Plant adaptation to water supply

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Introduction:

We did our project in the Botanical Garden of Ulm University with different plant adaptations from drought to montane tropical rainforests, because it is necessary to understand different adaptations (humidity, temperature, water supply,sunlight intensity) in the variety of plants.

Plants need a lot of water because plants use much more water than most animals and also contain more water than animals. The amount of water a plant needs depends on the type of plant, amount of light gets, and how old the plant is. Plant also need water for photosynthesis – photosynthesis is what plants do to create their food, and water is critical to this process. The other reason is that plants need water because the reactions that take place in the cell to make energy also require a water medium. In addition, today's changes in the environment (especially temperature increase) are happening faster and on a larger scale than in the past, which makes it difficult for plants to adapt. Changes in climate can affect the types of plants that can grow in an area.

There were many authors who worked on similar projects, such as Turner (1986), who briefly reviewed the current developments on the role of leaf hydration, the leaf growth and photosynthesis. He concluded that changes in growth and stomata locations are not always closely correlated with changes in leaf hydration.Morgan (1984) wrote that the type of water stress may vary from small fluctuations in atmospheric humidity and net radiation in more moisture habitats to extreme soil water deficits and low humidity in arid environments. Another publication which was written by Tumer & Begg (1981) is„ Plant-water relations and adaptation to stress“. We read two main reviews for our project. The first one was “Impacts of warming on tropical lowland rainforest“ (Corlett 2011) - it was focused on the impact of rising temperature. The second review was „Climate change and evolutionary adaption“ (Hoffmann & Sgro 2011) – it was about evolutionary adaptations which can help species counter stressful conditions. We also had an article „A global over view of drought and heat-induced tree mortality reveals emerging climate change risks for forest“ (Allen et al. 2010) which revealed the potential for amplified tree mortality due to drought and heat in forests worldwide.

In our project we elaborated a lot of adaptations types which are very useful for plants in deserts, in lowland tropical rainforests and in montane tropical rainforests.

Materials and Methods:

The plants with the different plant adaptations were growing in the different greenhouses of the botanical garden at the University of Ulm. There was also made a reference on how they deal with water. Therefore some photos and examines of the cellular structure of the different plants were taken and regarded under the microscopes.

Results:

The world map (Fig.1) shows the occurrence of the different biomes we observed in green houses of the botanical garden.

We looked for the different plant adaptations in each biome.

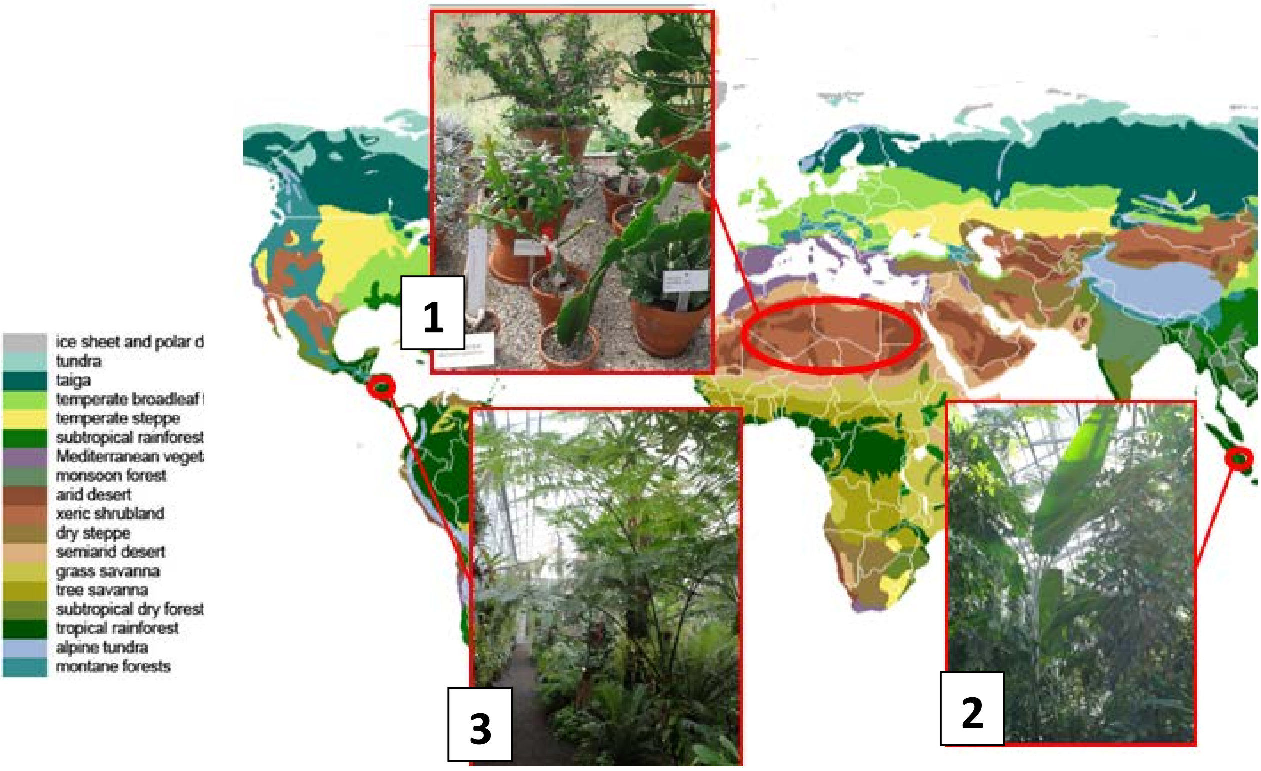

Fig.: 1 World map: Distribution of biomes. 1: desert, 2: tropical lowland rainforest, 3: montane tropical rainforest

Deserts are characterized by little precipitation and lack of vegetation due to high radiation.

Fig.: 2 Cactaceae with spiky spines and a spherical steem

The main plant families of this biome are Cactaceae, Euphorbiaceae and Asteraceae. Because of these stress factors the plants have developed many morphological adaptations to survive in this environment. One of these special adaptation and familiar traits are the spines. A spine means a reduced leaf and protects plants against herbivores and against the loss of water (see Fig. 2). The spine is a convergent adaptation which occur in Cactaceae and Euphorbiaceae. So the spherical stem is the only part of these plants which has a photosynthetic activity (Fig. 2).

Fig.: 3 Euphorbiaceae with stem and leaf succulence

The ball-formed or spherical stem has also a very important function in water supply, because of this shape the surface is minimized and the volume increased. When the surface is smaller less radiation impinges on this and due to this less transpiration occurs. The surface is covered with a thick waxy cuticula layer against water loss. Storing water, there are some more adaptations for example the succulence. There are three types of succulence: stem, leaf and root succulence. Succulence is a convergent adaptation. Figure 2 shows a stem succulence. Figure 3 shows a Euphorbiaceae with stem and leaf succulence. A physiological adaptation is CAM photosynthesis. The stoma remain closed during the day and open at night to reduce transpiration.

Lowland tropical rainforests:

We also looked at the adaptations of plants located in the lowland tropical rainforests.

The lowland tropical rain forests are mainly characterized by the precipitation. A normal yearlong

Fig.: 4 Different layers of vegetation

1: forest bottom, 2: understory layer, 3: emergent layer, 4: canopy precipitation is between 2000-4000 mm. The average temperature is around 28°C. The temperature difference of ~10°C between night and day is even bigger than the difference in daily temperature during the whole year. It never has a real period of drought. Another important aspect for the rain forests are the different layers of vegetation. (Fig. 4)

There different layers from bottom up are: the forest bottom, the understory layer, a canopy layer and the emergent layer. (Fig. 4)

Only ~2% of the sunlight arrives the bottom layer, therefore the few plants that grow in this layer needs adaptations for catching the small amount of sunlight.

Fig.: 5 some epiphytes (Orchidaceae)

In the canopy layer occure lots of high growing plants (between 30 and 45 m). There are also a lot of epiphytic plants.(See Fig. 5). In the emergent layer are trees that grow higher than 45 meters. (Tiina Tosens, 2015)

For all that different layers the plants need special adaptations to survive. As already mentioned the plants in the bottom and the understory layer need to adapt to low sunlight. Therefore the higher growing of this layer have some white parts within their leaves. These parts allow the sunlight to go through the leaves and reach the smaller growing plants.

Fig.: 6 white parts within the leaves

The plants of the canopy layer have large range of different adaptations to the high precipitation. Their leaves are mostly shaped with a drip tip. The drip tip is a small, thin extension of the leave which helps the leaves to get rid of the rain water. They also have a waxy layer that protects the leaves of dirt and water. (Fig. 7) (Tiina Tosens, 2015)

Another adaptation which is mostly common for epiphytes are air roots. Because of the lack of nutrients in the soil the epiphytes have migrated to the upper parts of the trees. To get enough nutrients and water they developed aerial roots which absorb the water from the air and their leaves are arranged like bowls to catch the water falling down from the plants above. Both adaptations are important for the water and nutrient uptake without any soil that can store nutrients and water for the plants.

Fig.: 7 drip tip

The biggest problem the plants in the emergent layer have to deal with is the water transport from the bottom to the top. If the transpiration is too high, the plant loses to much water in a short time, so the under pressure gets too high. The water that is transported up starts boiling or the gases within the water start forming bulbs because of the high pressure. Both – the boiling and the bulb forming gases - destroy the cells. So the leaves close their stomata when it's too warm, so the transpiration is kept on a low level.
More or less the plants of the lowland tropical rainforest and the montane rainforest have the same adaptations and the same problems to deal with.

The type of water stress in the montane rainforest biome (Fig. 8) are
more or less the same as in the lowland rainforests, effect the
circumstance that the temperature is lower and that there's a higher
precipitation, condensing as fog. That's why there are so many mosses
and epiphytes occuring in the montane rainforest, which are adapted to this

Fig. 8: greenhouse: montane rainforest

environment by living on trees and collecting their water directly from the air. Many other plants adapted to this environment by creating air roots (Fig. 9) for the same reason. Due to the harsher environment, compared to the warmer lighter lowland rainforest, the understory layer of the montane rainforest is reduced ore entirely missing.

Fig.: 9 air roots

As in the lowland rainforests, the plants have to get rid of water, due to the huge amounts of water and the high humidity. That's why many plants have evolved a hairy surface (to use the lotus effect, Fig. 10), a special leaf shape or waxy cuticules – on the other hand, they are also a good protection from pathogens and lichens.


Fig.: 10 hairy leaf surface

The soil of montane rainforests are very bad in storing water (due to the very thin organic soil layer on the bedrock), and so even in this extremely humid biome, there are succulents or plants that create watertanks with their leaves, like many orchids and bromeliaceae (Fig. 11).

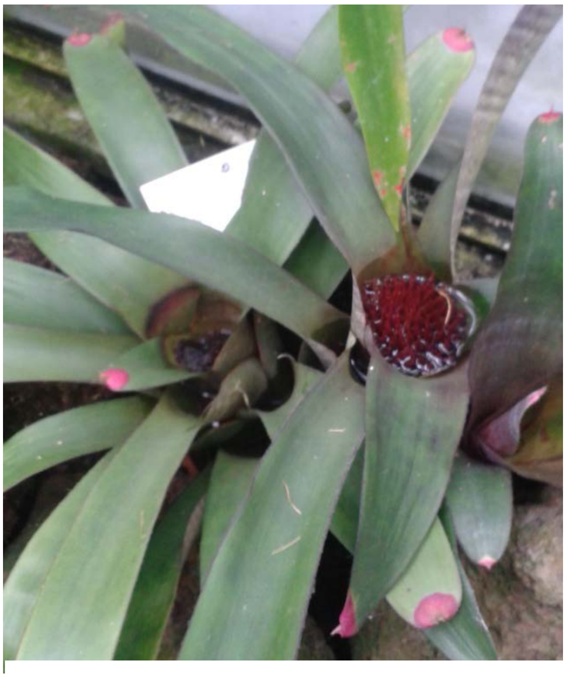
Fig.: 11 Bromeliaceaes that create watertanks with theirs leaves

Discussion:

Our presumptions were confirmed by our results:
There are different plants which have different adaptations for water supply. In the desert the precipitation is very slight so the plants have to store water (for example different types of succulents) or reduce evaporation (CAM-photosynthesis) to avoid desiccation. The precipitation in the tropical lowland forest and in the montane rainforest is admittedly higher as in the desert but there are also plants that have to take care of water supply for example epiphytes. Orchids can catch water from the air with theirs air roots. Due to the high humidity they have to clean their leaves to avoid pathogenous infections.

Conclusion:

Climate change is a great challenge to our ecosystems and especially to our plants. Due to the more and more increasing emissions of greenhouse gases caused by the industry of human civilization, the temperature increases more rapidly. Because of the higher temperatures plants have to deal with bigger problems in water storage.
It is a very important for them to keep the water supply in balance. This begs the question: What are the impacts of global warming on these biomes for example the tropical rainforests and how could plants react to this changes? These forests are the most species-rich ecosystems in the world and play a crucial role in regulating carbon and water feedbacks in the global climate system (Richard T. Corlett 2011). But not the increasing temperatures is the problem because during the 1960s, the warmest tropical rainforest had a mean annual temperature of 28 °C (Richard T. Corlett 2011). The main problem is the drought. Because of increasing temperatures the air can absorb more vapor. So it is impossible to separate warming from changes in water relation. But how does the plants respond to this changing in temperature? The species can response differently. They can acclimate, adapt or die. But in this time the scientists have not enough exact information to predict how the species will respond to this warming and what are the consequences.
However, current and future canopy leaf temperatures in tropical rainforest seem unlikely to be high enough to cause irreversible heat damage (Richard T. Corlett 2011).

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Personal quotes of Dr. Tiina Tosens from the Estonian University of Life science, Department of plant physiology, during the Summer school “Soil & water 2015”