# Linsmaier and Skoog (LS) Medium

Article Title: Linsmaier and Skoog (LS) Medium in Plant Tissue Culture: Origins, Uses, and Formulation

**Origin**

The Linsmaier and Skoog (LS) medium, a cornerstone in plant tissue culture, was developed by Emil M. Linsmaier and Folke K. Skoog in 1965. Their groundbreaking work, published in the journal *Physiologia Plantarum*, aimed to create a defined, nutrient-rich environment optimized for the in vitro growth and development of diverse plant species. Unlike earlier media, which often relied on undefined components like coconut milk or yeast extract, the LS medium aimed for a precisely defined composition, facilitating reproducibility and a better understanding of nutritional requirements for plant cells. Their initial focus was on providing a versatile medium suitable for a wide range of plant species, notably addressing challenges in the propagation and regeneration of woody plants, which proved particularly problematic with existing media.

**Applications**

The LS medium has proven remarkably versatile, finding widespread use in numerous plant tissue culture applications. Its primary applications include:

- **Callus induction:** LS medium, often with the addition of specific plant growth regulators (PGRs) such as 2,4-Dichlorophenoxyacetic acid (2,4-D) or Picloram, serves

as an excellent base for initiating callus formation from various explants (e.g., leaf segments, stem sections, cotyledons).

- **Organogenesis:** By manipulating the concentrations of auxins and cytokinins, researchers can direct callus development towards shoot or root organogenesis, crucial for plant regeneration and cloning. The balance of these hormones within the LS medium is a key factor in controlling this process.
- **Rooting:** LS medium, supplemented with auxins like indole-3-butyric acid (IBA) or indole-3-acetic acid (IAA), is often employed for rooting stem cuttings and regenerated shoots, leading to the development of complete, independent plantlets.
- **Embryogenesis (somatic and zygotic):** While not as widely used for embryogenesis as Murashige and Skoog (MS) medium, LS medium has shown success in inducing and developing somatic embryos in several plant species.

The medium’s versatility extends to a broad range of plant species, although it has shown particular success with woody plants and certain orchids, areas where earlier media formulations often fell short. Successful applications have been reported in numerous studies involving economically important plants, contributing to improved propagation techniques and genetic transformation strategies.

**Formulation**

The LS medium’s composition consists of macronutrients, micronutrients, vitamins, and typically, plant growth regulators (PGRs). The specific concentrations can vary slightly depending on the plant species and the desired

outcome. However, a typical formulation includes the following:

| Component | Concentration (mg/L) | Role |
|---|---|---|
| $NH_4NO_3$ | 1650 | Nitrogen source |
| $KNO_3$ | 1900 | Nitrogen and potassium source |
| $CaCl_2 \cdot 2H_2O$ | 440 | Calcium source |
| $MgSO_4 \cdot 7H_2O$ | 370 | Magnesium and sulfur source |
| $KH_2PO_4$ | 170 | Phosphorus and potassium source |
| $FeSO_4 \cdot 7H_2O$ | 27.8 | Iron source |
| $MnSO_4 \cdot H_2O$ | 2.2 | Manganese source |
| $ZnSO_4 \cdot 7H_2O$ | 0.87 | Zinc source |
| KI | 0.83 | Iodine source |
| $H_3BO_3$ | 6.2 | Boron source |
| $CuSO_4 \cdot 5H_2O$ | 0.025 | Copper source |
| $Na_2MoO_4 \cdot 2H_2O$ | 0.25 | Molybdenum source |
| $CoCl_2 \cdot 6H_2O$ | 0.025 | Cobalt source |
| Nicotinic acid | 1 | Vitamin |
| Pyridoxine HCl | 0.5 | Vitamin |
| Thiamine HCl | 0.1 | Vitamin |
| Myo-inositol | 100 | Carbon source, cell wall component |
| Sucrose | 30000 | Carbon source |
| Agar | 7000-8000 | Solidifying agent |

**Common Modifications:** The concentrations of PGRs (auxins and cytokinins) are often adjusted depending on the specific application. For callus induction, higher auxin concentrations

are usually used, while shoot organogenesis typically requires a higher cytokinin-to-auxin ratio.

**Conclusion**

LS medium, despite being developed several decades ago, remains a valuable tool in plant tissue culture. Its strengths include its versatility across a range of plant species and its relatively simple, defined composition, simplifying experimental design and reproducibility. However, it also has limitations. The stability of some auxins in the medium can be a concern, requiring careful preparation and handling. It may not be optimal for all species or applications, and sometimes specialized media are preferred. Compared to MS medium (more prevalent today), LS is generally considered to support slightly slower growth but offers improved performance with specific woody plant species and orchids, where MS might be less effective. Alternatively, B5 medium offers a different balance of nutrients; often better suited for certain monocots and legumes. In conclusion, while newer media have emerged, LS medium maintains its relevance, especially in the cultivation and regeneration of specific plant types that respond favorably to its unique composition balancing nutrient needs as well as hormonal manipulations.