



# Adaptogenic Herbs in Ayurvedic Medicine: Pharmacognostic Insights and Clinical Potential

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## ABSTRACT

Adaptogens are a special type of medicinal plant used to treat the effects of stress and stimulate the body to respond to stress better. In Ayurveda, herbal rasayana drugs include *Withania somnifera* (Ashwagandha), *Ocimum sanctum* (Tulsi), *Tinospora cordifolia* (Guduchi), and *Glycyrrhiza glabra* (Yashtimadhu), thus these drugs are thought to have rejuvenative effects. This review presents a summary of the pharmacognostic details and preclinical (animal) evidence of these herbs with focus on morphological, microscopic and phytochemical characteristics and the stress modulating effects of these herbs. In animals, there is a consistent effect demonstrating that these adaptogens normalize the hypothalamic-pituitary-adrenal axis, recover antioxidant defenses, lower corticosterone and other markers of oxidative stress, and enhance behavioral and immunological resistance. The data confirm conventional assertions and note their neuroprotective, immunomodulatory and anti-stressive effects. Nonetheless, loopholes exist as far as the aspect of standardization, dose optimization, adverse effects in the long term, and mechanism of action of phytoconstituents are concerned. In conclusion, this review highlights the potential therapeutic value of Ayurvedic adaptogens as natural, clinically safe therapeutic agents, and demands rigorous and mechanistic research to incorporate them into evidence-based medicine.

## Key Words:

Adaptogens, Ayurveda, Pharmacognosy, *Withania Somnifera*, *Ocimum Sanctum*, *Tinospora Cordifolia*, *Glycyrrhiza Glabra*, Immunomodulation, Animal Models

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## 1. INTRODUCTION

The class of medicinal plants called adaptogens have been drawing considerable interest in both traditional and modern medicine due to the ability of the plants to improve the body to resist stress and maintain homeostasis<sup>1</sup>. These herbs are considered as a variety of medical treatments classified as rasayana in Ayurveda, which are rejuvenative therapies to ensure longevity, vitality, and disease resistance. Classical Ayurveda recommends a number of herbs, including *Withania somnifera* (Ashwagandha), *Ocimum sanctum* (Tulsi), *Tinospora cordifolia* (Guduchi) and *Glycyrrhiza glabra* (Yashtimadhu) which are said to be essential to enhance the body defenses and

balance body-mind<sup>2</sup>. The recent scientific understanding of adaptogens, which came about in the middle of the 20th century, corresponds well to these early ideas, providing a platform through which the convergence between historic knowledge and modern pharmacology on the topic of stress-related health issues may be discussed<sup>3</sup>.

### 1.1. Background information and context

Ayurveda (ancient Indian system of medicine) has placed particular importance on the use of certain natural herbs that help to enhance vitality, aid in stress response, and thus support good health<sup>4</sup>. The herbs are subset of rasayana herbs described in classical Ayurveda and are similar to modern concepts of adaptogen, natural products that have been found to either increase the body natural ability to adapt to stressors, or increase non-specific biological resistance. The modern concept of an adaptogen bears some similarity to the Ayurvedic concept, as the definition of this term was codified in the middle of the 20th-century<sup>5</sup>. The best-researched Ayurvedic adaptogens include *Withania somnifera* (*Ashwagandha*) and *Ocimum sanctum* (*Tulsi*), *Tinospora cordifolia* (*Guduchi*), and *Glycyrrhiza glabra* (*Yashtimadhu*). Preclinical and pharmacognostic data demonstrate that these herbs have multifaceted effects with antioxidant, immune modulatory and regulation of the hypothalamic-pituitary-adrenal (HPA) axis which provide scientific confirmation to the traditional uses.

### 1.2. Objectives of the review

- To provide an updated overview of major Ayurvedic adaptogens, with emphasis on their pharmacognostic characteristics.
- To synthesize preclinical evidence supporting their adaptogenic and stress-modulating potential.
- To critically evaluate the strengths, limitations, and research gaps in current findings.
- To highlight directions for future studies that could bridge traditional knowledge with modern clinical applications.

### 1.3. Importance of the topic

As stress related disorders have turned into a worldwide healthcare problem, the need to find secure, herbal and successful treatment options is increasing. The existing options to improve resilience and neuroprotective systems include Ayurvedic adaptogens that provide a good chance to combine classic knowledge with the latest knowledge in pharmacology and benefit a comprehensive approach to resilience, neuroprotection, and general health<sup>6</sup>. They guarantee authenticity and standardization because of their knowledge on their pharmacognostic properties, and preclinical studies provide scientific background of its therapeutic properties. Besides confirming traditional claims made, this review also underlines that serious study efforts are needed to streamline their application in evidence-based medicine<sup>7</sup>.

## 2. PHARMACOGNOSTIC INSIGHTS INTO ADAPTOGENIC HERBS

Pharmacognostic profiling is the foundation of any herbal research primarily because it leads to the right identification, authentication and quality control of crude drugs. Ayurveda has

traditionally placed a strong emphasis on careful identification of medicinal herbs in order to achieve their therapeutic value, a principle which may have much applicability in pharmacognosy today. Adaptogenic herbs in particular are well-known in terms of their morphological, anatomical, and phytochemical characteristics, which are helpful in authentications of plant materials<sup>8</sup>, in addition to avoiding wilful fraud of adulteration and misidentification, a phenomenon prevalent in the herbal drug market. Setting pharmacognostic standards is thus something important in a bid to restore reproducibility in a clinical effect, consistency in a given formulation and protecting the consumer. The following subsections describe some of the well-studied Ayurvedic adaptogens with information on their key diagnostic characteristics, main phyto compounds, and how these compounds contribute to the adaptogenic effect.

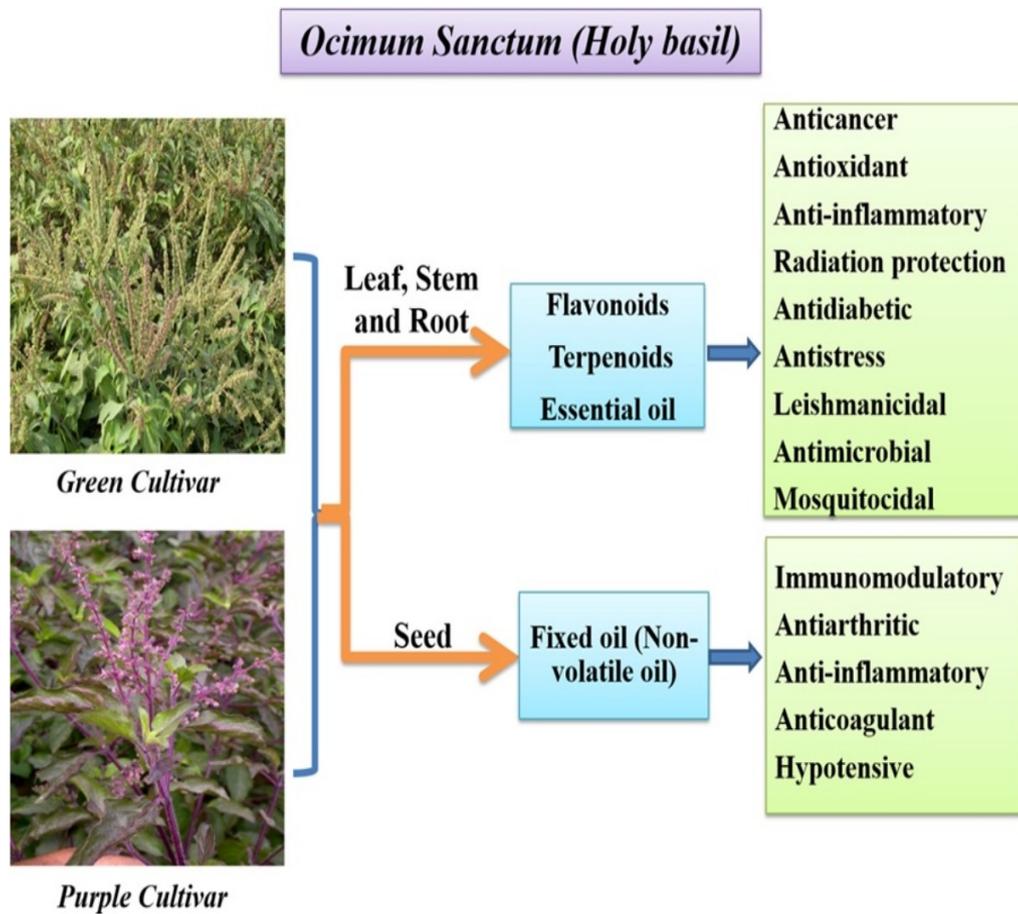
### 1) Ashwagandha (*Withania somnifera*)

Ashwagandha (also known as Indian ginseng) is one of the most widely appreciated rasayana herbs of Ayurveda. Ashwagandha, as the main medicinal mother (Ayurvedic) part, has roots that are stout, tuberous, and yellowish-brown in color with a characteristic smell of a horse due to which it was named so (i.e., Ashwagandha). Microscopically there are good clear starch grains, simple fibers, and numerous parenchymatous cells, which helps to differentiate it with possible adulterants<sup>9</sup>.

Biochemically, Ashwagandha also contains withanolides, a group of steroidal lactones like withaferin A and withanolide D, which are well-known to possess their systems of potent anti-stress and neuroprotective properties. Further substances such as alkaloids (somniferine, withanine) and saponins increase its pharmacologic profile. These constituents have an inter-related effect by turning down the hypothalamic-pituitary-adrenal axis (HPA), improving oxidative balance and enhancing cognitive resilience when subjected to stress. Therefore, Ashwagandha would be a good drug model of how the pharmacognostic and phytochemical data directly relates to the adaptogenic activity.

### 2) Tulsi (*Ocimum sanctum*)

Tulsi or otherwise known as Holy Basil is of great cultural and medical significance in Indian homes and is considered to be synonymous with spirituality and wellness. One can recognize the plant easily because of its green or purplish leaves on opposite phyllotaxy and because it lends a strong aromatic fragrance (because of its high content of essential oils). Under a microscope, Tulsi leaves can be characterized by the presence of glandular trichomes, cells of the epidermis around which their margins are driven, and oil globules, which can be used as good indicators of pharmacognostic authenticity.



**Figure 1:** Pharmacognostic usage of Tulsi (*Ocimum sanctum*)<sup>10</sup>

The main phytoconstituents are essential oils eugenol and carvacrol, triterpenes e.g. ursolic acid and flavonoids e.g. apigenin, luteolin. These are some of the attributes behind Tulsi to be an antioxidant, an immuno-modulator, a well-known recuperative agent and anti-stress compound. It is notable that Tulsi has the potential to balance cortisol, reduce oxidative harm, and improve immunity, hence the direct connection of its phytoconstituents to becoming stress-resistant.

### 3) Guduchi (*Tinospora cordifolia*)

Guduchi or Amrita (Nectar) is a climbing shrub in which use is gained by using its stem and aerial roots. Morphologically, the corky warts on its sucker-like stems of green color are its prominent characteristics. A microscopic view of the cortex shows even well-formed cortex with plenty of starch grains and mucilage, which facilitates correct identification<sup>11</sup>.

Phytochemically, Guduchi has diterpenoid lactones (tinosporin, cordifolide), alkaloids (such as magnoflorine) and glycosides, as well as polysaccharides. This trio of compounds are what underpin its immuno-adaptogenic and anti-inflammatory potential. Notably, Guduchi up-regulates innate and adaptive immunity, down-regulates inflammatory cytokines, and boosts oxidative defense, thus boosting the systemic resilience to stress. It has an adaptogenic value as it

concurrently plays the roles of both immune modulator and stress resistor, which lends it much significance in adaptogenic research.



Figure 2: Diverse Properties of Guduchi (*Tinospora cordifolia*)<sup>12</sup>

4) Yashtimadhu (*Glycyrrhiza glabra*)

Yashtimadhu -the licorice- is a perennial herb and its sweet root has long cylindrical fibrous roots, highly valued. Macroscopically, the roots can be differenced on account of their sweet taste, whereas microscopically, the roots contain thick cork layer, lignified fiber, and starch- rich parenchyma. These characteristics not only make them genuine, but these characteristics also correlate to pharmacological effects of the plants.

The main active ingredient is glycyrrhizin, a triterpenoid saponin which gives licorice its typical sweetness and explains its therapeutic effects. There are other flavonoids (liquiritin, isoliquiritigenin) and a coumarin, which enhance its pharmacological potential. The combination of its constituents results in neuroprotective, antioxidant and anti-inflammatory effects which makes Yashtimadhu an important adaptogen with ability to help against gastrointestinal as well as against stress adaptation.

Table 1: Pharmacognostic Features and Phytoconstituents of Major Ayurvedic Adaptogens<sup>13</sup>

Herb (Botanical Name)	Morphological Features	Microscopic Features	Major Phytoconstituents	Adaptogenic Relevance
Ashwagandha ( <i>Withania somnifera</i> )	Thick, tuberous, yellowish-brown roots with characteristic odor	Starch grains, fibers, parenchyma	Withanolides (withaferin A, withanolide D), alkaloids (somniaferine, withanine), saponins	Anti-stress, neuroprotective, rejuvenating
Tulsi ( <i>Ocimum sanctum</i> )	Green/purple aromatic leaves, opposite phyllotaxy	Glandular trichomes, oil globules	Essential oils (eugenol, carvacrol), ursolic acid, flavonoids (apigenin, luteolin)	Antioxidant, immunomodulatory, anti-stress
Guduchi ( <i>Tinospora cordifolia</i> )	Succulent green stems with aerial roots and corky warts	Cortex with starch grains, mucilage	Diterpenoid lactones (tinosporin, cordifolide), alkaloids (magnoflorine), polysaccharides	Immuno-adaptogenic, anti-inflammatory, stress-relieving

<b>Yashtimadhu</b> ( <i>Glycyrrhiza glabra</i> )	Long, cylindrical, fibrous, sweet-tasting roots	Thick cork, lignified fibers, starch-rich parenchyma	Glycyrrhizin, flavonoids (liquiritin), coumarins	Neuroprotective, antioxidant, anti-inflammatory
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Experts on pharmacognosy give the first scientific allowance of Ayurvedic adaptogens on being tested as true, high-quality and consistent herbal products<sup>14</sup>. The examples presented of these herbs demonstrate how customary knowledge with links to morphology, microscopy, phytochemical constituent, and their pharmacological consequences could be integrated into maintenance of modern-day drug discovery and treatment responses. The information provided in Table 1 shows how their pharmacognostic properties and phytochemical compounds are directly applicable to the adaptogenic potential they have making their claims as evidence-based herbal products even more credible in their use as interventions to complement the treatment of stress-related disorders.

### 3. PRECLINICAL EVIDENCE FROM ANIMAL MODELS

Target-based research Clues about the Ayurvedic herbs adaptogenic properties are found in animal models. In contrast to human trials, animal models can enable stress to be induced, given precise measures of biochemical measurers, and observing at the level of the organ's pathology<sup>15</sup>. The adaptogenicity of the plants is normally determined with help of such stresses as immobilization or cold-restraint or forced beats, visitor shock or foot-shock stress, or chronic irregular stress fields. Such models simulate real-life physical, chemical, and psychological stressors, thus being valid in the test of anti-stress agents. The highlights of the main Ayurvedic adaptogens are mentioned below.

#### → Ashwagandha (*Withania somnifera*)

Ashwagandha is the most studied herbal product on anti-stress and anxiolytic effects. In immobilization and cold-constriction stress tests, the supplementation of Ashwagandha root extract lowered serum corticosterone levels to signify the suppression of hypothalamic-pituitary-adrenal (HPA) axis activation. Treated rodents exhibited enhanced endurance and decreased fatigue during forced swim and treadmill experiments and increased physical resilience<sup>16</sup>.

Biochemical analyses revealed the normalization of the antioxidant defense system including superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx), whereas the degree of lipid peroxidation was decreased (MDA levels). General protection against stress-induced utilization of adrenal and gastric ulceration was also evidenced by histopathological studies. A combination of these data points to the conclusion that Ashwagandha functions by means of neuroendocrine modulation and reduction of oxidative stress.

#### → Tulsi (*Ocimum sanctum*)

Preclinical bath studies have reported a consistent anti-stress, antioxidant, and adaptogenective effect of Tulsi. Tulsi extracts have been found to normalize hypertrophy of adrenal glands and involution of thymus in stressed rodents that are typical reactions to prolonged stress. Moreover,

the animals treated with Tulsi presented a reduction in the level of plasma cortisol, blood glucose, and cholesterol, thus portraying adaptation to systemic stress.

On the bio-chemical ground, Tulsi lowered oxidative stress levels, and replaced antioxidant enzyme activities as well as alleviated DNA injury in chronically stress animals. Behavioral tests also indicated decreased anxiety-like behavior i.e. open-field and elevated plus maze. These findings substantiate the role of Tulsi as adaptogen on physiological and psychological functioning<sup>17</sup>.

→ **Guduchi (*Tinospora cordifolia*)**

Guduchi has also shown considerable immuno-adaptogenic properties in experimental studies in animals. In stress-induced conditions, Guduchi extracts have potentiated both the humoral and cell-mediated immunity, as seen by elevated antibody response and boosted lymphocyte proliferation. It also regulated cytokine production, especially downregulating pro-inflammatory cytokines (TNF-alpha, IL-6) and upregulating the anti-inflammatory cytokines (IL-10)<sup>18</sup>.

Biochemical tests were indicative of the fact that by using Guduchi the antioxidant defense was increased with enhancement of SOD, catalase and glutathione levels. It also enhanced the functioning of mitochondrion in hepatic and neural tissues in a situation of chronic stress. These effects indicate the dual adaptogenic effect of Guduchi, resistance to stress due to regulation of the HPA axis and modulation of the immune system.

→ **Yashtimadhu (*Glycyrrhiza glabra*)**

Yashtimadhu animal studies have demonstrated these to be neuroprotective and adaptogenic. In experimental models of stress induced by in rodents, licorice root extracts reduced lipid peroxidation and corrected antioxidant enzyme levels in the brain and liver tissues. Neurobehavioral assessments indicate improved memory retention and decreased anxiety indicating safeguards against cognitive degeneration in times of stress.



**Figure 3:** Yashtimadhu (*Glycyrrhiza glabra*)<sup>19</sup>

Phytoconstituent glycyrrhizin is extremely important to reduce oxidative stress, enhance cell membranes stability, and regulate corticosteroid. In addition, animals treated with Yashtimadhu showed decreased adrenal hypertrophy, restored gastric mucosal integrity and also restored stress-induced hyperglycemia.

These observations identify Yashtimadhu as a potent adaptogen with an emphasis on neuroendocrine and gastrointestinal defence.

### **Methodological Approaches in Animal Studies**

To support the adaptogenic nature of these herbs research workers have adopted a variety of experimental methods which include:

- **Acute acute stress paradigms:** Including the cold-restraint, foot-shock, and forced swim procedures, to determine short-term anti-stress responses<sup>20</sup>.
- **Chronic stress paradigms:** The models of chronic unpredictable mild stress (CUMS) were used to simulate the chronic context of human stress.
- **Behavioral assessments:** Such as, open field test, elevated plus maze and forced swim test to evaluate anxiety, depression and endurance.
- **Biochemical measurements:** Measurement of oxidative stress (MDA, etc.), antioxidants (SOD, CAT, GPx), neuroendocrine (corticosterone, ACTH), and immune cells (cytokines, lymphocyte counts).
- **Histopathological analysis:** Analysis of organ-level alteration (hypertrophy of adrenal, ulceration of the gastric and neural tissue damage).

These methodologies would provide a three-dimensional confirmation of the adaptogenic properties via the connection of behavioral resiliency and biochemical as well as morphological adaptations in the stressed animals.

Significantly, the validity of these methods is bolstered by the inputs of the recent literature, which combines pharmacognostics authentication, phytochemical profiling and preclinical tests. The key findings of the selected studies, focusing on similarities or differences in terms of methodology and their implications as far as the preclinical adaptogen research is concerned, are listed in Table-2.

**Table 2:** Reference Table

Author's	Focus of Study	Method	Key Findings	Relevance to Preclinical Evidence
Parganiha (2025) <sup>21</sup>	Comparative pharmacognostic and phytochemical appraisal of <i>Withania somnifera</i> , <i>Plumbago zeylanica</i> , and <i>Asparagus racemosus</i> .	Pharmacognostic evaluation (microscopy, morphology), phytochemical screening (TLC/HPTLC, spectroscopy).	Identified diagnostic features of roots and phytoconstituents (withanolides, plumbagin, shatavarins).	Supports pharmacognostic standardization and provides chemical basis for adaptogenic and immunomodulatory studies in animals.

<b>Sadhu et al. (2025)<sup>22</sup></b>	Introduction to molecular pharmacognosy using genomics, metabolomics, and molecular pharmacology.	Integrative molecular techniques (genomic markers, metabolite profiling, molecular docking).	Linked phytoconstituents with receptor-level activity and stress-related signaling pathways.	Validates adaptogen activity mechanistically in animal models, strengthening translational value.
<b>Gond et al. (2025)<sup>23</sup></b>	Review of phytochemical and pharmacological profiles of Ashwagandha, Giloy, turmeric, and neem.	Literature-based review of chromatography, spectroscopy, and pharmacological animal studies.	Confirmed antioxidant, immunomodulatory, and neuroprotective properties of key herbs.	Ensures reproducibility in preclinical stress models; bridges phytochemistry and adaptogenic outcomes.
<b>Dipankar et al. (2025)<sup>24</sup></b>	Detailed review on Ashwagandha's immunomodulatory, neuroprotective, and adaptogenic effects.	Compilation of in vivo (animal) and early clinical trial data.	Demonstrated Ashwagandha's role in HPA-axis regulation, oxidative stress reduction, and improved cognition under stress.	Reinforces preclinical findings with clinical extrapolation, highlighting translational relevance.
<b>Panossian et al. (2021)<sup>25</sup></b>	Broad review on adaptogens in TMS and modern pharmacology.	Systematic review of pharmacological, biochemical, and neuroendocrine studies.	Explained biphasic dose-response of adaptogens, modulation of stress mediators (e.g., cortisol, NO).	Provides mechanistic framework for interpreting animal data within holistic stress-response models.
<b>Balkrishna et al. (2024)<sup>26</sup></b>	Exploration of Ayurveda's Doctrine of Signatures in relation to plant selection.	Ethnopharmacological and conceptual analysis of traditional texts correlated with experimental reports.	Suggested rationale for why herbs like Ashwagandha and Tulsi are linked with stress-resistance.	Contextualizes preclinical work by connecting Ayurveda's traditional logic with modern findings.

#### 4. CRITICAL EVALUATION OF STRENGTHS AND WEAKNESSES

The corpus of preclinical data on Ayurvedic adaptogens presents a useful foundation concerning their potentially pharmacological efficacy, but also indicates methodological and translational pitfalls. Critical appraisal of the existing literature reveals a number of strengths which could give greater merit to the report, as well as weaknesses presuming to the restricted generalization in practice. Such appraisal is vital in determination of reliability of new data and where additional research is needed. The strengths and the weaknesses are summarized in Table 3 and discussed in details below.

##### ❖ Experimental Design

A great advantage of preclinical research is that stress-induction methods in animal models are highly reproducible, and hence results regarding adaptogenic activity can be consistent across laboratories. Colds and cold restrained stress, immobilization stress, and chronic unpredictable mild stress models are some of the models deployed in controlled study of biochemical, behavioral, and of physiological response. These models have proved to be consistent in showing the stress-protecting capacity of Ayurvedic adoptogens<sup>27</sup>.

Nevertheless, the absence of standard experimental procedures can be also observed as a rather serious drawback. The difference in animal species, stress paradigms, dosage forms and extraction methods between different studies pose challenges to draws to comparisons between the results. Such a heterogeneity poses a challenge to reproducibility and compromises the chance of meta-analysis or system reviews that would underlie clinical translation into understandings and practices.

##### ❖ Pharmacognostic Reliability

The other strength is that authenticated raw drugs are used with pharmacognostic and phytochemical profiling, a unique point that guarantees the right bioactive constituents and the right natural plant material is under testing<sup>28</sup>. This measure increases reproducibility and precludes misidentification or adulteration of the herbs, which plague herbal research.

However, there is scarce research on correlating particular phytoconstituent to their adaptogenic effects. Such compounds as withanolides (Ashwagandha), glycyrrhizin (Yashtimadhu) have been cited but most are based only on crude extracts and not on the isolation of effectiveness of the parts and characterization of individual bioactive molecules. This discrepancy makes is hard to figure out whether adaptogenic effect is attributable to individual compounds, synergy or the complete extract.

##### ❖ Observed Outcomes

In several preclinical trials, the results are largely coherent, as levels of antioxidant defense improve, stress hormones diminish, and endurance both physically and mentally improves. These findings demonstrate great strength to the adaptogenic properties of Ayurvedic herbs and justify the traditional categorization of the Ayurveda remedies as rasayana.

A majority of the reported research is short-term and therefore may shed little light on longer-term effects<sup>29</sup>. There have been limited studies examining chronic effects, safety, or toxicity of long-term use, which is especially pertinent considering adaptogens are commonly used chronically as traditional medicine. Such lack of longitudinal data limits the possibility to initiate the full evaluation of their therapeutic potential in chronic stress, or lifestyle-related disorders.

❖ **Relevance for Future Research**

The available evidence establishes a solid foundation of mechanics concerning adaptogens that relate to their effect on the HPA axis, control of oxidative stress, and in stimulating immune response. These observations pave the way towards working out of standardized formulations and finding out new leads in drugs which may be present in phytoconstituents.

However, lacking dose-response studies, thresholds of toxicity, and explorations of multi-systemic interactions are a major shortcoming. In the absence of these data it becomes difficult to determine safe therapeutic levels, to predict adverse effects, or to have drugs approved by regulatory bodies to be used in a clinical setting. What is more, there is very little research investigating the possibility of a herb-drug interaction that should be considered since adaptogens are frequently used concomitantly with conventional medications.

**Table 3:** Summary of Strengths and Weaknesses in Preclinical Studies on Ayurvedic Adaptogens<sup>30</sup>

Aspect	Strengths	Weaknesses
<b>Experimental Design</b>	Stress induction in animals is reproducible and controlled, minimizing variability.	Lack of standardized models across studies leads to difficulty in comparison and reproducibility.
<b>Pharmacognostic Reliability</b>	Use of authenticated raw drugs with phytochemical profiling ensures accuracy and reproducibility.	Limited efforts to link individual phytoconstituents to their adaptogenic roles.
<b>Observed Outcomes</b>	Consistent results across models: improved antioxidant defense, reduced stress hormones, better endurance.	Many studies emphasize short-term outcomes without exploring chronic administration or long-term safety.
<b>Relevance for Future Research</b>	Provides a strong baseline for mechanistic understanding and development of herbal formulations.	Insufficient data on dose-response relationships, toxicity thresholds, and multi-systemic interactions.

In summary, in spite of all the convincing evidence that Ayurvedic adaptogens have the beneficial effect of the body under stressful stimulus, as well as modulatory effects on the immune system, in order to be translated into the clinic, stronger and consistent methods are needed. Further studies

must be centered on the harmonization of methods, constituent-specific studies and long-term safety studies. The combination of the above weaknesses will not only improve the evidence base, but also lead to the integration of Ayurvedic adaptogens into evidence based modern medicine.

## 5. DISCUSSION

The results of this review suggest that Ayurvedic herbs have multiple adaptogenic effects and this will bring a unification between traditional therapeutic declarations and contemporary scientific confirmation<sup>31</sup>. Based on the pharmacognostic markers, the phytochemical composition, and animal-based data, the study highlights their effect on stress control in terms of biochemical (at the cellular level), neuroendocrine, and immunological functions. Notably, the convergence of convergent preclinical data with a centuries-old Ayurvedic tradition of rasayana supports their applications as broadly-acting, resilience-enhancing and health-preserving agents. This section elucidates on the body of evidence reviewed, its implications on overall understanding as well as the research gaps that remain to be closed in order to translate to effective clinical and therapeutic models.

### 5.1. Interpretation of Findings

The animal study findings in this review reveal that Ayurvedic adaptogens, especially *Withania somnifera* (Ashwagandha), *Ocimum sanctum* (Tulsi), *Tinospora cordifolia* (Guduchi)<sup>32</sup>, and *Glycyrrhiza glabra* (Yashtimadhu), have a coherent ability to promote anti-stress and immunomodulating impacts in preclinical studies. They exert their effects by a variety of mechanisms: modulation of the hypothalamic-pituitary-adrenal (HPA) axis, inhibition of oxidative stress, restoration of antioxidant enzymes and modulation of immune parameters<sup>33</sup>. Authenticity and identification of bioactive phytoconstituents (withanolides, eugenol, diterpenoid lactones, and glycyrrhizin) are guaranteed as a result of pharmacognostic profiling since it is applicable to any bioactive phytoconstituent.

Internal stress in stress paradigms, these herbs reduce biochemical stress markers such as corticosterone and malondialdehyde (MDA), correct organ-level pathology (hypertrophy of the adrenals, gastric ulceration), and improve behavioral outcomes including decreased anxiety-like behaviors, and increased endurance<sup>34</sup>. These results confirm Ayurvedic assertions of their rasayana (rejuvenative) effects as well as their pan-adaptogenic potential.

### 5.2. Significance and Implications

Incorporation of conventional ayurvedic knowledge with contemporary pharmacological efficacy indicates potential of the adaptogenic herbs in the stress related conditions, neurodegeneration and immune disorders. These herbs present a simple, whole plant approach and therapeutic alternative to health problems in an age where chronic stress is taking a psychological and physiological toll in the population, including metabolic, cardiovascular, and mental health indicators<sup>35</sup>.

Pharmacognostic standardization can extend to drugs discovery and formulation of herbs. True identification and chemical fingerprints minimize adulteration, increase consistency of results, and breakpoints to control quality<sup>36</sup>. As well, there is evidence in the form of animal studies that add

to the evidence base that is necessary to win regulatory approval and subsequent clinical translation.

In addition to personal well-being, the consumption of adaptogens fits the trends of integrative medicine and sustainable healthcare across the globe. They can also be substituted by their integration into preventive health approaches, especially in resource-poor environments. Besides, adaptogens constitute prospects of novel pharmacological agents with multiple-acting actions, which can be considered especially valuable in the management of complex disorders such as chronic stress and age-related decay<sup>37</sup>.

### 5.3. Research Gaps and Future Directions

- Although the results of these studies are rather encouraging, there are still gaps in translational value of the existing studies. First is methodological heterogeneity, which remains a problem in preclinical studies, as experimental animal species, stress paradigms, dosages, and extraction methods vary. This involves standardized protocols being fundamental in the development of a sound evidence base<sup>38</sup>.
- Second, dose-response relationships are poorly studied as well as chronic toxicity tests. Though safe in the short term, long-term potential risks with morning glory and hepatic-stress or endocrine imbalance may be a risk. Extensive toxicological evaluations have to be done to determine safe effect dose ranges.
- Third: phytoconstituent- activity correlation is limited. Even with the assumed mechanisms of action as those of withanolides and glycyrrhizin, there is a paucity of studies isolating these to establish their independent or synergetic actions<sup>39</sup>. The final evaluation should employ advanced technologies like metabolomics, systems pharmacology, etc. to elucidate mechanisms.
- Lastly, future studies must take their methodology in the direction of systems biology where genomics, proteomics, and metabolomics work in combination to outline the overall effects of adaptogens on the mechanism of stress response. Herb-herb interactions should also be explored as practiced in Ayurveda since we may be missing synergistic effects with individual herb studies<sup>40</sup>.

## 6. CONCLUSION

This review indicates that Ayurvedic stress-modulator herbs, which include *Withania somnifera* (Ashwagandha), *Ocimum sanctum* (Tulsi), *Tinospora cordifolia* (Guduchi), *Glycyrrhiza glabra* (Yashtimadhu), have a potent therapeutic effect due to their strong pharmacological support based on their pharmacognostic characterization and preclinical animal research. Their capacities to normalize the HPA axis, replenish the antioxidant stores, stimulate immune responses and the preventive roles against biochemical and morphological changes induced by stress are valid key findings. The implication of this study is that it can bridge the gap between ancient Ayurvedic medicine and modern pharmacology by proving that these herbs do indeed live up to the historical expectation of being rasayana but also have future potential to be added to integrative, preventive medicine. Nonetheless, there are issues of standardization of methods, optimization of dose and clarity of mechanisms. Research ought to concentrate on standardized research, constituent-specific research, and long-term safety analysis in the future to promote successful transformation

to evidence-based therapeutic use. Cumulatively, plant adaptogens of the Ayurvedic tradition appear promising natural, safe and sustainable substances with the potential of playing great roles in facilitating solutions to present stress-related health-related challenges.

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