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Ecological Investigation on Diversity of Standing and Seed Bank Vegetation Along The Bank of Kali River in Its Meerut Segment

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Abstract

Soil seed banks serve as reservoirs of seeds for subsequent regeneration of plants. Soil seed banks were investigated along the Kali river bank (KRB) in Meerut region of Uttar Pradesh. The study aimed at examining species richness and diversity, determining seed densities, assessing the spatial distribution of seeds in the soil and comparing the similarity in species composition between the standing vegetation and soil seed bank. A total of 33 plant species were identified in the top 15 cm soil layers with density of 1558 seeds/ m^2. Herbs, climber and woody plants were represented by 1547, 7 and 4 seed/m^2 species respectively, in 20 families and 31 genera. The diversity and evenness of the soil seed bank in the KRB was 3.16 and 0.90, respectively. Top Five plant species were identified from the soil seed bank, namely Parthenium hysterophorus L., Chenopodium album L. Phalaris minor Retz, Megathyrsus maximus (Jacq.) B.K. Simon & S.W.L. Jacobs, Amaranthus viridis L. The overall horizontal distribution of seeds varied among sampling quadrats while the vertical distribution of seeds exhibited the highest densities occurring in the upper layer (0-5 cm) of the soil and gradually decreasing densities with increasing depth. Parthenium hysterophorus found in all layer while others varied, the nativity as well as exotic species also decrease. The similarity in species composition between the soil seed bank flora and standing vegetation was low (27%). The results demonstrated that herbaceous species in KRB store quantities of seeds in the soil and most of the woody species do not accumulate more seeds in the soil suggests that their regeneration from seeds would be unlikely if mature individuals disappeared (die or are harvested). Because of its diverse seed banks, the herbaceous flora would have a better chance of re-establishing in the event of anthropogenic or natural disturbances. Therefore, the future of the KRB flora seems to depend on the successful conservation of the standing vegetation.

Keywords: - Soil seed bank, Kali River, similarity, diversity, regeneration

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INTRODUCTION

Soil seed banks are the reservoir or collection of viable seeds in the soil and associated litter at any given time potentially capable of replacing adult plants [34]. They have both a spatial and temporal dimension and can be either transient (germinating within a year after dispersal) or persistent (seeds that remain in the soil for more than a year) [45, 14, 34]. Soil seed banks play a critical role in the regeneration of plant species by replacing adult ones [37]. They also play an important role in vegetation maintenance, succession, ecosystem restoration and conservation of genetic variability [39, 15]. Major sources of natural regeneration are seed rain, seedling banks, coppices and soil seed banks [8, 1, 39, 12]. Seed banks are critical repositories of woodland diversity that can contribute to local population persistence and biodiversity maintenance through temporal storage effects [3].

Vegetation regeneration extends beyond mere reproduction to include germination of propagules and successive growth and survival of young trees until they are mature [48]. Plants produce seeds, which disperse from the mother plant by different mechanisms, including wind, water runoff and animal vectors [2, 9], and become incorporated into the soil and form part of a store or bank of seeds [32, 14]. Germination of these seeds may take place immediately or may be delayed for an indefinite period [7]. Most of the seeds in the seed bank come from nearby parent plants, while some seeds may be contributed by plant communities a long distance away from the parent plants [54]. The distribution of seeds, in terms of diversity, time and space, is a controller of population development and necessary for plant diversity maintenance in fragmented landscapes [25].

Although soil seed banks are understood to be crucial to the vegetation dynamics and restoration of many ecosystems, little is known about their role in riparian zones [47, 4]. Riparian plant communities are exposed to frequent natural (flooding, fire and browsing) and human (tree cutting and cultivation) disturbances in the riparian zones. As the human population grows, demand for natural resources and ecosystem services also increases [37]. In countries like Kenya, rapid population growth, deforestation, overgrazing, agricultural activities, fuelwood collection and construction material has resulted in the decline of riparian ecosystems [22]. Conservationists may benefit from the knowledge of the relation between soil seed bank and aboveground vegetation, as this might help to make informed decisions on management of exotic species, diversity restoration and better understand the resilience of an ecosystem [11]. The relationship between soil seed banks and their standing vegetation is the key point in evaluating the revegetation potential [16].

Despite the importance of soil seed banks in the regeneration of plant species, information on the soil seed banks of riparian vegetation in the Meerut, including the Kali river, is lacking. Riparian vegetation along the Kali River is exposed to communal land use, which might also be a threat. The vegetation is cleared to make way for human settlements, fields and kraals [23, 6]. This study is, therefore, relevant in a system such as the kali river bank which is characterized by changing weather seasons and changes in river flows, to explain patterns of diversity and dynamics of riparian vegetation in these habitats. The results will be helpful for vegetation restoration and riparian ecosystem conservation in the Meerut region, and in similar regions all over the world.

Riparian vegetation in the Meerut region has extensive economic, social and environmental benefits. However, despite its relevance, it is threatened by changes in variation in hydrology, anthropogenic activities and other environmental conditions. Kali river riparian communities may change rapidly in response to both long- and short-term disturbances caused by human exploitation and domestic animals. For riparian woodland species to be managed sustainably, information on the current regeneration status and soil seed banks of the trees under different land uses is needed.

The major objective of the study was (i) to assess species composition of standing vegetation and seed bank along the bank of polluted Kali River. (ii) assess the spatial (vertical and horizontal) distribution of density of seeds in the soil and (iii) understand the similarity between the standing vegetation and soil seed bank flora of the riparian vegetation along the Kali river in Meerut region of western Uttar Pradesh.

Materials and Methods

Study Area

The study area was located at the bank of Kali River in Meerut located between longitude 77.7°E and 78.5°E, and latitude 28.9°N and 29. 6°N. The Kali River is an important water body here that provides water for irrigation and other domestic purposes. The river also supports a rich biodiversity of flora and fauna. However, the river faces several challenges due to rapid urbanization, such as pollution and encroachment of the edge. The study on surface vegetation and seed bank was conducted along the bank of Kali River in the Meerut region of western Uttar Pradesh India in on a 3 km stretch from IIMT Meerut Mawana road Junction to Jalalpur Village. The annual floods peak at Meerut between July and October. The Kali River passes through Jalalpur Village in northern Meerut. During low flooding periods, the Kali River becomes dry from January to June. In terms of temperature in the area, the Kali river is characterized by maximum temperatures ranging between 30 to 45 °C in the summer (march to July) and minimum temperature between 10 and 20°C in winter (November to January). (Yadav and Narayan. 2022); the soils along the Kali River are generally sandy. The Kali River supports a variety of different plants species.

Floristic analysis of Surface Vegetation (SV)

Recurrent seasonal visits were conducted between 2019 and 2020 to record different plant species in the marked study area along the bank of Kali River. The collected plant samples were identified by using local flora and herbarium OF BSI, Dehradun. The nativity of identified species was recorded following the e-flora and published work [53].

Seed Bank (SB) Study

Thirty soil samples, each of size 25 cm × 25 cm were collected in the month of February in 2019 from three different depths (0-5 cm, 5-10 cm and 10-15 cm) with the help of spoon and knife in plastic bags(each layer separately).These soil samples were labelled and brought to green house in the university campus , incubated in open topped plastic pots (size : depth 10 cm , bottom and top diameters 16 cm and 20 cm) with perforation to allows free drainage of excess water. The soil samples were regularly watered and seedling emergent monitored. They were allowed to grow to identifiable stage, counted, recorded and discarded. The seedlings were identified to the species level.

Daily temperatures in the enclosure ranged from 18-47 °C. Every four weeks, the soil samples were stirred to stimulate further seed germination. The seedling emergence was monitored upto ten months.

Data Analysis

Similarity between SV and SB flora was estimated according to Jaccard's Similarity Co-efficient (JSC) according to Krebs (1989) formula:

$$JSC = a \div (a + b + c).$$

where a = number of species common to both SV and SB, b=number of species found only in SV and c= number of species recorded only in SB

Species richness (S) was determined as the total number of different plant species recorded from the soil seed bank and standing vegetation and did not consider the proportion and distribution of each species. The Shannon Diversity Index (H') [19] was calculated for seed banks vegetation. The following formula was used to determine the Shannon Diversity Index:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where, H' = Shannon 'diversity Index, S = species richness, Pi = proportion of abundance of the its species.

Evenness or equitability, was measured following [19]. Shannon's Evenness or Equitability Index (E) assumes a value between 0 and 1, with 1 being complete evenness. The following formula was used to calculate evenness.

E = H′ /lnS.

where, E = evenness and S = species richness.

Results

Standing Vegetation

A total of 81 species representing 39 families were recorded (Table 1). Fabaceae was the largest family with 12 species, followed by Poaceae (11), Amaranthaceae (7), Malvaceae (4), Asteraceae, Brassicaceae, Moraceae, Solanaceae had 3 species each and Caryophyllaceae, Cyperaceae, Euphorbiaceae, Lamiaceae had 2 species each. The remaining families had only one species each. A total of 72 genera were encountered. *Ficus* and *Urochloa* were the richest genus with three species each followed by, *Alternanthera, Cyperus, Senna, Solanum, Vigna* with 2 species each. The other genera had one species each. Herbs were highest in number (79%) followed by tree (16%), shrubs (2.5%) and climbers (2.5%). A total of 29 flora were native and 52 exotics.

Seed Bank Vegetation

In contrast, the soil seed banks along Kali River bank recorded only 33 species, representing 20 families, with herbs, Tree and Climbers species represented by 29 (87.88%), 3 (9.09%) and 1 (3.03%) species, respectively. The Poaceae was the largest family with (6 species), followed by Amaranthaceae (5), Asteraceae (3), Malvaceae and Moraceae 2 species each. The remaining families had only one species each. Seed bank recorded 10 native and 23 alien flora.

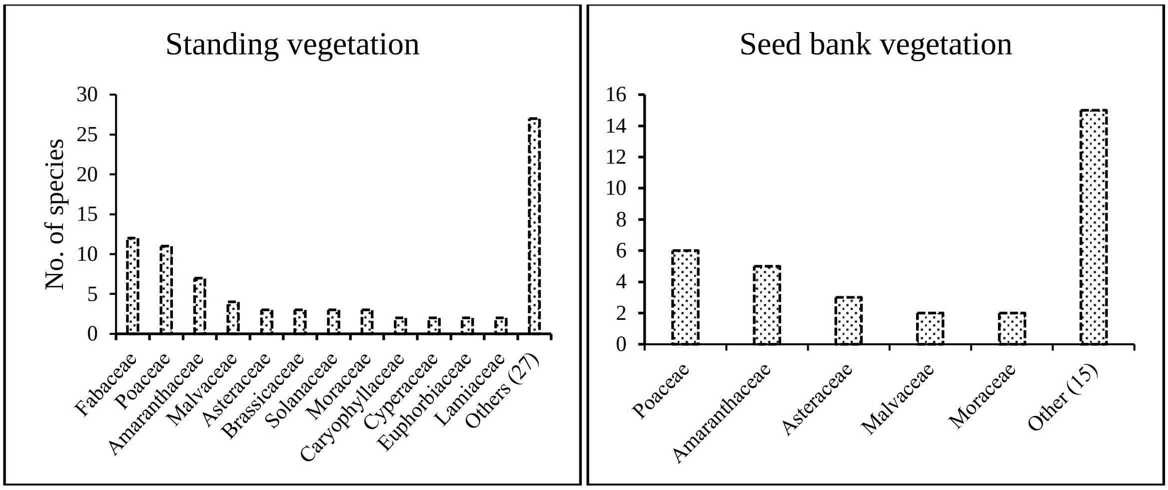

Fig. 1. Dominant angiospermic families occurs standing and seed bank vegetation along Kali river bank in Meerut region

Similarity in plants species composition

The similarity in plant species composition between the soil seed flora and standing vegetation along the Kali River was very low. Of the 81 species recorded in the standing vegetation only 31 of them were recorded in the soil seed flora (JCS = 0.27) (Table 1). The Shannon diversity index and Evenness of the species along the Kali River were 3.16 ± 0.10 and 0.90 ± 0.05, respectively.

Table: 1 Species composition of standing vegetation (SV) and seed bank (SB) along the Kali river bank in Meerut region,

S.N.	NAME OF SPECIES	FAMILY	Life Form	Habit	Nativity	SV	SB
1	*Abutilon indicum* (L.) Sweet	Malvaceae	A	H	India	+	-
2	*Achyranthes aspera* L.	Amaranthaceae	A	H	North America	+	+
3	*Aegle marmelos* (L.) Correa	Rutaceae	P	T	India	+	-

4	*Alternanthera philoxeroides* (Mart.) Griseb	Amaranthaceae	A	H	Tropical America	+	-
5	*Alternanthera sessilis* (L.) DC.	Amaranthaceae	A	H	Tropical America	+	+
6	*Amaranthus viridis* L.	Amaranthaceae	B	H	Tropical America	+	+
7	*Argemone mexicana* L.	Papaveraceae	A	H	South America	+	+
8	*Azadirachta indica* A. Juss.	Meliaceae	P	T	India	+	-
9	*Boerhavia diffusa* L.	Nyctaginaceae	A	H	India	+	-
10	*Brassica rapa* L.	Brassicaceae	A	H	Europe	+	-
11	*Calotropis procera* (Aiton) W.T. Aiton	Apocynaceae	P	S	Africa	+	-
12	*Cannabis sativa* L.	Cannabaceae	A	H	Asia	+	+
13	*Celosia argentea* L.	Amaranthaceae	A	H	Africa	+	
14	*Centella asiatica* (L.) Urb.	Apiaceae	A	H	India	+	+
15	*Chenopodium album* L.	Amaranthaceae	A	H	Europe	+	+
16	*Cleome viscosa* L.	Cleomaceae	A	H	Tropical America	+	-
17	*Cocculus hirsutus* (L.) W.Theob.	Menispermaceae	A	C	India	+	-
18	*Commelina benghalensis* L.	Commelinaceae	A	H	India	+	-
19	*Corchorus olitorius* L.	Malvaceae	A	H	Africa	+	-
20	*Croton bonplandianus* Baill.	Euphorbiaceae	A	H	South America	+	-
21	*Cucumis melo* L.	Cucurbitaceae	A	C	India	+	-
22	*Cynodon dactylon* (L.) Pers.	Poaceae	B	H	India	+	+
23	*Cyperus iria* L.	Cyperaceae	A	H	Tropical America	+	-
24	*Cyperus rotundus* L.	Cyperaceae	A	H	Europe	+	+
25	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	A	H	India	+	+
26	*Dalbergia sissoo* Roxb. ex DC	Fabaceae	P	T	India	+	-
27	*Delonix regia* (Bojer ex Hook.) Raf.	Fabaceae	P	T	Africa	+	-
28	*Dicliptera paniculata* (Forssk.) I. Darbysh.	Acanthaceae	A	H	Tropical America	+	-
29	*Digitaria sanguinalis* (L.) Scop.	Poaceae	A	H	India	+	+
30	*Dysphania ambrosiodes* (L.) Mosyakin & Clements	Amaranthaceae	A	H	Tropical America	+	+
31	*Eclipta prostrata* (L.) L.	Asteraceae	B	H	Tropical America	+	+
32	*Eragrostis tenella* (L.) P. Beauv. Ex Roem.&Schult.	Poaceae	B	H	India	+	-
33	*Euphorbia hirta* L.	Euphorbiaceae	A	H	Tropical America	+	+
34	*Ficus benghalensis* L.	Moraceae	P	T	India	+	+
35	*Ficus religiosa* L.	Moraceae	P	T	India	+	

36	*Ficus virens* Aiton	Moraceae	P	T	India	+	+
37	*Gamochaeta pensylvanica* (Willd.) Cabrera	Asteraceae	A	H	Tropical America	-	+
38	*Grona triflora* (L.) H. Ohashi & K.Ohashi	Fabaceae	A	H	India	+	-
39	*Indigofera tinctoria* L.	Fabaceae	A	H	India	+	-
40	*Ipomoea indica* (Burm.) Merr.	Convolvulaceae	P	C	Tropical America	-	+
41	*Lantana camara* L.	Verbenaceae	P	S	Tropical America	+	-
42	*Lepidium didymum* L.	Brassicaceae	A	H	South America	+	-
43	*Ludwigia perennis* L.	Onagraceae	A	H	Africa	+	+
44	*Lysimachia arvensis* (L.) U.Manns & Anderb.	Primulaceae	A	H	Europe	+	+
45	*Malvastrum coromandelianum* (L.) Garcke	Malvaceae	A	H	Tropical America	+	+
46	*Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs	Poaceae	A	H	Africa	+	+
47	*Melilotus indicus* (L.) All.	Fabaceae	A	H	India	+	-
48	*Mesosphaerum suaveolens* (L.) Kuntze	Lamiaceae	A	H	Tropical America	+	-
49	*Nicotiana plumbaginifolia* Viv.	Solanaceae	A	H	Tropical America	+	-
50	*Ocimum tenuiflorum* L.	Lamiaceae	A	H	India	+	-
51	*Oldenlandia corymbosa* L.	Rubiaceae	A	H	India	+	+
52	*Oxalis corniculata* L.	Oxalidaceae	A	H	Europe	+	+
53	*Parthenium hysterophorus* L.	Asteraceae	A	H	North America	+	+
54	*Phalaris minor* Retz.	Poaceae	A	H	India	+	+
55	*Phyllanthus amarus* Schumach. & Thonn.	Phyllanthaceae	A	H	Tropical America	+	-
56	*Pithecellobium dulce* (Roxb.) Benth.	Fabaceae	A	T	Tropical America	+	-
57	*Populus deltoides* W.Bartram ex Marshall	Salicaceae	P	T	North America	+	-
58	*Portulaca oleracea* L.	Portulacaceae	A	H	South America	+	-
59	*Prosopis juliflora* (Sw.) DC.	Fabaceae	P	T	North America	+	-
60	*Psidium guajava* L.	Myrtaceae	P	T	Tropical America	+	-
61	*Ranunculus sceleratus* L.	Ranunculaceae	A	H	Asia	+	+
62	*Rumex dentatus* L.	Polygonaceae	A	H	Europe	+	+
63	*Saccharum spontaneum* L.	Poaceae	A	H	Asia	+	-
64	*Senna occidentalis* (L.) Link.	Fabaceae	A	H	South America	+	-
65	*Senna tora* (L.) Roxb.	Fabaceae	A	H	South America	+	+
66	*Setaria verticillata* (L.) P. Beauv.	Poaceae	A	H	India	+	+

67	*Sisymbrium irio* L.	Brassicaceae	A	H	Europe	+	-
68	*Solanum nigrum* L.	Solanaceae	A	H	Tropical America	+	-
69	*Solanum villosum* Mill.	Solanaceae	A	H	India	+	-
70	*Spergula arvensis* L.	Caryophyllaceae	A	H	India	+	-
71	*Stellaria media* (L.) Vill.	Caryophyllaceae	A	H	India	+	+
72	*Torenia crustacea* (L.) Cham. & Schltdl.	Linderniaceae	P	T	Asia	+	+
73	*Trianthema portulacastrum* L.	Aizoaceae	A	H	Tropical America	+	-
74	*Trifolium hybridum* L.	Fabaceae	A	H	Europe	+	-
75	*Triumfetta rhomboidea* Jacq.	Malvaceae	A	H	Tropical America	+	+
76	*Typha angustifolia* L.	Typhaceae	A	H	Tropical America	+	-
77	*Urochloa eminii* (Mez) Davidse	Poaceae	A	H	Africa	+	-
78	*Urochloa lata* (Schumach.) C.E. Hubb.	Poaceae	A	H	India	+	-
79	*Urochloa ramosa* (L.) T.Q. Nguyen	Poaceae	A	H	India	+	-
80	*Vigna radiata* (L.) R. Wilczek	Fabaceae	A	H	India	+	-
81	*Vigna unguiculata* (L.) Walp.	Fabaceae	A	H	Africa	+	-
82	*Xanthium strumarium* L.	Asteraceae	A	H	Tropical America	+	-
83	*Ziziphus jujuba* Mill.	Rhamnaceae	P	T	Asia	+	-

Codes

A: Annual, B: Biennial, P: Perennial, H: Herb, T: Tree, C: Climber, S: Shrub, Symbols **+** and **-** indicate presence and absence respectively

Density of seeds in the soil

The overall density of seeds recovered from the soil samples collected in the KRB was 51.93 seeds m−2 (Table 2). The densities of seeds for herbs, climber and woody species were 51.56, 0.23 and 0.13 seeds $m^{-2,}$ respectively. Of these, 907, 527, and 124 seed m^{-2} were recorded from the first (0–5 cm), second (5–10 cm) and third (10–15 cm) layers, respectively (Table 2). The five species with the highest densities of seeds were *Parthenium hysterophorus* L. (154 seeds m^{-2}), *Chenopodium album* L (126 seeds m^{-2}), Phalaris minor Retz. (125 seeds m^{-2}), *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs (117 seeds m^{-2}) and *Amaranthus viridis* L (96 seeds m^{-2}), and the species with the lowest densities were *Torenia crustacea* (L.) Cham. & Schltdl. *Ficus benghalensis* L. *Ficus virens* Aiton each represented by only one seed m^{-2}.

Table 2. Floristics composition of seed bank and their densities occurs different depth at Kali river in Meerut region.

S.N.	**Name of Species**	**Family**	**Habit**	**Soil Depth(cm)**			
				0-5	**5-10**	**10-15**	**0-15**
1	*Parthenium hysterophorus* L.	Asteraceae	H	82	56	16	154
2	*Chenopodium album* L.	Amaranthaceae	H	74	43	9	126
3	*Phalaris minor* Retz.	Poaceae	H	66	49	10	125
4	*Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs	Poaceae	H	73	32	12	117

5	*Amaranthus viridis* L.	Amaranthaceae	H	56	32	8	96
6	*Cannabis sativa* L.	Cannabaceae	H	53	34	2	89
7	*Stellaria media* (L.) Vill.	Caryophyllaceae	H	46	32	11	89
8	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	H	52	23	1	76
9	*Digitaria sanguinalis* (L.) Scop.	Poaceae	H	37	21	2	60
10	*Euphorbia hirta* L.	Euphorbiaceae	H	35	21	3	59
11	*Setaria verticillata* (L.) P. Beauv.	Poaceae	H	32	21	0	53
12	*Ranunculus sceleratus* L.	Ranunculaceae	H	29	15	8	52
13	*Eclipta prostrata* (L.) L.	Asteraceae	H	23	15	8	46
14	*Alternanthera sessilis* (L.) DC.	Amaranthaceae	H	27	8	3	38
15	*Achyranthes aspera* L.	Amaranthaceae	H	23	11	1	35
16	*Oldenlandia corymbosa* L.	Rubiaceae	H	19	12	3	34
17	*Malvastrum coromandelianum* (L.) Garcke	Malvaceae	H	19	11	3	33
18	*Ludwigia perennis* L.	Onagraceae	H	21	11	0	32
19	*Cyperus rotundus* L.	Cyperaceae	H	5	15	7	27
20	*Dysphania ambrosiodes* (L.) Mosyakin & Clements	Amaranthaceae	H	16	9	0	25
21	*Senna tora* (L.) Roxb.	Fabaceae	H	13	12	0	25
22	*Gamochaeta pensylvanica* (Willd.) Cabrera	Asteraceae	H	15	7	2	24
23	*Centella asiatica* (L.) Urb.	Apiaceae	H	15	6	2	23
24	*Cynodon dactylon* (L.) Pers.	Poaceae	H	11	3	9	23
25	*Rumex dentatus* L.	Polygonaceae	H	12	7	3	22
26	*Lysimachia arvensis* (L.) U.Manns & Anderb.	Primulaceae	H	15	5	1	21
27	*Oxalis corniculata* L.	Oxalidaceae	H	13	7	0	20
28	*Argemone mexicana* L.	Papaveraceae	H	9	4	0	13
29	*Triumfetta rhomboidea* Jacq.	Malvaceae	H	8	2	0	10
30	*Ipomoea indica* (Burm.) Merr.	Convolvulaceae	C	5	2	0	7
31	*Torenia crustacea* (L.) Cham. & Schltdl.	Linderniaceae	T	1	1	0	2
32	*Ficus benghalensis* L.	Moraceae	T	1	0	0	1
33	*Ficus virens* Aiton	Moraceae	T	1	0	0	1

Codes
H-Herb, T- Tree, C-Climber

Table 3: Depth wise distribution of soil seed banks, no. of species and 3 top dominating species and nativity along KRB

Depth	Top Three Dominants			No. of species	Seed no.	Native	exotic
0-5	*Parthenium hysterophorus*	*Chenopodium album*	*Megathyrsus maximus*	33	907	10	23
05-10	*Parthenium hysterophorus*	*Phalaris minor*	*Chenopodium album*	31	527	8	23

10-15	*Parthenium hysterophorus*	*Megathyrsus maximus*	*Stellaria media*	22	124	7	15
0-15	*Parthenium hysterophorus*	*Chenopodium album*	*Phalaris minor*	33	1558	10	23

Spatial distribution of seeds in the soil

There were great variations in the numbers of seeds distributed horizontally across all the quadrats sampled, ranging between 15 and 82 seeds (Table 3). Also, the overall vertical/depth distribution of seeds in the soil exhibited a higher density of seeds at the first layer and declining trends thereafter. The total densities of seeds recovered from the first, second and third soil layers were 904 (58.2%), 527 (33.8%), and 127 (8%), respectively (Table 2). Of the total number of species recovered from the soil seed bank study, 33 species, represented in all the layers had 1558 seeds $m^{-2.}$ Which *Parthenium hysterophorus* dominated in all three layers, the sub dominants varied in different layers. Native species and exotics were higher in number in top layer and decreased with increasing soil depth, However, exotics were larger in number compared to native once at all soil depths.

Discussion

Soil seed banks, in the present study represented by all viable seeds present on or in the soil and associated litter/humus, exhibited variations in space and displayed both horizontal and vertical dispersion, reflecting initial dispersal onto the soil and subsequent movement [33, 39]. They ostensibly reflected partly the history of the vegetation along Kali River bank (KRB) and can play an important role in its regeneration or restoration after disturbances. Such Soil seed banks finding can be exploited to manage the composition and structure of existing vegetation and restore or establish native vegetation [45, 40]. Ecosystem perturbation of KRB is intelligible from a large gap in floristic count recorded above ground (81) and belowground (33).

The results revealed that the KRB can be characterized as possessing large populations of buried seeds of mainly the herbs including grasses, (88 %) and a few woody species (9 %) in the soil. The dominance of herbaceous species in the soil seed banks of KRB showed similarities with findings from several other studies undertaken elsewhere [4, 17, 18, 41, 38, 39, 42, 30, 31, 27, 15, 29, 43, 21, 24, 50]. The dominance of herbaceous species could be attributed to ease of dispersal by various agents, such as wind and water, because of their light weight.

It is interesting to note that of the 33 species that were encountered in the soil seed bank in the present study, eight were exotic plant species (Table 2). Intrusion of non-native species to the ecosystem, where they have not previously occurred, has been reported to cause or likely to adverse impact to human health, economy and environment [26]. Some exotic species generally expand to new areas by birds, animals, water and wind dispersal [10]. These exotic plant species reportedly after ecosystem functions [26], resulting in biodiversity loss and a changed capacity to provide services. They often colonize an environment and adversely reduce the diversity of local species since they are aggressive competitors [51], as evinced by the large population size of *Parthenium hysterophorus* in the seed bank in this study. Those that are highly invasive and strongly modify their area of predominance [28].

The diversity value of the soil seed bank in KRB (3.16) was lower than that reported from light livestock grazing sites (7.93) and very light pressure sites from a Savanna woodland watering point (7.85) in West Africa by Sanou et al. (2018). The overall density (1558 seeds m^{-2}) of the seeds recovered from soil samples collected in the KRB was much lower than densities from Tibetan Plateau (5419 seeds), Alpine wetland on the Tibetan Plateau (6436 seeds), Mexican riparian tropical dry forest (10,033 seeds), Neotropical floodplain (33,181 seeds) and Savanna woodland watering point in West Africa (3948 seeds). This could be attributed to polluted water Kali River that influenced survival of plant species in seed bank along its bank as suggested by Singhal et al. (2016) at Bulandshahar segment of KRB.

Although there was considerable variation among species in the vertical distribution of their soil seed banks, the overall trend of depth distributions of the soil seed bank and number of species exhibited the highest densities in the upper 5 cm of soil and, then, gradually decreasing densities with increasing depth. This is consistent with several previous reports on the depth distributions of soil seed banks [41, 39].

The seeds in the soil reflected partly the composition of the standing vegetation at present and partly the vegetation cover that existed in the past at the site. However much lower SB flora compared to SV flora recorded in this study calls for further understanding of the soil characteristics and regeneration status of SV flora. However, Soil seed banks of riparian corridors are very dynamic in space and time [35, 4]. They form a part of the existing flora at the site with a high potential as sources of regrowth in the event of any disturbance in the future [38]. The spatial distribution of seeds of different species varied greatly, both vertically and horizontally. These variations may reflect differences of species in terms of seed longevity in the soil, mode of seed dispersal, seed predation and, probably, differences in local edaphic conditions where seeds land [41, 38, 5, 20].

Species forming soil seed banks are characterized by producing numerous small seeds, mechanisms for long-distance dispersal, formation of persistent soil seed banks and the capacity to remain viable in a dormant state for a long period of time [46, 38, 39, 44]. In the present study, the fact that many species have seeds deeply distributed in the soil.

CONCLUSION

In conclusion, the present study revealed large variation of species composition between standing vegetation and seed bank flora and a considerable intrusion by invasive flora in both surface and subterranean vegetation, reflective of increasing influence of alien flora in determining vegetation structure along Kali River bank.

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