochloa colonum	0.77	0.073	2.0	1.5	1.0	---	11.36	8.78	7.66	8.08	0.06	0.05	0.13	0.158
Euphorbia he[redacted]terophylla	5.88	0.2	30.4	8.9	9.33	2.5	19.51	2.6	14.94	0.31	0.05	0.006	0.06	0.001
Euphorbia hirta	0.29	0.003	14.0	5.7	13.0	8.1	2.71	0.65	2.67	0.04	0.38	0.084	0.37	0.006

germination were always high at the spontaneous change of day and night illumination than at complete dark. Therefore, it can be stated that natural day and night illumination is favourable for the germination of weed seeds. Further, the species *Euphorbia heterophylla* showed higher percentage germination (38.4%) at natural day and night illumination than germination (9.3%) at dark. However, many authors have reported varied germination responses of different weed species to the external environmental conditions (Mayer and Mayber, 1963; Rao, 1983; Peng, 1984; Wilson, 1987). Some species need light induction while some other species are indifferent or could germinate only at complete dark. Thus, there is wide variation of germination characteristics among different weed species to the external environmental conditions. Also, there was a variation in germination characteristics not only among different weed species but also within the seeds harvested from same panicle. This is an important ecological mechanism to survive weed species under frequent disturbances of habitat conditions like agricultural systems.

In addition, freshly harvested seeds of some weed species do not require light for germination but light is an essential factor for germination when thy bury under the soil for certain period of time (Horm and Miller 1972; Peng, 1984). This pave the way for weed seeds to remain viable in greater soil depth where germination and emergence of seedlings can not be taken place and allow to germinate and produce seedlings when they come to the surface by soil cultivation. This is a useful strategy of weed seeds to persist in the soil seed bank.

Table 4.2 shows the depth of emergence of the five selected weed species with their 1000 seed weight. In generally, larger seeds were able to emerge from greater depth. This can be attributed to the availability of sufficient amount of food material in the seeds to emerge from greater depth [illegible];

Table 4.2. Depth of emergence (%) of seedlings of five selected weed species.

Species	1000 s.w.	Total no. of emerged seedlings	% emergence								
			surface	0-1cm	1-2cm	2-3cm	3-4cm	4-5cm	5-6cm	6-7cm	7-8cm
Borreria hispida	2.8[illegible]	171	2.32	15.11	13.95	18.60	21.51	12.20	14.53	1.16	---
Dactyloctenium aegyptium	0.23	15	46.66	33.33	13.33	6.66	---	---	---	---	---
Echinochloa colonum	0.77	11	45.45	---	---	18.18	9.09	9.09	18.18	---	---
Euphorbia heterophylla	5.88	28	7.14	28.57	17.85	17.85	14.28	3.57	7.14	---	3.57
Euphorbia hirta	0.05	03	33.33	33.33	---	---	---	---	33.33	---	---
Total	9.76	228	134.9	110.34	45.13	45.13	44.88	24.86	73.18	1.16	3.57
Average	[illegible]	45.6	26.98	22.06	9.02	9.02	8.97	4.97	14.63	0.23	0.71

Harper, 1977;). Highest number of emerged seedlings of *Borreria hispida* at different depth could be attributed to its recorded higher percentage germination (52.6% light and 36.5% dark) and the greater seed size (1000-sw 2.83g). The major fractions of emerged seedlings of the two grasses species;
Dactyloctenium aegyptium (46.66%) and *Echinochloa colonum* (45.45%) were recorded from the surface seeds. The species *Echinichloa colonum* had emerged even at 6 cm soil depth, but *Dactyloctenium aegyptium* failed to emerge beyond 3 cm soil depth. However, more than 70% of *Echinochloa colonum* had emerged from 0 - 5 cm depth. In the case of two broad leaves weed species, the percentage emergence from surface seeds were 2.32 and 7.14 for *Borreria hispida* and *Euphorbia heterophylla* respectively. However, these two broad leaves weed species had emerged even at 8 cm soil depth. Therefore, it appears in this study that larger seeds are able to emerge from greater depth. This confirm the similar results reported by Harper (1977). However, more than 70% of the emerged seedlings of *Borreria hispida* and more than 80% of the emerged seedlings of *Euphorbia heterophylla* had recorded between 0 - 4 cm depth.

There were only 03 emerged *Euphorbia hirta* seedlings. Thus valid conclusion can not be made on this results. The recorded germination of this species in germination study was 14%. Thus, such a low seedling emerge of this species is not clear.

The seeds were allowed to germination and seedling emergence in a loose soil (compaction was 60 - 80 KPa at field capasity) with silt loam textural consistency. But most of dry zone soil comes under the category of Redish Brown Earth with sandy clay loam textural consistency. Thus, due to the higher soil compaction, this type of seedling emergence in greater soil depth can hardly be expected under field condition.

Then, there is gradual decline in the percentage of emergence with soil depth. This can be attributed to the shortage of necessary growth factors such as light, air, etc. with increasing soil depth for germination and emergence of weed seedlings.

Dactyloctenium aegyptium seeds which were only above 3 cm depth had given seedlings. This can be attributed to its smaller seed size (1000 seed weight was 0.23 g).

It also appears in the table 4.2 that none of the tested weed species had produced emerged seedlings from the seeds beyond 9 cm soil depth. This can be attributed to the nonavailability or inadequate supply of growth factors; i.e. light, temperature, aeration, etc. for germination and emergence of seedlings from the seeds at greater soil depth.

The seedlings of *Borreria hispida* and *Euphorbia heterophylla* emerged at a range of 0 to 7 cm and 0 to 8 cm depth respectively. Due to the larger seed size (1000-sw = 2.83g and 5.88g respectively), the amount of food reserve available was adequate to supply energy to penetrate the seedlings from greater depths. *Borreria hispida* showed its maximum percentage of emergence (21.51%) at 4 cm depth while *Euphorbia heterophylla* (28.57%) was at 1 cm soil depth.

Echinochloa colonum emerged only at 0, 3cm, 4cm, 5cm and 6cm depths with maximum emergence (45.45%) at zero depth. The total number of emerged seedlings of this species was comparatively less. This can be attributed to the recorded low rate of germination (2% in light and 1% in dark) of this species (Table 4.1).

Although *Dactyloctenium aegyptium* seeds have emerged in the soil box, they did not germinate in the petridishes. Similarly, *Euphorbia hirta* seeds germinated in petridishes, but did not emerge in the soil box. The reasons for such a differences were not clear in these experiments.

Table 4.3, 4.4, 4.5 and 4.6 describe the relationship of depth of emergence to the days after sowing for *Borreria hispida*, *Dactyloctenium aegyptium*, *Echinochloa colonum* and *Euphorbia heterophylla* respectively. In generally, all four tested weed species had taken longer time to emerge from greater depth. In other way, the seeds which were placed at shallow depth could produce quick seedlings. Also, there was discontinuous emergence extending period more than 40 days for some species. This is ecologically importance for the survival of species specially under unpredictability in habitat condition.

The first appeared seedling of *Borreria hispida* was at "0" depth and took 3 days after sowing for emergence. However, it took 9 days to emerge first seedling at 7cm depth. The first seedling of 2cm depth took 4 days, 3cm depth took 4 days, 4cm depth took 5 days, 5cm depth took 7 days and 6cm depth took 8 days. Thus, there was a gradual increase of time taken for emergence of seedlings when increasing depth of seed bury. Similar pattern was observed in other species too. This delay of emergence at greater depth can be attributed to the resistance enforced by soil over seedling emergence.

Some seedlings of *Borreria hispida* and *Euphorbia heterophylla* had germinated at higher soil depths, but did not emerge. Some of them had dead and rotten, some were grown up about 2.5cm to [illegible]cm. This may be due to lack of food reserved, high soil compaction and activities of microbes, parasites and predators [illegible] the seedlings.

While examining at soil profile, it was observed that the seeds of *Borreria hispida* which were at 20cm depth had germinated and the shoots were penetrated upto 6cm - 8.5 cm height through the soil. Similarly, *Euphorbia heterophylla* seeds which were at 11cm depth had germinated and the shoots were penetrated [illegible]cm - [illegible]cm height through the soil. When considering seed size, *Euphorbia heterophylla* is heavier than *Borreria hispida*. Therefore, this may perhaps be due to the variation seed vigor among different weed species.

There were some viable seeds of the tested species at greater depths without germination. This is an example for the seed dormancy enforced by external environmental conditions. Under such circumstances, the dormancy will remain until the seeds expose to favourable environment for germination by turning the soil or any other activities. This is a greater survival mechanism of weeds. Thus, they can produce vigorous and healthy plants by crossing with next generations when germinate at next season. This is also an another important mechanism to face the natural selection successfully and to survive. Also, this is very important in weed control as some plant species may incorporate in this way and can become weediness in agricultural systems. Development of tolerable weed species to control practices such as chemical selection and crop mimicry are some of the example for such situation.

ble 4.3. Percentage emergence at each day after sowing and total number of emerged seedlings of *Borreria hispida* at different depths.

Depth of emergence	Days after sowing																T.no. of e.s.
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	
surface	---	---	0.6	0.6	---	---	---	---	0.6	0.6	---	---	---	---	---	---	04
0 - 1cm	---	---	0.6	4.1	2.9	1.2	0.6	1.2	1.7	2.3	---	0.6	---	---	---	---	26
1 - 2cm	---	---	---	2.3	5.8	0.6	0.6	1.2	0.6	---	1.7	1.2	---	---	---	---	24
2 - 3cm	---	---	---	1.2	4.6	2.3	---	2.3	---	0.6	4.6	2.9	---	---	---	---	32
3 - 4cm	---	---	---	---	1.2	4.6	1.7	3.5	2.3	0.6	1.7	5.2	0.6	---	---	---	37
4 - 5cm	---	---	---	---	---	---	1.2	2.9	1.7	1.2	---	3.5	1.7	---	---	---	21
5 - 6cm	---	---	---	---	---	---	---	4.1	2.9	0.6	---	2.3	1.7	1.7	0.6	0.6	25
6 - 7cm	---	---	---	---	---	---	---	---	0.6	---	---	0.6	---	---	---	---	02
Total no. of e.s.	---	---	02	14	25	15	07	26	18	10	14	28	07	03	01	01	171

Table 4.4. Percentage emergence at each day after sowing and total number of seedling of <u>Dactyloctenium aegyptium</u> at different depths.

Depth of emergence	Days after sowing																														Total
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
surface							13.3	[illegible]									-	-	-	-	-	-	-	-					13.3		[illegible]
[illegible]								6.7									-	-	-	-	-	13.3	6.7	-						6.7	[illegible]
[illegible]						6.7												-	-	-	6.7	-	-								[illegible]
[illegible]																	-	-				-						6.7			[illegible]
Total						01	02	04									-	-	-		01	02	01	-				01	02	01	[illegible]

Table 4.5. Percentage emergence at each day after sowing and total number of emergence seedlings of *Echinochloa colonum* at different depths.

Depth of emergence	Days after sowing.																		T.no .of. e.s.
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	
surface	---	---	---	---	---	---	---	36.4	---	---	---	---	---	9.1	---	---	---	---	05
0 - 1cm	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	--
1 - 2cm	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	--
2 - 3cm	---	---	---	---	9.1	---	---	---	---	---	---	---	---	---	---	---	---	9.1	02
3 - 4cm	---	---	---	---	9.1	---	---	---	---	---	---	---	---	---	---	---	---	---	01
4 - 5cm	---	---	---	---	9.1	---	---	---	---	---	---	---	---	---	---	---	---	---	01
5 - 6cm	---	---	---	---	---	---	---	9.1	9.1	---	---	---	---	---	---	---	---	---	02
T.no.of e.s.	---	---	---	---	03	---	---	04	01	---	---	---	---	01	---	---	---	01	11

Table 4.6. Percentage emergence at each day after sowing and total number of emerged seedlings ng of *Euphorbia heterophylla* at different depths.

Depth of emergence	Days after sowing																												[illegible]
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
surface	.				--	---	--	---	7.[illegible]	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	[illegible]
0 - 1cm			.	--	---	---	---	3.6	---	---	---	---	---	---	3.6	3.6	---	---	---	7.1	---	---	---	---	3.6	---	3.6	3.6	[illegible]
1 - 2cm	.	.		3.6	---	---	3.6	---	3.6	---	---	---	---	---	3.6	---	---	---	---	---	3.6	---	---	---	---	---	---	---	[illegible]
2 - 3cm	.			---	---	---	3.6	---	---	---	---	3.6	---	---	3.6	---	---	---	---	---	---	---	---	---	---	---	--	7.[illegible]	[illegible]
3 - 4cm	.			.	---	---	---	3.6	---	---	---	---	---	3.6	---	---	---	---	---	---	---	---	---	---	3.6	---	--	[illegible]	4
4 - 5cm	.		.	.	---	---	---	---	---	---	---	---	---	---	---	3.6	---	---	---	---	---	---	---	---	---	---	---	---	[illegible]
5 - 6cm				--	---	---	---	---	---	---	---	---	3.6	---	---	---	---	---	3.6	---	---	---	---	---	---	---	---	---	[illegible]
6 - 7cm					---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
7 - 8cm		.			---	---	---	---	3.6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	--	-	.
Total no.			.	[illegible]	-	--	02	[illegible]	04	--	.	01	01	--	03	02	--	--	01	02	01	--	--	--	02	--	[illegible]	04	[illegible]

Chapter 05

CONCLUSIONS.

1. The natural day and night illumination is favourable for weed seed germination than complete dark.

2. The weed seed size has no relationship to the percentage germination and the rate of germination.

3. Weed seeds which were at lower soil depths only can germinate and produce seedlings.

4. The seedlings of larger weed seeds can penetrate through greater soil depths than seedlings of smaller weed seeds.

Weed seeds at greater soil depths take longer time for germination and emergence of their seedlings.

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