DYNAMICS OF SILYMARIN COMPLEX UNDER SALT STRESS IN *SILYBUM MARIANUM* L.

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Abstract: *Soil salinity is one of the major abiotic stresses limiting plant growth and productivity worldwide, especially in arid and semi-arid regions. This study investigates the dynamic changes of the silymarin complex in the medicinal plant Silybum marianum L. under different levels of salt stress. Silymarin, a mixture of flavonolignans including silybin, silydianin, and silychristin, is known for its strong antioxidant and hepatoprotective properties. Experimental results revealed that moderate salt stress significantly enhances silymarin accumulation, while severe stress leads to its decline. These changes are closely associated with the activation of antioxidant defense systems, enzymatic regulation, and phenylpropanoid pathway modulation. The findings highlight the adaptive metabolic response of S. marianum to salinity and its potential for optimized cultivation under controlled stress conditions.*

Keywords: *Silybum marianum, silymarin, salinity stress, flavonolignans, secondary metabolites, antioxidant system, biosynthesis.*

Introduction: Salinity is a growing environmental constraint affecting more than 20% of irrigated lands globally. In Central Asia, including Uzbekistan, soil salinization has become a critical factor influencing agricultural sustainability and medicinal plant productivity. Salt stress disrupts plant water relations, ion homeostasis, and metabolic balance, leading to oxidative stress through excessive accumulation of reactive oxygen species (ROS).

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Silybum marianum L. (milk thistle) is a well-known medicinal plant widely used in pharmaceutical industries due to its bioactive compound—silymarin. Silymarin is a complex of flavonolignans synthesized via the phenylpropanoid pathway and plays a significant role in plant defense mechanisms against environmental stresses.

Despite extensive pharmacological studies on silymarin, limited information is available regarding its biosynthetic dynamics under abiotic stress conditions, particularly salinity. Understanding these mechanisms is essential for improving both plant resilience and the yield of pharmacologically important compounds.

Materials and Methods

The experiment was conducted under controlled laboratory and greenhouse conditions. Seeds of *Silybum marianum* were germinated and grown under different salinity treatments using sodium chloride (NaCl):

- 0 mM (control)
- 50 mM (low stress)
- 100 mM (moderate stress)
- 150 mM (high stress)

Parameters analyzed:

- Morphological traits (plant height, leaf number, biomass)
- Photosynthetic activity (chlorophyll content)
- Silymarin content (High-Performance Liquid Chromatography – HPLC)
- Antioxidant enzyme activities (SOD, CAT, POD)
- Osmolyte accumulation (proline content)
- Lipid peroxidation (malondialdehyde – MDA level)

Data were statistically analyzed using ANOVA with significance at $p < 0.05$.

Results and Discussion: Growth Response under Salt Stress

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Increasing salinity levels negatively affected plant growth. At 150 mM NaCl, significant reductions in biomass, root length, and leaf development were observed. This is attributed to osmotic stress and ion toxicity, particularly Na^+ and Cl^- accumulation.

Silymarin Accumulation Dynamics: Silymarin content showed a biphasic response to salinity:

- **Control (0 mM):** baseline silymarin level
- **50 mM NaCl:** increase by ~20%
- **100 mM NaCl:** peak accumulation (~35–45% increase)
- **150 mM NaCl:** sharp decline below control levels

Moderate stress appears to stimulate secondary metabolism as a defense response, while excessive stress inhibits biosynthetic pathways due to cellular damage.

Antioxidant Defense Mechanisms: Salt stress induced oxidative stress, leading to enhanced activity of antioxidant enzymes:

- Superoxide dismutase (SOD)
- Catalase (CAT)
- Peroxidase (POD)

These enzymes mitigate ROS damage and are functionally linked to increased synthesis of phenolic compounds, including silymarin.

Biochemical and Molecular Insights: Silymarin biosynthesis is regulated via the phenylpropanoid pathway, where phenylalanine ammonia-lyase (PAL) acts as a key enzyme. Moderate salinity upregulates PAL activity, enhancing flavonolignan production.

However, under severe stress:

- Enzyme denaturation occurs
- Energy metabolism is disrupted
- Lipid peroxidation increases (high MDA levels)

These factors collectively suppress silymarin synthesis.

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Conclusion: The study demonstrates that salinity significantly influences the biosynthesis of silymarin in *Silybum marianum* L. Moderate salt stress (50–100 mM NaCl) enhances silymarin accumulation by activating antioxidant and metabolic pathways, whereas high salinity (≥150 mM NaCl) inhibits its production due to metabolic disruption.

These findings provide a scientific basis for optimizing cultivation strategies of medicinal plants in saline environments and suggest that controlled stress application may improve the yield of valuable secondary metabolites.

Practical Implications

- Controlled salinity can be used as an elicitor to increase silymarin yield
- Suitable for cultivation in moderately saline soils
- Important for pharmaceutical raw material production

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