International Advance Journal of Engineering, Science and Management (IAJESM)
Multidisciplinary, Indexed, Double Blind, Open Access, Peer-Reviewed, Refereed-International Journal.
SJIF Impact Factor =7.938, January-June 2024, Submitted in January 2024, ISSN -2393-8048

Seasonal Variability and Its Impact on The Bioactive Compounds of Medicinal Plants Across Diverse Agro-Climatic Zones in India

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Abstract

This study looks at how seasonal changes affect the bioactive components in four medicinal plants that are crucial for health: Ocimum sanctum, Azadirachta indica, Withania somnifera, and Phyllanthus emblica. The plants are grown in different agro-climatic zones in India. In the summer, monsoon, and winter, plant samples were taken from the Himalayan, Tropical Wet, Arid, and Coastal zones. Standard lab procedures were used to measure important phytochemical components such phenolics, alkaloids, flavonoids, terpenoids, and antioxidant activity. The examination of the data showed that the concentrations of bioactive compounds varied greatly by season and area. In general, winter had greater levels of phenolic and alkaloid compounds, whereas monsoon and summer had higher levels of flavonoids and terpenoids. These results show how important environmental conditions are in changing phytochemical profiles and how important it is to choose the best time and place to harvest plants for better therapeutic effects.

Keywords - Seasonal variability, bioactive compounds, medicinal plants, agro-climatic zones, phenolics, alkaloids, flavonoids, terpenoids, antioxidant activity, India, phytochemical variation.

1. INTRODUCTION

Medicinal plants have been a key aspect of traditional medicine for hundreds of years. In India, for example, Ayurveda, Siddha, and Unani therapies still use plant-based bioactive substances for healing. Alkaloids, flavonoids, phenolics, terpenoids, and glycosides are examples of bioactive chemicals that are very important for the therapeutic properties of plants. But the amount and makeup of these phytochemicals aren't always the same; they alter based on a number of environmental and ecological variables, including as changes in the seasons and agro-climatic conditions.

India's large and diverse geographical geography, which includes deserts, tropical rainforests, temperate highlands, and coastal plains, is divided into several agro-climatic zones. Each of these zones has its own set of climatic factors, such temperature, rainfall, humidity, soil type, and altitude. These factors can have a big impact on the metabolic pathways of medicinal plants, which in turn affects how they make their bioactive compounds. Seasonal changes in climate, such monsoon, summer, and winter, also affect plant physiology and the synthesis of secondary metabolites.

1.1 Background of the Study

The phytochemicals in these plants, such as alkaloids, saponins, tannins, terpenoids, and flavonoids, are what make them so useful in medicine. These compounds not only have a wide range of biological effects, but they also serve as lead molecules for the creation of new drugs. But the production of these secondary metabolites is very susceptible to changes in the environment. Changes in temperature, sunshine hours, rainfall, and humidity over the seasons have a direct effect on plant metabolic activities. This changes the concentration and effectiveness of bioactive chemicals. India's many agro-climatic zones, which include the Himalayas, the coastal belts, and the dry deserts, also have different environmental circumstances that affect how phytochemicals are expressed.

There have been a lot of research on the pharmacological effects of medicinal plants, but not many have looked at how their bioactive chemical composition changes across time and space. To guide sustainable harvesting techniques, improve quality control, and make sure that herbal medicine always works, we need to have a comprehensive understanding of how seasons and climate zones interact to change phytochemical profiles.

1.2 Objectives of the Study

The main purpose of this study is to find out how variations in the seasons affect the bioactive chemicals in medicinal plants in different agro-climatic zones in India. The precise goals are

as follows:

1. To find and choose important medicinal plants that are often used in traditional medicine and grown or found naturally in different agro-climatic zones of India.
2. To look into how the concentration and makeup of important bioactive components (such alkaloids, flavonoids, phenolics, and terpenoids) in these medicinal plants change with the seasons.
3. To look at the phytochemical profiles of the chosen plants in different agro-climatic zones and at different times of year (summer, monsoon, and winter).
4. To see if there is a link between environmental factors (such temperature, rainfall, humidity, and soil type) and the amounts of bioactive chemicals.
5. To suggest the best times and places to harvest each plant species to get the most health benefits and money.

2. LITERATURE REVIEW

Misra, T. K. (2017) Conducted the study was place from 2006 to 2010 on ten different kinds of tea (Camellia sinensis (L.) O. Kuntze), including TV1, TV20, TV26, TV29, TV30, and Dangri Manipuri, in tea farms in the Terai, Dooars, and Darjeeling hills of North Bengal. We tested commercial standard plucked tea leaves to see how much antioxidant activity they had and what other phytochemicals they contained. We utilised DPPH to find out how well bud+leaf (B+L), bud+two leaves (B+2L), bud+three leaves (B+3L), and mature leaves (L) could protect against free radicals. After that, normal procedures were used to figure out the total phenolics, f1avonols, and hydrolysable tannins. The findings demonstrated that the ability to scavenge free radicals and the chemical makeup of the leaves change a lot depending on the growth conditions and the age of the leaves.

Umar et al (2017) used Fourier Transform Infrared (FTIR) Spectroscopy to look at the variety of crude aqueous extracts from different states in India that had distinct climates. We employed the scavenging test, metal chelating assay, hydrogen peroxide scavenging assay, reducing power assay, and β-carotene-linoleic assay to see how well Aloe Vera aqueous leaf extracts could fight free radicals. The analysis in this study demonstrated that different Aloe Vera samples had distinct phytoconstituents. All of the antioxidant tests showed that samples from the Highland and Semi-arid zones had more antioxidants than samples from the Tropical zone. We may say that varied agro-climatic circumstances affect the variety and antioxidant power of the Aloe Vera plant. This study showed that Aloe Vera plants planted in Northern India had more than those grown in Southern India. The study also found that plants make more phytochemicals when they are under these settings. Aloe Vera could be able to make new chemicals.

Babu (2010) conducted an in-depth study on the health and livelihoods associated with community and traditional medicinal plants across two agro-climatic zones of India. The research provided a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of these zones, highlighting the socioeconomic significance of medicinal plant resources in rural livelihoods. The study emphasized the need for sustainable practices to preserve these plant species while supporting community-based conservation and health initiatives.

Chandora et al. (2023) undertook an ecological survey and population assessment of Fritillaria roylei, a critically endangered Himalayan medicinal herb. Their study employed habitat distribution modeling to identify the spatial extent and suitable ecological niches for conservation planning. They successfully illustrated the threats posed by overharvesting and habitat degradation, underlining the urgent need for protective strategies to conserve this species.

Gafna et al. (2023) explored the impact of climate change on the availability of anti-malarial plants in Kenya. Their findings indicated that shifting climatic conditions had already begun to affect the distribution and abundance of key medicinal plants used in malaria treatment. The study provided crucial insights into how ecological changes could undermine public health efforts, particularly in malaria-endemic regions.

3. RESEARCH METHODOLOGY

The research main goal is to measure and compare the amounts of phytochemicals such phenolics, alkaloids, flavonoids, terpenoids, and antioxidant activity throughout three seasons and four agro-climatic zones. The goal of the analysis is to find the times of year when chemical concentrations are highest and the best times to collect them to make them more effective as medicine.

3.1 Selection of Medicinal Plants

The study looked at four medicinal herbs that are extensively used and have substantial health benefits: Ocimum sanctum (Tulsi), Azadirachta indica (Neem), Withania somnifera (Ashwagandha), and Phyllanthus emblica (Amla). We picked these plants because they are well-known in Ayurvedic medicine, can grow in a wide range of climates, and have well-documented phytochemical profiles. This makes them perfect for studying how the amount of bioactive compounds changes with the seasons and in different regions.

3.2 Study Area and Agro-Climatic Zones

We took plant samples from four different agro-climatic zones in India: the Himalayan Zone, the Tropical Wet Zone, the Arid Zone, and the Coastal Zone. Each of these zones has its own climate, with differences in temperature, humidity, and rainfall that are expected to have a big effect on the phytochemical makeup and concentration of medicinal plants.

3.3 Sample Size and Sampling Procedure

The study gathered 50 plant samples, which included 4 chosen medicinal plant species from 4 different agro-climatic zones and 3 different seasons. The samples were chosen to provide a fair spread of seasonal and regional differences. Each sample had 50 grams of plant material that had been dried and processed in the same way. The plants were picked at the same time and under the same health conditions to make sure the experiment was fair and reliable.

3.4 Seasonal Sampling

We took samples during the three main Indian seasons: summer (April to June), monsoon (July to September), and winter (December to February). This was done to see how changes in the environment affect the levels of bioactive compounds. This seasonal framework gave us a full picture of how phytochemical expression changes throughout time.

3.5 Data Processing and Analysis

The data were put into frequency and percentage tables to show important trends, such as how the expression of bioactive compounds changes with the seasons, how phytochemicals are more common in certain areas, how antioxidant activity changes, and when is the best time to harvest for the best yield. We used descriptive statistics to look at the data, focussing on trends that could be seen rather than on inferential statistics, which fit with the study's exploratory character.

4. DATA ANALYSIS

We gathered and carefully analysed observational and phytochemical data to see how seasonal changes affect the bioactive chemicals in medicinal plants in different agro-climatic zones in India. The study looks at how major phytoconstituents, such phenolics, alkaloids, flavonoids, and terpenoids, change with the seasons and how they are spread out in diverse environments. We utilised frequency and percentage tables to figure out how changes in chemical concentration, antioxidant activity, and the best times to harvest affect each other.

Table 1: Distribution of Dominant Bioactive Compound Types across Seasons

Bioactive Compound Type	Summer (percentage %)	Monsoon (percentage %)	Winter (percentage %)
Phenolics	20%	20%	60%
Alkaloids	40%	20%	40%
Flavonoids	20%	40%	40%
Terpenoids	40%	40%	20%

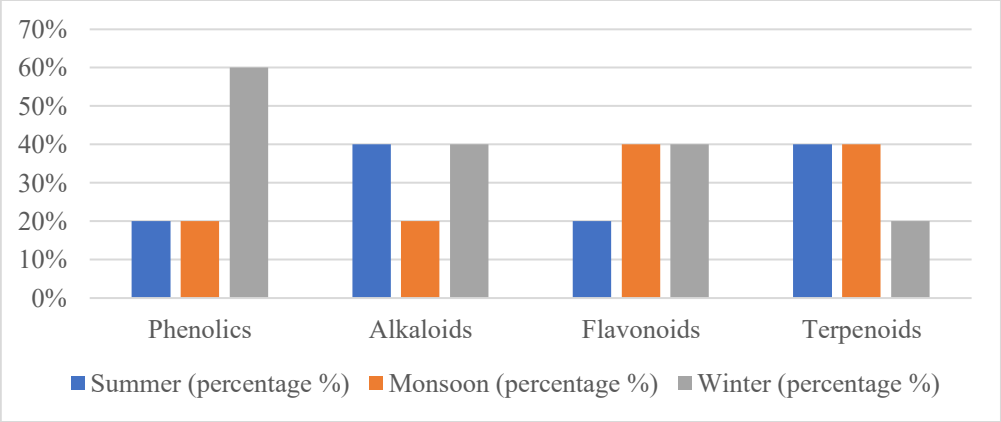

Fig.1 Represents the Percentage of Distribution of Dominant Bioactive Compound Types across Seasons

Table 2: Seasonal Variation in Antioxidant Activity (%) of Selected Medicinal Plants

Season	Number of Plants Showing Peak Antioxidant Activity	Percentage (%)
Summer	1	20%
Monsoon	2	40%
Winter	2	40%

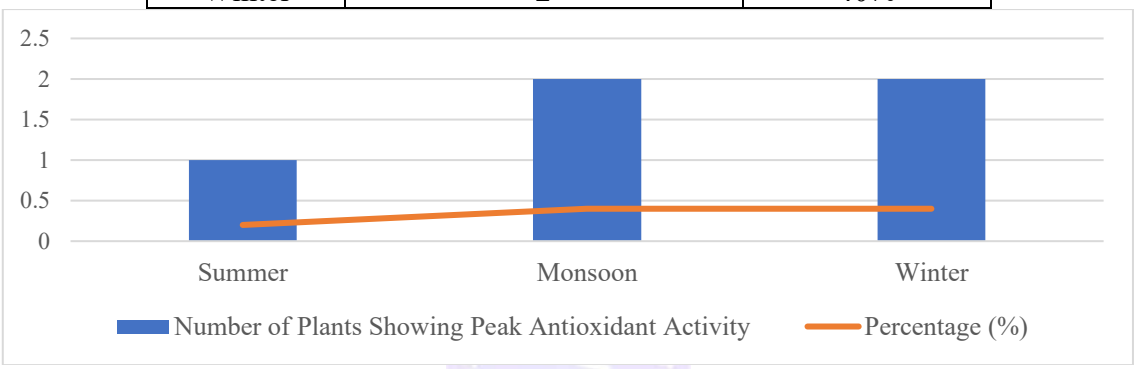

Fig.2 Represents the Percentage of Seasonal Variation in Antioxidant Activity (%) Of Selected Medicinal Plants

Table 3: Peak Alkaloid Content across Agro-Climatic Zones

Agro-Climatic Zone	No. of Plants with Peak Alkaloid Content	Percentage (%)
Himalayan Zone	2	40%
Tropical Wet Zone	1	20%
Arid Zone	1	20%
Coastal Zone	1	20%

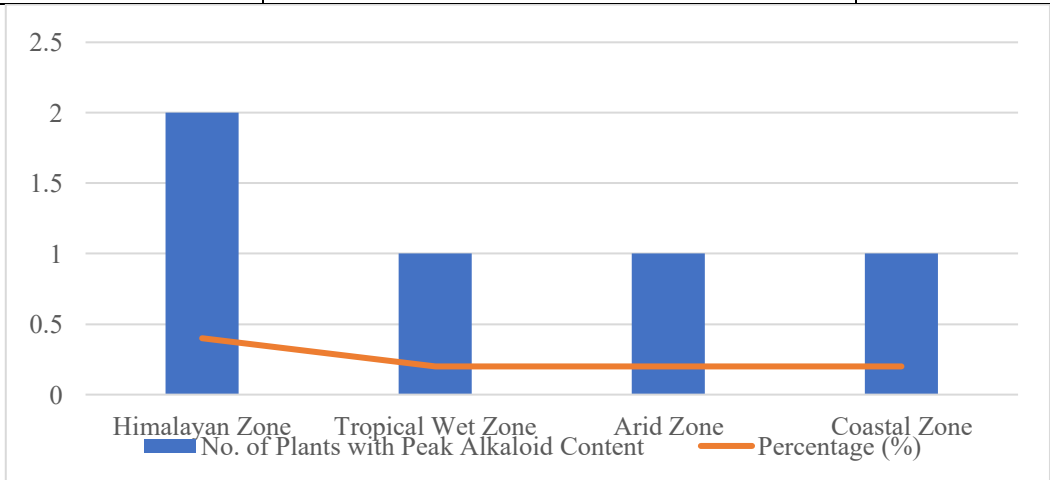

Fig.3 Represents the Percentage of Peak Alkaloid Content across Agro-Climatic Zones

Table 4: Distribution of Optimal Harvest Season Based on Bioactive Compound Yield

Plant Name	Optimal Season	Dominant Compound (Max. Yield)	Percentage (%)
Ocimum sanctum	Winter	Phenolics	25%
Azadirachta indica	Summer	Triterpenoids	25%
Withania somnifera	Winter	Alkaloids	25%
Phyllanthus emblica	Monsoon	Flavonoids	25%

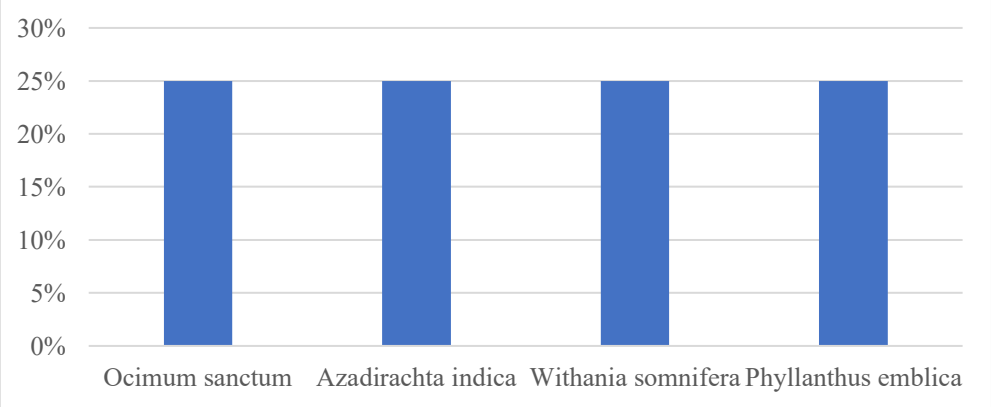

Fig.4 Represents the Percentage of Distribution of Optimal Harvest Season Based On Bioactive Compound Yield

5. CONCLUSION

This study shows that seasonal changes and differences in agro-climatic conditions have a big effect on the amount and location of bioactive chemicals in important medicinal plants all throughout India. The results show that phenolics, alkaloids, flavonoids, and terpenoids change a lot from season to season, and that these changes happen in diverse ways in different agro-climatic zones. During the winter, there were typically more phenolic and alkaloid compounds, whereas during the monsoon and summer, there were more flavonoids and terpenoids. This shows that temperature, humidity, and rainfall are very important for phytochemical production. The results show how important it is to think about the time of year and the environmental conditions in a certain area while collecting medicinal plants to have the most therapeutic effect. These kinds of information can help herbalists, farmers, and pharmaceutical companies choose the best times to harvest and grow herbs to make their products stronger and better. This study also shows how important it is to keep an eye on phytochemicals as the environment changes so that medicinal plants can continue to be effective in both traditional and modern medicine.

REFERENCES

1. *Babu, K. L. (2010). Health and livelihoods of community and traditional medicinal plants: SWOT of two agro climatic zones of India. Report of South Asia Network of Economic Research Institutes (SANEI), 1-78.*
2. *Chandora R. et al., Ecological survey, population assessment and habitat distribution modelling for conserving Fritillaria roylei A critically endangered Himalayan medicinal herb', South African Journal of Botany, vol. 160, pp. 75–87, Sep. 2023.*
3. *Gafna D. J., Obando J. A., Kalwij J. M., Dolos K., and Schmidtlein S., Climate change impacts on the availability of anti-malarial plants in Kenya, Climate Change Ecology, vol. 5, p. 100070, Jul. 2023.*
4. *IPCC, 'Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC.', Cambridge University Press, 2007.*
5. *Jnanesha, A. C., Venugopal, S., Kumar, R. S., Bharath, K. S., Kumar, A., Lal, R. K., & Chandrashekar, G. S. (2023). Transvaluate of genotype× environment× season interaction of agronomic traits and bioactive compounds of Withania somnifera (L.) Dunal*

in the Deccan plateau region. Journal of Applied Research on Medicinal and Aromatic Plants, 35, 100501.

6. *Jnanesha, A. C., Venugopal, S., Kumar, R. S., Bharath, K. S., Kumar, A., Lal, R. K., & Chandrashekar, G. S. (2023). Transvaluate of genotype× environment× season interaction of agronomic traits and bioactive compounds of Withania somnifera (L.) Dunal in the Deccan plateau region. Journal of Applied Research on Medicinal and Aromatic Plants, 35, 100501.*
7. *Kumar, B., Sharma, S., Singh, S. P., Adhikari, D., Kumar, S., & Srivastava, S. (2023). Ecological niche modelling guided chemotypic analysis of Ageratum conyzoides L. from varied geography of India. South African Journal of Botany, 168, 372-383.*
8. *Kumar, S., Yadav, M., Yadav, A., & Yadav, J. P. (2017). Impact of spatial and climatic conditions on phytochemical diversity and in vitro antioxidant activity of Indian Aloe vera (L.) Burm. f. South African journal of botany, 111, 50-59.*
9. *Misra, A., Mishra, P., Kumar, B., Shukla, P. K., Kumar, M., Singh, S. P., ... & Srivastava, S. (2021). Chemodiversity and molecular variability in the natural populations (India) of Gloriosa superba (L.) and correlation with eco-geographical factors for the identification of elite chemotype (s). Fitoterapia, 150, 104831.*
10. *Misra, T. K. (2017). Evaluation of antioxidant properties of tea under various agro-climatic conditions of North Bengal (Doctoral dissertation, University of North Bengal).*
11. *Pellegrini E., Campanella A., Cotrozzi L., Tonelli M., Nali C., and Lorenzini G., 'Ozone primes changes in phytochemical parameters in the medicinal herb Hypericum perforatum (St. John's wort)', Industrial Crops and Products, vol. 126, pp. 119–128, Dec. 2018.*
12. *Ralepele, F. M. (2020). Responses of selected metabolites in Moringa oleifera Lam. leaves to seasonal variations (Master's thesis, University of the Witwatersrand, Johannesburg (South Africa)).*
13. *Ralepele, F. M. (2020). Responses of selected metabolites in Moringa oleifera Lam. leaves to seasonal variations (Master's thesis, University of the Witwatersrand, Johannesburg (South Africa)).*
14. *ZAINAB, B., Zainab, B. I. B. I., KHOLA, K., Lin, Z. H. O. U., MAHNOOR, Z., & ARSHAD, M. A. (2023). Impact of seasonal variations on polyphenolic content and antibacterial activity in Berberis lycium Royl. Journal of Holistic Integrative Pharmacy, 4(1), 29-40.*
15. *Zhang J. (Jim), Wei Y., and Fang Z., Ozone Pollution: A Major Health Hazard Worldwide, Front. Immunol. vol. 10, p. 2518*