**////Title: Exploring the Evolution of Plant Chemical Defences**

**////Standfirst:**

When it becomes too cold or a predator draws near, animals can flee to nicer locales. Plants, on the other hand, do not have this luxury. Instead, they have evolved chemical defences to deter pests and respond to changes in their environment. Dr Ella Katz of the University of California, Davis, is interested in the wide variety of chemical defences found in plants. In a recent study, she and her colleagues show that geography, environment, population history and genetics all combine to produce different chemical defences within the same plant species.

**////Main text:**

To survive and reproduce, all organisms must quickly adapt to changes in their environment. Plants, which are rooted into the ground and cannot flee from threats, instead use sophisticated chemical defences. Among these are metabolites – chemicals produced during metabolism – that help defend the plant against different threats.

Given that even neighbouring environments can present unique stressors, the chemical makeup of a plant’s metabolites is likely to change based on various local factors. This means that even within the same species, different populations of plants can have quite different metabolite compositions.

Though metabolites variation is expected, we still do not know which factors drive plants to develop new metabolites rapidly and how differences in a plant’s metabolites may be reflected in their genetics. Since different plant species living in the same environment are exposed to the same ecological pressures, many scientists suppose that they may also share the same genes that control metabolite production.

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To better understand the factors influencing the development of new metabolites, Dr Ella Katz studied the metabolite compositions of 797 European variants of a common weed called *Arabidopsis thaliana* [ah-rah-buh-**dop**-suhs thah-lee-**aa**-nah]. The team hoped to relate the chemotype [kee-moh-type] – the dominant metabolite of each variant – with aspects of the plant’s environment and its genetic code.

The researchers published their findings in a recent article in the journal *eLife* [ee-life]*.* Here, they summarise how various environmental, ecological, and population factors influence the range of specialised metabolites found across the 797 variants.

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To assess variation in metabolites across Europe, the team analysed *Arabidopsis* seeds from different locations in and around Europe. They chose to focus their effort on examining the distribution and composition of glucosinolates [gloo-koh-sin-oh-lates], a diverse class of metabolites found within the mustard family, which includes *Arabidopsis*. Given that the major genes involved in glucosinolate production are already known, this chemical group is an ideal model to use when examining the relationship of plant genetics, environment, and metabolite structure.

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Dr Katz’s initial analysis showed that the 797 *Arabidopsis* variants expressed 23 different chemical forms of glucosinolate across Europe.

However, these glucosinolates were not distributed equally across Europe. In fact, the team found that the plant’s chemotype within a population was significantly correlated with geographic location. In southern Europe, including the Iberian Peninsula and the Balkans, two dominant chemotypes were geographically isolated. However, in Northern and Central Europe, there was much more variability, with more chemotypes that had overlapping geographic distributions.

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The team then examined the relationship between chemotype and the local environment. For every location, they collected data on the following environmental factors: distance from the coast; amount of precipitation during the wettest and driest months; maximum temperature in the warmest month; and minimum temperature during the coldest month.

The researchers then ran these data through a mathematical model, which revealed different relationships between the environmental conditions and chemotype based on geographic area, particularly between Northern and Southern Europe. These results demonstrate that while the environment influences chemotype everywhere, it does not always do so in the same way.

For instance, the minimum temperature during the coldest month and precipitation in the wettest month each had a different relationship with the chemotype depending on geography. For example, if rainfall was strongly related to chemotype in Northern Europe, it was not necessarily a strong influence on plants found in Southern Europe.

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Finally, they investigated the evolution of three genes that are known to produce glucosinolates. They were most interested to find out whether variants of these genes evolved independently. If so, they wondered whether the genes evolved from parallel evolution – in which lineages begin from the same state and evolve in a similar way into the new state – or from convergent evolution – where lineages start at different states and independently evolve to the same new state.

They found that all three genes experienced a blend of convergent and parallel evolution. By unlocking the evolutionary history of the genes involved in chemical defences, we can better understand the variation of glucosinolate traits based on location.

For example, the chemotypes found in one region appear to be influenced by a mix of gene flow across the continent along with local environmental pressures. This means that analysing the genetic evolution of these chemotypes – when considered with environmental parameters – may track the movement of the Arabidopsis variants across Europe as they expanded and adapted to new environments.

Dr Katz and her team also showed that variation in one gene influenced that of the other genes, suggesting that this may be because the expression of one type of metabolite may either hinder or bolster that of another in a complex network of interactions helping a plant to survive.

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This work shows that the rapid diversification of chemical defences is critical if a plant is to move and adapt to a new environment or stressor. The complex relationship of geography, environment, and ecology in influencing the development of three genes related to chemical defences highlights that plant evolution is driven by a complex network of forces and mechanisms.

Expanding these analytical methods to different plant species in different environments will further deepen our understanding of the processes that influence chemical variation in plant populations. This work will allow us better understand how a plant adapts to its environment and how the environment leaves its fingerprint on a plant’s DNA.

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This SciPod is a summary of the paper ‘Genetic variation, environment and demography intersect to shape Arabidopsis defense metabolite variation across Europe’ from *eLife:* [doi.org/10.7554/eLife.67784](https://doi.org/10.7554/eLife.67784)

For further information, you can connect with Ella Katz at elkatz@ucdavis.edu