commercially viable grades (>200–300 g/t) of Sc are rare\(^2\). The Sc concentration in some of the garnets analysed in this study is found to be between 244 and 386 ppm, which are promising and commercially viable.

Sc is a costly metal and its global production is small (~10 tonnes per year) as a by-product from mining of ores of titanium, rare earths,apatite and uranium\(^3\). Despite its scarcity, over the past two decades, there have been multiple potential, high-value commercial uses for Sc. The principal uses are in Sc–Al alloys and in solid oxide fuel cells. Minor amounts of Sc are also used in a variety of other applications, including electronics, lasers, mercury vapour lamps and lighting.

All garnet samples collected from different domains do not have high concentrations of Sc and REY. Hence, characterization of garnets having high values of Sc, Y and REE, and their delineation in the coastal sands are of paramount importance.

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Seediness as an invasive trait in *Mimosa diplotricha* Sauvalle in a tropical grassland

For successful invasion into an ecosystem, a species always depends upon some traits such as high growth rate, successive reproduction, higher number of seeds with low mass, seed viability and seedling mortality\(^1\). Among these traits, the reproductive behaviour of a plant is mainly associated with its invasiveness\(^2\). Seed production and germination are the two key processes associated with the initial phase of plant establishment, which determine the fate of an invasive plant in a new region\(^1\), and that is especially true for annuals reproducing exclusively by seed\(^1\).

*Mimosa diplotricha* Sauvalle is a fast-growing, thorny, biennial or perennial shrub native to Tropical America. In India, the plant is invasive from Kerala and Northeast Indian states (http://www.fao.org/forestry/13377-0977cb34791475-aaba7a36064f097778.pdf accessed on 25 March 2014). In Northeast India, it had become invasive in the protected grasslands of Brahmaputra floodplains including Kaziranga National Park and Rajiv Gandhi Orang National Park which are
important habitats for threatened mega-
herbivores and other important fauna of the
region4–7. The present study was carried
out in Rajiv Gandhi Orang National
Park, Assam (92°16′–92°27′E and
26°29′–26°40′N). The park covers an
area of 78.8 km² and is located in the
Brahmaputra floodplain region of Dar-
rang and Sonitpur districts of Assam.
The area comprises grasslands dotted
with woodlands and water bodies.

*M. diplotricha* produces seeds in pods,
which are found in clusters (Figure 1). In
the present study, 16 individual plants
were selected from different grassland
areas of the park during January–
February 2013. The total number of
seeds produced by *M. diplotricha* was
calculated following the formula: (no. of
seeds per plant) = (no. of pod-clusters of
that plant) × (no. of pods per pod-cluster
of that plant) × (no. of seeds per pod)6. The
total number of pod-clusters in each
plant were counted, out of which 10 pod-
clusters were selected, each randomly
from four different plants. The pods were
counted from each pod-cluster, out of
which 10 pods were selected randomly.

The length of each selected pod was
measured with a vernier calliper, and the
number of seeds was recorded. Seeds
were categorized into healthy and dam-
aged based on visual observation9,10.

*M. diplotricha* produced 128 ± 49.41
SE, at 95% CI (n = 16) number of pod
clusters per plant. Each pod cluster pro-
duced 30 ± 2.21 SE, at 95% CI (n = 40)
number of *Mimosa* pods with a range of
14–50 pods per cluster. Each pod pro-
duced 3 ± 0.11 SE, at 95% CI (n = 400)
seeds with a range of 1–6 seeds per pod.
There was a significant relationship
between the pod length and the number
of seeds per pod (r = 0.7, P < 0.01,
df = 398). Out of the three seeds,
2 ± 0.15 SE, at 95% CI (n = 400) seeds
with a range of 1–6 were firm and
healthy; while ± 0.12, at 95% CI
(n = 400) seeds (range 1–5) were dam-
aged per pod. Significantly more number
of seeds (74%) were healthy than dam-
aged (26%) (t = 7.41, P < 0.01). An indi-
vidual *M. diplotricha* plant produced an
average of 13121 ± 5057, at 95% CI
(n = 16) seeds per plant with a range of
2457–42274 seeds.

High seed production is characteristic
of plants that follow *R* selection strate-
gy11. By producing seeds in bulk, these
plants are capable of outcompeting others
and invade an area easily. Seeds of *M.
diplotricha* are known for their high via-
bility and can stay viable up to 50
years12. The germination percentage of
*M. diplotricha* seeds can exceed 90%
when subjected to scarification followed
by exposure to favourable temperature
conditions13. This may be the reason for
higher germination in *M. diplotricha*
when they are burnt in the field13. As
the grasslands are subjected to fire annually
during the months of February–March
for management purpose, *M. diplotricha*
is facilitated to fulfil their prerequisite
for mass germination14. In the following
months, due to the pre-monsoon shower
and favourable temperature condition,
the seeds germinate profusely. We also
observed mass germination in *M.
diplotricha* just after the pre-monsoon
showers during March–April. As the
seeds were small, they easily mixed with
soil at the surface layer; moreover, the
pods of *M. diplotricha* are also provided
with hairy coating, which makes them
suitable for zoochory (http://www.cabi.
org/isic/datasheet/34196 accessed on 8
August 2016). *M. diplotricha* is also
helped in dispersal by dominant mega
herbivores13,16 like Greater One-Horned
Rhino (*Rhinoceros unicornis*), which
carries it along for long distances (per-
sonal observation). High seed production
with low seed mass in *M. diplotricha* is
one of the major traits that makes it a
successful invader in its non-native envi-
ronment. An understanding of seed pro-
duction and germination behaviour will
help in preparing a better management
plan for countering the invasive species
in the National Park where it is wreaking
havoc by degrading the grassland habitat.

Figure 1. Different stages of *Mimosa diplotricha*: a, Flowering thicket; b, Pod-clusters;
c, Mature pods.

and Leishman, M. R., Global Ecol. Bio-
2. Rejmánek, M. and Richardson, D. M.,
3. Crawley, M. J., Harvey, P. H. and Pur-
vis, A. N. D. A., Philos. T. R. Soc. B.,
4. Lahkar, B. P., Talukdar, B. K. and Sar-
5. Uma Shankar, Yadav, A. S., Rai, J. P. N.
and Tripathi, R. S., In Invasive Alien
Plants an Ecological Appraisal for the
Indian Subcontinent (eds Bhatt, J. R. et
6. Choudhury, M. R., Deb, P., Singha, H.,
Chakdar, B. and Medhi, M., Ecol. Eng.,
7. Uma Shankar, Hima-Paryavan, 2002,
14 & 15, 6–8.
8. Witkowski, E. T. F. and Wilson, M.,
9. Camargo-Ricalde, S. L., Dhillon, S. S.
and García-García, V., J. Arid Environ.,
10. Silva, L. M. and Fernandes, G. W.,
592–597.
12. Aigbokhan, E. I., Osazuwa-Peters, O. L.
and Ilubon, K. O., Niger. J. Bot., 2010,
24, 141–151.
13. Bahar, N., Indian For., 2014, 140,
544–546.
Freshwater constitutes a little less than 3% of the total volume of water present on the earth’s surface. However, freshwater ecosystems have a strong bearing on the economy of a country by providing potable water, fish and fodder for the local people. They are also the most vulnerable habitats as they act as major sinks for weathered sediments, sewage and waste disposal from catchment areas. Human interferences within the lacustrine systems have significantly altered them. The primary anthropogenic activities responsible for the degradation of lacustrine ecosystems include massive population growth, deforestation, land reclamation and other land-use/land-cover changes. Two primary concerns regarding the vulnerability of these freshwater ecosystems include extensive sedimentation and accumulation of organic matter. The organic content of the sediments reflects the quantity of living organisms in and around the lake systems, including the level of lake productivity and leaching from humus-rich catchment soils. While the changing climate plays an important role in changing these ecosystems, anthropogenic-induced variations in the nutrient load inputs have had a distinct effect on the freshwater lakes during the past few centuries.

The Kashmir Himalayan lakes (Wular, Dal, Manasbal and Anchar Lake), located within the inter-mountain settings receive exceptionally high amounts of sediments from the tectonically active hinterlands. Furthermore, the unique climate of the Kashmir Himalayan region with intense cold winters and steep slopes augments the physical weathering of the exposed surfaces resulting in increased erosion and subsequent deposition of sediments in these freshwater lakes. The lakes in Kashmir Valley are the potable sources of freshwater for the region, but due to their exploitation for various purposes like drinking, domestic use, agriculture and hydropower, these freshwater ecosystems are getting eutrophic and are shrinking in area at a rapid pace. The sedimentation rate reported from a few of the Himalayan lakes reveals contribution of sediments due to both natural and human interference. High sedimentation rates are reported from the Kashmir Himalayan lakes1. For example, Manasbal Lake shows a sedimentation rate of 0.44 cm/yr, and the average sedimentation rates of the Dal and Mansas lakes are 0.93 and 0.23 cm/yr respectively1. Since these lakes also act as hotspots for tourism, high anthropogenic gross pollutants settles within these lakes. Traditionally, our lake management strategies are primarily focused on flood management, wherein these lakes act as flood buffer systems by absorbing excess water during the floods2. For instance, during the September 2014 Jhelum basin flood, Wular Lake acted as one of the major regulators by absorbing excess water carried by the Jhelum River. However, if the sediment accumulation in the lakes increases and remains unchecked, it will lead to rising bed levels and increased flood risks.

The Wular, Dal, Manasbal and Anchar lakes are classical examples of lacustrine ecosystems where sediment and organic matter management is urgently needed. All these lakes are severely polluted by the human population living in the hinterland. The main culprits are the sewage inputs by local population, floatables, including polythene covers and used plastic bottles, medicinal trash, agriculture fertilizers, etc. (Figure 1).

Therefore, any extensive sediment and organic matter management strategy would involve a proper balance between the local population and lake ecosystems. The situation has further worsened during the past few centuries as the trophic status of these lakes has altered from oligo to eutrophic conditions due to intense human activities. Recently, the Supreme Court of India has directed the Jammu and Kashmir government to concentrate on efforts to restore and ensure proper conservation of the pristine beauty of these lakes. The suggested measures are catchment area treatment, including afforestation and construction of check dams, construction of settle basins at the lake–river interface, marginal dredging, diversion of inflow of sewage and agricultural waste products, selective weeding, restricted population growth along the lake margins, etc. It is imperative to mention here that in Sydney, Australia, ‘Pratten traps’ (capture netting system) have been used at drainage inlets to capture the trash and other gross pollutants, allowing only water to flow into the lakes. This can be one of the effective systems to trap solid gross pollutants from settling in the lake systems in Kashmir Valley.

Studies regarding the environmental conditions of these lake ecosystems have mostly focused on the impact of increased human population along the hinterlands...