with substantially high amounts of nutritionally important polyunsaturated fatty acids (PUFAs) such as linolenic acid, a-linolenic acid, stearidonic acid, arachidonic acid, eicosapentaenoic acid and docosahexaenoic acid, it ranged from 10% to 70% of total fatty acids. More than 90% of the species showed nutritionally beneficial n6/n3 ratio (0.1 : 1–3.6 : 1)[22].

Eighteen abundant tropical seaweeds were chosen to estimate their phenolic, flavonoid and amino acid composition[23]. LC-MS analysis revealed the presence of polyphenols and flavonoids, including ascorbic acid, gallic acid, catechins, myricetin, proanthocyanin, kaempferol, quercetin, apigenin and lutein. The highest amount of ascorbic acid (26.3 mg g^{-1} dry weight (DW)) was detected in *U. fasciata*, followed by *U. lactuca* (20 mg g^{-1} DW) and *Grateloupia indica* (11.5 mg g^{-1} DW). Gallic acid was reported in all green and red species, with the highest (9 mg g^{-1} DW) in *Amphiroa anceps*, followed by *Caulerpa racemosa* var. *macrophysa* (8.5 mg g^{-1} DW) and *C. corynephora* (4 mg g^{-1} DW). The highest catechin content was found in *A. anceps* (14 mg g^{-1} DW), followed by *C. racemosa* var. *macrophysa* and *Spatoglossum asperum* (11 mg g^{-1} DW). The highest amounts of leucine (0.2 mg g^{-1} protein), lysine (0.5 mg g^{-1} protein), methionine (0.4 mg g^{-1} protein), phenylalanine (0.2 mg g^{-1} protein), valine (1.3 mg g^{-1} protein), proline (48 mg g^{-1} protein) and tyrosine (28 mg g^{-1} protein) were detected in *Caulerpa* spp. High contents of sulphur-rich methionine (1 mg g^{-1} protein) and cysteine (9 mg g^{-1} protein) were found in *Gracilaria corticata*.

Way forward

The food-processing domain in India is currently growing at 8.41% per annum, and is expected to reach USD 544 billion by 2020–21. The market is driven by innovative ideas and thus there is ample scope of incorporating seaweeds as flavouring or garnishing agents in over 1000 types of available snack foods. Further, under the 'Pradhan Mantri Matsya Sampada Yojana' commercial opportunities in this arena are high[24].

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MEETING REPORT

Water security in the Himalaya through spring-ecosystem assessment and management*

Natural springs are the main source of freshwater for millions of people across the Himalaya. About 60% of the local habitants of the Indian Himalayan Region (IHR) depend on the springs to meet their daily water requirements. According to a rough estimate, there are three million springs in the IHR alone and approximately 50% of them have dried up or become seasonal[1]. Drying up of springs or declining water discharges as well as quality degradation of spring water have manifold repercussion in the IHR; drying up of spring-fed rivers, water insecurity in mountain habitats, decrease in agricultural practices, travelling long distances to fetch water (especially by women), shifting of natural water supply scheme to borewell or pumped water supply system and disturbance in spring water-dependent flora and fauna are some of them. This not only leads to migration of people, but also disturbs the hill economy in a negative manner along with change in ecology in the spring ecosystem. It also sabotages the social, cultural and religious relevance in the IHR[2]. While addressing the pan-Himalayan solution to these problems, it has been noted that neither the interaction of dependent ecosystem services of springs is documented or studied, nor has there been a systematic effort or methodology for comprehensive spring ecosystem health assessment. Therefore, realizing the wide-ranging socio-ecological values of springs and threats for their well-being, an effort is being made to understand the spring

*A report on the multi-stakeholders' Consultation Meeting on 'Spring Ecosystem: Definition, Scale and Assessment Protocol' organized by the Centre for Land and Water Resource Management, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, through a webinar on 2 September 2020.

ecosystem and thereby ascertaining its role in water security in IHR. In this context, a transformative programme entitled 'Water security in Himalaya through spring-ecosystem assessment and management' has been formulated at the G.B. Pant National Institute of Himalayan Environment (GBP-NIHE), Kosi-Katarmal, Almora, under the aegis of the Ministry of Environment, Forest and Climate Change, GoI, and is being implemented in four states of the IHR (Uttarakhand, Himachal Pradesh, Sikkim and Arunachal Pradesh). Subsequently, the programme aims to enrich the contemporary scientific knowhow on the interaction of biotic and abiotic factors affecting spring ecosystem of the Himalaya. Since there remains substantial disparity in definition, scale and health assessment protocols of the Himalayan spring ecosystem, a multi-stakeholders' Consultation Meeting was organized with two specific objectives: (i) establishment of standard definition and boundary of spring ecosystem in the context of IHR, and (ii) finalization of parameters affecting spring ecosystem variability. The meeting was attended by a spectrum of thematic experts, including academicians, eminent scientists and researchers from seven different national institutions of repute through a webinar mode.

The welcome address highlighted the importance of springs for ensuring freshwater security in the IHR, which is at present threatened by the drying up of springs due to various natural and anthropogenic factors; therefore rejuvenation of springs is receiving utmost importance across the Himalaya. While highlighting the contributions of GBP-NIHE in conservation and management of spring sources, multidimensional issues of springs were discussed through different initiatives that were taken up by the Institute, such as springshed management, spring sanctuary concept, Jal Abhayaranya or water sanctuary project, etc. Extensive research was suggested on constituents and boundaries of the spring ecosystem, and parameters that represent its physiology, whereby a scientifically tenable concept of the spring ecosystem and its health could evolve.

Two technical sessions were held during the meeting. During the first session, the keynote address focused on classification and characteristics of the Himalayan springs, wherein the drying up of springs due to erratic rainfall pattern, ecological degradation and seismic activities was highlighted. It was mentioned that the problem gets exemplified by the high dependency of the Himalayan population on spring water. Hydro-geological characteristics of the Himalaya (as an abiotic system) drive the discharge characteristics of various springs. Therefore, it is necessary to identify the types and characteristics of the springs in order to understand how they behave in space and time. The next presentation was on definition and scale issues of the spring ecosystem. Springs are immeasurably small compared to rivers and lakes, but play leading roles in the hydrological cycle. While pointing out the absence of precise definition of spring ecosystem in the literature, the following definition was proposed – 'A naturally occurring water unit that drains the landscape which encompasses all biotic components (living/beneficiary) in that area functioning together with all the abiotic factors (physical/nonliving) of the environment, both of which are responsible for quality and quantity (availability) of spring water'. This functional definition helps in preliminary understanding of the spring ecosystem boundary which may overlap or coincide with the watershed boundary, forest ecosystem, wetland ecosystem or any other landscape boundary. The spring ecosystem boundary must capture, address, reflect and be representative of the multi-dimensions of biotic and abiotic components and their interaction.

The following remarks were made by the experts on presentations of the first technical session: (1) The approach of spring ecosystem should be shifted from description (of geomorphology) to dynamics (quantification and modelling) of the system that will help to predict the behaviour of the system based on its quantifiable components. (2) Springs are a bio-geophysical system; therefore the spatial and temporal scale of interaction between the different components should be taken into consideration while defining the boundary of the spring ecosystem. (3) Defining the boundary of the spring ecosystem is challenging; it can be defined topographically and/or geologically. However, the latter is more complex and difficult. (4) The spring ecosystem boundary can be estimated by hypothesizing the boundaries and testing the hypothesis through an experiment or analysis using available datasets. (5) The definition and boundary of the spring ecosystem are mainly influenced by changing patterns of climatic forcing, hydrological cycle and the respective total water storage which is reflected in the discharge rate of springs; and therefore the definition should look for the scale interaction among these components.

The second technical session started with a presentation on the overall possible arena of spring ecosystem assessment in IHR. Springs are valued as ecologically, socio-culturally and spiritually important landforms. Considering the conceptual spring ecosystem model depicted by Stevens and Springer[3], various ecosystem services of springs, viz. regulating, provisioning and cultural services were enlisted during the presentation. A systematic inventory of the spring ecosystem will provide reliable information, for which an open source and spatially explicit modelling tool – InVest (Integrated Valuation of Ecosystem services and tradeoffs) was suggested for mapping and valuing goods and services from the springs. The subsequent presentation was focused on a framework for spring ecosystem health assessment protocol. A three-level inventory approach was highlighted. Six different components, viz. aquifer and water quality, geomorphology, human use and influence, institutional context, habitat and microhabitat, site biota (including their sub-parameter) were proposed for consideration to assess the spring ecosystem health[4]. Keeping in view of the dynamic and static nature of these components, the final framework of their monitoring and subsequent spring ecosystem assessment protocol needs to be developed with the aim to make a simplified assessment protocol, and scaling and grading criteria across the Himalaya.

The following remarks were made by the experts on presentations of the second technical session: (1) The synergies and trade-off between different ecosystems services should form an integral part of the ecosystem assessment process or protocol. (2) The spring ecosystem assessment can follow nested hierarchy system with starting point as the spring, a bio-geo-physical entity, and then to processes quantification. (3) Keeping in view the spring ecosystem and its topographical exposure, the upstream–downstream linkages within the ecosystem must be included in the assessment. (4) The dependency of people on springs must be documented while selecting the springs for study or while preparing a report card of the spring ecosystem.

During the concluding open discussion on the overall deliberations of the meeting, it was summarized that: (1) it is difficult to understand several geomorphic diversities in the IHR with respect to the spring ecosystem;

(2) the spring ecosystem is complex and dynamic in nature, and is dependent on variable conditions and gradients of different component, and (3) presently, a descriptive knowledge of the spring ecosystem is available; but a quantitative knowledge is lacking.

The following recommendations were made at the end of the meeting, which has paved the way for future research on spring ecosystem: (1) The data deficiency must be considered to create a database in order to facilitate research on the spring ecosystem across the Himalaya. (2) The spring ecosystem definition must cover all bio-geo-physical aspects of spring and its services; whereas boundary should coincide with the area of (its) influence. (3) Spring ecosystem research could cover (a) quantitative geomorphology, (b) quantitative ecosystem services, (c) quantitative hydrology, and (d) quantitative socio-economics. (4) The spring ecosystem assessment protocol must cover all the possible parameters that connect the physiology of the spring ecosystems. (5) The concept, methodology or modelling techniques developed or used in other contemporary scientific field may be explored for its possible application to understand, monitor and assess the spring ecosystem health.

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OPINION

CRISPR/Cas9 as a dexterous tool to mend plant *MIR* genes for agronomic trait improvement

Swati Verma

As quoted by Thomas E. Lovejoy, 'Natural species are the library from which genetic engineers can work. Genetic engineers don't make new genes, they rearrange existing ones'. The CRISPR/Cas9 genetic scissor has proved to be a wonder tool for carrying out these gene rearrangements.

Being sessile, plants have developed an intricate signal transduction system to respond to different environmental cues. On perceiving environmental stresses, signal transduction in plants commences into activation or repression of genes by regulatory molecules to generate an appropriate physiological response[1]. MicroRNAs (miRNAs) are small, 20–24 nucleotide length, non-coding RNAs involved in post-transcriptional regulation of gene expression through mRNA cleavage or translational repression of targets. These small regulatory molecules are known to play big roles in influencing gene expression during plant development and stress responses[2].

Till date, plant miRNA-based research mainly emphasized on analysing miRNA expression using high-throughput sequencing and miRNA-target prediction. These studies have revealed unique and conserved expression profiles of plant miRNAs under normal and stressed conditions and have led to the identification of a large number of novel miRNAs in plants[3]. The increasing amount of miRNA-related systems biology data needs more comprehensive exploration. In the recent past, use of

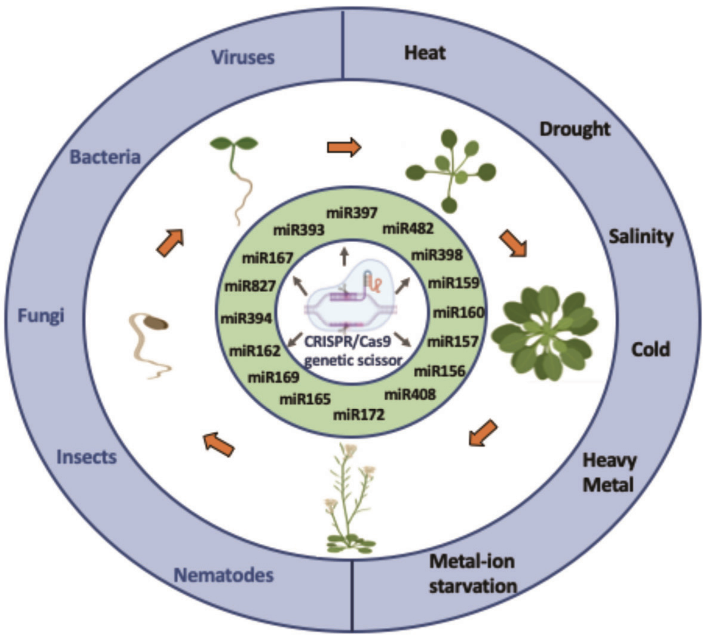

Figure 1. Potential candidate miRNAs involved in regulating various aspects of growth and development, and stress responses in plants, as targets for CRISPR/Cas9 genome editing. (Image created on BioRender.com.)