Forests Phenolic Compounds Instigate Cloud Precipitation

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Research

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Abstract

Background

The wind shakes trees uttering their leaves generating heat within. Mechanosensing is a crucial process in regulating trees’ growth and development. Mechanical stresses generate internal and external signals in trees. The aim is to establish the myriad of communication signals between forests, their ecology, wind and the clouds.

Results

As result of leaves’ flutter trees open their stomata releasing phenolic compounds into the atmosphere. These aerosols linger in the atmosphere till they collide with the incoming clouds, condensing their particles causing precipitation.

Conclusion

While the relationship between deforestation and global warming has already been established by many scientists, the communication between trees, wind and cloud is dynamic, which without the three together earth’s climate will persist towards desolation. Forests endure wind forces, causing their leaves to flutter, which prompt them to release phenolic compounds forming lakes of aerosols above the forests, instigating cloud precipitation.

Introduction

Mechanosensing is an important process contributing to the regulation of plant growth and development (Berlyn, 1961; Hamant, 2013). Mechanical stresses generate internal signals produced during tissue and cellular development (Ingber, 2005; Hamant et al., 2008) or via external signals from the ecosystem, particularly the wind (Moulia et al., 2011). A number of factors influence mechanosensing, though some factors predominate in certain situations. It has been shown that trees display adaptation to the local wind environment. Like other plants, trees can enhance their endurance to transpirational flow by opening and closing their stomata. Wind is one of several factors that can interact virtually to affect stomatal function. Winds can alter leaf form and temperature, which means that the short-term outcomes of wind on photosynthesis are diverse and unpredictable (van Gardingen and Grace, 1991; Telewski, 1995).

The mechanics of plant responses to wind have been widely researched (de Langre, 2008). Much of the research focuses on tree pliability (Mayer, 1987; Kerzenmacher and Gardiner, 1998; Selier and Fourcaud, 2005; Rodriguez et al., 2012) or crop crown movement (Py et al., 2005, 2006; Dupont and Gosselin, 2010). Wind has been found to influence the time-averaged transformation settings and form of leaves via the mechanism of reconguration (Vogel, 1989; Gosselin et al., 2010; Tadrist et al., 2014). Regarding leaf sway, Roden (2003) patterned aspen leaf flutter as a specific recurrent rotation, and Niklas (1991) identified poplar leaf sway as a possible example of the conventional linked type of fluttering (Tadrist et
The fluttering of leaves generates energy for plants and causes stress. Plants are highly sensitive to a range of effects, from significant to minor physical damage, and respond to mechanical stresses promptly or over longer periods depending on the degree of stress detected (Chehab et al., 2008; Chen et al., 2005; Karban and Baldwin, 1997). Plants respond to stress by producing phytohormones and volatile terpene compounds (VTCs) and by triggering defence-associated genes (Chehab et al., 2009; Green and Ryan, 1972), which can result in development deceleration, leaf deterioration and possible organ detachment (Jaffe and Biro, 1979). It has been found that shaking cocklebur plants causes a surge in leaf senescence (Salisbury, 1963) and that placing seedlings on a shaker table causes phloem to proliferate (Berlyn lab, unpublished). Other research has shown that plants respond to mechanical stimuli through chlorophyll content modification and stomata closure, which leads to senescence and abscission (Biddington, 1986).

Tree survival depends on the chemistry of phenolic compounds, which are a class of chemicals characterised by a hydroxylated benzene ring (Smith, 1997). In trees, phenolics are present as polymers, acids or glycosylated esters (Harbome, 1979) and perform diverse roles. Phenolic compounds or polyphenols are one of the most widespread class of compounds in plant ecology, and there are more than 8,000 known phenolic structures (Tsao, 2010). These phenolics exists in almost all plant organs and have myriad functions based on their structure; they act as skeletal components of different tissues and as pigments in a variety of plant organs (Ignat et al., 2011). Polyphenols are secondary metabolites that are essential for plant development and propagation (Tanase et al., 2019). Phenolic acids are present in the combined soluble form conjugated with sugars or organic acids and comprise elements of composite structures, such as lignins and hydrolyzable tannins (Tomás-Barberán and Clifford, 2000).

Phenolics are esterified with sugar moieties or are equally purified in the entire plants; most are present in cell walls or stored in vacuoles (Smith, 1997). Disruption to cells caused by environmental stress or laboratory tissue emulsification can generate phenolic compounds, which separate enzymatically from their ester bonds and quickly alter cell components, such as enzymes and proteins (Chalker-Scott and Fuchigami, 1989). Any form of mechanical damage is likely to intensify phenolic synthesis (Thor and Hall, 1984; de Jaegher et al., 1985; van Loon and Gerritsen, 1986) and accumulation (Baldwin and Schultz, 1983; Barker and Peterson, 1984; Kimmerer, 1988), particularly in cell walls (Berlyn and Mark, 1965; de Jaegher et al., 1985; Biggs, 1986; Rickard and Gahan, 1983; Biddington, 1985). Phenolics are functional compounds in plants, acting as a stress-defensive mechanism and attracting or defending against herbivores and plant pathogens (Treutter, 2005). Phenolics are widely distributed in plants, including in the roots, shoots, woody tissues, leaves, phloem, flowers and leaf buds, pollen and styles (Misirli et al., 1995).

Plants play an essential role in the biogeochemical sequences of carbon and water and, therefore, are an important element affecting the Earth’s climate (Carslaw et al., 2010). Further, plants continually release responsive biogenic volatile organic compounds to the atmosphere, where they contribute to atmospheric gas-phase chemistry and particle construction (Mentel et al., 2013). Plants are the main source of volatile organic compound emissions globally (Guenther et al., 2012). Once released into the atmosphere, plant
volatiles undergo oxidative processes that produce low-volatility vapours and biogenic secondary organic aerosol (Riccobono et al., 2014; Tröstl et al., 2016). Atmospheric aerosols affect the climate by dispersing and absorbing radiation and by contributing to the development of clouds (IPCC, 2013; Pajunoja et al., 2015). This paper aims to examine the ongoing and interconnected relationship between forests and wind, which is integral to internal and external communication, cloud formation and precipitation.

**Materials And Methods**

The last-standing forest in Hourieland is located in the Nehle Valley north of the ancient town of Akra, between Hasya Qalotk in the Pîris Range and Seré Akra Range (current Kurdistan; Figure 01). The majority of trees in the forest are *Berî (Oak; quercus)* and related species, including the common Berî that produces acorns; the *Mazi* that produces berries the size of hazelnuts, which are used for beer and medicine; *Gordîl (Dyer’s oak; Quercus lusitanica)*; and *Mask*, which produces legume-rich leaves and mango-sized loofah. Less common trees in the same forest include the *Pistachio (pistacia)*; the *Bink*, which produces legume-rich leaves and medicine; the *Dindar* (the rare Hurrian *Dindar* medicinal berry tree); the *Kavot* (the rare Hurrian medicinal berry tree); the *Kezan* (*pistacia atlantica*), which produces hard shell wild pistachios; and the *Banoshk*, which produces soft shell wild pistachios. Most of these trees are evergreen. Evergreen, leathery-leaved shrubs and trees characterise temperate forests in much of the southern hemisphere, as well as Mediterranean scrub, slightly wetter sclerophyll forests, and even wetter temperate rain forests in areas of winter rainfall on the west sides of the continents at mid-latitude. Evergreen, needle-leaved conifers dominate many boreal forests at high latitudes in the northern hemisphere (Small, 1972; Givinish, 2002). Chabot and Hicks (1982) argued that frequent frosts favoured vessel-less (and, perhaps coincidently, evergreen) conifers at high latitudes and altitudes. These trees shed their leaves in spring during and after leaf growth (Nitta and Ohsawa, 1997), though most species keep two or more cohorts of old leaves in the early mid-spring (Suehiro and Kameyama, 1992). The conditions are comparable to sclerophylls in the Mediterranean Basin, which shed their leaves mainly in spring (Escudero et al., 1992; Rapp, 1969; Montserrat-Martí and Pérez-Rontomé, 2002), although the leaves of some species constantly regenerate to compensate for old, damaged leaves and those consumed by herbivores. This area was the subject of a 10-year study conducted by the author of the present study. From 2009 to 2019, the Nehle Valley underwent an extreme change in ecology and weather and succumbed to the same deforestation that the rest of Hourieland had been subjected to.

| Nehle Valley: | Warê Mirdavia: |
|---------------|----------------|
| NW:           | 36.913567, 43.841455 |
| SW:           | 36.891880, 43.806437 |
| NE:           | 36.905539, 43.882053 |
| SE:           | 36.871353, 43.847721 |
While some plots of lands were planted with sumac shrub on the deforested southern slopes of the Hasya Qalotka Range, the upper valley was almost completely forested in 2009. The forest was almost completely deforested by villagers from 2010 to 2017 to clear space for planting sumac. From 2009 to the end of February 2019, the author observed, monitored and photographed the Nehle Valley. The snow height was measured at two points: in the lower part of Ba-Mij-Mij village in the lower valley and the middle of the upper valley. Snow cover at the lower valley was measured every day. Upper valley snow was quantified by measuring the uncovered part of a 15.3 m old mulberry tree in the middle of the valley. The measurement was confirmed every 5–10 days per snow season by wildlife hunters. Snow was quantified in several ways. The snow level in the lower valley was gauged using a scaled 1 m steel beam. A scaled cane (Figure 02) was used in the upper valley measurements, which were performed by the author and wildlife hunters. The wildlife hunters used their open hands for this purpose, which measured around 0.25 m. Forest quantification for the lower valley was measured through GPS. Meanwhile, the upper valley was measured through an old method that used two 50 m ropes knotted together and stretched to create a 90° angle that measured 2500 m². A total of 5% of the forest in the upper valley had previously been cleared in the 1960s and onwards when villages in the Nehle Valley camped during the summer (Figure 03).

While the oak tree family is ubiquitous in Hourieland, the rare dindar, bink, kavot, kazan and banoshk species only grow in upper valleys that are adapted to heavy snow cover, and all are endangered. The author, always accompanied by the elder Dad Kadan and several of his trusted relatives, quantified the lost forest and measured the sumac farms. The area was also calculated through visual observation of the two peaks at the Hasya Qalotka Range and the two peaks at the Deré Kadana Range. A Panasonic camcorder AG-HPX500, Nikon D5600 SLR camera and mobile phones were used to film the burnt and cleared areas. Using the rope method, the Waré Mirdavia forest was calculated at approximately 10 Km², as shown in Figure 03. For each clearing, the USGS map was marked with the yellow coloured lot measuring 2500 m² by the author and the crew, and for each sumac farm, a rust coloured lot was added for every 2500 m². The green lots indicated what was left of the forest. Each 1 K² consisted of 400 lots. As the upper valley area measured approximately 10 x 1 K², there were a total of 4,000 lots.

As proper weather balloons were not available in Hourieland, a cluster of small balloons filled with helium and fitted in polyester fabric was utilised (Figure 04). The balloons were secured to a tree trunk in the upper valley with a 1 km main thick rope. Every 100 m, a 25 m single-coloured fabric strip was attached to the main rope to visually gauge the direction and speed of the wind. A second auxiliary 1 km thick rope was used to transport equipment to the upper sphere. A third 2 k+ m thinner rope was passed through a ring at the base of the weather balloon and was subsequently passed through two more rings enclosing the auxiliary transport rope. The base of an empty one-litre aluminium bottle was secured to the end of the 2 k+m third rope (Figure 05A and B). Water was boiled in a deep pan, and the aluminium bottle was immersed until it filled up and reached the temperature of the water. The aluminium bottle was lifted out of the pan, and a cork with four horizontal channels on its side was placed against the bottle's orifice. The
bottle was turned upside down to allow the hot water to pour out. The bottle was immediately secured with the cork to insulate it from the air. The pressure inside the bottle pulled the cork into the bottle's neck quickly so that the bottle became airless. A fourth 1 km thin rope was secured through the middle of the cork. A U-shaped steel bar with a hole for the cork's rope to pass through and a spring secured against the cork's top was tightened to the bottle's neck by a steel ring fastener (Figure 05A and B). During high winds that shook the trees and fluttered their leaves, the aluminium bottle was lifted 50 m above ground. The third and fourth thin ropes were pulled down at the same time that the cork was pulled out of the bottle's neck, which allowed the phenolic saturated air to fill the bottle through the four horizontal channels on the side of the cork. Once the third and fourth ropes were loosened, the steel spring pushed the cork back up the bottle's neck, securing the phenolics in the aluminium bottle. This bottle was then lowered to the ground, and its contents were tested using an olfactometer. The process was repeated, and the airless aluminium bottle was sent up to 50 m above the previous collection position until the last reading was collected at the base of the weather balloon. Wind speed was also measured using a portable anemometer. As it was cumbersome to send the anemometer up using the balloon ropes, one of Dad Kadan's relatives climbed up the peaks of the Hasya Qalotka and Deré Kadana ranges each time the phenolics were counted in the day or night during late autumn.

Deforestation can occur when populations increase, cash cropping escalates or when power tools are used for clearing and cultivating (Vanclay, 1993). In the present study, the constant deforestation of both the lower and upper valleys caused snow cover to decline. From 2009 to 2017 in the winter and spring seasons, the lower valley experienced fog from dawn to midday. The village of Ba-Mij-Mij, which translates to ‘Wind-Fog-Fog’, lost its characteristic fog in 2018 and 2019. In this period, the temperature was 11 degrees in the lower valley and 35 degrees in the upper valley, which was higher than the previous years at any season in 2019. Snowfall in the upper valley, which often lasted for 4–5 months in November, December, January, March and April, declined from 2010 onward after deforestation began, until the catalyst in the summer of 2017 when the road reached the upper valley and beyond. The road made it easier for all the villagers to reach the forest by vehicles, allowing them to log more than what they needed, and facilitated easy transport of the logged timber. Large waterfalls jet straight out of mountain cliffs through four large oval holes measuring 3 x 2 m, 3.3 x 1.7 m, 4 x 2.5 m and 3.5 x 2.7 x m called Sar Rij 1, 2, 3 and 4 in Zéwa Gulley (Figure 06). Sar Rij translates as ‘cold storage’, reflecting the fact that stores in the mountains were fed straight from the snow cover above, and freezing waters passed through large holes in the cliff face. Sar Rij 2, 3 and 4 dried out in summer 2012. Sar Rij 1, which is located in Waré Dosteka east of Waré Mirdavia, last produced water in spring 2017 and subsequently dried out. Hundreds of additional springs also dried out, except for six of the Zéwa Gulley ground springs that emanate from Waré Dosteka and that supply the Zéwa waterfall. The Waré Mirdavia, Shïva Zaman, Shïva Mirdavia and Shïva Shara streams supplied some water throughout the seasons until summer 2017. Their resources declined in the winter and spring in 2018, and the Dođi and Hertun rivers dried up in late June 2018.
Results

The irresponsible clearing without replacing the steep surfaces with the sumac weed, decimated the forest in the upper valley (Table 01) (Figure 03).

(Figure 03) shows the following quantifications for the upper valley known as Waré Mirdavia:

500000 m² of forest were cut down during 2010-2011, while only 52500 m² of land was planted with lacquer trees;

200000 m² of forest were cut down during 2011-2012, while only 45000 m² of land was planted with lacquer trees;

400000 m² of forest were cut down during 2012-2013, while only 15000 m² of land was planted with lacquer trees;

200000 m² of forest were cut down during 2013-2014, while only 35000 m² of land was planted with lacquer trees;

1137500 m² of forest were cut down during 2014-2015, while only 35000 m² of land was planted with lacquer trees;

582500 m² of forest were cut down during 2015-2016, while only 27000 m² of land was planted with lacquer trees;

1000000 m² of forest were cut down during 2016-2017, while only 45000 m² of land was planted with lacquer trees;

4132500 m² of forest were cut down during 2017-2018, without planting any new crop. In spite the author’s objection and warnings, the villagers carved a dirt road through the Zéwa Gulley up to the upper valley, Waré Mirdavia, in the process destroying the Zéwa Gulley waterfalls and 2 springs out of 6 as well an ancient dwelling, which probably dated 1000s of years.

In 2018-2019 the villagers collectively cleared 847500 m².

Fish farms were decimated. The available water from the severely downgraded Zéwa Gulley waterfalls became strictly rationed, causing angst and disputes.

While more than five readings were conducted in measuring snow depth intermittently, (Table 02) shows the decline in snow cover over the 10 year period of the study at both the lower and upper valleys. With less snow cover days spring season would logically yield less water discharge to downstream areas, as well as gradual increase in temperature, particularly in summer when water was needed most. The extreme decline in snow precipitation maybe caused by the extreme decline in forest cover.
On closer inspection at tree level, the portable olfactometer registered the presence of phenolics by all the
trees in the forest. To determine the quantity of phenolic compounds in the oak, dye oak, mazi, mask,
pistachio, bink, dindar, kavot, kazan and banoshk, the author took 10 x 100 g samples from each tree. The
samples were separately mixed with 250 g combination of methanol (CH\textsubscript{3}OH)/acetone ([CH\textsubscript{3}]\textsubscript{2}CO)/water (H\textsubscript{2}O), boiled in a kettle each at 80-90° C. The author obtained total phenols from the ten tree species.

The result of the 100 g samples taken from the 10 trees after separately mixed with 250 g mixture of
methanol (CH\textsubscript{3}OH)/acetone ([CH\textsubscript{3}]\textsubscript{2}CO)/water (H\textsubscript{2}O), boiled in a kettle each at 80-90° C came as follows:

To state total phenols in a sample of 100 g of the oak tree the author performed the extraction, added FC
reagent and read the absorbance at 753 and its curve resulted 0.33885

Total phenolics results for the oak are below:

\[ Y = \text{Absorbance} \]
\[ X = \text{concentration from the calibration curve} \]
\[ X = y + \frac{0.307}{11.924} \]
\[ X = 0.33885 + \frac{0.307}{11.924} = 0.364596 \text{mg/mL} \]

TPC = \( cV/m \)

c= concentration from the calibration curve
V= Volume of the extract used
m= Mass of the extract used
0.0257463938

Total Phenolic Compound TPC (at 5º C) = 0.364596 X 1/0.01 = 36.4596 MGE/g

Phenolic communication quantification is demonstrated in the following novel equation at both 5º C and
15º C:

\[ \text{Temp (ºC) x phenolic curve (MGE/g) x max phenolic temp level (100) = phenolic communication (µ m}^3) \]
\[ t \times \varphi_c \times \varphi_{(\wedge t)} = \varphi_{\cap} \]
\[ 5º C \times 0.33885 \text{ MGE/g} \times 100º C = 169.425 \text{ µ m}^3 \]
\[15^\circ C \times 0.33885 \text{ MGE/g} \times 100^\circ C = 508.265 \mu m^3\]

| Tree     | Absorbance | Curve  | TPC     | Phenolic communication at 5\(^\circ\) C |
|----------|------------|--------|---------|----------------------------------------|
| Oak      | 753        | 0.33885| 36.4596 | 169.425                               |
| Dye oak  | 749        | 0.33705| 36.2796 | 168.525                               |
| Mazi     | 786        | 0.3537 | 37.9446 | 176.85                                |
| Mask     | 785        | 0.35325| 37.8996 | 176.625                               |
| Pistachio| 779        | 0.35055| 37.6296 | 175.275                               |
| Bink     | 779        | 0.35055| 37.6296 | 175.275                               |
| Dindar   | 789        | 0.35505| 38.0796 | 177.525                               |
| Kavot    | 761        | 0.34245| 36.8196 | 171.225                               |
| Kezan    | 764        | 0.3438 | 36.9546 | 171.9                                  |
| Banoshk  | 765        | 0.34425| 36.9996 | 172.125                               |

| Tree     | Absorbance | Curve  | TPC     | Phenolic communication at 15\(^\circ\) C |
|----------|------------|--------|---------|----------------------------------------|
| Oak      | 753        | 0.33885| 36.4596 | 508.265                                |
| Dye oak  | 749        | 0.33705| 36.2796 | 505.575                                |
| Mazi     | 786        | 0.3537 | 37.9446 | 530.55                                 |
| Mask     | 785        | 0.35325| 37.8996 | 529.875                                |
| Pistachio| 779        | 0.35055| 37.6296 | 525.825                                |
| Bink     | 779        | 0.35055| 37.6296 | 525.825                                |
| Dindar   | 789        | 0.35505| 38.0796 | 532.575                                |
| Kavot    | 761        | 0.34245| 36.8196 | 513.675                                |
| Kezan    | 764        | 0.3438 | 36.9546 | 515.7                                  |
| Banoshk  | 765        | 0.34425| 36.9996 | 516.375                                |
Data were obtained from plants on the ground. However, due to the heat generated by the fluttering of leaves, the phenolics collected using the aluminium bottle from the atmosphere between 800 m and 2,000 m above sea level showed a higher percentage, and quantification varied from 1,000–2,000 µ from 2009–2016. The quantification later decreased to 200–300 µ in 2017 and decreased again in 2018 (Table 03). The lake of phenolics changed constantly according to the intensity of the wind and the amount of time that the leaves fluttered. Therefore, the more live tree leaves, the more leaves that fluttered and the more phenolics were discharged above the forest.

**Discussion**

Trees endure significant wind forces and usually survive with little or no wounding (James and Haritos, 2014). The dynamic responses of trees have been studied using multifaceted prototypes and multi-model approaches that specify the morphology of trees and the dynamic interfaces of branches, which can affect the damping reaction in winds (Rodriguez et al., 2008). The damping reaction has the important effect of causing tree leaves to flutter and subsequently, friction and heat. When an object moves along a surface or through a viscous liquid or gas, the force resisting its motion is referred to as ‘friction’. Frictional forces are nonconservative and convert the kinetic energy of a material in sliding contact to internal energy (Krim, 2012). Fluctuations of particles have the same origin as dissipative frictional forces in which one force (wind) performs work against another (wind) that tries to shift a system in a particular direction (Einstein, 1906; Krim, 2012). If the two mica surfaces of a single leaf are made to slide relative to each other with a molecularly thin film between them (i.e., molecules between the upper and underside of a leaf; Figure 07), a viscous friction form is expected to occur for liquid-like behaviour, assuming that the shear occurs in the film and not at the mica-liquid boundary (Klein and Kumacheva, 1995–1998; Docherty and Cummings, 2010; Mate and Marchon, 2000). Even without acknowledging wind-affected movement, the wind has an important effect on the thermal condition of plants (Schuepp, 1972; Vogel, 2009) and in gaseous interactions and transference (Grace, 1978; Defraeye et al., 2012). In the presence of a gradient of gas concentration, molecular agitation is responsible for the transfer of mass, which is generally referred to as ‘diffusion’, although this word can also be applied to momentum and heat (Monteith and Unsworth, 2013). Based on the notion that the significance of leaf design lies in hydraulic and thermal management (Nicotra et al., 2011), Rupp and Petra (2019) proposed the theory of leaves as heat and mass exchange biostructures. The leaf surface heat transfer coefficient increases with increasing wind speed and decreases as the measuring position moves along the wind direction from the leading edge (Jürges, 1924; Yoshida et al., 2012; Asawa et al., 2016; Kinoshita and Yoshida, 2017). The effect of wind on the movement of the leaves of trees is crucial for biological purposes (e.g., photosynthesis, pathogen development and herbivory) and also has indirect influences, such as on wi-fi transmission or animal communication (Tadrist et al., 2018).

Leaf fluttering has various effects on vital biological plant processes. For example, leaf fluttering can reduce insect herbivory (Yamazaki, 2011) and enhance heat exchange (Schuepp, 1972; Grace, 1978), gas trade (Nikora, 2010) and photosynthesis (Roden and Pearcy, 1993; Roden, 2003). The fluttering of leaves
may also be important in decreasing the water content of leaves and disposing of pathogens in water droplets. Tree foliage may interrelate by shaking, touching, leaf-to-leaf rubbing or by closing into bundles (Vogel, 1989), assuming that all foliage is the same except for their position in relation to photosynthesis (Pearcy, 1990; Rascher and Nadbal, 2006).

In line with optimisation theory, stomatal aperture varies over time to mitigate water loss for the required amount of carbon gain (Cowan, 1977). For example, there is no carbon gain in plants at night as the stomata shut due to the absence of photosynthetically active radiation, which is essential for the light reaction of photosynthesis. However, the fractional shutting of the stomata of some trees at night may present an ecological advantage. Under these conditions, fractional stomatal shutting can be encouraged by enabling trees to continue photosynthesis until evening and improving photosynthetic efficiency earlier in the morning than competitors (Daley and Phillips, 2006). However, wind can close stomata (Kozlowski, 1979). In the present study, trees were found to open their stomata at night, not due to the presence of light, but because they were violently shaken by the wind (Figure 07). When strong winds pass through a tree, fluttering the leaves rapidly, heat is generated from the accelerated movement. The mechanically heated tree responds by sending phenolic compounds to the stomata to defend itself from ‘attack’ by a herbivore, when the wind is responsible for the assault. At higher than usual temperatures at night or daytime, phenolic compounds saturate the guards surrounding the stomata gates, mostly at the lower side of the leaves, which forces the stomata to swell and open and enables the accumulated phenolic compounds to escape through the gates and attack the predator. The wind then carries the escaped lightweight phenolic compounds into the air. Aerosols are solid or liquid particles that are sufficiently small to remain suspended in the atmosphere for long periods (Monteith and Unsworth, 2013). The phenolic compound particles subsequently collide with incoming or stationary cloud particles, which causes them to become heavier and form snow, which descends to the ground due to gravity.

Slight (i.e., ~100 m) differentials in topography and vegetation considerably change the near-surface flow field through mechanical means, such as flow parting around obstructions, improved turbulence from amplified surface coarseness, and speeding-up over elevations and thermally driven flows stimulated by local variant ground heating in montane areas (Defant, 1949; Banta, 1984; Banta and Cotton, 1982; Whiteman, 2000; Zardi and Whiteman, 2013; Chrust et al., 2013). The first indications of imminent precipitation are low surface, chaotic and violent winds that shake the trees and floating clouds of dust that accumulate on leaves, followed by a cleansing process. The end of this period is called a ‘perfume front’, whereby wind violently shakes the trees, fluttering their leaves, triggering stress mechanism responses, generating heat and stimulating the fresh and clean leaves to release phenolic substances (Figure 08). Mechanical stress as a consequence of shaking and bundling has been shown to prompt the biosynthesis and adaptation of ethylene and VTCs in balsam fir trees (Korankye et al., 2018).

The signalling mechanism between the wind and forests, which is the natural seeding of clouds, was observed by the author over 10 years and for numerous generations by Hurrian elders and their ancestors (Figure 08). In 1991, during the first Gulf War, the soot from burning oil fields in Kuwait precipitated over Hourieland. The falling soot was given the name ‘black rain’ and also fell as black snow on the
mountains. Clouds may have formed from nearby open waters, including the Mosul Dam, and the Hurrian forests. However, the presence of large amounts of seeding soot in the clouds suggests that the clouds may have travelled over 1,000 km from the southern Gulf north towards Hourieland, covering the mountains and the phenolic lakes in Hourieland, where cloud precipitation then occurred.

The olfactometer reading of the space above the forest recorded a higher quantity of phenolics than the usual forest sphere. While the usual forest sphere phenolics hovered around 200–300 1-m^3 at 5°C and 500 1-m^3 at 15°C, 50 m above the tree line, the olfactometer registered around 1000–2000 1-m^3 (Figure 09). The measurements were taken at several elevations from the valley below up to the mountain ridge. A weather balloon 1,000 m above the ground was used for the upper valley of Waré Mirdavia. Snow often precipitated at night and continued the next day or for many days or months depending on the topography, size and density of the lake of phenolics. The lake of phenolics is as large, dense and quantifiably high as the number of trees on the ground. The more forested an area, the more precipitation occurred.

In one of Dad Kadan’s childhood anecdotes, the upper valley had over 50 m of snow, and all four Sar Rîj jet spectacular waterfalls into the Zéwa Gulley. In the lower valley, he would climb a ladder to the roof of the family home, crawl up through the chimney and walk over the roofs till he reached his uncle’s home, where he would climb down the chimney into the house. A one-story Hurrian rock house was 3.5 m high, which meant that the snow in the lower valley in the 1950s was 3.5 m high. In 1968 at age three, the author listened to his uncle Roj sing the lyric ‘the perfume front hit my face among the trees of the Black Forest’ and wondered what kind of perfume front the song referred to. In 2009, the author asked the Ba-Mij-Mij elder Dad Kadan that question, and the answer, which has been known to the Hurrian people for thousands of years, was that trees communicate with clouds through scent, and that scent precipitates snow in winter and rain in spring. Forests are thought to have declined by around a third over the past three centuries in China, the Middle East, North Africa, eastern North America and Southeast Asia (Ramankutty and Foley, 1999). Deforestation has considerable and pervasive adverse effects on climate, hydrology, soil and biodiversity and also affects humans and the economy (Meyfroidt and Lambin, 2011). Large swaths of native forests have been destroyed to produce resources. In their limited and reduced condition, the remaining native forests face the possibility of the rapid and severe stress of climate change and amplified climate variability (Dale et al., 2001). The mountain cryosphere of snow, ice and permafrost plays an important role in these ecosystems and is a crucial source of water for downstream regions (Huss et al., 2017). Multifaceted interactions between cloud cover, solid and liquid precipitation, surface albedo and net radiation contribute to further degradations in glacier mass balance and snow-covered topographies (Painter et al., 2012). As a result, glacierised mountains are threatened by conditions that lead to declines in snow and ice cover (Huss et al., 2017). Ellison et al. (2017) argued for the need to reverse the pattern of deforestation, explaining the cooling and hydrologic effects of forests on the earth. Their findings are in line with new research that suggests that forests act as ‘biotic pumps’, ‘generators’ or ‘recyclers’ to regulate the surrounding water balance (Makarieva et al., 2006; Makarieva and Gorshkov, 2007; Sheil and Murdiyarso, 2009; Ellison et al., 2012; Sheil, 2014). A concerted effort to
promote forestation, therefore, is needed to counter the catastrophic effects of global warming and preserve living standards.

**Conclusion**

Wind is a quintessential element in its relay with forests, clouds and their topography. Numerous studies established that forests have a definite impact on precipitation, so as the topography of the targeted region, in this instance a seldom researched area called Hourieland. In this poorly managed area the last forest was cleared to plant the poor yielding sumac shrub, without utilizing most of the cleared land. It resulted in extreme decline in snow cover, and even drought. The study of this locality observed the various wind speeds, levels and directions, which set the ecology of the montane orography, where surface fog and spherical clouds interacted with the trees to dust, wet, and cleanse the forest. The wind exerted force against the trees, fluttering their leaves, causing them to heat up, prompting the trees’ external and internal signaling mechanisms to react, emitting phenolic compounds. These light weight aerosols formed a lake above the forest. The wind also generated and transported clouds from nearby and distant open waters. The cloud particles collided with the lake of phenolic compounds above the forest resulting in precipitation. Large scale deforestation resulted in less or not enough phenolics to form a lake of phenolics above the forest location, resulting in less aerosol and cloud particle reaction, and less precipitation of snow cover.

**Abbreviations**

VTC: volatile terpene compounds

CH₂OH: methanol

\([CH₃]₂CO\): acetone

H₂O: water

FC reagent: Folin-Ciocalteu

TPC: Total Phenolic Compound

**Declarations**

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Key Message

Forests produce abundance of phenolic compounds which condense clouds particles, forming ice particles and resulting in precipitation.

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Tables

**Table 01: Forest percentage loss compared to Sumac farm increase in the upper valley.**

| Year       | Forest % | Sumac % |
|------------|----------|---------|
| 2009-2010: | 95       |         |
| 2010-2011: | 90       | 0.525   |
| 2011-2012: | 88       | 0.785   |
| 2012-2013: | 84       | 1.225   |
| 2013-2014: | 82       | 1.7     |
| 2014-2015: | 71       | 1.975   |
| 2015-2016: | 60       | 2.125   |
| 2016-2017: | 50       | 2.575   |
| 2017-2018: | 10       | 2.575   |
| 2018-2019: | 5        | 2.575   |

**Table 02: quantifying depth of snow, duration and temperature in the lower and upper valleys.**
| Year        | Location          | # of days snow on ground | Snow depth readings/m | Max depth/m | Temp.°C |
|-------------|-------------------|--------------------------|-----------------------|-------------|---------|
| 2009-2010:  | Upper Valley:     | 149                      | 6                     | 7.2         | 7.8     | -40     |
|             | lower valley:     | 90                       | 0.4                   | 0.5         | 0.5     | -11     |
| 2010-2011:  | Upper Valley:     | 143                      | 5.2                   | 6.3         | 6       | -40     |
|             | lower valley:     | 76                       | 0.38                  | 0.45        | 0.43    | -10     |
| 2011-2012:  | Upper Valley:     | 140                      | 4.6                   | 5           | 5.2     | -38     |
|             | lower valley:     | 70                       | 0.34                  | 0.41        | 0.42    | -9      |
| 2012-2013:  | Upper Valley:     | 138                      | 4.3                   | 4.8         | 4.1     | -37     |
|             | lower valley:     | 66                       | 0.36                  | 0.4         | 0.35    | -7      |
| 2013-2014:  | Upper Valley:     | 134                      | 4.3                   | 4.4         | 4.1     | -31     |
|             | lower valley:     | 40                       | 0.28                  | 0.3         | 0.27    | -6.5    |
| 2014-2015:  | Upper Valley:     | 97                       | 2.5                   | 2.8         | 3       | -26     |
|             | lower valley:     | 31                       | 0.2                   | 0.22        | 0.25    | -5      |
| 2015-2016:  | Upper Valley:     | 63                       | 1.4                   | 1.9         | 2       | -24     |
|             | lower valley:     | 28                       | 0.21                  | 0.23        | 0.25    | -5      |
| 2016-2017:  | Upper Valley:     | 46                       | 1.1                   | 1.22        | 1.25    | -20     |
|             | lower valley:     | 21                       | 1.6                   | 1.8         | 0.2     | -5      |
| 2017-2018:  | Upper Valley:     | 27                       | 0.3                   | 0.3         | 0.27    | -9      |
|             | lower valley:     | 0                        | 0                     | 0           | 0       | 0       |
| 2018-2019:  | Upper Valley:     | 0                        | 0                     | 0           | 0       | 0       |
| Year       | Upper Valley: | Ground wind K/h | Mid wind K/h | Upper wind K/h | Phenolics µ |
|------------|---------------|-----------------|--------------|----------------|-------------|
|            |               | dusting         | dew          | frosting       | rounding    | Phenolics µ |
| 2009       | 100-130       | 10-20           | 40-60        | 10-20          | 1000-2000   | 120-150     |
| 2010       | 100-130       | 10-20           | 40-60        | 10-20          | 1000-2000   | 120-150     |
| 2011       | 100-130       | 10-20           | 40-60        | 10-20          | 1000-2000   | 120-150     |
| 2012       | 100-130       | 10-20           | 40-60        | 10-20          | 1000-2000   | 120-150     |
| 2013       | 100-130       | 10-20           | 40-60        | 10-20          | 1000-2000   | 120-150     |
| 2014       | 100-130       | 10-20           | 40-60        | 10-20          | 1000-2000   | 120-150     |
| 2015       | 100-130       | 10-20           | 40-60        | 10-20          | 1000-2000   | 120-150     |
| 2016       | 100-130       | 10-20           | 40-60        | 10-20          | 1000-2000   | 120-150     |
| 2017       | 110-140       | 10-20           | 50-70        | 10-20          | 200-300     | 120-150     |
| 2018       | 110-140       | 10-20           | 60-90        | 10-20          | 50-100      | 120-150     |
| 2019:      |               |                 |              |                |             |             |