SOIL SEED BANK PROFILE OF A FREQUENTLY MOWED LAWN IN NNAMDI AZIKIWE UNIVERSITY, AWKA, NIGERIA

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ABSTRACT

Seed bank study of a frequently mowed lawn at the Nnamdi Azikiwe University, Awka, Nigeria was undertaken between August 2015 and March 2017 to compare the soil seed bank with above-ground vegetation and the relationship between both. Soil samples were randomly taken from four points in a sampled area of 100 m^2 at depths of 0-5 cm, 5-10 cm and 10-15 cm. Species were identified by using manuals, on-line identification kits as well as by some ecologists. Results showed that *Imperata cylindrica was* dominant; in the seed bank at 0-5 cm, an unknown species A (Asteraceae) was dominant; *Oldenlandia corymbosa* was observed at depths of 5-10 cm and 10-15 cm. The Shannon-Wiener index for the above-ground species was summed at 39, H^1 (2.22), H_{max} (3.03) and Equitability ratio (0.72). Sorensen's coefficient was 0.037. Six species occurred in the above-ground and seed bank. The study concludes that original species in the seed bank could have been replaced by new species such as *Imperata cylindrica* and *Commelina* species due, perhaps, to succession and extinction. It is recommended that restoration of the pioneer species should commence with the propagation of seed bank species and that mowing should only be allowed at pre-bloom stage.

Key words: Seed bank; soil; lawn; Nigeria

INTRODUCTION

Seed bank is the reservoir of viable seeds which are present in the soil surface and soil profile. According to Kellerman and Van Rooyen (2007), seed bank represents a pool of vegetative potential and a source of genetic inheritance which plays a vital role in vegetation establishment after a disturbance. The absence of a soil seed bank has important consequences for the dynamics of species or vegetation type because in such cases the vegetation cannot regenerate from the soil stored seed bank after disturbances have occurred. A soil seed bank, therefore, is not a static entity and the seed density and species composition of the seed bank flora constantly vary in time and space.

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The success of a seed bank depends on the seed density that are ready to germinate, when replacement of a plant is necessary and when the environmental conditions for establishment are favourable. Menalled (2001) noted that weed seeds could be distributed both horizontally and vertically in the soil profile. Weed seed bank usually provides physical history of failures and successes of cropping systems and management. Dainou *et al*. (2011) reported a significant correlation between seed density and species richness of the soil flora, indicating heterogeneity of the samples with numerous rare and infrequent species. They suggested that not all plant species in a community are necessarily represented in the soil seed bank and that many factors are responsible for seed bank composition.

Andreas and Michaela (1999) reported that plant species decline due to abandonment of meadows which cannot be reversed by mowing. They concluded that the plant species composition cannot be restored by mowing alone because many plant species in meadows do not have persistent seed banks; besides, immigration in distances of more than 25 metres and successful establishment were very unlikely. Ma *et al*. (2015) studied the effect of a 10-year management regime on soil seed bank in saline-alkaline grassland and observed that fenced mowed grassland sites had high density and species richness in both soil seed bank and above- ground vegetations. They concluded that the soil seed bank composition and diversity of *Leymus chinensis* in saline-alkaline grassland was significantly affected by the management regimes implemented and that it was significantly related to the above-ground vegetation and soil properties. They suggested transplanting as the most effective approach for rapid restoration of target species.

Mowing has been reported as a tool for the restoration of species in ecosystems. Stromberg *et al*. (2009) observed that mowing could control exotic annuals and non-native grasses in California grasslands. They suggested that mowing should be done after exotic annuals have produced immature seeds or before perennials have initiated annual growth and that frequent mowing in some sites might favour native forbs over exotic grasses in the short- term because the soil seed bank of annual exotics are generally not long-lived. Therefore, repeated, well-timed mowing (before the weeds start flowering) might favour native perennials. Tipping (2008) studied the population of plumeless thistle and musk thistle which were mowed at various stages of growth at two separate sites in Maryland during a 6-year period to elucidate relationships among seed rain, soil seed bank and population recruitment. The majority of seeds (96%) in the soil profile were distributed within 7.6 cm of the surface at both sites. Tipping (2008) observed that the population of plumeless thistle and musk thistle which were mowed at various stages of growth affected seed rain, soil seed bank and population recruitment positively or negatively. It was concluded that other factors might limit the recruitment and maintenance of musk thistle, such as allelochemical production by parents, and inter-specific plant competition. The density of musk thistle declined over an 11-year period while plumeless thistle remained unchanged. The disproportionate seed-destroying activities of the weed biological control agent, musk thistle (*Rhinocyllus conicus*), may explain this difference.

This study was aimed at establishing the seed bank status of the various plant communities, and to determine the species composition, density, frequency and diversity of frequently mowed lawn at the Nnamdi Azikiwe e-library in Awka, Anambra State.

MATERIALS AND METHODS

The frequently mowed lawn was located near the Unizik e-library and was mowed quarterly and subsequently four times annually with mowing machines.

The study plot was within the Awka capital territory, Anambra state (Latitudes $6^{o}12^{1}25^{1}$ N$7^{o}04^{1}04^{1}$ E / 7.06778º E coordinates (https://eh.m.wikipedia.org> wiki Awka retrieved 16/08/2018). Richard (2005) noted that Awka lies between latitudes 7^{0} 00^{1} N and 7^{0} 10^{I} N, and 6.2220º N, 7.0821º E (https//www.google.com retrieved 18/02/2019).Also, Awka lies on latitude 6.2127 and longitude 7.0720((https://eh.m.wikipedia.org>wiki. Awka retrieved 18/02/2019). Awka is sited on a tropical valley but most of the original rainforest had been lost due to clearing for farming and human settlement. The wooded savannah grassland predominates primarily to the North and east of the city. South of the town on the slopes of Awka- Orlu uplands are some examples of soil and gully erosions.(See location diagram).

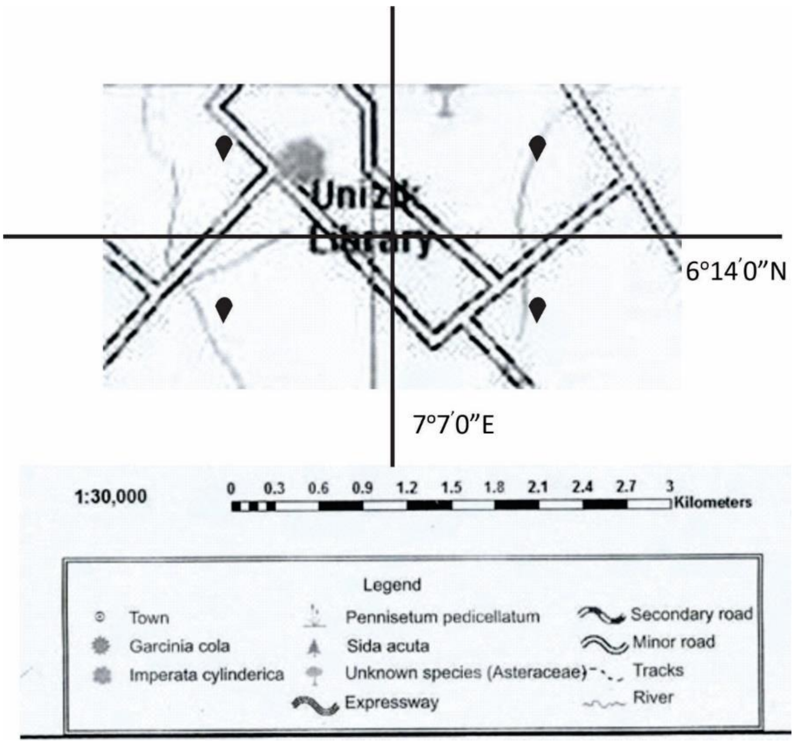

Figure 1: Location diagram of study plot

Above-ground Sampling method (Frequently mowed lawn near Unizik e-library)

By means of simple random sampling, four belt transects were chosen from a sample area of 10 x 10 metres, which were marked out using a measuring tape, to give a sampling area of 100 m². Also, a baseline of 10 metres was created and ten belt transects of 1 m x 10 m were created. A 1m x 1m quadrant was used to sample each transect ten times. By simple random sampling, four out of the ten belt transects were selected for quadrant sampling, giving a total of 40% sampling intensity. All plant species found inside the quadrant were counted as species present.

Soil Sampling Method

The sampled plot was divided into four (4) equal parts. In each quarter, three (3) randomly selected points were sampled using a soil Auger of 7.5 cm diameter. The different horizons of the soil (0-5 cm, 5-10 cm and 10-15 cm) of each quarter of the plot were collected and mixed together for the soil study. Soil seed bank density, composition, vertical distribution and composition were assessed, using the method of Degafi and Berhanu (2013). The litter layer was included in the soil samples as the 4th layer because of its potential to contain a high number of seeds (Esmailzadeh *et al.,* 2011). The samples were taken from similar layers of these four points within a plot and were mixed to form a composite soil in order to reduce variability.

Sampling was completed within two weeks to avoid differences between habitats, which could result in any temporal bias in seed availability and composition, following the method of Toledo and Ramos (2011).

Seedling Emergence Test

Soil samples collected from the study site were spread on plastic trays measuring 29 cm x 20 cm x 6 cm, which were used as germination trays. Each plastic tray was perforated at the base at 1cm and the perforation was covered with cotton wool to avoid leakage of soil samples and to facilitate drainage of excess water in the samples. The soil samples were kept in a screen house (212 cm x 154 cm x 190 cm) in the Department of Botany, Nnamdi Azikiwe University, Awka on 20/9/2016. The screen house was covered with plastic roofing sheets to allow light penetration. The plastic trays were placed on a wooden basement of about 40 cm from the floor. The soils were watered daily to field capacity (about 100 cl of tap water) for six months and the soil turned every two weeks to allow light for germination. The soil was stirred continuously to identify germinated seedlings. Each soil sample was replicated twice. Emerged seedlings were counted and recorded at 3, 6, 9 and 12 weeks after sowing, when most of the germinated seedlings had completed their life cycles; during the remaining 3 months, only persistent seedlings emerged at sporadic intervals. The experiment in the screen house lasted for six months.

The germinated seedlings were collected for identification by using relevant manuals and internet resources. The daily temperature of the screen house was the same with the prevailing atmospheric temperatures for the period of the experiment. Photographs of the seedlings were confirmed by an ecologist (Professor E.I. Mbaekwe) and a taxonomist (Professor C.U. Okeke) as well as with the aid of *Tropical Weeds of West Africa* by Akobundu and Agyakwa (1998). Soil samples were stirred after each assessment to stimulate germination by bringing to the surface other seeds that might have been deeply buried. The emerged seedlings were identified, counted, recorded and discarded. The experiment was terminated on March 31, 2017.

Data Analysis

Data collected were used to compute species density, relative density, frequency and relative frequency as follows:

$$Density = \frac{No\ of\ each\ species}{Total\ area\ sampled}$$

$$\text{Relative density} = \frac{\text{Density of each species}}{\text{Total density of all species}} \times \frac{100}{1}$$

$$\text{Frequency} = \frac{\text{No. of times a species occurred}}{\text{Total No of times searched for}} \times \frac{100}{1}$$

$$\text{Relative Frequency} = \frac{\text{Frequency of each species}}{\text{Total frequency of all species}} \times \frac{100}{1}$$

Weed Seed Bank Estimation

The number of weed seeds in the seed bank (Y) per land area (m^2) was estimated by multiplying the number of seeds in the soil sample (G) by the inverse ratio of the volume of soil in the auger sample to the volume of soil in 1 m^2 area sampled to the depth of the auger (15 cm) (Takim *et al.*, 2013).

Volume of soil from the auger sample (V_1)

$$\boldsymbol{V1 = \pi r^2 h}$$

Where,

π = 22/7; r = radius of the auger; h= depth of sampling

Volume of soil from 1 m^2 area sampled (V2)

$$\boldsymbol{V2 = L\ x\ B\ x\ H}$$

Where,

L = Length; B = breadth; H = depth of sampling.

G = Number of emerged weed seedlings per soil sample.

Seed Abundance = Number of observed germinants in the soil seed bank (Butler and Chazdon, 1998).

Relative Seed Abundance of species = Species seed abundance/ total no of species observed

$$\text{Seed Density} = \frac{\text{Seed Abundance}}{\text{Total area of soil sampled}}$$

The Importance Value Index (IVI) was determined by adding all the relative values of each species.

Shannon-Wiener index of diversity was used to determine the species diversity of the sampled plots using the formula:

$H^l = \sum [(Pi) \times \ln (Pi)]$

Where,

H^1= Shannon diversity index

Pi = Proportion of individuals or the abundance of the i^{th} species expressed as a proportion of total number of all species

ln = $logbase_n$

Evenness (Equitability) was measured as the relative abundance of the different species making up the richness of an area and when compared with the similarity of the population size of each of the species present. Shannon's equitability (J) or Evenness was calculated as follows:

$J = H^1/H_{max} = H/\ln S$

Where,

J = Evenness

H^1= Shannon-Weiner diversity index

H^1_{max} = lnS (where S is the number of species)

RESULTS

Above-ground species abundance of frequently mowed lawn at Unizik e-library, Awka

Table 1 shows that the most abundant species was *Imperata cylindrica* with a total number of 1,510 species, a density of 15.10, relative density of 38.84%, frequency of 87.5% , relative frequency of 2.02% and IVI of 36.86. This was followed by *Commelina spp* with a total number of 519 species, density of 5.19, relative density of 11.98%, frequency of 80%, relative frequency of 1.85% and IVI of 13.82. The third most abundant species was *Aspilia africana* with a density of 3.07, relative density of 7.08%, frequency of 77.5%, relative density of 1.79% and the IVI of 8.87. The least abundant species were *Sphenoclea zeylaca* (Onagraceae), *Phyllanthus amarus* (Fabaceae) and *Leptochlea filiformis* (Poaceae) with a total number of species of 1, density of 0.01, relative density of 0.02, frequency of 2.5, relative frequency of 0.06 and IVI of 0.08.

Table 1: Above-ground species abundance of frequently mowed lawn, Unizik e-library, Awka

Plant species	No of Times	Total No. Plant spp.	Density	Relative Density	Frequency	Relative Frequency	IVI
Desmodium scropurius	34	241	2.41	5.56	85	1.96	7.52
Alchornea cordifolia	7	21	0.21	0.48	17.5	0.4	0.89
Alchornea laxiflora	1	8	0.08	0.18	2.5	0.06	0.24
Andropogon gayanus	14	76	0.76	1.75	35	0.81	2.56
Aspilia africana	31	307	3.07	7.08	77.5	1.79	8.87
Axonopus compressus	33	23	0.23	0.53	82.5	1.9	2.43
Calapagon mucunoides	2	12	0.12	0.28	5	0.12	0.39
Centrosema pubiscens	4	69	0.69	1.59	10	0.23	1.82
Chromolaena odorata	14	74	0.74	1.71	35	0.81	2.51
Cleome rutidosperma	1	3	0.03	0.07	2.5	0.06	0.13
Commelina spp	32	519	5.19	11.98	80	1.85	13.82
Cynodon dactylon	2	60	0.6	1.38	5	0.12	1.5
Cyperus iria	4	66	0.66	1.52	10	0.23	1.75
Emilia spp	4	12	0.12	0.28	10	0.23	0.51
Euphorbia heterophylla	12	36	0.36	0.83	30	0.69	1.52
Euphorbia hirta	6	246	2.46	5.68	15	0.35	6.02

Imperata cylindrica	35	1510	15.1	34.84	87.5	2.02	36.86
Ipomoea congesta	3	43	0.43	0.99	7.5	0.17	1.17
Ipomoea involucrata	3	9	0.09	0.21	7.5	0.17	0.38
Ipomoea spp	15	69	0.69	1.59	37.5	0.87	2.46
Kyllinga squamulata	1	30	0.3	0.69	2.5	0.06	0.75
Leptochlea filiformis	1	1	0.01	0.02	2.5	0.06	0.08
Mimosa invisia	2	4	0.04	0.09	5	0.12	0.21
Mimosa pudica	1	5	0.05	0.12	2.5	0.06	0.17
Oplimenus burmanii	8	54	0.54	1.25	20	0.46	1.71
Paspalium scrobiculatum	2	35	0.35	0.81	5	0.12	0.92
Phyllanthus amarus	1	1	0.01	0.02	2.5	0.06	0.08
Platostoma africana	3	25	0.25	0.58	7.5	0.17	0.75
Rhynchospora corymbosa	2	26	0.26	0.6	5	0.12	0.72
Scorphullus spp	11	79	0.79	1.82	27.5	0.63	2.46
Sida acuminata	4	105	1.05	2.42	10	0.23	2.65
Sida acuta	1	10	0.1	0.23	2.5	0.06	0.29
Simlax spp	1	5	0.05	0.12	2.5	0.06	0.17
Spermacoce verticillata	5	105	1.05	2.42	12.5	0.29	2.71
Sphenoclea zeylaca	1	1	0.01	0.02	2.5	0.06	0.08
Tridax procumbens	3	11	0.11	0.25	7.5	0.17	0.43
Melastoma strumcapitalum	1	5	0.05	0.12	2.5	0.06	0.17

Seed bank abundance status of frequently mowed lawn

The results of the seed bank abundance status of frequently mowed lawn at various depths are shown in Tables 2, 3 and 4. Table 2 shows that at 0-5 cm depth the seed bank of Unknown species (A) (46.90 %) was more abundant than the other seed banks followed by *Oldenlandia corymbosa* (25.28 %) and *Cyperus esculentus* (20.30 %). Table 3 shows that at 5-10 cm depth the seed bank of *Oldenlandia corymbosa* (49.40 %) was more abundant than the other seed banks followed by the Unknown species (A) (33.27 %) and *Cyperus rotundus* (28.97 %). Table 4 shows that at 10-15 cm depth the seed bank of *Cyperus esculentus* (48.94 %) was more abundant than the other seed banks, followed by *Oldenlandia corymbosa* (40.95 %) and the Unknown species (A) (17.81 %).

Table 2: Seed bank abundance status of frequently mowed lawn at 0 – 5 cm depth

Plant species	Family	Number-of Emergence	Seed Bank Density
Oldenlandia corymbosa	Rubiaceae	15	7.64
Mitracarpus villosus	Rubiaceae	14	7.13
Cyperus esculentus	Cyperaceae	16	8.15
Cyperus rotundus	Cyperaceae	5	2.55
Eleusine indica	Poaceae	6	3.05
Unknown species A	Asteraceae	39	19.86
Ludwig decurrens	Onagraceae	4	2.04
Kyllinga pumila	Cyperaceae	3	1.53
Spigelia anthelmia	Lognaniaceae	4	2.04
Chromolaena odorata	Asteraceae	1	0.51
Bidens pilosa	Asteraceae	1	0.51
Calapagonium mucunoides	Fabaceae	1	0.51
Digitaria gayana	Poaceae	2	1.02
Total		111	56.52

Table 3: Seed bank abundance status of frequently mowed lawn at 6-10 cm depth

Plant species	Family	Number-of Emergence	Seed Bank Density
Eleusine indica	Poaceae	2	0.51
Cyperus rotundus	Cyperaceae	16	4.07
Cyperus haspan	Cyperaceae	3	0.76
Oldenlandia corymbosa	Rubiaceae	35	8.91
Unknown species (A)	Asteraceae	20	5.09
Chromolaena odorata	Asteraceae	3	0.76
Spigelia anthelmia	Lognaniaceae	2	0.51
Phyllanthus amarus	Euphorbiaceae	1	0.25
Aspilia africana	Asteraceae	1	0.25
Kyllinga pumila	Cyperaceae	4	1.02
Cyperus esculentus	Cyperaceae	2	0.51
Mariscus flabelliformis	Cyperaceae	4	1.02
Total		93	23.67

Table 4: Seed bank abundance status of frequently mowed lawn at 11-15 cm depth

Plant species	Family	Number of Emergence	Seed Bank Density
Oldenlandia corymbosa	Rubiaceae	20	3.39
Phyllanthus amarus	Euphorbiaceae	2	0.34
Unknown species (A)	Asteraceae	8	1.36
Cyperus esculentus	Cyperaceae	26	4.41
Kyllinga pumila	Cyperaceae	2	0.34
Tridax procumbens	Asteraceae	1	0.17
Cyperus haspan	Cyperaceae	4	0.68
Digitaria gayana	Poaceae	1	0.17
Spigelia anthelmia	Lognaniaceae	1	0.17
Mariscus flabelliformis	Cyperaceae	7	1.19
Portulaca oleraceae	Portulaceae	3	0.51
Total		**75**	**12.73**

Shannon-Weiner Species Diversity Index for the above-ground vegetation of frequently mowed lawn at Unizik, Awka

The Shannon-Weiner species diversity showed the equitability of 0.72, which implies that the proportion of species distribution was above average and evenly distributed. In this study a small sample size was used in the whole community so that the ratio of the number of species to their productivity within the trophic level where they occurred was above average.

Table 5: Shannon-Weiner diversity index for above-ground vegetation of frequently mowed lawn, Unizik e-library, Awka

Community Type	Total Number of Species	H^1	H max	Equitability
Frequently mowed lawn, Unizik e-library	39	2.22	3.03	0.72

Sorensen's coefficient index for frequently mowed lawn, Unizik-e library, Awka

The Sorensen's similarity index was used for comparison between the above-ground vegetation and the seed bank vegetation (Table 6). The rate of similarity was very low (0.036 or 3.6 %). Only six species occurred in both seed bank and above-ground flora.

Table 6: Sorensen's coefficient index for frequently mowed lawn community at Unizik e-library

Plot	*A*	*Vegetation (B)*	*Seed bank (C)*	*2A*	*2A+B+C*	*2A/(2A+B+C)*
Frequently mowed lawn, Unizik e-library	6	38	279	12	323	0.036

A-Number of species in both above-ground and seed bank
B- Number of species in above-ground only
C- Number of species in seed bank only

Figure 2 shows that the total number of species in the above-ground vegetation was 38 while the total number of species in the seed bank was 279. Only six species were found in both the above-ground vegetation and the seed bank.

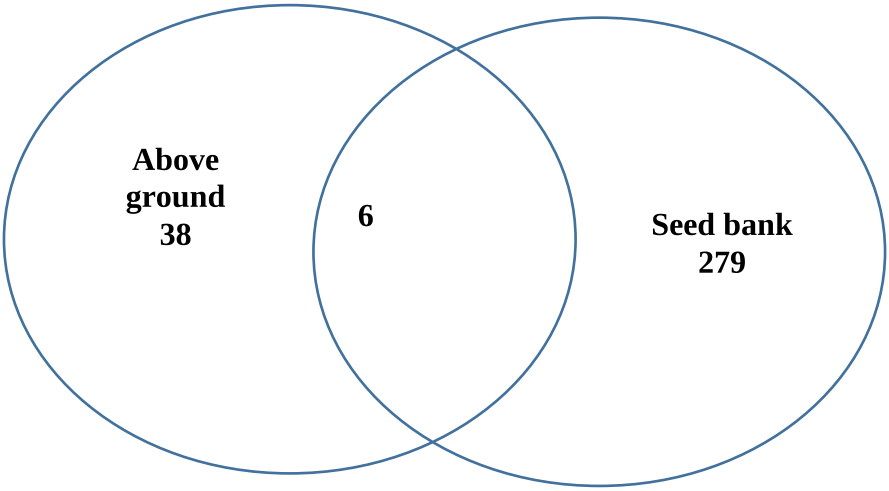

Figure 2: Venn diagram for frequently mowed lawn at Unizik e- library

DISCUSSION AND CONCLUSION

Results of this study confirmed the findings of Ma *et al.* (2015) who observed that fenced mowed grassland sites had higher densities and species richness in the seed banks and in the above- ground vegetation when compared with the non-mowed sites. In this study, species richness decreased with soil depth. Generally, the seed bank populations were lower than the above-ground vegetation. The results corroborated the findings of Tippings (2008) who observed that majority of seeds (96%) were distributed in the soil profile within 0-7.5 cm depth of the soil. In this study, some seeds were found around 0-10 cm as well as 15 cm depth. Stromberg *et al*. (2009)

suggested that mowing could be used to control exotic annuals and non-native grasses as a restoration measure and that if exotic annuals, such as Asteraceae and Cyperaceae families, are dominant in the seed bank, mowing could be done at the pre-bloom period. Stromberg *et al*. (2009) noted that seed bank of annuals are not long-lived; in other words, they are transient and their population declines with time. Ecologists consider mowing as a tool for restoration because it can control exotic annuals with immature seeds, as well as perennials that have not initiated normal growth. In some cases, frequent mowing favours non-native forbs more than the exotic grasses in the short-term because the soil seed banks of exotic annuals are short-lived. Therefore, repeated well-timed mowing can favour native perennials.

The mechanism of using mowing as a restoration strategy can be explained by the fact that each weed usually bears seeds on a stalk which was the former flower stalk and these stalks take time (several weeks) to mature. Regular mowing keeps removing the stalks and flowers before they mature into seed heads. Since many annuals complete their life cycle within one season, mature and re-seed themselves, mowing can be a strategy to stop an entire new generation of weeds from being deposited into the soil, thereby making the already existing seed bank to exhaust itself over time. Justin *et al*. (2018) noted that repeated mowing could be used as a restoration strategy to reduce exotic and non-native grasses such as *Stripa pulchra* in an ecosystem. Since the number of species present in the seed bank (239) was higher than the above- ground species (39) in the present study, it is likely that the native species have been replaced by exotic species. Other factors that can limit recruitment and maintenance of seeds of some plant species include the production of allelochemicals in the soil by the parent plants for inter-specific competition. It has been suggested that transplanting could be an effective approach for the restoration of target species.

The seed bank studies of the frequently mowed lawn of Unizik e-library revealed that 39 species were observed in the above-ground vegetation while 279 species were present in the seed bank vegetation. The study showed that there is a gradual displacement and replacement of pioneer species by exotic and invasive species, which may lead to the complete extinction of the former if the trend is not checked. Seed bank study of an ecosystem is very important for the successful and meaningful restoration. An understanding of the seed bank studies helps in the establishment of an integrated weed management model which eliminates the presence of weeds without use of pesticides and insecticides. Frequent mowing should be discouraged to avoid introduction of exotic and invasive species. Mowing should only be used as a weed management tool at pre-bloom stages of weed development.

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