

Plant Latex- A Concise Review on the Exudate

Sanjukta Rajhans¹ and Himanshu Pandya²

Department of Botany, Bioinformatics, Climate Change Impacts Management
Gujarat University, School of Sciences, Ahmedabad, Gujarat, India
sanjuktarajhans@gmail.com

Abstract: *In this review article an effort has been made to provide basic knowledge about plant latex. In this paper the origin and evolutionary aspects of latex has been mentioned. The geographical distribution and classification along with the physical and anatomical traits have also been brought into limelight. Moreover, the presence of phytochemicals, proteins and variation of the content of rubber in latex has been referred in the paper respectively. This paper would be of great help in gaining deeper knowledge about the plant latex for future researches.*

Keywords: Laticifers, Rubber, Diversity, Secretion

I. INTRODUCTION

In nature latex is found as a thick milky emulsion. Sometimes, it may be thin and clear and the colours may vary. It is not necessary that only white colour is found to be present in the latex. This emulsion coagulates on exposure of the air. The exudation occurs after an injury takes place. Latex is different from other plant saps; it is produced separately (Mishra and Parida, 2020). The exudate is produced by specialized cells known as the laticifers. The laticifers are further classified into two sub-classes, articulate and non-articulate laticifers. Latex has been reported to occur in around 900 genera and 12000 species. Like the other plant parts, latex is also rich in many phytochemicals. These phytochemicals play vital roles in the lives of plants and human beings (Chavan *et al.*, 2015).

II. ORIGINS OF LATICIFER AND LATEX

The laticifers exist irregularly throughout the plant kingdom, it has been proposed that the laticifers and latex have independently evolved many times (Farrell *et al.*, 1991). The way of development and the differences in the structures observed among the several types of laticifers (Dussourd and Denno, 1991) reinforce the idea that the laticifer and latex have evolved independently and convergently. However, at present there is no evidence how and from what the laticifer and latex have evolved (Konno, 2011).

III. COMMON AND CONVERGENT CHARACTERISTICS OF LATICIFERS AND LATEX

Diversity of the latex constituents has been observed among the closely related species. In contrast to this latex of plant species that are distant in phylogeny often reveal similar or the same constituents in common that seem to have evolved convergently. A very evident example is the frequent presence of rubber molecules (cis-1,4-isoprenes polymer) in the latex of the plant families Apocynaceae, Asteraceae, Moraceae, etc. (Mooibroek and Cornish, 2000). Rubber commonly occurs in the latex of distant plant groups, as stickiness is one of the basic and common features necessary for the function of latex. The existence of rubber in latex among the different groups with completely different laticifer structures, including both articulated laticifers and the nonarticulated laticifers (Moraceae, Apocynaceae) shows the probability that rubber in latex have evolved convergently in numerous plant groups (Konno, 2011).

IV. DIVERSITY OF LATEX COMPONENTS WITHIN FAMILIES, GENERA, AND SPECIES

In spite of its similar appearance, latex components are occasionally diverse even between closely related species in the same families and genera. An evident example is of family Moraceae, comprising around 1000 species of latex-exuding plants. The latex components vary among the species. Cysteine protease is the major defense substance in the latex of *Ficus virgata* and several other *Ficus* species, (Konno *et al.*, 2004) but, in some species in place of cysteine protease, phenanthroindolizidine alkaloids exist as defense substances (Konno, 2011). Meanwhile, the latex of mulberry trees (*Morus* spp.) that are toxic to insects are sugar-mimic alkaloids like DNJ (Deoxynojirimycin), D-AB1 (1,4-dideoxy-1,4-imino-D-

arabinitol) (Konno et al. 2007) (Shunze Jia *et al.*, 2020), and a unique chitin-binding protein, MLX56 (Wasano *et al.*, 2009). These defense substances are completely different from the *Ficus* species.

Further, it has been observed that the compositions (molecular species and concentration) of sugar-mimic alkaloids vary significantly amongst the mulberry populations in the same or in sibling species from different places in East Asia (Konno *et al.*, 2006). Therefore, it is clear that components in the latex of plants belonging to Moraceae family are distinct within a family, a genus, and even within a species. Similarly, in the genus *Asclepias* of Apocynaceae family (Seiber *et al.*, 1982; Rasmann *et al.*, 2009), and genus *Euphorbia* of Euphorbiaceae family (Lynn and Clevette-Radford, 1987), diversity of the latex components has been observed. In the latex of *A. speciosa* and *A. californica* cardenolides were completely absent whereas, high concentrations of cardenolides were found in the latex of *A. curassavica* and *C. procera* (Seiber *et al.*, 1982). It was also observed that among the species containing cardenolides, the composition of cardenolides in latex varied greatly (Seiber *et al.*, 1982; Rasmann *et al.*, 2009). The reason for diversity in the latex constituents would have resulted from plant-herbivore interactions that the species have experienced (Konno, 2011).

V. GEOLOGICAL DISTRIBUTION OF LATEX

It has been observed that latex frequently occurs in plant families and species in tropical regions (12.2% for families and 14.0% for species). While in temperate areas less laticiferous plants (4.9% for families and 5.9% for species) has been observed (Lewinsohn, 1991). In comparison to 8.9% of worldwide latex bearing plants (Farrell *et al.* 1991) it has been discovered that 20-35% plants of Tropical America (Amazon) exude latex (Lewinsohn, 1991). Meanwhile, only 15-30% plants exude latex in the tropical Africa region (Reitsma, 1988). The reason for this kind of difference in the percentage is the interaction between the plants and the herbivorous insects. In the tropical regions this interaction is more intense than the temperate areas as the frequent occurrence of latex bearing plants is consistent with the defending roles of latex and laticifer against herbivorous insects.

VI. CLASSIFICATION OF LATICIFERS

Laticifers are further classified into two subclasses i.e., nonarticulated laticifers and articulated laticifers (Figure 1) (Dussourd and Denno, 1991; Hagel *et al.*, 2008).

Nonarticulated laticifers develop from a small number of initial cells in the embryonic stage that elongate and frequently branch without any cell division. These laticifers are vast consisting of multicellular tubular cells. As the laticifers branch, without merging, they form tree-like shapes without loop structures. Example of nonarticulated laticifers can be observed in the species of family Caricaceae and Moraceae (Dussourd and Denno 1991; Hagel *et al.*, 2008).

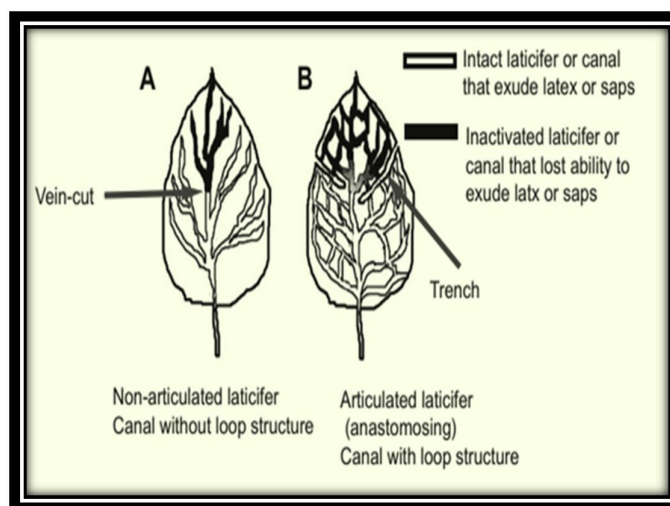


Figure 1: Articulated and Non-Articulated Laticifers adapted from (Konno, 2011)

Articulated laticifers develop from longitudinal chain of cells. Later the cell walls separating individual cells disappear forming a tube-like structure (Dussourd and Denno, 1991; Hagel *et al.*, 2008). It is observed in the species belonging to

Asteraceae, Caricaceae etc. both longitudinal and lateral merges occur forming net-like structures with loops (anastomosing laticifers). While for example in the species of Convolvulaceae only longitudinal merges occur further forming linear structures without loops (non-anastomosing laticifers) (Dussourd and Denno 1991; Hagel *et al.*, 2008).

VII. PHYSICAL TRAITS OF LATEX

7.1. Colour

In general latex is a non-transparent white sap found in *Asclepias syriaca*, *Ficus carica*, *Hevea brasiliensis*, *Papaver somniferum*, etc. While, in contrast to this some plants contain distinct colors or are completely transparent in nature. The colour of latex is yellow-orange but transparent in *Chelidonium majus*, while in *Nerium oleander* the it is completely transparent. The laticifers of *Ficus septica* exude pale yellow and non-transparent latex, while *Ficus benguetensis* contains orange non-transparent latex (Konno, 2011).

7.2 Stickiness and Clots

In some plant species like *Asclepias syriaca*, *Hevea brasiliensis*, and *Lactuca sativa* latex is highly viscous (Dussourd and Eisner 1987; Dussourd 1995), whereas the latex of *Morus* spp., *Nerium oleander* etc. latex exudation is non-sticky. In most cases, after the exudation latex becomes stickier, and in some case finally develop clots. Solidification of fluid is called as clotting while stickiness is correlated with elasticity, high viscosity and adherence to a surface. The stickiness of latex acts as a defense function against the herbivores by gluing the mouth parts (Dussourd, 1993) and trapping the body of the insects (Dussourd, 1993, 1995). Rubber particles play important role in providing stickiness to the latex (Gidrolet *et al.*, 1994). It is obligatory for the plant to maintain high pressure inside the laticifers so that the latex has easy flow inside the laticifers and exudes large amount of latex at the site when any damage occurs. Without clotting of the latex at the damaged sites, pressure of the latex flow would decrease speedily and not flow from the wounds on subsequent damages caused by insect bites. Thus, clotting and stickiness both play an essential role against herbivores insects and other organisms as well.

7.3 Amount of Secretion of Latex

Within the same family, genus and among the closely related species, the amount of latex exudation from a point of damage vary greatly. For example, the latex exudation from the young leaves of *Asclepias barjoniifolia* is four times more, per equal size of wound in comparison to the leaves of *Asclepias angustifolia* (Rasmann *et al.*, 2009). Similarly, *Ficus variegata* and *Ficus virgata* exude white non-transparent latex in large amount compared to the very small amount of orange-coloured non-transparent latex oozed by *Ficus benguetensis* (Konno, 2011).

VIII. ANATOMY OF LATICIFERS

Latex is an exudate that is reserved in the extremely elongated cells that extend along the plant and this canal structure that secretes latex is called laticifer. As a large part of laticifer cells are occupied by big vacuoles that develop in the course of laticifer formation (Cai *et al.*, 2009), the majority of latex secreted is likely to originate in vacuoles. Sometimes it is possible that the exuded latex may also comprise of fluid from the cytoplasm of laticifer cells. This is due to the degradation and mixing of the cytoplasm of laticifer cells with vacuoles in the finishing stage of laticifer development (Zhou and Liu, 2010). Laticifers are spread in the roots, stems, petioles, leaves and leaf veins of the plants.

IX. COMPOSITION OF PLANT LATEX

9.1. Existence of Various Chemicals and Proteins

Latex contains a great variety of secondary metabolites and proteins, especially for the defense purpose in a species-specific manner. A variety of secondary metabolites such as alkaloids, cardenolides, phenolics, terpenoids, etc. have been found in the plant latex. Apart from the secondary metabolites wide range of proteins such as chitin-binding proteins, chitinases, glucosidase, lectins, oxidases, phosphatase, proteases etc. exist in latex. Recent studies have suggested that many of these proteins and secondary metabolites in laticifers and latex play defensive roles against herbivore insects.

9.2. Content of Rubber in Latex

Rubber (cis-1,4-isoprene polymer) is a terpenoid widely found present in the latex of various plant species. Rubber is known to be present in the latex of around 8 plant families and 300 genera (Bushman *et al.* 2006; Metcalfe, 1967; Mooibroek and Cornish, 2000). The two important traits observed in latex i.e., stickiness and white colour is due to the presence of rubber as particles dispersed in fluid. Rubber in latex may play important roles in sealing wounds and protecting the plants from infection and further oozing of latex (Konno, 2011). The frequent existence of latex in high concentration in many unrelated families like Euphorbiaceae, Moraceae, Apocynaceae etc. indicates that rubber plays a very common and important role in latex.

9.3. Alkaloids

Alkaloids are alkaline compounds containing nitrogen. These are often found to be present in the plant latex of many plants. Some of these affects particularly neurotransmission, these are considered toxic to many animals. Plant families like Apocynaceae, Campanulaceae, Moraceae, Papaveraceae etc. are rich in latex containing alkaloids. Morphine in *Papaver somniferum* (Papaveraceae), (Itenovet *al.* 1999; Hartmann 1991) isoquinoline alkaloids like chelidonine, copticine and sanguinarine in *Chelidonium majus* (Papaveraceae) (Tomè and Columbo, 1995) and piperidine alkaloid like Lobeline in *Lobelia cardinalis* (Campanulaceae) (Oppelet *al.*, 2009) have been found in the latex. Morphine affects the central nervous system of humans (Waldhoer *et al.* 2004) and sanguinarine affects neurotransmission as it inhibits various neuroreceptors and this makes sanguinarine toxic to the vertebrates and insects (Schmeller *et al.*, 1997). Lobeline effects on the nicotinic acetylcholine receptors (Felpin and Lebreton, 2004). Apart from these the sugar-mimic alkaloids are present in the latex of mulberry trees, *Morus* spp. (Moraceae) (Konno *et al.*, 2004). These alkaloids are toxic to several insects as they inhibit glucosidases (Hirayama *et al.*, 2007).

9.4. Phenolics

Phenolics are known to function as plant defenses. These phytochemicals are sometimes found in the plant latex in large amounts. For example, the latex of *Ipomoea batatas* (sweet potato) (Convolvulaceae) contain high concentration of phenolics like eicosyl, hexadecyl and octadecyl ester of p-coumaric acids. These altogether make up to 3% of fresh vine latex and 10% of root latex of the “Jewel” variety of sweet potato (Snook *et al.*, 1994).

9.5. Terpenoids

Numerous sesquiterpene lactones including lactucin have been found in *L. sativa* (cultivated lettuce) of Asteraceae family (Sessa *et al.* 2000). The sesquiterpene lactones, lactucopicrin and 8-deoxylactucin prevent feeding by locusts (Rees and Harborne, 1985). These sesquiterpenes also have antifungal properties. Lettucenin A, in latex inhibits the growth of pathogenic fungus *Cladosporium herbarum* (Sessa *et al.*, 2000). The latex of *Euphorbia biglandulosa* and other species of the *Euphorbia* genus contain phorbol, its derivatives (Noack *et al.*, 1980) and diterpenoids in the plant latex. These phytochemicals are toxic for insects and are responsible for causing tumor and skin inflammation (Gershenzon and Croteau, 1991).

9.6. Cardenolides

Cardenolides are a group of cardiac-active steroids. These steroids are present in latex of many plants belonging to Apocynaceae family. Cardenolides inhibit the Na⁺ /K⁺ -ATPase. In tropical Southeast Asia, the latex of the plant *Antiaristoxicaria* (Moraceae) is used in preparations of dart poisons as, the latex is rich in cardenolides (Carter *et al.*, 1997). Cardenolides are known for their defensive roles against the herbivores. An evident example is of *Asclepias curassavica*, the latex of the plant is rich in cardenolides and after the ingestion of the latex the generalist caterpillars, *Trichoplusiani* (Noctuidae), showed toxic symptoms like convulsions with spasms, immobilization, regurgitation and unresponsiveness lasting over a day (Dussourd and Hoyle, 2000).

X. CONCLUSION

The evolutionary aspects, diversity, physical traits and anatomical features makes latex an interesting topic for research. The content of latex and the amount of rubber in it, varies greatly from family, genus and species, further studies are required

for understanding such variations. In the branch of phytochemistry, the study of latex can be taken up further for studying the chemical composition of the latex. Therefore, it can be concluded that the plant latex opens new doors for future research studies.

REFERENCES

- [1]. Bushman, B. S., Scholte, A. A., Cornish, K., Scott, D. J., Brichta, J. L., Vederas, J. C., Ochoa, O., Micheltore, R. W., Shintani, D. K., & Knapp, S. J. (2006). Identification and comparison of natural rubber from two *Lactuca* species. *Phytochemistry*, 67(23), 2590-2596.
- [2]. Cai, X., Li, W., & Yin, L. (2009). Ultrastructure and cytochemical localization of acid phosphatase of laticifers in *Euphorbia kansui* Liou. *Protoplasma*, 238(1-4), 3-10.
- [3]. Carter, C. A., Forney, R. W., Gray, E. A., Gehring, A. M., Schneider, T. L., Young, D. B., Lovett Jr., C. M., Scott, L., Messer, A. C. & Richardson, D. P. (1997). Toxicaricoid A. A new cardenolide isolated from *Antiaristoxaria* latex-derived dart poison. Assignment of the ¹H- and ¹³C-NMR shifts for an antiarigenin aglycone. *Tetrahedron*, 53(40), 13557-13566.
- [4]. Chavan, B. A., Hundiwal, J. C., & Patil, A. V. (2015). Plant Latex: An Inherent Spring of Pharmaceuticals. *World Journal of Pharmacy and Pharmaceutical Sciences*, 4(4), 1781-1796.
- [5]. Dussourd, D. E. & Denno, R. F. (1991). Deactivation of Plant Defense: Correspondence Between Insect Behavior and Secretory Canal Architecture. *Ecology*, 72(4), 1383-1396.
- [6]. Dussourd, D. E. & Hoyle, A. M. (2000). Poisoned plusiines: toxicity of milkweed latex and cardenolides to some generalist caterpillars. *Chemoecology*, 10(1), 11-16.
- [7]. Dussourd, D. E. (1993). Foraging with finesse caterpillar adaptations for circumventing plant defense. In N. E. Stamp, & T. M. Casey (Eds.), *Caterpillars: Ecological and Evolutionary Constraints on Foraging* (pp. 92-131). Chapman & Hall.
- [8]. Dussourd, D. E. (1995). Entrapment of Aphids and Whiteflies in Lettuce Latex. *Annals of The Entomological Society of America*, 88(2), 163-172.
- [9]. Farrell, B. D., Dussourd, D. E., & Mitter, C. (1991). Escalation of plant defense: do latex and resin canals spur plant diversification? *The American Naturalist*, 138(4), 881-900.
- [10]. Felpin, F. X., & Lebreton, J. (2004). History, Chemistry and biology of alkaloids from *Lobelia inflata*. *Tetrahedron*, 60(45), 10127-10153.
- [11]. Gershenzon, J., & Croteau, R. (1991). Terpenoids. In G. A. Rosenthal & M. R. Berenbaum (Eds.), *Herbivores: Their Interactions with Secondary Plant Metabolites* (2nd ed., pp. 615-219). Academic Press.
- [12]. Gidrol, X., Chrestin, H., Tan, H. L. and Kush, A. (1994). Hevein, a Lectin-like Protein from *Hevea brasiliensis* (Rubber Tree) Is Involved in the Coagulation of Latex. *The Journal of Biological Chemistry*, 269(12), 9278-9283.
- [13]. Hagel, J. M., Yeung, E. C. & Facchini, P. J. (2008). Got milk? The secret life of laticifers. *Trends in Plant Science*, 13(12), 631-639.
- [14]. Hartmann, T. (1991). Alkaloids. In G. A. Rosenthal & M. R. Berenbaum (Eds.), *Herbivores: Their Interactions with Secondary Plant Metabolites* (2nd ed., pp. 79-121). Academic Press.
- [15]. Hirayama, C., Konno, K., Wasano, N., & Nakamura, M. (2007). Differential effects of sugar-mimic alkaloids in mulberry latex on sugar metabolism and disaccharides of Eri and domesticated silkworms: enzymatic adaptation of *Bombyx mori* to mulberry defense. *Insect Biochemistry and Molecular Biology*, 37(12), 1348-1358.
- [16]. Itenov, K., Mølgaard, P., & Nyman, U. (1999). Diurnal fluctuations of the alkaloid concentration in latex of poppy *Papaver somniferum* due to day-night fluctuations of the latex water content. *Phytochemistry*, 52(7), 1229-1234.
- [17]. Jia, S., Li, Y., Dai, X., Li, X., Zhou, Y., Xu, Y., & Wang, H. (2020). Physiological adaptations to sugar-mimic alkaloids: Insights from *Bombyx mori* for long-term adaptation and short-term response. *Ecology and Evolution*, 10(18), 9682-9695.
- [18]. Konno, K. (2011). Plant latex and other exudates as plant defense systems: roles of various defense chemicals and proteins contained therein. *Phytochemistry*, 72(13), 1510-1530.

- [19]. Konno, K., Hirayama, C., Nakamura, M., Tateishi, K., Tamura, Y., Hattori, M., & Kohno, K. (2004). Papain protects papaya trees from herbivorous insects: role of cysteine proteases in latex. *The Plant Journal: For Cell and Molecular Biology*, 37(3), 370-378.
- [20]. Lewinsohn, T. M. (1991). The geographical distribution of plant latex. *Chemoecology*, 2(1), 64-68.
- [21]. Lynn, K. R. & Clevette-Radford, N. A. (1987). Biochemical Properties of Latices from the Euphorbiaceae. *Phytochemistry*, 26(4), 939-944.
- [22]. Metcalfe, C. R. (1967). Distribution of latex in the plant kingdom. *Economic botany*, 21(2), 115-127.
- [23]. Mishra, A. & Parida, S. (2020). Latex of Plants: Wonders of Nature for its therapeutic potentials and a valuable resource towards new drug development. *International Journal of Botany Studies*, 5(6), 334-338.
- [24]. Mooibroek, H. & Cornish, K. (2000). Alternative sources of natural rubber. *Applied Microbiology and Biotechnology*, 53(4), 355-365.
- [25]. Noack, E. A., Crea, A. E. G., & Falsone, G. (1980). Inhibition of mitochondrial oxidative phosphorylation by 4-deoxyphorbol triester, a poisonous constituent of the latex sap of *Euphorbia biglandulosa* Desf. *Toxicon*, 18(2), 165-174.
- [26]. Oppel, C. B., Dussourd, D. E., & Garimella, U. (2009). Visualizing a Plant Defense and Insect Counterploy: Alkaloid Distribution in *Lobelia* Leaves Trenched by a Plusiine Caterpillar. *Journal of Chemical Ecology*, 35(6), 625-634.
- [27]. Rasman, S., Johnson, M. D. & Agrawal, A. A. (2009). Induced responses to herbivory and jasmonate in three milkweed species. *Journal of Chemical Ecology*, 35(11), 1326-1334.
- [28]. Rees, S. B., & Harborne, J. B. (1985). The role of sesquiterpene lactones and phenolics in the chemical defense of the chicory plant. *Phytochemistry*, 24(10), 2225-2231.
- [29]. Reitsma, J. M. (1988). Forest vegetation of Gabon. *Tropenbos Technical Series*, 1(1), 5-142.
- [30]. Schmeller, T., Latz-Brüning, B., & Wink, M. (1997). Biochemical activities of berberine, palmatine and sanguinarine mediating chemical defense against microorganisms and herbivores. *Phytochemistry*, 44(2), 257-266.
- [31]. Seiber, J. N., Nelson, C. J., & Lee, S. M. (1982). Cardenolides in the latex and leaves of seven *Asclepias* species and *Calotropis procera*. *Phytochemistry*, 21(9), 2343-2348.
- [32]. Sessa, R. A., Bennett, M. H., Lewis, M. J., Mansfield, J. W., & Beale, M. H. (2000). Metabolite profiling of sesquiterpene lactones from *Lactuca* species. Major latex components are novel oxalate and sulfate conjugates of lactucin and its derivatives. *The Journal of Biological Chemistry*, 275(35), 26877-26884.
- [33]. Snook, M. E., Data, E. S., & Kays, S. J. (1994). Characterization and Quantification of Hexadecyl, Octadecyl and Eicosyl Esters of p-Coumaric Acid in the Vine and Root Latex of Sweetpotato [*Ipomoea batatas* (L.) Lam.]. *Journal of Agricultural and Food Chemistry*, 42(11), 2589-2595.
- [34]. Tomè, F., & Colombo, M. L. (1995). Distribution of alkaloids in *Chelidonium majus* and factor affecting their accumulation. *Phytochemistry*, 40(1), 37-39.
- [35]. Waldhoer, M., Bartlett, S. E., & Whistler, J. L. (2004). Opioid receptors. *Annual Review of Biochemistry*, 73(1), 953-990.
- [36]. Wasano, N., Konno, K., Nakamura, M., Hirayama, C., Hattori, M., & Tateishi, K. (2009). A unique latex protein, MLX56, defends mulberry trees from insects. *Phytochemistry*, 70(7), 880-888.
- [37]. Zhou, Y. F., & Liu, W. Z. (2010). Laticiferous canal formation in fruits of *Decaisneafargesii*: a programmed cell death process? *Protoplasma*, 248(4), 683-694.