

A Review on Application of Bioinformatics in Medicinal Plant Research

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Abstract

Plants serve as a source of medicine from historic times and more commercially important drugs are based on the origin of plants. The traditional approach in discovering plant-based drugs involves a significant amount of expenditure and time. In labor-intensive approach, more struggles were involved and hence there was a rapid development of high-throughput technologies. In the era of post genomics, generation of data was high-throughput and hence, bioinformatics plays a crucial role. In general, rational analysis is vital for drug designing and discovery. However, more attention is required to address the potential application of bioinformatics with respect to plant-based knowledge. In this chapter, a review bioinformatics studies were focused to identify the contribution in medicinal plants research. In particular, specific areas were highlighted in medicinal plant research where the potential application of methodologies in bioinformatics may result in a rapid and cost-effective lead generation towards finding remedies from plants.

Keywords: Medicinal plants; Bioinformatics; Lead generation; Drug discovery

Introduction

Plants are a valuable resource for a variety of products. Plant materials are used for many purposes including food and medicine. In case of medicine, the uses of plant-based materials were also present in ancient civilizations. There are several ancient records that provide evidence regarding use of plant sources of remedies [1,2]. The knowledge from ancient systems of plant-based remedies has also been used by the modern pharmaceutical industry. There is thus an immense potential for discovery of new drugs from plants based on the ethno-medicinal data [3,4]. About one-third of currently available drugs come from natural products that have a plant origin [5]. Even though plant-based remedies have much potential towards advancing modern medical treatments, research continues to lag behind (especially when compared to the interest in developing synthetic drugs for commercial use) [6].

This may be partly because conventional plant drug discovery methodologies can be slow and expensive [7]. Nonetheless, there may be utility to increase research in the area of medicinal plants. The available literature and resources in this area is generally scattered, which hinders the ability to readily leverage available information about medicinal plants. There are several computational approaches for analyzing the diversity of compounds. These approaches have played a significant role in computer-aided drug design [8]. The field of drug design and discovery from medicinal plant requires the application of such approaches for quicker and efficient progress so as to cope up with the continually demanding pharmaceutical needs.

Bioinformatics offers a suite of essential techniques for analyzing and interpreting huge volumes of information generated using molecular biology-based techniques. With the advancement of high-throughput

techniques, such approaches have become essential in analyzing and integrating data to infer knowledge from a whole systems point of view. To increase our understanding of cellular processes associated with plants, an in depth analysis of genomic, proteomic and metabolomic information is required. Bioinformatics approaches offer essential tools for the identification of genes and pathways that may be associated with important bioactive secondary metabolites from medicinal plants [9].

In this review the focus is on the potential applications of computational methodologies for the overall advancement of plant-based drug discovery. Different areas are explored where use of such approach can lead to valuable findings in a cost and time efficient manner. Aspects related to the integration of scattered information, analysis of molecular data, drug discovery and design, authentication and toxicology are discussed with focus on computational methods.

Bioinformatics & Plant Research

A limited number of plants have whole-genome sequence data available. To date, the majority of genomics resources for plants have come from ESTs. Transcript-level information could be valuable to molecular biology-based research relative to medicinal plants. Transcriptome data has been used to identify putative genes and networks involved in secondary metabolite production in medicinal plants [10-12]. Analysis of transcriptome data can also be helpful in predicting transcription factors, response elements and effector genes involved in bioactive metabolite synthesis [13-15]. For example, ethylene responsive element binding genes were analyzed in *Salvia miltiorrhiza* [16]. Another example is the identification of miRNAs, their targets and transcription factors involved in secondary metabolism pathways from *Salvia sclarea* L. [17]. Once EST data are generated and assembled, an essential next step is annotation. There are several resources like KEGG genes, SwissProt, TAIR, NCBI's nonredundant and nucleotide databases that provide a platform for annotation of sequence data. EST data can also be used for mining of molecular markers [18-20]. Identification of molecular markers can be used in studies involving linkage mapping, comparative genomics, identification of different species and distribution of genes on chromosomes [21-24]. Compared to other EST-based markers, Simple Sequence Repeat (SSR) markers have been shown to be most advantageous because of their multi-allelic nature, reproducibility, codominant inheritance, high abundance and extensive genome coverage [25]. SSR Locator is an example of a computational approach for detection and characterization of SSRs and mini-satellite motifs [26].

Bioinformatics approaches can be used to create coexpression networks from transcriptome data, providing possible leads to gene discovery in related plant species. In particular, the use of comparative genomics provides basis for exchange of information among the different species. Plant-specific data sets can be retrieved from PLEXdb [27], GEO [28] and EBI ArrayExpress [29]. Coupled with the study of co-expression networks, it may be possible to discover genes of interest and their function. For example, transcriptome data from barley have been collected and used to create a coexpression network [30]. Results from coexpression analyses were further used to derive subnetworks ('modules') associated with biological functions, with particular emphasis given to identifying modules related to drought stress and cellulose biosynthesis. This genome scale sequence comparisons have been shown to reveal several Triticeae species-specific genes that are related to specific regulatory networks [31].

Pathway analysis can be valuable approach for identifying potential functional roles of genes. The KEGG is a resource that provides a platform for pathway analysis of secondary metabolites from several organisms [32]. The KEGG Drug database further provides information related to two types of molecular networks: (i) interaction of drugs with target molecules and (ii) biosynthetic pathways of natural products in various organisms. KEGG Drug contains chemical structures or components of prescription and Over-The-Counter (OTC) drugs as well as drugs from TCM [33]. This information could potentially be used for drug discovery from the genomes of plants. Another resource for pathway analysis of secondary metabolites indexed in KEGG is PathPred [34]. PathPred is web server that predicts pathways of multi-step reaction for a given query compound, starting with a similarity search against the KEGG COMPOUND database. This server was designed for pathways associated with microbial biodegradation of environmental compounds and biosynthesis of secondary plant metabolites. Nonetheless, PathPred reflects generalized reactions shared among structurally related compounds.

With a myriad of advances in 'omic' technologies, bioinformatics plays essential role in facilitating systems level understanding of metabolic processes. Integration of transcriptomic and metabolomic data facilitated by data mining techniques offers many opportunities to study metabolic pathways [35]. Expression patterns of intensities of ESTs and mass peaks classified by batch-learning self-organizing maps revealed regulatory linkages among nutrient deficiency, primary metabolism and glucosinolate metabolism [36]. Gene-metabolite coexpression analysis led to identification of terpene synthase genes involved in volatile compound formation in cucumber [37].

Rischer, et al. [38] analyzed a gene-metabolite coexpression network of the medicinal plant *Catharanthus roseus* to identify possible genes and metabolites associated with the biosynthesis of terpenoid indole alkaloids. Integrated gene-metabolite expression analyses have thus shown potential for examining metabolic regulation of nonmodel plants of potential medicinal value.

Bioinformatics provides essential mechanisms to analyze bulk information generated from high throughput techniques. In particular, such approaches have made it possible for the identification of putative genes, pathways and networks involved in synthesis of bioactive metabolites in medicinal plants. In addition to facilitating the analysis of high-throughput data, bioinformatics approaches can be important for connecting scattered pieces of evidence into meaningful hypotheses thereby generating potential leads for experimental validation.

Conclusion

Plants can be a valuable source of pharmacologically important compounds. Bioinformatics approaches may provide an essential set of tools for designing efficient and targeted searches for plant-based remedies. This review highlighted the different aspects associated with medicinal plant research where bioinformatics strategies could be employed to attain significant progress. The combination of bioinformatics strategies may enable a new era of plant-based drug discovery.

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