**Table 2.** Seedling length of the brocolli plant after interaction with culture filtrates of *P. indica* and nanoparticles

| | Control | CNTs | TNPs | AgNPs |
|---|---|---|---|---|
| Mean ± standard deviation | 5.25 ± 0.64 | 6.875[a] ± 0.18 | 8.575 ± 0.15 | 6.375[a] ± 0.66 |
| CD | 0.737 | | | |

[a] In each column, means followed by the same letters are not significantly different using ANOVA and DMRT at 5% probability level.

*P. indica* culture filtrate is known to enhance seed germination and growth of several plants[17]. An independent test was performed with the culture filtrate of the nanomaterials-treated fungal broth on the seeds of broccoli (*Brassica oleracea* var. *italica*). The results indicate stimulation of seed germination by TNP followed by CNT (Table 2), and thus have excellent potential for producing liquid biofertilizers.

From the present experimental results, it can be concluded that besides acting as an antimicrobial agent, the nanomaterials may also influence growth promotion of fungi depending upon the stage of inclusion. Further, the nanomaterials-treated *P. indica* culture filtrate has also shown to be helpful in seed germination and growth of seedlings in plants. Nanomaterials have already been reported to enhance plant growth directly[8]. In future, it can be utilized not only as a microbial growth enhancer, but also as a potential tool for early diagnosis of diseases.

Future research needs to address questions such as to what extent molecular and genetic mechanisms may mediate microbial responses to nanomaterials exposure and furthermore, how to control such responses for utilizing their maximum beneficial effects.

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# Importance of upper ocean heat content in the intensification and translation speed of cyclones over the Bay of Bengal

It is a well-known fact that the frequency of cyclones is 3–4 times higher over the Bay of Bengal (BOB) compared to the Arabian Sea (AS). Most of these storms generally move in the west-northwesterly direction and some take a recurve and hit Bangladesh. In addition to atmospheric parameters, it is now realized that the upper ocean heat content (UOHC) plays a vital role in the intensification of storms rather than sea-surface temperature (SST). Studies on the intensification of hurricane *Opal* over warm core rings, and *Bret* over high heat potential ($> 90$ kJ/cm$^2$) were reported earlier[1,2]. Rapid intensification of *Nargis* over the warm ocean region was reported[3] due to high enthalpy flux (300% higher than climatological) and UOHC (77–105 kJ/cm$^2$). A recent study[4] showed a negative relationship between the translation speed of a storm ($U_h$) with UOHC and the depth of 26°C isotherm (D26) in the western-north Pacific Ocean (PO). Hence UOHC and D26 gained importance in forecasting the intensification and movement of storms. Sadhuram *et al.*[5] showed that a threshold value of about 60 kJ/cm$^2$ may be necessary for the genesis and intensification of the storms in BOB during post-monsoon season.

In this study an attempt has been made to examine the relationship between

UOHC and $U_h$ for the severe cyclones during 1990–2006. $U_h$ has been computed from 6 h track positions of each storm (www.imd.gov.in; T3.0 onwards) and the corresponding UOHC (it was given as 'tropical cyclone heat potential' prior to the storm) data were taken from the NOAA website (http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.EMC/.CFS/.DAILY/.BelowSeaLevel/)[6]. Data for 13 severe cyclones during premonsoon (April and May) and postmonsoon (October and November) seasons were used in the computations. Details of the period, lowest central pressure (mb) of the storm, maximum sustained wind speed (kn) and the intensity (*T* number) of the storms are shown in Table 1. Low (< 2 m/s) and high (> 9 m/s) values of $U_h$ were avoided in the analysis. Due to nonavailability of real-time datasets, we were forced to use the pre-storm UOHC data from the NOAA website.

From the scatter plot (Figure 1), an inverse relationship could be seen between UOHC and $U_h$. The correlation is –0.29 ($N = 104$), which is statistically significant at 99% level. The regression equation is shown below:

$$U_h = -0.03 * \text{UOHC} + 6.1. \tag{1}$$

As $U_h$ depends on a number of factors which vary from cyclone to cyclone, it is obvious to expect the wide scatter with UOHC. For example, high correlation ($r = -0.73$; $N = 11$; significant at 99% level) was observed between UOHC and $U_h$ in case of *Sidr*. Lin *et al.*[4] developed an equation for western-north PO utilizing the extensive real-time datasets of several storms as

$$U_h = -0.05 * \text{UOHC} + 9.4. \tag{2}$$

It may be mentioned here that UOHC is high due to the presence of warm core eddies in the western-north PO. Though BOB is known for eddies, they are highly variable with space and time. A detailed analysis on the genesis of tropical cyclones, and the role of both atmospheric and oceanic conditions in west-north PO was reported earlier[7]. The physical and dynamic parameters during *Sidr* in BOB and the atmospheric and oceanic conditions over AS during 5–9 May 2004 cyclone were reported recently[8,9]. The above equations were tested for *Sidr* and *Nargis*, which were not included in developing eq. (1).

**Table 1.** Storm period, lowest central pressure (hPa), maximum sustained wind speed (knots) and *T* number for 15 severe cyclones during 1990–2006 (source: www.imd.gov.in)

| Period of cyclone/name | Lowest central pressure (hPa) | Maximum sustained wind speed (knots; highest) | *T* number (maximum) |
|---|---|---|---|
| 4–10 May 1990 | 924 | 127 | 6.5 |
| 24–30 April 1991 | 918 | 127 | 6.5 |
| 16–21 November 1992 | 952 | 102 | 5.5 |
| 29 April–2 May 1994 | 940 | 115 | 6.0 |
| 21–25 November 1995 | 956 | 102 | 5.5 |
| 4–6 November 1996 | 988 | 77 | 4.5 |
| 15–19 May 1997 | 964 | 90 | 5.0 |
| 15–17 October 1999 | 968 | 90 | 5.0 |
| 25–29 October 1999 (Orissa super cyclone) | 912 | 140 | 7.0 |
| 26–29 November 2000 | 958 | 102 | 5.5 |
| 10–19 May 2003 | 980 | 75 | 4.5 |
| 16–19 May 2004 | 952 | 90 | 5.0 |
| 25–29 April 2006 (*Mala*) | 954 | 100 | 5.5 |
| 11–15 November 2007 (*Sidr*) | 944 | 115 | 6.0 |
| 27 April–2 May 2008 (*Nargis*) | 962 | 90 | 6.0 |

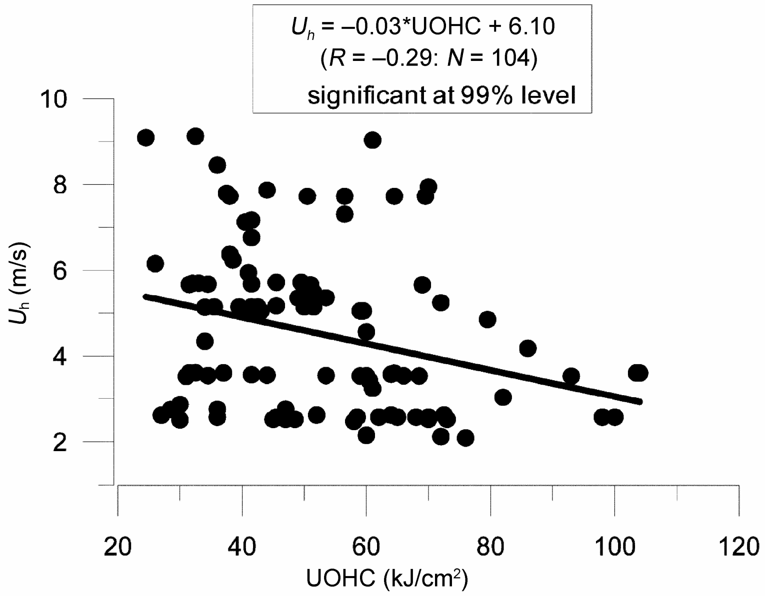

**Figure 1.** Scatter plot between UOHC (kJ/cm$^2$) and $U_h$ (m/s) (based on the data for 13 severe cyclones during 1990–2006).

(i) *Sidr* (11–15 November 2007): The storm crossed west Bangladesh at 1700 UTC of 15 November 2007 with a storm surge of about 4–5 m height. This was the most powerful cyclone to impact Bangladesh since 1991. More than 3000 people were killed and the total damage and loss was 1.6 billion US dollars[10].

A deep depression in the southeast BOB intensified into a cyclonic storm *Sidr* on 12 November 2007 at 10.5°N, 91°E. It further intensified to a very severe cyclone, slightly moved north-westwards and thereafter moved in a northerly direction up to 1200 UTC of 15 November. Initially, moderate upper level wind shear inhibited organization, whereas strong diffluence aloft aided developing convection. Vertical wind shear decreased. Winds reached a peak of 215 km/h on 15 November. The lowest central pressure was 944 hPa. UOHC and D26 were 84 kJ/cm$^2$ and 78 m respectively, in the central BOB on 15 November 2007, from the nearest Argo data. SST was more than 28°C. The warm

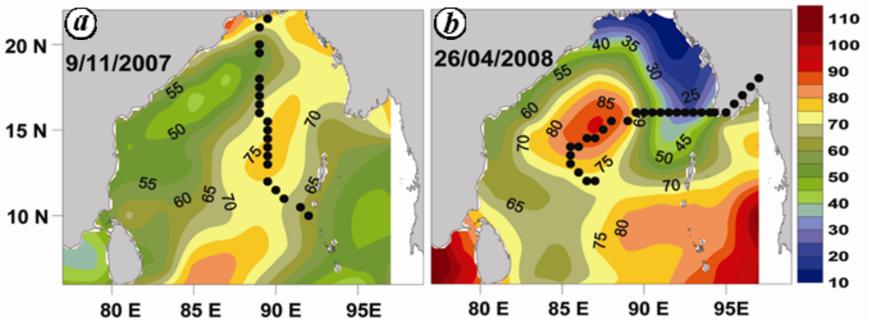

**Figure 2.** Distribution of UOHC (kJ/cm$^2$) prior to (***a***) *Sidr* and (***b***) *Nargis*. Storm tracks (dotted line) are also shown.

**Table 2.** Observed and estimated values of $U_\mathrm{h}$

| | $U_\mathrm{h}$ (m/s) | | |
|---|---|---|---|
| Storm/date | I | II | III |
| *Sidr* | | | |
| 13 November 2007 | 4.2 | 3.8 | 5.6 |
| 14 November 2007 | 4.0 | 3.9 | 5.8 |
| 15 November 2007 | 7.5 | 4.3 | 6.4 |
| *Nargis* | | | |
| 30 April 2008 | 3.7 | 3.5 | 5.1 |
| 1 May 2008 | 3.9 | 3.8 | 5.7 |
| 2 May 2008 | 5.2 | 5.3 | 8.0 |

I, Observed; II, From eq. (1); III, From eq. (2); After Lin *et al.*[4].

deep layer with high UOHC provides large enthalpy flux (latent + sensible heat flux) which helps in the intensification of the storm. In a recent study[11], performance of various storm track prediction models (including *Sidr*) were compared and it was inferred that the WRF model performed best. Kotal *et al.*[8] also compared a few models and concluded that the ECMRWF model is better than others. They have developed a statistical–dynamical scheme using different dynamical and physical parameters for storm-track prediction and tested it for *Sidr*.

(ii) *Nargis* (27 April–2 May 2008): The severe cyclone *Nargis* devastated Myanmar with 600 mm rain and 3–4 m storm surge. About 130,000 people were killed and 1.5 million were affected[3,12]. The system intensified as a deep depression on 27 April with a ridge to its north. It moved north-northwest as the banding features improved. It was stationary on 28 April due to the ridges in SE and NW. It intensified on 29 April and later slightly weakened due to subsidence and dry air, as a result of decrease in deep convection near the centre. The storm started moving northeast around the periphery of a ridge to its southeast. After turning eastward, it rapidly intensified on 1 May due to improved outflow in association with a upper-level trough. The vorticity at 850 mb increased from 60 to $210 \times 10^{-6}\ \mathrm{s}^{-1}$ from 28 April to 2 May in the eastward direction[13]. SST was 29–30°C during mid-April 2008 and wind shear in the troposphere was 30% weaker than normal. Mixed layer of the ocean was shallow (about 10 m)[12]. The system intensified over the warm ocean where UOHC and D26 were 77–105 kJ/m$^2$ and 73–101 m respectively. The enthalpy was 900 W/m$^2$, which was 300% higher than the climatological value (about 300 W/m$^2$). It intensified from category-1 (75 kn) to category-4 (115 kn) on 1 May. Vertical wind shear was 4–7 m/s, which was also favourable. Without this warm and deep layer, it would not have intensified even though the atmospheric conditions were favourable[3]. Outgoing long wave radiation was 110 and 150 W/m$^2$ during *Sidr* and *Nargis* respectively. Track prediction of *Nargis* using WRF model and other atmospheric conditions have been reported earlier[13]. We have tested eqs (1) and (2) for the above two cases.

Distribution of UOHC in BOB prior to the storms (i.e. on 9 November 2007 and 26 April 2008) is shown in Figure 2. Storm tracks (dotted lines) are also shown. UOHC was above 70 kJ/cm$^2$ in the central BOB and it was more than 50 kJ/cm$^2$ in the north BOB prior to *Sidr* (9 November 2007; Figure 2 *a*). High values of 80–85 kJ/cm$^2$ were observed (pre-storm; 26 April 2008) in the central Bay where *Nargis* recurved and started moving in the NE direction. Low values of 25–45 kJ/cm$^2$ were observed off Myanmar coast (Figure 2 *b*). UOHC at 6 h track positions was taken from the NOAA website to compute $U_\mathrm{h}$ from eqs (1) and (2). The observed and estimated (from eqs (1) and (2)) values of $U_\mathrm{h}$ (daily average) are shown in Table 2. It is interesting to see that there is good agreement between the observed and estimated values from eq. (1), whereas the estimates from eq. (2) are generally high, except on 15 November 2007 for *Sidr*. It may be mentioned here that eq. (2) is mainly meant for the category-4 storms [Saffir–Simpson tropical cyclone scale based on 1 min (10 min) maximum sustained winds – category-1: 34–43 (30–37), category-4: 59–71 (52–61) m/s] and the definition is different from the India Meteorological Department (IMD). classification of *T* numbers (*T*4: 32–59.5 m/s; *T*6.5: 60 m/s and above). Secondly, it was based on real-time data of a number of storms while it could not be done for BOB due to lack of datasets during cyclones.

This is a preliminary study using a small sample of dataset (13 cyclones during 1990–2006) and we hope that the relationship between UOHC and $U_\mathrm{h}$ may be better if extensive real-time datasets are used. Atmospheric conditions are not unimportant. But without the supply of sufficient enthalpy flux from the ocean, storms may not intensify. Since the UOHC of the pre-storm conditions is used here, there is a possibility to estimate $U_\mathrm{h}$ in advance from the predicted storm track.

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# *Camelina sativa*: a new crop with biofuel potential introduced in India

In the present world scenario bio-diesel has been accepted as a clean alternative fuel. Thus even before the Copenhagen Summit on climate change was held during December 2009, the participating world countries had already started fixing the mammoth targets for emission cut, which require more stringent steps in the energy sector to keep the environment clean despite maintaining good economic growth. India with its robust economic growth (8% annually) is likely to account for 15% of world's oil demand by 2040 (ref. 1). To meet such a huge demand for fuel and to realize self-reliance in energy, India is keen on a National Bio-fuel Policy, which aims to set a target of meeting about 20% blending of bio-fuels with petrol and diesel by the year 2017. Potential sources of renewable bio-fuel are bio-diesel, grain ethanol and green diesel. India's ethanol production is about 1.96 billion litres (from sugarcane molasses only), of which only 628 million litres is available for fuel purpose which translates to hardly 5% petrol blending[2]. Though the Government of India is vigorously pursuing the policy of bio-diesel from non-edible sources, specially jatropha, research on other crops with bio-fuel potential is also required to be taken up in order to have year-round supply of raw materials for commercial oil extraction from plants as well to achieve the target on time which will be environmentally compatible.

Camelina (false flax, gold-of-pleasure, *Camelina sativa* [L.] Crtz.) is an underexploited oilseed crop of the family Brassicaceae (Figure 1). It has agronomic low-input features[3] and an unusual fatty acid composition with high levels of alpha-linolenic acid[4] vis-à-vis unusually high cholesterol and brassicasterol content (188 and 133 ppm) than other vegetable oils[5]. Seed oil content of camelina has been reported between 320 and 480 g/kg and seed yield up to 2800 kg/ha (refs 6–8). Although high cholesterol and presence of eicosenoic acid (15%) pose a hurdle for its approval as food oil[9,10], the presence of omega-3 fatty acids makes its oil unique and nutritionally rich. Cold-pressed meal of camelina after oil extraction contains 10–14% oil by weight and protein (40%) with lower glucosinolate levels, making it a desirable animal feed[11]. With a variety of non-food usages of the oil as drying oil and in environmentally safe painting and coating applications[6,7], minimal agronomic input requirement for cultivation makes it a potential crop for use as bio-fuel without interfering with the edible oil trade and competition for available resources.

According to the published reports, yield potential of jatropha has been in the range of 1–10 t/ha/yr (ref. 12) depending upon the growing conditions and age of the plantation, with oil content of 30–40% and oil potential of about 1890 l/ha/yr (ref. 13). On the other hand, camelina, an annual plant with a maturity of 90–100 days, possesses 35–40% oil exhibiting a potential of 1400–1500 l/ha/yr, provided two crops are grown with an average seed recovery of 1700 kg/ha. Camelina can be used as a potential intercrop in the jatropha plantation during orchard establishment phase in North India, especially during winter months when jatropha sheds its leaves, to have a year round supply of raw materials.

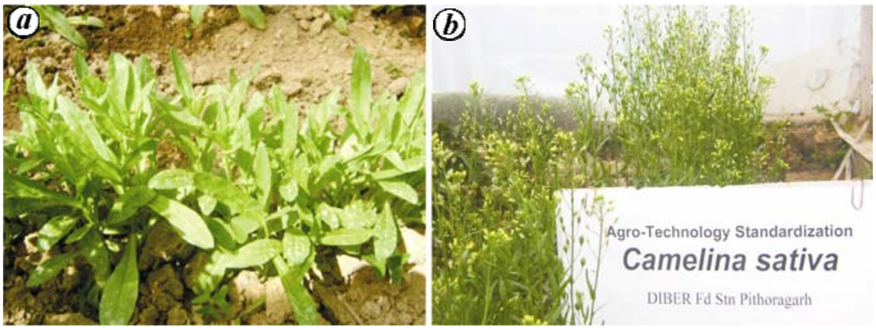

**Figure 1.** ***a***, Camelina: thirty days after emergence. ***b***, Flowering stage.