novel rotavirus vaccine was developed and produced here after decades of work[17]. Currently there are two attempts to make anti-COVID-19 vaccine in India, one from Zydus-Cadilla and the other from Serum Institute in collaboration with the US-based Codagenix. Based on available reports it appears that clinical trials for these vaccine candidates could be months away. In a pandemic situation being faced currently, we need to have technology already in place so that a quick response is possible. We can consider this situation similar to war for which the country is kept ready to mount a quick response at all times. There is dire need to form multidisciplinary scientific teams quickly with rapid fund mobilization and administrative approvals so that work can start immediately to find scientific solutions. Overall a major investment through budgetary and administrative support for science is required so that our scientists can prepare us for any eventuality. The funding required is miniscule compared to the economic and human losses that we are going through. In addition, once the pandemic subsides, the infrastructure created can be utilized to tackle major unsolved problems that are currently in the background. Some of these are consequences of climate change, food security, clean energy and water that require our urgent attention. Moreover, there are several other diseases (genetic disorders, some forms of cancer, drug-resistant tuberculosis) for which there are no treatments. We should not forget about these patients who are facing death and disability every day. Once this pandemic is over and the country has spent some funds on COVID-19 research, we should not go back to a lull and wake up when there is another pandemic. Scientific and technologic preparedness can only come through continuous and ongoing commitment.

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Can sulphated polysaccharides from seaweed provide prophylactic and/or therapeutic solution to COVID-19 pandemic?

Ashish Kumar Jha, Suseela Mathew and C. N. Ravishankar

The novel Coronavirus or severe acute respiratory syndrome virus or SARS-CoV-2 has spread throughout the world in a very short period. Till date, there is no approved medicine or pharmaceuticals product found to be effective against COVID-19. Sulphated polysaccharides from seaweed possess antiviral, anti-inflammatory, anticoagulant, antinociception, antitumor, antiallergic and immunological activities which can be useful to fight Coronavirus COVID-19 pandemic.

Coronavirus is an enveloped virus with a positive sense single stranded RNA as its genetic material. The name corona comes from peculiar crown-like spikes over its outer surface. The novel Coronavirus or severe acute respiratory syndrome Coronavirus or SARS-CoV-2 is a new Coronavirus that originated in Wuhan, China in December 2019 and has soon spread throughout the world. As it is an etiological agent for Corona Virus Disease-19 (COVID-19), a contagious disease which can spread from person to person, the World Health Organization declared it as pandemic and a public health emergency. COVID-19 is characterized by mild to a severe disorder of the upper respiratory tract which can even manifest severe interstitial pneumonia and acute respiratory distress syndrome (ARDS)[1]. Though it is believed that the COVID-19 is a respiratory tract infection, a study has shown that it should be considered as a systemic disease which includes almost all the systems and involves respiratory, gastrointestinal, neurological, cardiovascular, hematopoietic and immune systems[2]. Older people with comorbidities like hypertension, diabetes, heart ailment and lung disorder are at higher risk but at the same time the younger population without any noticeable health issue may also face lethal complications such as myocarditis and disseminated intravascular coagulopathy (DIC) which is characterized by the presence of small blood clots in bloodstream, ultimately blocking the small blood vessels.

Unfortunately, according to WHO till date, there is no approved medicine or pharmaceutical product found to be effective for the treatment of COVID-19 and the commonly used medicines are considered as 'off label' by the regulatory authority. But the experts and medical practitioners of different countries are using a treatment on trial and error basis. The information available in the scientific domain suggests that there are a number of potential drugs available but their efficacy for the treatment of COVID-19 is yet to be established. Some of the important drugs used against COVID-19 are chloroquine, hydroxychloroquine, remdesivir, ribavirin, ritonavir, favipiravir, Umifenovir interferon-β1, lopinavir, aerosolized interferon α, oseltamivir, etc.[3]. In many countries including India, plasma therapy has also been tried. Among the common line of medication, chloroquine and hydroxyl chloroquine are approved medicines for prophylactic and therapeutic uses in malaria[3] but the anti-inflammatory and broad spectrum antiviral activities of these medicines are supposed to play a role in the treatment of COVID-19 patient[4]. Remdesivir, ribavirin, ritonavir and favipiravir are antiviral drugs which inhibit the viral replication probably by blocking viral RNA polymerase[3].

Sulphated polysaccharide

The marine environment is a natural habitat for a great variety of living organisms and contains more than 80% of plant and animal species in the world[5]. Such a genetic diversity renders chemical diversity which is a promising source for new drug development. The enormous ecological resources of the sea have been exploited since ancient times and included the use of marine animals and algae as the sources of medicine. Marine life forms are evolved to have the capability to grow and reproduce in extreme environments like high salinity, temperature and pressure. These organisms possess unique metabolic and physiological properties to thrive under the extremities through their metabolic processes generating various metabolites. Seaweed is easily accessible and one of the most abundant life forms of the marine ecosystem. In general, they are classified based on their photosynthetic pigments as red seaweeds (Rhodophyta), brown seaweeds (Phaeophyta) and green seaweeds (Chlorophyta). Besides being a source of healthy food due to low calorie and significantly higher mineral and fibre content, it is an important resource of diverse kinds of bioactive principles. Derivatives of seaweeds are known to have a variety of activities such as anticoagulant, antioxidant, antibacterial, antiviral, anticancer, anti-hyperlipidemic, antihepatotoxic properties, etc.[6]. The sulphated polysaccharide is one such molecule present in seaweed having immense pharmacological activities which have generated interest among researchers. Sulphated polysaccharides are complex poly-anionic macromolecules containing sulphate moieties and sugar backbone. Due to their unique chemical structures, these compounds can interact with a wide variety of matrix and cellular proteins[7] which manifest different pharmacological and therapeutic properties.

The common sulphated polysaccharide of red seaweeds are agaran and carrageenan, whereas fucoidans, laminaran and alginates are from the brown seaweeds and ulvans from the green seaweeds.

Several studies have been conducted to affirm the bioactivities of sulphated polysaccharide from marine seaweeds[8]. It has attracted the attention of scientists throughout the world for its diverse bioactive properties.

Sulphated polysaccharide from seaweed has been used for the pharmaceutical purposes[9]. The probable mechanism of antibacterial activity is attributed to the glycoprotein receptors on the surface of polysaccharide which bind to the bacterial cell wall compound, which in turn increases the permeability of cytoplasmic membrane causing protein leakage and binding to bacterial DNA. Fucoidan and laminarin from brown seaweed have been used as oral antibiotics to inhibit the growth of *Staphylococcus aureus* and *E. coli*[9]. Several polysaccharides isolated from red and green seaweeds have been evaluated for its antiviral activities[10]. They are known to inhibit enveloped viruses like retroviruses HIV type 1 type 2, cytomegaloviruses, herpesviruses (HSV type 1 and 2), pseudorabies virus, flaviviruses (dengue virus type 2), orthomyxoviruses (influenza A virus) and few other viruses[11]. The inhibitory effect of sulphated polysaccharides mainly depend on their ability to inhibit the initial attachment of the virus to the target cells which in turn block the viral entry[11]. Carrageenan, a sulphated polysaccharide from red seaweed, has been tried as a therapeutic agent for respiratory weaknesses like the common cold, influenza virus H1N1. *In vitro* study has shown that iota-carrageenan is active against novel pandemic H1N1/2009 influenza[12]. Its effect on herpes, hepatitis A, dengue viruses has also been evaluated. Carrageenan, in spite of inhibiting the penetration of the virus on host cells, inhibits the synthesis of viral protein inside the cells. The sulphated polysaccharide from red and brown seaweeds exhibits excellent total antioxidant capacity, hydroxyl radical scavenging activity, superoxide radical scavenging, ferrous chelating ability and reducing power activity[13].

Anticoagulant activity of the sulphated polysaccharide is proven, it is understood that the sulphated polysaccharide interferes with coagulation factor and prolong or inhibit the coagulation. The underlying mechanism of coagulation is by inhibition of thrombin, a blood coagulation factor. Different variants of carrageenan have different anticoagulant properties. A study has shown that the most active carrageenan (λ) fraction has one fifteenth of the activity of heparin which means λ carrageenan has mild anticoagulation property[14]. Immunomodulatory role of sulphated polysaccharide is well studied[15]. It is observed that some of the sulphated polysaccharides modulate the immunological principle by inducing nitric oxide (NO) and various cytokine production through upregulation of mRNA expression. The study also shows that the use of sulphated polysaccharide increases the secretions of interferon and interleukins, suggesting that it is a strong immune-stimulator[13].

The available knowledge has shown that the sulphated polysaccharide is a wonder molecule with immense medicinal properties and it works on different types of bacteria and enveloped viruses which are similar to the SARS-CoV-2. Therefore in a world where more than 5 million infected people are struggling to get some relief and medical professionals and researchers are still fighting to reach any conclusive solution or effective medicine for SARS-CoV-2, sulphated polysaccharide from seaweeds can be a potent molecule to fight against COVID-19 pandemic. Even molecules like carbohydrate binding proteins, lectins could also be used as tool against SARS-CoV-2. A carbohydrate binding protein, Griffithsin, derived from red algae *Griffithsia* sp. – has shown *in vitro* and *in vivo* antiviral activity against enveloped viruses, and has registered low host toxicity[16], making it a candidate molecule to be studied against SARS-CoV-2.

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SCIENTIFIC CORRESPONDENCE

Estimation of leaf chlorophyll content in wheat using hyperspectral vegetation indices

Chlorophyll, the green-coloured pigment, converts light energy to stored chemical energy in the presence of water and carbon dioxide. Hence, crop yield is directly related to chlorophyll content, but large-scale determination of this parameter by conventional methods involves investment of time, money and manpower. In contrast, remote sensing, based on measuring the reflected radiation from plant canopies, plays a unique and essential role to assess chlorophyll content at different crop-growth stages in a reliable and operational way. Absorbance by carotenoids greatly restricts the use of blue peak in chlorophyll estimation. Similarly, in the red region (660–680 nm), absorption saturates at low chlorophyll content and hence is not suitable for high chlorophyll estimation. However, reflectance in the 550 and 700 nm wavelengths gets saturated at higher chlorophyll content and can be successfully used for chlorophyll estimation. Spectral indices based on these spectral bands have been developed and successfully used for chlorophyll estimation. In the present study, we estimate chlorophyll content in wheat leaf using spectral reflectance indices in a field experiment with treatments of crop residue mulch, irrigation and nitrogen.

The study was conducted to evaluate the effect of irrigation, nitrogen and mulch in wheat at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi (77°89′N, 28°37′E, 228.7 amsl) during *rabi* season of 2012–2013 and 2013–2014. Two levels of irrigation (I_2: crown root initiation and flowering stage; I_4: crown root initiation, tillering, flowering and grain filling stage) were imposed as main plot along with two levels of mulch (M_0: without mulch, M_1: with maize straw mulch @5 t ha^{-1}) as sub-plot and three levels of nitrogen (N_0: no nitrogen, N_{60}: 60 kg N ha^{-1}, N_{120}: 120 kg N ha^{-1}) as sub-sub-plot. The total nitrogen amount was applied in three growth stages (sowing, 50%; CRI, 25% and flowering, 25%), whereas total P and K were applied at sowing during the cropping season. All the treatments were laid out in split–split plot design.

The spectroradiometer (ASD FieldSpec, Analytical Spectral Devices Inc., USA) was used to measure reflectance (350–2500 nm) of plant canopy during 11.00 to 13.00 h on sunny days. All the measurements were taken at 1 m distance from the top of the plant with 25° field of view. The spectral signature and leaf chlorophyll content of the crop were observed at flowering stage. The reason for choosing flowering stage is that leaf chlorophyll content is highest at this stage and then decreases towards grain-filling stages due to dilution effect. The leaf chlorophyll content was measured by DMSO method.

The performance of the model was assessed by comparing the statistics (R^2,