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Research Article

Dynamics of Soil Seed Bank under Changing Climate: A Potential Threat to Natural Vegetation

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ABSTRACT

Reports claim that climate aberration is affecting the growth and ecological distributions of plant, like other kingdoms. The alive entities, similar to plant seeds, living in the soil are under the potential risk. The reservoir of plant seeds in the soil, developed through by natural consequences, is called soil seed bank. Natural plant seeds that stay covered in soil eventually germinate into new plant at preferable time to preserve the natural vegetation and suitable ecological distribution of plant species. In plant life cycle, redevelopment of plant from seed is most important because it determines plant's capability of recruitment, dispersal, evolution and persistence under adverse conditions. In this article, we have discussed the effects of climate change, particularly temperature, rainfall and forest fire on soil seed bank. A mitigation strategy has also been proposed to minimize the effects of climate change on soil seed bank.

Key words: Soil seed bank, Natural vegetation, Changing climate

Introduction

The irreversible changes in global climate attributes have marked impact on all the ecosystems, starting from terrestrial to aquatic, on the earth. Winter season is becoming warmer (due to increase in atmospheric temperature), number of forest fires are increasing, rainy areas are getting low rainfall, dry areas are facing intense and sporadic rainfall and atmospheric CO_2 concentration is rising at a very faster rate. These steady changes have resulted in altered environment where the living organisms are facing difficulties to perform their normal course of physiological and biochemical processes. Besides affecting other kingdom, these fluctuations are also disturbing the plant growth and its ecological distributions. Earlier we have discussed that the increasing irregularities in climatic variables have threatened the quality of medium of plant reproduction *i.e.* seed (Maity and Pramanik, 2013). It was warned that the biochemical composition and resultant performance of seeds are vulnerable to climate aberration and the effect is being realized in many scientific studies (Maity *et al*., 2016). If altered environment is imposed during sowing and successive plant growth stages even by changing the normal sowing date, the crop performance is hampered heavily in terms of the phenology (Maity *et al*., 2014), pollinators' activity (Maity *et al*., 2012) and physiological phenomena, which ultimately alters the seed yield (Maity *et al*., 2012 and Vijay *et al*., 2015) and seed quality (Maity

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and Chakrabarty, 2013). It is mainly the aboveground phenomena and more precisely, the influence of climate change on mother plant which bears the seeds supposed to be used for raising next agricultural crop. But the concern of plant performance in the era of climate change can't be confined on aboveground. The soil, which is the sole lifeline of one third of the whole living world in the earth, is also under the threat of climate change. Therefore the living entities, like plant seeds, residing in the soil are under the potential danger. In the present article, we are going to discuss on the fraction of natural plant seeds that remain buried in soil and germinate later on to maintain the natural vegetation and proper ecological distribution of plant species.

The reservoir of plant seeds in the soil, developed through by natural consequences, is called soil seed bank. A seed bank is the collection of dormant seeds inside the soil with the ability to germinate for upto hundreds of years (Wilson, 2015) and play an acute role in floral dynamics. In plant life cycle, redevelopment from seed is most important because it determines plant's capability of recruitment, dispersal, evolution and persistence under adverse conditions. Key traits like seed mass, seed dispersal, dormancy mechanisms and seed germination requirements determines the plant's ability to move ranges or convalesce from distress and can be related to native or worldwide extinction possibilities (Walck *et al*., 2011). Accordingly, successful recruitment of plants will determine the native floral populations and dynamics. The dormant seeds in soil seed bank can stabilize population dynamics by diffusing risk and lessening large variations in response to temporary environmental distresses (Leishman *et al*., 2000) and also help population recovery after disturbance (Grime, 1989). All the phases of plant life history especially the developmental stages are projected to be disturbed by climate change (Walck *et al*., 2011).

Climate Change Effects

Climate change is becoming an ever increasing global threat which is difficult to ignore. The major underlying cause is anthropogenic, *i.e.* excessive use of fossil fuels, destruction of forests for industrialization and urbanization with rapid overgrowing population (Mukherjee *et al*., 2016). IPCC (2007) reported that in the 21st century, all the land regions around the globe will experience warming beyond global mean. In many locations, there will be increased air temperature along with frequent occurrences of tremendous 'heat waves'. Air and soil temperature shows a strong direct correlation (Ooi *et al*., 2009) and a general increase in air temperature will inevitably lead to an increase in soil temperature (Karmakar *et al*., 2016). Climate change will cause unequal, intensive and sporadic distribution of rainfall with less average rainfall for dryland and fire-prone areas. Overall, climate change affects normal temperatures and temperature extremes; scheduling and patterns occurrences of precipitation in different geographic locations; snowmelt, runoff, evaporation, and soil moisture; the incidence of disturbances like drought, disease and insect epidemics, severe storms, and forest fires; atmospheric chemistry and subsequently air quality; and human settlement and land use change. In addition to these changes, climate change will affect the soil system by altering soil properties, functions and processes. In nature, as the plant life cycle perpetuates to next generation through the seed which is stored in soil after falling from mother plant on maturity, the altered soil climate is obviously supposed to alter the normal germination phenomena.

Climate Change and Soil Seed Bank

Research on influences of climate change on seeds have been acknowledged before now (Maity and Pramanik, 2013; Maity *et al*., 2016) and include lower seed production and germination by soil warming; modifications in germination timing; low seedling survival; reduced survival of seeds in soil; and decreased seed-bank viability (Cochrane *et al*., 2015) (summarized in table 1). Frequent and seasonal change in precipitation and temperature (typical features of climate change) will disrupt germination mechanism of seed. Seed ecology and seed bank persistence will be affected

Table 1. Effect of climate change on soil seed bank

Variables of climate change	Soil seed bank	References
Increased air temperature	Seedling mortality, change in maternal environment, less viable seeds	Leishman *et al*., 2000 and Lloret *et al*., 2004
Vaiable rainfall	Early germination, less survival of seedling, altered species dynamics, risk of extinction	Wilson, 2015 and Kimball *et al*., 2010
Higher soil temperature	Break down of physical dormancy and greater premature germination, less viable seeds, reduced seed bank persistence	Ooi *et al*., 2009 and Bullock, 2000
Heat waves and Drought	declines in population dynamics and drops in population size , premature germination in unsuitable places	Bullock, 2000 and Yates *el al*., 2007
Accelerated soil erosion	more seed removal from seed bank	García-Fayos *et al*., 1995
Forest fire	Frequent forest fire in same location provides less maintainance time for seed bank , affecting population dynamics	Regan *et al.*, 2010
Enhanced fungal growth	More fungal growth due to high soil temperature, soil moisture and humidity casuses decay of seeds, seed mortility through fungicide	Leishman *et al*., 2000

under projected climate change because there a solid mechanistic of association prevails between climatic factors and seed dormancy and germination (Ooi *et al*., 2012). As a result, there will be alteration in demographic rates and possibly a disparity in the scheduling and settlement of germination for different plant species (Walck *et al*., 2011 and Fordham *et al*., 2012). The impact of climate change on soil seed bank and species distribution is depicted in Fig. 1.

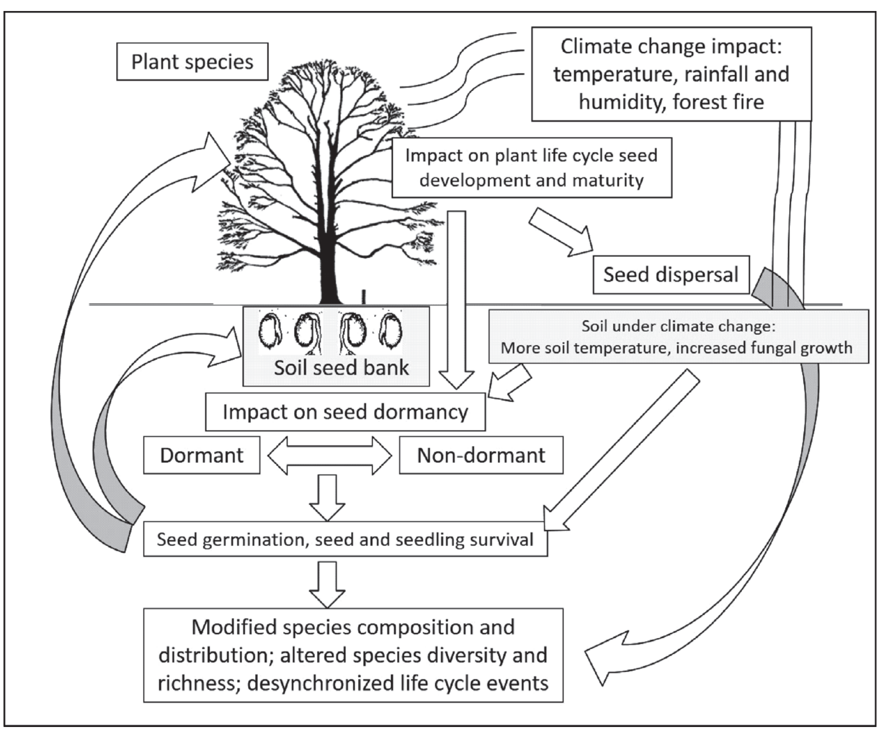

Fig. 1. Schematic diagram presenting impact of climate change on soil seed bank and species distribution as well

Effect of altered temperature

Change in hydrological cycles, glacial recession, forest fire and increased atmospheric CO_2 levels have caused repressed seeds in soil seed bank to grow. Due to projected high air temperature, soil seed bank will be disturbed in two ways; (1) firstly, increase in seedling mortality due to more soil moisture evaporation, leading to recruitment failure with a net seed loss from the seed bank (Lloret *et al*., 2004); and (2) secondly, change in maternal environment due to increased air temperatures (Lloret *et al*., 2004). If the parent plants experiences high temperature during seed production, then the less dormant seeds become less sensitive about at what time to emerge, thereby, physiological dormancy is not maintained (Fenner, 1991). Seed longevity of the semi-arid species *Wahlenbergia tumidifructa* reduces due to higher temperatures experienced by the parent plants (Kochanek *et al*., 2010), and the species' bet-hedging capability may be compromised under future environmental conditions.

Frequent heat wave will induce premature seed germination (Bullock, 2000) which will lead to seedlings emergence in the situation inappropriate for recruitment, ultimately causing reduction in seed bank longevity. Seed recruitment models under future climate forecast declines in population dynamics and drops in population size in response to particular climate events like drought (Yates *et al*., 2007). Location, timing of germination and recruitment will be hampered due to more summer temperature and long span of growing season along with high evapotranspiration (Mondoni *et al*., 2012 and Shevtsova *et al*., 2009). Seed dormancy breaks up naturally by changing environment and promotes germination at an undesirable time (Maity and Pramanik, 2013). Species producing lesser seedlings will be more susceptible to local extinction. Response of different species to climate change will result in new community diversity and structure.

High air temperatures will cause the seeds to experience altered soil temperature conditional to habitat and plants type (Harte *et al*., 1995). Soil warming in a temperate grassland changed recruitment of perennial species due to changes in soil water potential (Hovenden *et al*., 2008). Projected higher soil temperatures would cause net loss to seed bank dynamics by affecting dormancy and germination process rather than seed mortality (Daws *et al*., 2007 and Santana *et al*., 2010) and reduces the number of viable seeds by producing soil temperature lethal to seeds (Ooi *et al*., 2009). Increased soil temperatures will affect most of the plant species especially with physical dormancy. A threshold soil temperature should be there for breaking physical dormancy of as minimum percentage seeds in seed bank.

Effect of altered rainfall pattern

A warmer climate may lead to intensification of the hydrological cycle, resulting in higher rates of evaporation and increase of liquid precipitation These processes, in association with a shifting pattern of precipitation, may affect the spatial and temporal distribution of runoff, soil moisture, groundwater reserves etc. and may increase the frequency of droughts and floods (Pathak *et al*., 2014). Several studies have concentrated on phenological impacts to floral populations because of changes in rainfall timing. Temporal changes in the arrival of first rainfall alter the species-specific germination temperatures, thus affecting the final species composition (Kimball *et al*., 2010) and genetic variability. Unexpected rain in a particular area will initiate seed germination, but follow-up rains are not always sufficient for plants to complete their life cycle. As a result, risk of extinction is there. More erratic rainfall or recurrent droughts along with increased soil and air temperatures will lead to less germination and seedling mortality (Miranda *et al*., 2009), low concentration of seeds in seed bank (Wilson, 2015) and ultimately seed bank persistence. Altered rainfall pattern will cause negative effect in seed bank accumulation, productivity, longevity of trees, as well as emergence of previously suppressed seed bank (Nadkarni *et al*., 2002).

Fungal pathogens play a vital role in maintaining soil seed bank. Due to change in rainfall, growth of fungal pathogen in soil is more because of high humidity, more soil moisture associated with higher soil temperature. Fungal pathogen can easily attack dormant seeds in soil by three ways; (1) seed coat contamination directly by necrotic action and indirectly by production of metabolic wastes (Leishman *et al*., 2000); (2) fungal growth inside the seed enhances metabolic activity of seeds; and (3) soil borne fungi responsible for increased rate of seed mortility (Wilson, 2015). These problems are becoming crucial in the dry areas which are experiencing more rainfall than ever before (Wilson, 2015). Application of fungicides to control soil borne fungi will cause negative impact on soil seed bank (Leishman *et al*., 2000). Under future climate change, decrease in reproductive accomplishment and mortality and variations in viable exchanges probably modify floral abundance, through certain species increasing whereas others decline (Evans and Heggings, 2015). Climate change will probably have significant effect on the floral species which are reliant on long-lived seed banks and the effect will vary species to species.

Effect of forest fire

Fire is a crucial ecological and evolutionary cause. Forest fire can directly promote or inhibit soil seed bank dormancy or germination by destroying non-dormant seeds or by breaking the dormant seed coat (Santos *et al*., 2010), thus leading to the changes in the composition by altering their relative proportions, diversity, and structure of subsequent vegetation when compared to similar unburned sites (Elliott *et al*., 2009). Fire can effect soil seed bank in two ways; (a) profuse germination right after fire by means of generalized dormancy broken by heat (Auld *et al*., 1991) and (b) frequent short, intense germination cycles over an extended period after fire (Keeley, 1991). Seed germination after fire depends on several factors like heating and temperature, ash content, soil water potential, litter cover and nitrogen content.

Mitigation Strategies

In such circumstances, where the effects of climate change particularly temperature, rainfall and forest fire are affecting soil seed bank, questions may arise about the way out. How can the effects of adverse climate be mitigated? Is it through research activities or ecological movements; government efforts or community participation?

Population of indigenous seeds are decreasing, emergence of seed is fluctuating, fungal pathogens have better conditions to reproduce, and restoration of original seed population is becoming difficult in the era of climate change (Wilson, 2015). Threats of climate change to biodiversity can be managed in better way through identification of those classes and habitations susceptible to decline. Ecological responses of susceptible plant species to projected climate change need to assess. This will require an assessment of their ecological response to future climate scenarios.

We need to assess the species ability to cope up with the future climate change through plastic ecological response or evolutionary approach. However, the level of environmental modification forecast under climate change provides a strong incentive for further experimental study. Studies exploring the mechanistic responses and the adaptive capacity of seed bank persistence in relation to changing environmental conditions are still astonishingly scarce, but are very vital for forecasting species persistence and handling biodiversity in the future.

Organized efforts from government bodies are required in regulating the grazing management decisions in forest areas. Appropriate time interval should be there for following *jhum* cultivation and /or slash and burning practice so that natural seed bank gets sufficient time for restoration. Soil erosion conservations measures should be taken in erosion prone area for restricting seed movement through water and wind erosion.

Conclusions

The increasing irregularities in climatic variables have threatened the quality of medium of plant reproduction *i.e.* seed. From the review, it is clear that changes in climate is going to affect the soil seed back very severely. Community efforts are required here to ensure the *in-situ* and *ex-situ* soil seed conservation. Awareness about the risk of natural gene pool erosion due to the changing climatic condition shall not only reduce the physical anthropogenic interference but shall ensure restoration too. Cannot we think for community soil seed bank? A concept that shall make a community concerned for indigenous way to conserve the natural soil gene pool. It is to consider a combined approach which is always better for its synergistic effect.

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