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Original Research Article

SOIL SEED BANK OF NATIVE AND EXOTIC PLANTS IN TWO ADJACENT ECOSYSTEMS OF MOIST TROPICS

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Abstract: Most of studies of exotic species in plant communities have focused on analyzing the distribution and occurrence in standing vegetation, but in this paper we have discussed ecological study of soil seed bank of native/exotic plants in two adjacent ecosystems of moist tropics. Soil seed bank are important component of ecosystems. It is viable seeds on soil surface or buried in the soil. Now-a-days soil seed bank of invasive plants has become important at various ecological aspects in terms of belowground diversity, standing vegetation dynamics and its importance at global scale due to interference of human, urban encroachment, agricultural productivity. So detail analysis of seed bank of native and invasive species in two adjacent ecosystems have examined in terms of seed density at different soil depth, their habit life form, nativity, seed bank types, phenological events along with economic and ethno utilization. Both native and exotic species are used in traditional medicine and making ropes, fibers and as forage and fodder for cattles. Phenological study of species is important to know ecological periodicity of flowering, fruiting, seed production, pollination and seed dispersal according to climate change.

Keywords: Soil seed bank, Exotic plants, Phenology, Ecosystem, Moist tropics.

Introduction: Soil seed bank is presence of viable seeds in dormant conditions within or on soil and on the soil surface (Simpson et al. 1989). It is an important component of various ecosystems. It is indicator of past, present and future plant population and community structure and determine future above-ground vegetation also determine size, composition, structure and dynamics of plants in different ecosystems. Seed longevity and persistence of plants in soil seed bank varies depending on species and the environmental conditions (Gioria and Pysek 2016). It has regenerative potential which consist of transient and persistent seed bank (Saatkamp et al. 2014). Seed bank play role in development of secondary succession generally in those ecosystems which contain specialized plant species which form persistent seed bank. Seed bank may be large or small, persistent or

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transient but they are always spatially and temporally variable (Bai et al. 2010). Climate changes visible not only in plant vegetation but also in soil seed banks. The climate change affect has impact on seed germination of native and exotic plants from soil seed banks. Populations of native seeds are decreasing and restorations of exotic seeds are increasing. Warming of winter and summer rain is reducing the number of viable seeds in seed bank of native weeds. The interest in the relationship between plant diversity and ecosystem functioning has increased substantially in last decade particular for invasion. So study of soil seed bank of native and exotic plants is crucial topic in ecology now-a-days. Long term persistence of exotic weeds has impact on natives and their displacement from their localities. The magnitude of the impact of exotic weeds on soil seed banks generally increases with its residence time (Gioria and Moravcova 2012).

Alien species are exotic organisms that occur outside their natural adapted ranges and dispersal potential (Raghubanshi et al. 2005). A few alien species become invasive when they are introduced intentionally or unintentionally outside their natural habitats into new areas where they express the capability to establish invade and out-compete native species (Sekar 2012). These species cause loss of biodiversity including species extinctions, changes in hydrology and ecosystem function (McGeoch et al. 2010). It is important to make an effective implication management of exotic species, knowledge about their ecology, morphology, phenology, reproductive biology, physiology, photochemistry, diversity, life-form, habitat, uses is essential (Sekar 2012). IUCN defines alien invasive species as an alien species which becomes established in natural or semi-natural ecosystems or habitat, an agent of change and threatens to native biodiversity. These exotic species cause threat to native species. These are accidentally introduced. Many are introduced due to their value as food source and as biological control agent. The exotic do not have natural predators, competitors, parasites that control their population to sustaining biodiversity. Invasion now-a-days is causing a substantial threat to biodiversity and ecological integrity of native habitats and ecosystems. These species have impact on native plant diversity, soil composition, biogeochemical cycles and loss of productivity of native plants and directly effect on ecosystems by altering their native environment. They also cause threat to endangered and threatened plants (Pimentel et al. 2005). The exotic species are both human introduced and naturally introduced (*Ageratum conyzoides*, *Parthenium hysterophorus*). These exotic weeds caused threat to native species in their habitats where these habitats are more disturbed.

Phenology is periodic time of all biological events occurring in a species. Phenology is biological clock or rhythm of all biological and phenotypic events or appearance taking place in an organism according to seasonal and climatic changes. This phenological study is important for understanding ecological adaptations, interactions of individual species and naturalization of both exotic and native weeds. Sometimes both native and exotic plants provide economic value in the form of vegetables, fuel, fodder, forage, oil, fiber and medicine. With the development of social sense in primitive mean their dependence on the plant resources increased not only for the food, but also for fodder, fuel, drugs and shelter (Singh et. al. 2010). Nearly 25,000 species are being used as traditional and herbal medicines in tropics.

Now-a-days it has been widely accepted that conservation of biodiversity should be our goal through the preservation and sustainability of natural habitats. There should be convincing scientific, economic and sociological reasons for giving main priority to the conservation of plant diversity. As we know India lives in villages specially very old and traditional villages with one of its mega-biodiversity countries of the world. Due to broad unique geographical location, diverse topography and climatic conditions India has rich and unique floral ad faunal diversity. India has been using its traditional knowledge to use its plant medicinal diversity in curing diseases and herbal products in skin and hair treatment. These medicines are being used in Ayurveda, Unani, Homeopath, Siddha etc. So use of this traditional knowledge of herbal medicine provides strong data for frequent utilization of a large number of medicinal plants of India (Pandey and Rastogi 2008).

It is very important to investigate the germination success of the native and exotic weeds and understand its ecological significance. In moist tropics, mainly researchers have more concentrated on ecology of standing vegetation, limited study have been done on soil seed bank diversity of native and exotic species, its ethno-ecological importance, so on this basis, we have discussed seed bank diversity in two adjacent ecosystems. The objective of this study is to analyze structure of soil seed bank in agro-ecosystem and grassland, and documentation of phenological events and economical utilization.

Materials and Methods

Study area: The study was carried out in district Gorakhpur of Uttar Pradesh lies between latitude $26^0$13’ N to $27^0$29’ N longitude $83^0$05 E and $83^0$56’ E. The area has monsoonal climate with summer, rainy and winter seasons. The annual rainfall during study period was about 1550 mm to 1890 mm and temperature with average maximum 36^0C and minimum 21^0C. The soil is slightly alkaline with sandy loam. The three permanent plots of 100 x 100 m have been established in both ecosystems, in which six excavating soil monoliths of 20 x 20 cm area with 0-10 cm, 10-20 cm and 20-30 cm depth weighed soil sample were taken.

The agro-ecosystem and grassland were selected were situated near Gorakhpur. The region is terai bhabhar which is subdivision of upper Indo-Gangetic plain. This region has very rich and vast plant diversity and ecological characteristics. The species which were recorded during study period in soil seed bank are considered in this paper.

Sampling of soil and seed identification (Seed bank study): Soil samples were collected in each season in month of each June and November during 2007-2009. All 72 samples of soil were poured in each earthen pot and watered regularly in shaded place. Seed banks (seed density/m^2) were estimated by seedling emergence method. The seedling emergence was carried out for one year for recording for late dormant plants. The plants were identified at species level. Those plants which were not identified grow till their flowering stage for proper identification. Weeds were identified with help of flora (Srivastava 1976; Ansari et al. 2006), monographs, pictures and other relevant literature. The seed bank types were recorded according to Thompson et. al. (1997).

Phenological observation and economical utilization: Phenological observations were made at 30 days intervals during the study period (2007-2009). Flowering and fruiting were done when more than 50% individuals of species showed that stage. Economical importances of plants were taken from interview of local people, local ayurvedic practitioners and villagers after completion of soil seed bank experiment by interview using questionnaire.

Results: The seed bank of plants was highly variable in density, abundance and composition. Detail of all plants described with habit, vernacular name, family, ecosystem, life-from, and seed bank types (Table 1). Seed bank comprises of total number of 39 species in both agro-ecosystem and grassland lying in 18 families, Poaceae was dominant family in both ecosystems. Poaceae have 14 members followed by Amaranthaceae, Asteraceae, Cyperaceae, Fabaceae each with three members and other thirteen families have one species each. Total 20 herbs, 14 grasses, 3 sedges, one shrub and one forb were identified. Seeds are studied, identified and incorporated into herbarium. There were 22 species in agro-ecosystem and 28 in grassland. Annual herbs were dominant in seed bank than perennials. Herbs were dominant than grasses and sedges. There were 11 species common in both ecosystems while 17 and 11 species were confined to agro-ecosystem and grassland respectively. Total 18 monocots and 21 dicots were recorded. Native species were dominant with 25 than exotic species (14). There were 14 (36%) exotic and 25 (64%) native species. Three types of seed bank were identified with transient seed bank (13), short-term persistent seed bank (18) and long-term persistent seed bank (8). Generally persistent seed banks of native perennial were recorded and exotic formed transient seed banks generally in this particular area. The transient seed bank of annual herb of exotic and natives contribute in standing vegetation and future deviation. Short term seed bank showed conservation strategies for important plants of moist tropics. Many species germinate throughout year in both ecosystems. In this study also recorded that exotic weeds rapidly emerged and but achieve low seed densities but increased frequently and abundantly in standing vegetation than native species. In some soil samples there was germination with high seed density of exotic plants. Seed germination rate is highest in rainy season due to favorable condition of strong moisture availability to both native and exotic plants. The seeds of perennial grasses and herbs have high seed density.

Detailed usage of all species which recorded in seed bank was mentioned with its exotic species nativity (Table 2). Native species were most abundant in the seed density and species richness but exotic were also with lower seed density. Whole plant part, leaves, fruits and seeds of plants used as forage, fodder, fiber and herbal medicine. These plants are primary health care necessity of local people and villagers, they generally used for their economical growth. Mainly these were being used to cure skin diseases, dysentery, fever, cold, cough and as antidote for poison. Annuals germinate whole according climatic changes and environment phenological periodicity. The ethno-botanical data documented from 31 species and 17 families, rest were used in making fibers, ropes and as fodder and forage. This shows that healthcare requirements were met from more than 79% of total plants. All these medicinal plants were reported by villagers, local vaidhyas and sold in near local town market by ayurvedic practitioners and medical stores. Some villagers do professionally. These were being used in curing skin diseases, wounds, fever, dysentery, and body pain but they can not be used to cure chronic diseases. Some of exotics were introduced due to their commercial utilization, economic values and for ornamental purposes. These exotics were competing with natives due to favorable soil nutrient enrichment. Flowering and fruiting of most plants were from July to April. It means maximum number of species get reproductive phase at the end of crop cycle in agricultural land.

The results showed that exotic have established high diversity with low richness in this region. Native have high seeds germination (seeds/m^2) than exotic in seed bank of both ecosystems. Each species have significantly ($p = 0.001$) maximum germination from upper soil surface (0-10cm) in comparison to lower soil depth (Table 3, 4), the seed emergence of each species significantly decreases with decreasing soil depth in both ecosystems. Mainly annual or perennial native grasses were having significantly higher seed density than exotics in both ecosystems.

Discussion: The species present in the soil seed bank serves as an indicator of the restoration. Agro-ecosystem and grassland constitute large and diverse soil seed bank of both native and exotics. The soil seed bank has potential to restore some components of a native plant community while also hindering restoration by providing a source of exotic species, so restoration of the both ecosystems may require active proper management. Grasses suppresses total plant diversity and prevent invasion is a key issue for developing better restoration plans of these ecosystems of moist tropics. These plants have a short vegetative period with high reproductive potential. These exotic compete with native species so both have equal importance. These are sometimes pioneer species in agricultural and grasslands. Weedy plants have high degree of diversity possibly due to the replacement of native species by alien ones (Zerbe et al. 2003) but here higher seed diversity is recorded for native species.

The present investigation in moist tropics revealed that considerably a sizeable number of exotics (36%) have contributed in short term persistent seed bank. It means, they also exist in standing vegetation give idea about future deviation of vegetation in the region. The native plants have high seed germination due to seed rain/dispersal. It can affect vegetation recovery by sieving as a source of new recruits which may be desirable if seed bank is dominated by native perennials, or it could be undesirable if there are high densities of exotic weed seeds (Sage Step News 2011) as in this study we found that annual and perennials were dominated having high seed density. The ecological and environmental characteristics of this region considered for production of annual and perennials but their growth appear largely influenced by seasonality (Aggarwal et al. 2012). These plants generally germinate maximum during rainy season and also exist in standing vegetation at that time may be due favorable soil moisture content (Sharma and Upadhaya 2002). Mainly grasses and graminoids grow by increasing their tiller and persist for long time and finally maintain high cumulative density of perennials and annuals (Srivastava and Singh 2005). These weedy plants generally have small sized seed so occur with soil layer in huge amount make them persistent for longer time in comparison of large size seeded plants having shorter dormant period. Transient seed banks are characterized by almost complete germination of seeds during the first year after seed production. In contrast, some ungerminated seeds in a persistent seed bank remain viable in the soil for more than 1 year. In this strategy, most seeds germinate within a year of seed set, but a small percentage of the remains viable in the soil for more than 1 year. Ungerminated seeds remaining viable in the soil may germinate and establish 2 or more years after they are produced. From above result we suggest that at present there is less impact of seed bank of exotics on natives but it is going very harmful in near future so they should properly managed and control with hindering native plants in particular region. In our optimistic view on the potential for restoration of ecosystem, Seabloom et al. (2003) suggest that augmenting the native seed bank be successful strategy, however exotics also have some contribution to seed bank so conversion and loss of habitat is due to human interferences, nitrogen deposition and urbanization (Syphard et al. 2007) because soil samples have more seed density of existing plant community rather exotic species the standing vegetation did influence the composition of seed bank in this study and may provide a window of opportunity for restoration when exotics are low in seed density (Cox and Allen 2008) we also support this prediction.

In this study, exotics introduced from other biogeographical regions of the world have adapted Indian environment and fast naturalizing to be part of our natural ecosystem (Aggarwal et al. 2012). These exotic species are of great economic importance than native weeds and are frequently being used also. These invasive are widely distributed among all categories of living organisms as well as all kinds of ecosystems throughout the world (Sekar 2012). Exotic species are non-native and come from out side through their seed dispersal potential. Differences between native and exotics in their requirements and modes of resource acquisition and consumption may cause a change in soil structure, its profile, decomposition, nutrient content of soil availability (Sekar 2012). Generally dominant warm-season grasses suppress total plant diversity and prevent invasion is a key issue for developing better restoration plans (Wilsey 2010). In last few years, the plants diversity of this region particular in agro-ecosystem and grassland is threatened due to overexploitation, rapid changes in colony so there is serious depletion of these valued economical plants as natural resources. Some exotic species now have become naturalized in this area.

Low water supply, soil moisture, temperature, amount and duration of rainfall and photoperiod directly affect the phenology of plants such as flowering fruiting and seed production. Global climate changes also shifted the timing of phenological events occurring in plants. Domestication of important economical plants should be done in tropical region. Those weeds should get more attention which is being medicinally used in curing same diseases as rare or threatened trees do. Phenology is an indicator of climate change so it can give idea about how exotic compete with native species in their new environment. Maximum climatic factors such as temperature, air, water soil moisture, and precipitation control phenological events in plants and directly affect diversity and ecological processes and phenology of plants. Soil seed bank and phenology of both native and exotic plants gives idea about their natural selection and their conservation biology.

Conclusion: We conclude that seed bank of exotic plants have little impact on natives due to low species richness and seed germination density at ecosystem level. It provides information of management and sustainability of plants diversity and ecosystem and impact of exotic on native plants also determine future plant population, diversity and deviation. Changes in seed bank directly associated with invasion, climatic conditions and environmental degradation. The plant diversity of annual, perennial herbs and grasses with their nativity work at regional level would be of good source of information on technical and taxonomic data, and their significant role in use of medicinal and economical purposes. There should be more study on phenology of plants for their relationship with climatic condition, biodiversity, ecosystem functioning proper management and conservation.

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Table 1. Species in soil seed bank of in different ecosystems of moist tropics of Uttar Pradesh (2007-2009). (A-Agro-ecosystem and G-Grassland,) and types of seed bank (STP-Short-term persistent, LTP-Long-term persistent).

Botanical name	Family	Vernacular Name	Habit	Ecosystem	Life-form	Form	Native/ exotic	Seed bank types
Achyranthes aspera Linn.	Amaranthaceae	Chirchira	Herb	G	Perennial	Dicot	Native	STP
Ageratum conyzoides Linn.	Asteraceae	Gandh	Herb	A, G	Annual	Dicot	Exotic	STP
Alternenthera sessilis Br.	Amaranthaceae	Saranchi	Herb	G	Perennial	Dicot	Exotic	Transient
Amaranthus viridis Linn.	Amaranthaceae	Jangali tarai ka sag	Herb	A	Perennial	Dicot	Native	STP
Ammania baccifera Linn.	Lythraceae	Banmirich	Herb	A	Annual	Dicot	Native	STP
Anagallis arvensis Linn.	Primulaceae	Armal	Herb	A, G	Annual	Dicot	Exotic	STP
Biophytum sensitivum DC.	Oxalidaceae	Vipreetlajja	Herb	G	Perennial	Dicot	Native	STP
Blepharis repens (Vehl) Roth	Acanthaceae	-	Herb	G	Annual	Dicot	Native	STP

Blumea lacera DC.	Asteraceae	Kukuraundha	Herb	A, G	Perennial	Dicot	Exotic	STP
Boerhavia diffusa Linn.	Nyctaginaceae	Purnava	Herb	A	Perennial	Dicot	Native	STP
Bonnaya brachiata Link & Otto	Scrophulariaceae	-	Herb	G	Annual	Dicot	Native	STP
Brachiaria ramose Linn.	Poaceae	Likhbans	Grass	A	Annual	Monocot	Native	STP
Cassia occidentalis Linn.	Fabaceae	Bada Chakwad	Shrub	G	Annual	Dicot	Exotic	STP
Centella asiatica (Linn.) Urban	Apiaceae	Mandukparni, Brahim-buti	Herb	G	Annual	Dicot	Native	STP
Chenopodium album Linn.	Chenopodiaceae	Bathua sag	Herb	A	Annual	Dicot	Native	LTP
Chrysopogon aciculatus Trin.	Poaceae	-	Grass	G	Annual	Monocot	Native	Transient
Commelina benghalensis Wall.	Commelinaceae	Kanchara	Herb	A, G	Annual	Monocot	Native	STP
Cynodon dactylon Pers.	Poaceae	Doob, Ghas	Grass	A, G	Perennial	Monocot	Native	LTP
Cyperus kyllingia Endl.	Cyperaceae	Motha	Sedge	A, G	Perennial	Monocot	Native	STP
Cyperus rotundus Linn.	Cyperaceae	Motha	Sedge	A, G	Annual	Monocot	Native	STP
Desmodium triflorum DC.	Fabaceae	Tikuli	Herb	G	Annual	Dicot	Native	STP
Dichanthium annulatum Forsk.	Poaceae	Janeva	Grass	A, G	Perennial	Monocot	Native	LTP
Digitaria ciliaris Pers.	Poaceae	Chipbanso	Grass	A, G	Annual	Monocot	Native	LTP
Echinochloa colona Linn. Link	Poaceae	Dhunia, Sama	Grass	A	Annual	Monocot	Exotic	Transient
Echinochloa crus-galli Beauv.	Poaceae	-	Grass	G	Annual	Monocot	Exotic	Transient
Eleusine indica Gaertn.	Poaceae	Malankuri	Grass	G	Annual	Monocot	Native	Transient
Eragrostis tenella R. & S.	Poaceae	Jugebans	Grass	G	Annual	Monocot	Native	STP
Eragrotis unioloides Nees	Poaceae	-	Grass	A	Annual	Monocot	Native	Transient
Euphorbia hirta Linn.	Euphorbiaceae	Dudhi	Forb	A, G	Annual	Dicot	Exotic	LTP
Evolvulus nummularis Linn.	Convolvulaceae	Bichhmalia	Herb	G	Perennial	Dicot	Exotic	LTP
Fimbristylis schoenoides Vahl	Cyperaceae	-	Sedge	G	Annual	Monocot	Native	Transient
Imperata cylindrical (Linn.) Raeuschel.	Poaceae	Sirhu, Dachela	Grass	G	Perennial	Monocot	Exotic	Transient
Ludwigia parviflora Roxb.	Onagraceae	Lwangi Jhar	Herb	A	Annual	Dicot	Native	Transient
Melilotus alba Lamk.	Fabaceae	Banmethi	Herb	A	Annual	Dicot	Exotic	Transient

Oplismenus burmannii Beauv.	Poaceae	Chitrbanso	Grass	G	Annual	Monocot	Native	LTP
Parthenium hysterophorus Linn.	Asteraceae	Gajarghas	Herb	A, G	Annual	Dicot	Exotic	LTP
Phalaris minor Retz.	Poaceae	Gehun ke mama	Grass	A	Annual	Monocot	Native	Transient
Saccharum spontaneum Linn.	Poaceae	Kass	Grass	G	Annual	Monocot	Exotic	Transient
Solanum nigrum Linn.	Solanaceae	Makoicha	Herb	A	Perennial	Dicot	Exotic	Transient

Table 2. Nativity, phenological events (flowering and fruiting) and usage of plants recorded in soil seed bank (2007-2009).

Weed species	**Nativity**	**Phenological events (flowering and fruiting)**	**Uses of each weeds**
Achyranthes aspera Linn.		Jul-Apr	Whole plant in fertility, toothache and abdominal pain
Ageratum conyzoides Linn.	Tropical America	Jul-Feb	Leaves and fruits in diarrhoea and dysentery
Alternenthera sessilis Br.	Tropical America	Jul-Aug	Whole plant in stomachache
Amaranthus viridis Linn.		Jul-Apr	Leaves in dysentery and as vegetable
Ammania baccifera Linn.		Jul-Feb	Leaves in skin infections
Anagallis arvensis Linn.	Europe	Nov-Apr	Leaves, fruits and seeds as diaphoretic and in leprosy
Biophytum sensitivum DC.		Oct-Mar	Leaves in diarrhoea
Blepharis repens (Vehl) Roth		Aug-Feb	Leaves as antibacterial and in fever cold cough
Blumea lacera DC.	Tropical America	Jan-Jun	Leaves in dysentery
Boerhavia diffusa Linn.		Aug-May	Whole plant in asthma
Bonnaya brachiata Link & Otto		Feb-Apr	Leaves in elephantiasis
Brachiaria ramose Linn.		Jul-Nov	Whole plants as fodder and forage
Cassia occidentalis Linn.	South America	Oct-Mar	Seeds in skin diseases
Centella asiatica (Linn.) Urban		Sep-Jan	Leaves in leprosy, fatigue, depression
Chenopodium album Linn.	Europe	Nov-Apr	Leaves as vegetable and sedative
Chrysopogon aciculatus Trin.		Jul-Nov	Root, stem and leaves as antidote snake poison
Commelina benghalensis Wall.		Jul-Nov	Whole plant in leprosy
Cynodon dactylon Pers.		Nov-Mar	Whole plant in skin treatment and as diuretic
Cyperus kyllingia Endl.		Aug-Nov	Whole plant as antidote to poison

Cyperus rotundus Linn.		Aug-Nov	Whole plant as diaphoretic, stomachache and astringent
Desmodium triflorum DC.		Sep-Mar	Roots, stem and whole plant in tonic and as diuretic
Dichanthium annulatum Forsk.		Sep-Feb	Whole plant in skin treatment
Digitaria ciliaris Pers.		Oct-Apr	Whole plant as fodder and forage
Echinochloa colona Linn. Link	South America	Oct-Mar	Leaves in dysentery
Echinochloa crus-galli Beauv.	South America	Sep-Dec	Leaves as antehelmintic
Eleusine indica Gaertn.		Oct-Apr	Whole plant in skin diseases
Eragrostis tenella R. & S.		Jul-Nov	Whole plant as fodder and forage
Eragrotis unioloides Nees		Aug-Dec	Whole plant as fodder and forage
Euphorbia hirta Linn.	Tropical America	Sep-May	Leaves in acidity
Evolvulus nummularis Linn.	Tropical America	Sep-Dec	Whole plant is antibacterial
Fimbristylis schoenoides Vahl		Jul-Mar	Whole plant as fodder and forage
Imperata cylindrica (Linn.) Raeuschel.	Tropical America	Oct-Feb	Whole plant in making ropes and fibers
Ludwigia parviflora Roxb.		Nov-Jan	Seeds in rheumatic pains
Melilotus alba Lamk.	Europe	Dec-May	Whole plant in ulcer treatment and eyesight
Oplismenus burmannii Beauv.		Jul-Dec	Leaves as fodder and skin diseases
Parthenium hysterophorus Linn.	North America	Sep-Jun	Whole plant as febrifuge
Phalaris minor Retz.		Oct-Apr	Whole plant as fodder and forage
Saccharum spontaneum Linn.	Tropical West Asia	Aug-Feb	Leaves and stem for fiber, fodder and forage
Solanum nigrum Linn.	Tropical America	Sep-Apr	Whole plant in cirrhosis

Table 3. Spatial variation of species recorded in soil seed bank by seedling emergence method in an agro-ecosystem of two annual cycles (2007-2009).

Species	**0-10 cm**	**10-20 cm**	**20-30 cm**	***F***	***p***
Ageratum conyzoides	424.8±15.6	292.5±26.2	199.7±15.4	32.928	0.000**
Amaranthus viridis	316.0±21.9	237.0±23.3	150.2±16.3	16.043	0.000**
Ammania baccifera	797.3±30.5	497.3±26.5	268.3±21.5	100.158	0.000**
Anagallis arvensis	399.7±16.8	341.2±36.7	217.2±20.2	12.778	0.001*
Blumea lacera	750.7±32.7	483.7±29.9	305.0±32.8	49.523	0.000**
Boerhaavia diffusa	309.7±140.8	181.8±81.9	97.3±44.7	1.201	ns
Brachiaria ramosa	612.5±41.0	454.2±11.1	333.5±9.5	30.947	0.000**
Chenopodium album	464.5±18.7	341.0±9.1	231.7±6.2	86.905	0.000**
Commelina benghalensis	462.3±51.4	355.8±40.3	259.3±42.9	5.042	0.021*
Cynodon dactylon	4097.0±246.1	1101.1±49.1	872.1±45.1	149.650	0.000**
Cyperus kyllingia	666.0±18.3	426.2±39.3	308.2±36.6	31.000	0.000**

Cyperus rotundus	4596.0±268.6	1125.5±63.9	808.5±86.4	166.0	0.000**
Dichanthium annulatum	4305.0±130.1	1404.3±43.4	994.0±47.9	463 .28	0.000**
Digitaria ciliaris	623.0±43.6	425.3±48.8	283.3±32.9	16.290	0.000**
Echinochloa colona	509.2±37.2	361.0±14.7	225.2±10.6	35.318	0.000**
Eragrotis unioloides	321.2±42.4	400.8±14.7	259.3±16.1	22.644	0.000**
Euphorbia hirta	4243.0±78.9	1589.2±60.6	1117.5±54.6	7.09	0.007*
Ludwigia parviflora	120.7±53.9	85.5±38.7	65.7±32.7	0.428	ns
Melilotus alba	186.6±83.7	164.0±23.5	127.0±57.8	0.173	ns
Parthenium hyseteophorus	524.3±15.6	464.7±61.8	273.8±19.8	11.528	0.001*
Phalaris minor	576.7±35.6	427.3±16.9	286.5±14.3	35.720	0.000**
Solanum nigrum	285.8±131.3	163.3±73.2	132.8±59.5	0.753	ns

Note: * $p < 0.05$, ** $p < 0.001$, ns = not significant

Table 4. Spatial variation of species recorded in soil seed bank by seedling emergence method in a grassland of moist tropics of two annual cycles (2007-2009).

Species	**0-10 cm**	**10-20 cm**	**20-30 cm**	***F***	***p***
Achyranthes aspera	372.8±62.9	244.5±36.5	150.2±32.7	5.887	0.013*
Ageratum conyzoides	645.5±91.4	375.5±31.3	181.8±26.5	16.194	0.000**
Alternenthera sessilis	135.3±62.9	76.3±35.2	45.5±20.3	1.112	ns
Anagallis arvensis	930.5±36.1	526.0±30.6	253.5±45.2	81.355	0.000**
Biophytum sensitivum	1238.2±63.3	763.5±48.2	322.7±26.2	89.59	0.000**
Blepharis repens	1099.2±72.6	610.2±103.4	267.3±69.7	25.187	0.000**
Blumea lacera	1535.0±168.1	675.2±99.5	277.0±50.9	30.410	0.000**
Bonnaya brachiata	1431.3±62.1	861.8±45.1	358.6±34.2	122.542	ns
Cassia occidentalis	315.7±14.9	200.3±90.5	132.2±60.1	0.756	0.000**
Centella asiatica	998.5±133.6	341.7±24.5	282.7±29.1	24.554	ns
Chrysopogon aciculatus	434.7±205.2	279.8±15.5	140.8±65.4	0.921	0.000**
Commelina benghalensis	1067.0±434.0	668.7±93.9	298.3±42.9	35.354	0.000**
Cynodon dactylon	2207.5±84.7	1483.0±55.9	812.0±92.4	77.506	0.000**
Cyperus kyllingia	1188.7±72.5	778.1±58.9	507.6±62.7	27.855	0.000**
Cyperus rotundus	1461.0±117.2	1283.5±152.9	501.3±120.1	15.183	0.000**
Desmodium triflorum	663.3±29.8	390.5±177.8	213.5±95.9	1.186	ns
Dichanthium annulatum	1630.0±74.1	922.1±96.3	553.2±61.1	48.512	0.000**
Digitaria ciliaris	1099.5±92.4	779.6±61.9	485.5±40.1	20.212	0.000**
Echinochloa crus-galli	630.0±140.6	349.3±164.7	148.7±67.5	0.890	ns
Eleusine indica	475.2±21.3	316.8±1430.7	253.5±114.2	0.494	ns

Eragrotis tenella	571.8±25.8	395.7±177.5	227.8±106.3	0.810	ns
Euphorbia hirta	1989.7±87.9	1429.3±73.3	823.2±97.9	45.002	0.000**
Evolvulus nummularis	921.5±268.2	625.0±95.1	413.7±21.8	19.056	0.000**
Fimbristylis schoenoides	668.2±327.9	368.0±171.1	196.3±89.1	1.181	ns
Imperata cylindrica	699.7±315.7	339.7±16.5	232.3±107.8	1.299	ns
Oplismenus burmanii	1218.5±161.7	644.8±94.9	435.6±280.9	14.492	0.000**
Parthenium hysterophorus	1118.3±90.1	743.0±70.1	507.2±29.8	20.467	0.000**
Saccharaum spontaneum	617.8±280.4	360.5±177.2	123.2±55.2	1.624	ns

Note: $^{*}p < 0.05$, $^{**}p < 0.001$, ns = not significant

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