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# SECONDARY METABOLITES AS PLANT DEFENSE MECHANISMS: A COMPARATIVE REVIEW OF WILD AND CULTIVATED SPECIES

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**ABSTRACT**

Plants are one of the most interesting groups in earth which possess many complex mechanisms to grow and survive. One among those is their defence mechanisms. Different plants have different defence mechanisms. For the same, secondary metabolites play an important role. These particular substances play as a barrier towards the attack from a-biotic stresses, pathogens, herbivores etc. Certain plant species contain only certain secondary metabolites. These can be species specific and sometimes concentrated on a specific plant lineage or environment. Main secondary metabolites in plants include Alkaloids, Phenols, Saponins, Terpenoids etc. In this review paper, I focussed on different defence mechanisms in plants with special reference to secondary metabolites comparing both Wild and Cultivated plant species which comes under important Medicinal, Aromatic and Food plants. In this study, I came to know that the wild species shows more Secondary metabolites concentration in comparison with the cultivated species. The study mainly focussed on the researches undergone in plants like *Centella asiatica* (L.) Urb., *Withania somnifera* (L.) Dunal , *Ocimum tenuiflorum* L., *Curcuma longa* L. etc. Also factors like Environmental stresses, Agronomic practices, genetics which affects the Secondary Metabolite production in plants have also been discussed. Based on this review, it is understood that, wild plant populations should be maintained/preserved for better qualities and the metabolite rich traits should be included in sustainable agriculture. I conclude this study by pointing out the research gaps and propose research works for future which can optimise the secondary metabolites in both wild and cultivated plant species.

***Key words*:** Secondary Metabolites, Defence Mechanism, Abiotic Stress, Sustainable Agriculture, Alkaloids, Pathogens.

## Introduction

Being a sessile and fascinating group, plants need more complex and sophisticated defence mechanisms. Secondary metabolites play a crucial role in the defence systems in plants. This is a diverse group of organic compounds which do not involve in the primary metabolic processes like growth and reproduction (Hanson, 2003). Instead, these compounds perform specialised functions which can protect the plant from pathogen attack, herbivores and abiotic stresses like soil salinity, Ultraviolet radiations, heat etc. (Mithofer & Boland, 2012).

Secondary metabolites are compounds like Tannins, Alkaloids, Glycosides, Terpenoides and Phenolics. They have the capacity to attract pollinators, deter herbivores by attracting predators of herbivores, secreting toxic substances etc. Also these substances have capacity to help plants to tolerate abiotic stresses like Soil Salinity, Heat, UV radiation etc. In accordance with the stress level and other factors secondary metabolites may vary in species, developmental stages, populations, environmental condition and areas. Each group has evolved unique properties to enhance plant survival. For instance, phenolic compounds often act as antioxidants protecting against oxidative stress, while alkaloids can deter herbivores through their toxicity (Wink, 2003).

The presence of secondary metabolites determines evolutionary adaptations as well as ecological success of plants based on their habitat. Plants growing in different habitats show exceptional differences in the presence of Secondary metabolites in them. According to Baldwin, 2001, the main factors which influence on the synthesis and accumulation of these compounds are genetic background, ecological interaction and environmental factors. In wild plant species where natural selection is intense, the presence of secondary metabolites will be high and robust. And in contrast, domesticating plants for better yield and edibility has reduced the presence of secondary metabolites which is pointed out in Milla *et al*., 2015; He *et al*., 2017. This can often make the cultivated plants more vulnerable towards pests and diseases. Also, it may affect their growth and yield, unintentionally increasing the dependency of plants on herbicides and pesticides.

It is very important to understand the comparative dynamics of the presence of secondary metabolites in wild and cultivated species. This comparison not only plays a crucial role in ecology & evolution but also in agriculture, conservation biology and pharmacology. This particular comparison revealed that there is a drastic difference in the presence of secondary metabolites in wild and cultivated species of plants. Similarly, studies on *Centella asiatica* (L.) Urb. Discovered that wild population of *Centella asiatica* (L.) Urb. Consistently exhibit higher madecassoside and asiaticoside compared to their cultivated counterparts (Chaurasia *et al*., 2017). Likewise, Withania *somnifera* (L.) Dunal and *Curcuma longa* L. investigations revealed that wild species consist of higher bioactive compound levels as compared to domesticated strains (Singh *et al*., 2015). From these examples or studies, it is clear that cultivation of a particular plant improves its yield and productivity where as in other hand it depletes their natural chemical defence mechanism.

Given the physiological, ecological, agricultural and medicinal importance, it is very important to understand how deeply domestication and cultivation affects a plant's level of secondary metabolites. This information not only make us understand the importance of conserving wild plant species but also offers new techniques or approaches to multiply/ breed the crops which maintains a balance between productivity and natural defence mechanism.

Therefore, the main objective of this particular study is to provide a detailed analysis of the secondary metabolites as plant defence mechanisms, focussing on a comparison between domesticated cultivated and wild plant species. This study mainly focussed on the recent research works where secondary metabolites are influenced by genetic and environmental factors. This also highlights the importance of conserving wild plant species and emerging opportunities of sustainable agriculture.

## Types of Secondary Metabolites and their Role in Plants as a Defence Mechanism

Secondary metabolites are classified into three major groups based on their chemical structures and biosynthetic origin. They are namely Phenolics, Terpenoids and Alkaloids along with other essential groups such as Saponins and Glycosides.

### Phenolic Compounds

Phenolic compounds are mainly known for their anti-herbivory, anti-microbial and antioxidant properties which protect the plant from many predators including animals. These compounds include Tannins, Lignins, Flavanoids, Phenolic acid and Coumarins. In the study of Dixon and Paiva, 1995 and Treutter, 2006, it is marked that Flavanoids protects the plants from UV radiation, deter insect herbivores and contribute to flower pigmentation. Also, Barbehenn and Constable, 2011 said that Tannins has property to reduce palatability and digestibility in herbivore forming complexes with proteins.

In studies of wild and cultivated *Centella asiatica* (L.) Urb. plants, Chaurasia *et al*., 2017, came in the conclusion that the content of flavanoid is very high in wild species when compared to cultivated *Centella asiatica* (L.) Urb. Population. Similarily, Singh *et al*., 2016 found out that wild *Ocimum sanctum* L. plants which are rich in phenolics shows higher resistance to fungal pathogen comparing the cultivated group.

### Terpenoids

Terprenoids are also called as Isoprenoids. This represents the largest group of Secondary Metabolites which includes Monoterpenes, Diterpenes, Sesquiterpenes and Triterpenes. This class has a property for direct and indirect defence. They attract natural enemies of the pests which attacks the plant, deter herbivores and also inhibits microbial pathogens. (Gerhenzon and Dudareva, 2007).

Weathers *et al*., 2011 compared wild species of *Artemisia annua* L. with its commercial cultivar and observed that the wild species produces a higher level of Artemisinin which comes under sesquiterpene with anti-malarial and anti- herbivore properties and the commercial cultivar produces a lesser level of the same metabolite. Also, wild individuals of *Mentha arvensis* L. contains monoterpene profiles like menthone and menthol compared to its cultivars. These metabolites help in insect repellence. (Kokkini *et al*., 1995).

**Table 1:** Represents Plant Secondary Metabolites and their role in Defence Mechanism.

| Secondary Metabolite | Example | Defence Mechanism | References |
|---|---|---|---|
| Alkaloids | Berberine, Nicotine, Caffeine, Morphine | Anti-microbial, Neurotoxins, Feeding Deterrents | Wink (2003); Zaynab *et al.*, (2018) |
| Terpenoids | Monoterpenes, Diterpenes, Sesquiterpenes | Anti-fungal, Insect repellent, Volatile defence | Gershenzon & Dudareva (2007); Tholl (2015) |
| Glucosinolates | Sinigrin,Glucoraphanin | Toxicity | Fahey *et al.*, (2001); Halkier & Gershenzon (2006) |
| Cyanogenic Glycosides | Dhurrin, Linamarin | Cell Damage and Toxicity | Gleadow & Moller (2014) |
| Saponins | Aescin, Dioscin | Anti-fungal, Insecticidal, Properties to disrupt membranes | Sparg *et al.*, (2004); Osbourn (1996) |
| Cardiac Glycosides | Digitoxin, Ouabain | Toxicity, Interfere in heart function | Agrawal *et al.*, (2012); Züst *et al.*, (2018) |
| Phytoalexins | Resveratrol, Capsidiol | Anti-microbial | Ahuja *et al.*, (2012); Hammerschmidt (1999) |
| Anthocyanins | Cyanidin, Delphinidin | Against UV damage | Gould (2004); Landi *et al.*, (2015) |
| Essential Oils | Thymol, Menthol | Insecticide, Anti-microbial | Isman (2000); Bakkali *et al.*, (2008) |

Holopainen and Gershenzon, 2010 in their studies suggested that the levels of Terpenoids have a great influence on environmental stressors and genotype. The plants which are exposed to stresses like drought and herbivory often shows higher terpenoid content and its expression enhance defence responses.

### Alkaloids

Alkaloids are one of the most noticeable and researched secondary metabolites. These are known for their potent activity. These are nitrogen fixing compounds too. This particular metabolite offers a bitter taste in plants to the herbivores and insects which are often toxic. Very common examples include Morphine in *Papver somniferum* L.; Nicotine in *Nicotiana tabacum* L. and Quinine in Cinchona bark. (Wink, 2003)

In the study of Baldwin, 2001, it is clear that wild tobacco (*Nicotiana attenuate* Torr. ex S.Watson) generates higher Nicotine content when compared to the cultivated tobacco varieties. This particular property provides the wild tobacco a greater tolerance/ defence against the common herbivore *Manduca sexta* L. This simple example clearly mentions how the defensive traits of a plant can be affected by domestication in favour of sensory characteristics and agronomy.

Singh *et al.*, 2015 explained the significant presence of Withanolides and Withaferin A (Bioactive alkaloids with antifungal and cytotoxic properties) in wild *Withania somnifera* (L.) Dunal compared to the cultivated forms.

### Glycosides, Saponins and other Compounds

Glycosides, Glucosinolates and Saponins also play an important role plant's defence. Glucosinolates has the capacity to break down into Isothiocyanates which is a toxic compound upon insect and pathogen attack. This particular compound is well known for this abundance in Brassica species. (Halkier and Gershenzon, 2006). When wild and cultivated *Brassica oleracea* L. is compared, a great difference in Glucosinolate levels can be observed clearly where higher level is found in wild species offering broader protection for wild (Kleibenstein *et al.*, 2001).

On the other hand, common Licorice (*Glycyrrhiza glabra* L.) contains Saponins which has the capacity to disrupt cell membranes of Fungi and Insects. This particular metabolite easily contributes to anti-fungal properties in plants. But its level has been reduced in cultivated species due to bitterness (Osbourn, 1996).

In case of Cassava (*Manihot esculenta* Crantz), a common human food contains cyanogenic glycosides which releases hydrogen cyanide as a defence mechanism. But the breeders have been raised low – cyanide cultivars for human consumption thereby decreasing the actual defence mechanism and protection in Cassava (McKey and Beckerman, 1993).

## Comparative Analysis of Secondary Metabolites in Wild vs Cultivated Species

Wild plant species do not get direct human intervention. These contain high genetic diversity due to natural selection and adaptation. Usually, the morphological traits for these groups will be smaller. Whereas, cultivated species are the result of selection and has been domesticated mainly for human needs. These contain lower genetic diversity due to selective breeding. Then traits are often modified for human use.

**Table 2:** Representing plants (Wild vs cultivated) exhibiting higher level of secondary metabolites.

| Plant Name | Secondary Metabolite Present | Higher level in |
|---|---|---|
| *Centella asiatica* (L.) Urb | Asiaticoside and Madecassoside | Wild |
| *Withania somnifera* (L.) Dunal | Withanolides and Withaferin A | Wild |
| *Rauvolfia serpentina* (L.) Benth. ex Kurz | Resperine | Wild |
| *Curcuma longa* L.: | Curcuminoids and Essential oils | Wild |
| *Zingiber officinale L.* | Gingerols and Shogaols | Wild |
| *Brassica oleracea* L. | Glucosinolate | Wild |
| *Solanum melongena* L. | Solasonine and Solamargine | Wild |
| Capsicum species | Capsicin | Wild |

However, the process of domestication has unintentionally reduced the levels of secondary metabolite content and diversity especially which are associated with plant defence. Several studies including the above have shown that the wild species possess higher secondary metabolites and greater diversity of bioactive content. Here, the comparison is divided into different groups mainly Medicinal Plants, Aromatic & Spice Plants and Food & Vegetable Crops.

### Medicinal Plants

***Centella asiatica* (L.) Urb.:** Higher levels of triterpenoids such as Asiaticoside and Madecassoside which are connected with anti-inflammatory effects and wound healing are present in wild *Centella asiatica* (L.) Urb. plants where the cultivated varieties which are selected mainly for rapid growth and yield shows lower levels of secondary metabolites. The wild species especially present in higher altitudes shows a higher level of Asiaticoside and Madecassoside comparing cultivated varieties (James *et al*., 2009 & Chaurasia *et al*., 2017).

***Withania somnifera* (L.) Dunal:** In the study of Singh *et al*., 2015, it is mentioned that Withanolides and Withaferin A which are known for their anticancer & immunomodulatory properties are abundant in wild varieties than in cultivars. As already understood, this decreases in the level of secondary metabolites in cultivar varieties may decrease the plant's therapeutic efficacy.

***Rauvolfia serpentina* (L.) Benth. ex Kurz:** According to the study done by Jain *et al*., 2010, the secondary metabolite presents in *Rauvolfia serpentina* (L.) Benth. Ex Kurz called as Resperine is notably higher in wild population than the cultivated one.

***Curcuma longa* L.:** Sasikumar, 2005 studied the wild *Curcuma longa* L. species of North Eastern India and found that, they have a broader profile of Curcuminoids and Essential oils than cultivated ones.

***Zingiber officinale* L.:** Based on the research carried out by Bhattarai *et al*., 2007, it is understood that Gingerols and Shogaols are highly present in the wild varities of *Zingiber officinale* L. than their cultivars which contribute to pungency and anti-inflammatory activities.

In medicinal plant species, domestication negatively affected the presence of secondary metabolite levels and thereby their therapeutic efficacy.

### Aromatic and Spice Plants

**Mentha species.:** Comparing wild and cultivated Mentha spp., higher diversity of Monoterpenes is present in wild population and low in cultivated ones as the cultivated varieties are often selected only for high menthol yield (Kokkini *et al*., 1995).

**Ocimum species:** Ocimum species has higher flavanoid and phenolic content which are best suited for pathogen resistance. When comparing wild and cultivated *Ocimum tenuiflorum* L., the profiles of flavanoids and phenols are more complex and better in wild population than those in cultivated varieties (Singh *et al*., 2016).

## The essential oil composition in aromatic plants is altered by domestication

### Food and Vegetable Crops

***Brassica oleracea* L.:** In cultivated varieties, reduced levels of Glucosinolate are seen which is induced to improve their palatability whereas in wild population, broader glucosinolate diversity is seen providing a complex defence against different fungi, pathogens and herbivores. (Kleibenstein *et al*., 2001)

***Solanum melongena* L. (Egg plant):** Solasonine and Solamargine, types of Glycoalkaloids which contribute pest resistance are higher in wild types and domesticated varieties have lesser content of the same due to selected breeding practices to reduce bitterness, which negatively influences on pest resistance (Miyatake *et al*., 2010).

**Capsicum species:** Capsaicin, a type of secondary metabolite which has the ability to deter herbivory and fungal infections is higher in wild Chilli peppers. Breeders have developed Capsicum with modified Capsicin levels based on culinary preferences, which naturally lowers the pest resistance in domesticated varieties (Tewksburt *et al*., 2008).

In domesticated food and vegetable crop varieties which are prioritized for taste and edibility, the presence of secondary metabolites is highly modified thereby reducing their natural defence abilities.

## Reasons for Lesser Secondary Metabolites Level in Cultivated Plants

There are many reasons for the reduction of secondary metabolites in domesticated varieties. As the cultivated individuals are grown in a protected environment and under managed conditions, they have lesser exposure to stresses which can naturally decrease the levels of secondary metabolites in them. Also breeding for selected traits like yield or biomass have the chance of diverting resources from secondary metabolism. Another important factor is breeding against toxicity and bitterness. As mentioned earlier, plants like Cassava, Bitter gourd etc. uses toxicity and bitterness as their defence mechanism. But, as these are used as a food variety, these properties are reduced or completely removed which naturally diminishes the production and effects of secondary metabolites.

### Conservation and Breeding

The lesser levels of secondary metabolites in domesticated plants mainly have deeper effects in its pharmaceutical qualities. As many medicinal plants are collected and processed for their medicinal values, the low levels of secondary metabolites in them may result in lower therapeutic value. Preservation of wild germplasm and sustainable agriculture are two of the best techniques which can enhance natural resistance in crops. We can develop Bio-pesticides, Bio-fertilizers or Stress –Resilience Enhancers using the compounds produced from wild varieties which can be applied to the domesticated verities and improve their natural defence mechanisms (Selmer and Kleinwachter, 2013). For instance, there has been a unique Withanolide profile seen in wild members of *Withania somnifera* (L.) Dunal which is not found in their cultivated individuals (Mirjalili *et al*., 2009). Only by re-introducing wild traits or using wild relatives and reducing chemical usage can improve the inbuilt chemicals compounds in crop plants. We can use conventional breeding practices, Marker Assisted selection, Genomic selection and CRISPR- based gene editing for incorporating wild genes to the cultivar varieties (Dhar *et al*., 2020)

### Biosynthesis of Secondary Metabolites in Wild Plants

There are distinct pathways for the biosynthesis of secondary metabolites which starts from primary metabolism. Comparing wild and cultivated species, these pathways are more diversified and active in wild population as they are more prone to environmental stresses and adaptation (Dixon and Paiva, 1995). One of the factors which enhance the biosynthetic pathways in wild population is their environmental stress (Ramesh and Kumar, 2016). Phenylproponoid Pathway is one among the secondary metabolism pathways. It originates from Phenylalanine and produces Lignins, Flavanoids and Phenolic Acids. The activity of Phenylalanine ammonia-lyase (PAL) is often more elevated in wild plant species (Dixon & Paiva, 1995). In Terpenoid pathway, terpenoids are produced via Mevalonate (MVA) and Methylerythritol Phosphate (MEP). The wild species which is more prone to herbivore attacks like *Artemisia annua* L. has enhanced Artemisinin through MVA pathway under stress (Lange *et al*., 2000). Biosynthesis of alkaloids from amino acids is termed as Alkaloid Biosynthesis. The expression of Resperine (an alkaloid) is higher in wild *Rauvolfia serpentina* (L.) Benth. Ex Kurz due to the expression of strictosidine synthase (Facchini, 2001). Aromatic amino acids and phenolic compounds are produced via linking carbohydrate metabolism. These compounds are more active in wild plant taxa under lesser amount of nutrient availability (Herrmann and Weaver, 1999).

### Regulation in Wild Plants

Genes like PAL, HMGR and various cytochrome P450s are highly up-regulated in wild plants during biotic and abiotic stresses (Hahlbrock and Scheel, 1989). Salicylic Acid, Ethylene and Jasmonic Acid pathways are key regulators of secondary metabolism under herbivory and infection (Pietrse *et al*., 2012). The epigenetic control like DNA methylation and Histone acetylation also influences metabolite expression which is more dynamic in wild plants (Kim *et al*., 2015). Biosynthetic enzyme's spatial; organization into metabolons is seen more in wild species under stress enhancing flux through key pathways (Jorgensen *et al*., 2005).

### Ecological Role of Secondary Metabolites

In wild plant members the activity of secondary metabolites is even higher as they are prone to different types of abiotic and biotic stresses. Singh *et al*., 2010 in his study mentioned that concentration of Rosmarinic acid, Eugenol and Apigenin contributing to antioxidant and antimicrobial defence is higher in wild comparing them with the cultivated varieties. In the study of Wink, 2003, the wild plants produce diversified toxic compounds like alkaloids, tannins, glucosinolates etc to cope up with herbivore and pathogen attack. For example: wild *Capsicum annuum* L. produces a higher Capsaicin to fight against mammal attack. (Tewksburt *et al*., 2008). The wild species are often easily accessible for UV radiation, drought, salinity etc. Hence more amount of Flavonols and Anthocyanins are being accumulated in wild species (Selmar and Kleinwachter, 2013). Also, there will be more competition in wild individuals for their survival. For the same, more Phenolics and Terpenoids are accumulated and exuded by the roots of wild plants which can suppress the germination of nearby species. (Inderjit and Durke, 2003).

### Challenges

This work of comparison of secondary metabolites as a defence mechanism in wild and cultivated plant species is a large and complex but a promising topic. However, future researchers can unlock the present challenges and enter in to a new era of understanding secondary metabolites as a defence mechanism more deeply and clearly. At present, one of the main challenges includes minimal analytical methods for standardization. As already understood, secondary metabolite profiles change according to environmental factors, stresses etc, so proper standardization if not present makes the comparison more difficult (Garg *et al.*, 2019). An example for the above point is the variability of Flavanoid quantification in wild Ocimum species in research papers due to the usage of different chromatographic techniques and solvents. Also, differentiation of genetic effects from environmental effects for comparison remains a major confusion/problem (Zhang *et al.*, 2022). Moreover, many wild species are researched with false transcriptomic or genetic data which is more difficult to understand its biosynthetic pathways. Ethical research works and providing benefits to indigenous communities are essential.

### Future Perspectives

It will be better to use more genetic data and combination of genomics, transcriptomics and metabolomics which let us understand clearly about biosynthetic pathways. Because only with the study of RNA sequence of *Withania somnifera* (L.) Dunal, the unique gene cluster regulating Withanolide biosynthesis was understood (Singh *et al*., 2021). Hence, more genomics level studies can discover even more interesting results. Genes transcribing for important and economic compounds can be inoculated from the wild population by the use of genetic engineering promising a large-scale production of valuable secondary metabolites. More studies on the effect of climates should be included which may deviate the study in to a new area. Also, more researches should be done on the effects of climate change in plant secondary metabolites as we have a lesser number of studies at present. Sustainable utilization should be focussed without disrupting the wild population during studies.

## Discussion

This comparative study on the secondary metabolites in Wild and Cultivated plant species revealed the importance of these compounds in plants defence. Their expression is also influential towards anthropogenic and environmental factors. The important secondary metablites like Terpenoids, Flavanoids, Phenolics, Glycosides etc defend from the attack of pathogens, herbivores and other abiotic stresses in a very unique way. These compounds not only play a pivotal role in plant defence mechanisms, but also, they have a higher pharmaceutical and industrial value. All the plants which have medicinal values are measured on the basis of the secondary metabolites present in them.

Generally, it is found that the wild species accumulate higher content and broader diversity of secondary metabolites comparing with their cultivated varieties. This can be due to the higher exposure of wild species to different types of biotic and abiotic stresses in the environment than the cultivated varieties (Wink, 2003; Mithofer & Boland, 2012). These selective pressures can make the synthetic pathways in the wild species produce more secondary metabolites as adaptive responses.

Conversely, the domesticated varieties which are selectively taken are altered based on different human needs like higher yield, ease of harvest, eatability, palatability etc. During these processes, the actual characters of a plant are fluctuated thereby down-regulating or losing the secondary metabolite production and the actual defence mechanisms (Osbourn, 1996; Treutter, 2006). As a result, these plant groups are partially or fully dependant on synthetic agrochemicals for disease management, thereby increasing the ecological footprint of agricultural systems.

However, modern technology and agricultural practices like controlled environment manipulation (nutrient, stress, light and temperature), elicitor application, metabolic engineering etc can be used to reinstate or amplify the production of secondary metabolites in cultivated species (Facchini, 2001; Singh *et al*., 2021). For instance, upregulation of alkaloid and flavonoid can be made possible by the use of Salicylic acid and Methyl jasmonate in many plants. Empirical study examples further highlight these differences. In the studies of Sasikumar, 2005; Chaurasia *et al*., 2017 and Mirjalili *et al*., 2009, it is observed that the wild genotypes of *Ocimum basilicum L., Centella asiatica* (L.) Urb., *Withania somnifera* (L.) Dunal have higher secondary metabolite content than their cultivated varieties. These findings are critical for quality control in the herbal drug industries.

Environmental factors are equally responsible for the alteration in the production of secondary metabolites in plants. For example, elevation can influence the flavonoid biosynthesis as the plant can be highly exposed to UV radiations at higher altitudes. Also, water availability, soil type & texture, plant-microbe interactions also modulate the expressions of biosynthetic genes (Hahlbrock & Scheel, 1989; Gerhenzon & Duderava, 2007). Therefore, understanding environment plasticity and genotype-by-environment interactions are very essential for the optimizing secondary metabolite levels in both wild and cultivated varieties. Furthermore, habitat degradation and climate change also pose an additional challenge in altering the natural cues that regulates secondary metabolite production. Hence, integrating conservation strategies with agricultural development should be engaged to ensure sustainable use of medicinal and aromatic plants.

## Conclusion

Secondary Metabolites in plants plays a crucial role in the total survival and growth of plants even when these are not directly linked to the primary activities. These compounds have a higher ecological, economic, physiological and biological importance. These compounds produce a barrier for all the predators or stresses of a plant. Every secondary metabolite is distinct and they have unique functions. On this study, it is very clearly understood that, wild plant population accumulates and produces a wider spectrum of secondary metabolites than cultivated varieties as wild species are susceptible to more stresses and attacks. Secondary metabolites also play an inevitable part in crop improvement, sustainable agriculture and pharmaceutical innovation.

Cultivated varieties that are raised for human needs show a drastic change in the levels of secondary metabolites. And, unintentionally the natural plant defence is being suppressed by domestication which can alter resilience and medical efficacy thereby changing the complete plant character in the future. Hence, preserving wild genes is not only crucial for ecological balance but also for better next generation crops which are both productive and resilient. A combination of genomics, metabolomics and bioinformatics can be used as a powerful tool for breeding programs and conservation strategies.

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