There was significant difference in physiological loss in weight (%) and firmness values of fruits and vegetables stored in the SPOSS than those stored in room (ambient) conditions. The shelf life for different fruits and vegetables when stored in the SPOSS increased by around 1–5 days compared to room storage (Table 1). This might be due to the fact that fruits and vegetables require low temperature and high humidity to help increase their shelf life.

The difference in initial and final firmness of produce was found to be highest in case of room storage in each of the fruits and vegetables, while the low difference was found in the SPOSS.

The SPOSS could be more efficient for the storage of fruits and vegetables where the climate is mainly hot and dry. It has advantages like low cost of manufacturing, negligible operational cost and is better than the mechanical refrigeration. It can be used in a place where cold storage facility is not available due to unavailability/erratic supply of electricity. With the help of storage of fruits and vegetables in SPOSS, the shelf life of these products is increased substantially enabling them to remain fresh and to reduce the losses. It would be of immense value to the farmers to increase their income by way of preserving the fresh produce with retention of quality.

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Polygonum polystachyum: peril to biodiversity of the alpine ecosystem, Western Himalaya, India

The serious problem facing the managers of protected areas and conservationists is how to maintain biodiversity in the face of natural and anthropogenic perturbations. Biological invasion as an anthropogenic ecological perturbation is threatening endemic biodiversity, preventing natural ecological succession and changing the community structure and composition, besides impacting the ecosystem services[1]. *Polygonum polystachium* Wall. ex Meisn., is an herbaceous native species to Himalayan Region that belongs to family Polygonaceae. It reproduces vegetatively from rhizomes as well as from seeds. It is considered one of the native aggressive colonizing species or local invader in Western Himalaya, and a noxious invasive species in other countries. This species has been colonizing and disrupting plant diversity of the world heritage site, Nanda Devi Biosphere Reserve (NDBR), Uttarakhand, India. The reserve has two core zones, i.e. Valley of Flowers National Park (VoFNP) and Nanda Devi National Park (NDNP) and both the National Parks (NPs; core area) have been inscribed on the World Heritage list by UNESCO. The reserve is characterized by richness, nativity and endemism of high-value medicinal plants (*Aconitum heterophyllum*, *Ephedra intermedia, Aconitum balfourii*, *Angelica glauca*, *Saussurea obvallata*, *Fritillaria roylei*, *Podophyllum hexandrum*, *Nardostachys grandiflora*, *Polygonatum cirrhifolium*, *Dactylorhiza hatagirea*, etc.), and wild edibles (*Rhododendron arboreum*, *Diplazium esculentum*, *Hippophae salicifolia*, *Morchella esculenta*, *Allium* spp., etc.). However, in recent decades, *P. polystachyum* has become a massive threat to plant diversity of the NPs particularly VoFNP and other alpine areas of the Reserve, as it grows vigorously and creates dense colonies by excluding other species (Figure 1). Initially, *P. polystachyum* was confined to the disturbed habitat types such as eroded slopes, bouldery area and avalanche-prone areas[2]. Presently, it is seen proliferating in large areas of VoFNP, many areas of NDNP and other alpine areas of the reserve. Therefore, the objective of the present study was to assess the status of *P. polystachyum* proliferation and its major impact on the plant diversity of NDBR.

P. polystachyum-dominated stands were taken as invaded sites and natural area as uninvaded sites for the present study. Quadrat method was used to study the plant species diversity and density in different habitat types. For sampling of herbaceous vegetation, 50 × 50 m plots were marked in each altitudinal belt and 25 quadrats (1 × 1 m) in each plot were laid randomly. The vegetation was analysed for various ecological parameters following Misra[3], Mueller-Dombois and

Ellenberg[4], and Shannon and Weaver[5]. Individual interviews were also conducted in selected villages of NDBR to know the perception of local people on colonization of *P. polystachyum* and its impact on plant diversity.

Considering one bunch *P. polystachyum* as one individual, the range of density was found maximum (0.37 to 2.24 Ind/m^2) in the invaded sites as compared to uninvaded sites (0 to 0.13 Ind/m^2) along altitudinal gradient (Figure 2). The density was highest in the camp sites previously used for night halt by herders of sheep/goat for grazing in the alpine pasture before the NPs were created in 1982. The study indicates that colonization by *P. polystachyum* suppresses the diversity of other species in the area. Our study observed that the invaded areas have low diversity as well as density of other species as compared to the uninvaded areas (Figure 2). The decrease in species richness in invaded plots depended on the type of habitat, but also interacted with species-specific differences in cover between the colonizing and associated dominant species.

The instability of land in the alpine meadows, due to natural disturbances or past anthropogenic pressures, is a major cause of high density of *P. polystachyum* and its colonization[2]. The problem of colonization is more evident in VoFNP as most of the area is invaded and now supports high density of *P. polystachyum*, resulting into depletion of habitat-specific species. The population density of many high-value medicinal and threatened plants like *Aconitum balfourii*, *Nardostachys grandiflora*, *Polygonatum cirrhifolium*, *Podophyllum hexandrum*, *Fritillaria roylei*, *Angelica glauca* and *Rheum webbianum* has declined in VoFNP, whereas the park was previously known for rich diversity of the above plants[2]. *Aconitum heterophyllum,* a critically endangered medicinal plant species, was reported by Frank Smythe in VoFNP five decade ago, however this species was not observed during our study as also indicated in earlier study[2]. The alpine areas are generally nutrient poor due to low accumulation of biomass and leaching of nutrients while *P. polystachyum* accumulates biomass faster and retains water, thus preventing leaching of nutrients from the soil. This is a probable cause of high density of the species in alpine areas of the Himalaya. Native colonizing and invasive species not only alter the competitive interactions that reduce native populations within a community, but they can also lead to extinction through competitive exclusion[1]. Important plant species that have limited distribution in the alpine ecosystem could be susceptible to further decline due to altered habitat conditions with increasing *P. polystachyum* cover every year in the region. Further, in the subalpine and alpine zones of the Himalaya, increasing intensity of harvesting of medicinal plants and change in climatic conditions have already adversely affected the habitats of many species, leading to a gradual loss in regeneration potential and diversity of several economically valuable species[2]. The threat to biodiversity is now increasing due to colonization of *P. polystachyum* and expansion of other opportunistic plants (such as *Impatiens sulcata*, *Osmunda clatoniana*, etc.).

Many patches of *P. polystachyum* have also been observed inside the forest and along the timberline of the reserve. Thus there is a possibility that regeneration of tree species might be impacted.

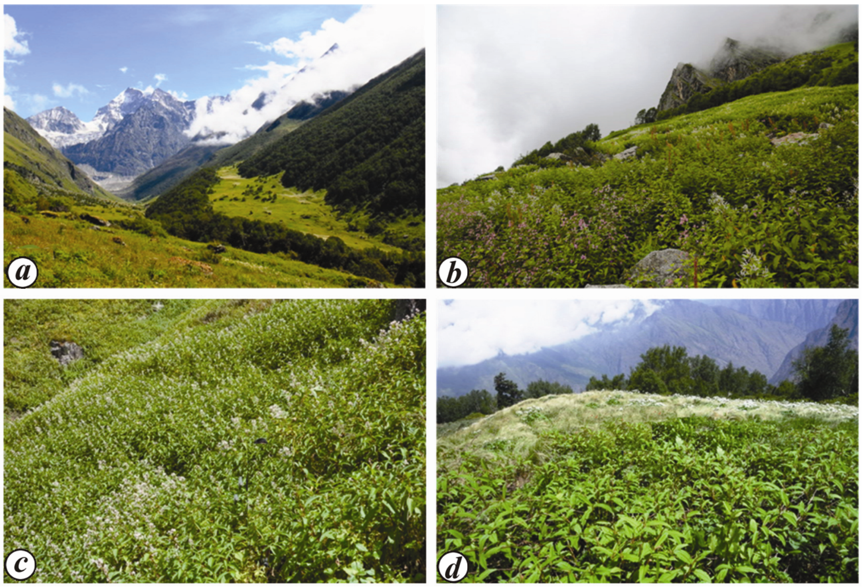

Figure 1. Colonization of *P. polystachyum* in sub-alpine and alpine ecosystems of NDBR. ***a***, ***b***, Valley of Flowers National Park; ***c***. Hemkund Sahib trek; ***d***, Lata-Khark.

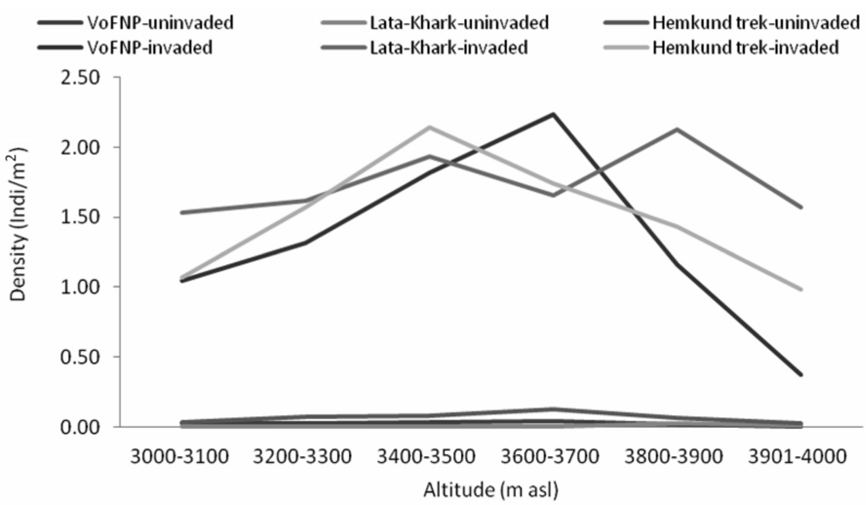

Figure 2. Population density (individuals/m^2) of *Polygonum polystachyum* in invaded and uninvaded sites along the altitudinal gradient in the Nanda Devi Biosphere Reserve.

Management of *P. polystachyum* has become a vicious circle in which the control activity and reappearance of new infestation of *Polygonum* are inextricably linked. Inhabitants of high-altitude villages, particularly those engaged in sheep/goat-rearing have noticed that *P. polystachyum* is expanding downward from the alpine/subalpine ecosystem to the forest ecosystem. The species was restricted to alpine meadows with very few pockets in the past three decades, but is now seen in large pockets along the timberline and the adjoining high-altitude villages. Management options are still not known for the Himalayan knotweed. The Forest Department has been trying to control the colonization of the species manually by cutting the aerial portion from the selected areas in VoFNP, while no conservative steps have been initiated in other parts of NDBR and the Western Himalayan region.

P. polystachyum, capable of forming dense populations, exerts severe effect on the plant species diversity of subalpine and alpine ecosystems in Western Himalaya. Long-term ecological monitoring studies are required to assess and understand the ecological impact of invasion by native invaders for effective conservation and management of alpine ecosystems or protected areas, particularly in the Himalayan region.

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Recycling sugar effluent in hybrid flow constructed wetland and reusing for agriculture

Globally, water constraint is gaining increasing public attention as a critical environmental dilemma due to population growth, urbanization, rapid industrialization and expansion and intensification of food production that need to be addressed. Water scarcity is a reality in many areas today, and it is being exacerbated due to climate change creating critical distress in the future. According to the United Nations, the world's population is expected to grow by one-third to over 9 billion by 2050, demanding 55% more water, while the amount of freshwater will not increase. Concurrently, the world is also facing water quality crisis as a result of increasing wastewater generation and unregulated discharge of contaminated water from point and non-point sources. Over 80% of the world's wastewater is released to the water bodies without treatment[1]. Accessing the contaminated water for various uses poses a threat, causing major health challenges, including costs to health care, decreasing labour productivity, and degrading ecosystem and biodiversity.

Agriculture is the highest water-consuming sector accounting for around 70% of global freshwater withdrawals, and even up to 90% in some fast-growing economies[2]. The projected irrigation demand exceeds the available freshwater threshold. With the widening gap between freshwater demand and lagging water supply[3–5], wastewater reuse is a commonly suggested option[3,6,7]. Either intentionally or accidentally, wastewater has long been used as a resource in agriculture across the world. Wherever unpolluted water is a scarce resource, particularly in arid and semi-arid regions, the water and nutrient values of wastewater are considered important drought-resistant resource by farmers. Estimated worldwide acreage of land irrigated with wastewater varies between 4.5 M ha (ref. 7) and 20 M ha (refs 8, 9), which is around 10% of irrigated land surface[10]. This corresponds to 200 million farmers irrigating with both treated and untreated wastewater[8].

Among all the sources, industries are the prime sources of generating wastewater and are the major contributors of toxic pollutants. UNESCO estimated that 5–20% of total available water is used by industries and found that 70% of its effluents in developing countries are discharged untreated[11]. In India, according to Dey[12], total industrial wastewater generated from all major industries is estimated to be 83,048 MLD; however, the CPCB[13] reported that about 60% of wastewater generated by industries is primary treated in conventional treatment plants. Among the industries in India, agro-food industries are fast-growing and rank sixth in the global market. As an agro-food industry, sugar industry contributes to about 12% of the world's sugar production with annual production capacity of 23 million tonnes. The sugar industry is a major water user and wastewater producer. According to Gunjal and Gunjal[14], there are around 530 sugar industries in India having crushing capacity of 1.6 million tonnes per day utilizing 3.2 million m^3 of water, generating 0.6 million m^3 of effluent per day. Reusing primary treated sugar effluent