



STRATEGIES TO ACQUIRE AND TRANSPORT MINERAL UNDER DEFICIT LEVEL

**Narmada.B.S.M., Nadaradjan.S., Manoj Kumar., Abirami.A., Bavya. N., Kavin.P.,
Muthumari.S., Narendran.M.C and Ramiashree.O.M.**

*PG Scholar & Faculty, Pandit Jawaharlal Nehru College of Agriculture and Research
Insititute, Karaikal 609603, U. T. of Puducherry, India*

**Corresponding Author Mail ID: yamininarmu@gmail.com*

ABSTRACT

This article dives deep into the survival playbook of plants when faced with nutrient scarcity and deficiency. It shines a spotlight on the arsenal of strategies plants pull out of their hat to stay afloat during tough times. From root to shoot, the paper walks through the nuts and bolts of various physiological and morphological processes that kick into gear under stress. These internal mechanisms act as the plant's lifeline—regulating nutrient uptake and keeping it firmly rooted even when the going gets tough. By peeling back the layers, this study lays bare the critical systems that help plants hold their ground and weather the storm of nutrient limitations.

INTRODUCTION

Plants are often caught in the crosshairs of seasonal and ongoing environmental and biodiversity stresses, which throw a wrench into their life cycle from sprouting to harvest. Abiotic stressors such as nutrient starvation, under- or over-fertilization, and toxic heavy metals like arsenic can throw plant growth off balance. Add to that the wild cards of climate floods, droughts, temperature swings, and heavy downpours and crops are often left fighting an uphill battle.

Even the growing medium in soilless farming whether sawdust, cocopeat, rockwool,

potting mix, or sterilized cotton can make or break plant development. These biotic and abiotic factors chip away at the nutritional balance plants need to flourish. Sometimes, plants are hit with a double whammy like pest infestations paired with drought or heat combined with rainfall which throws nutrient absorption and distribution out of gear.

To stay ahead of the curve, it's vital to keep a close eye on the plant's developmental phase and ensure nutrients are delivered right on the money. A well-timed and balanced supply of macro- and micronutrients can be the secret sauce to reducing stress susceptibility.

Each nutrient plays a unique role in the grand scheme of plant growth. The classification into macro, micro, and essential nutrients has highlighted their individual importance. Research shows that around 20 elements are either essential or beneficial for plants. When it comes to nutrients, it's not just about quantity it's about quality too. A misstep in either can tip the scales and hinder growth.

Plants often find themselves between a rock and a hard place when facing nutrient deficiencies one of the most damaging stressors. The road to a healthy yield is paved with the right type and dose of nutrients at each growth stage. Shockingly, nutrient

deficiency affects nearly 60% of soils, putting a serious dent in plant productivity. Yet, plants have learned to roll with the punches, developing survival strategies even when nutrients are in short supply.

Shrinking farmland, the commercialization of agriculture, and rising pollution levels have added fuel to the fire, further impacting crop health and output. Soil characteristics are the linchpin in determining how plants respond to nutrients. Acidic mineral soils, in particular, are a thorn in the side of plant growth across many regions. Fortunately, plants have developed adaptive and tolerance mechanisms to weather both nutrient shortages and toxicities.

The concentration of mineral nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, zinc, boron, aluminium, and sulphur can swing wildly depending on soil conditions and growth stages. A shortfall in any of these can lead to stunted growth and poor yields. On the flip side, a plant's nutritional status hinges on timely and appropriate fertilizer application. To hit the nail on the head, agronomic practices must be fine-tuned to align with nutritional needs and strengthen stress resilience.

FUELING GROWTH: NUTRIENTS AND FERTILIZER SYNERGY

Iron deficiency in plants can be tackled by adding elemental sulphur to fertilizer, which worked wonders in durum wheat boosting growth and yield. Nutrients often work hand in glove, and tailored fertilizer mixes help fill gaps in macro and micronutrients. In coffee, magnesium is the secret sauce for CO₂ uptake, but too much can throw potassium off balance. Phosphorus is a double-edged sword essential yet costly so smart use is key.

Nitrogen is the lifeblood of crops; its shortage sends plants into overdrive, but weak nitrate transporters can throw a wrench in nutrient flow. Silicon, taken up by roots, packs a punch against stress and heavy metals, lifting yields across crops. Sodium plays water manager, expanding leaf area and boosting root transport. Boron keeps cell walls steady, helping plants stretch through stress without missing a beat.

ADOPTION STRATEGIES IN PLANTS TO WITHSTAND UNDER NUTRIENTS DEFICIENCY STRESSES

Root system architecture

The architecture of a plant's root system plays a vital role in enhancing nutrient and water uptake, directly contributing to growth and overall productivity. A well-developed root structure boosts the plant's ability to capture available nutrients from the soil efficiently. Hydrogen sulphide supports root development and promotes nodulation. It also plays a key role in signalling pathways involving auxin and nitric oxide (NO), aiding in stress relief and stimulating the formation of lateral roots.

Secretion of organic acids by plants

Organic acids (OAs) are the unsung heroes of plant cellular metabolism, keeping things running smoothly even under stressful conditions. When the going gets tough, plants release OAs into the soil, which proves to be a game-changer. These acids improve mineral uptake, provide a shield against toxic metals, and even help with carbon sequestration. As chemically charged agents, OAs balance excess ions, regulate cellular pH, and keep osmotic potential in check. Citric acid, in particular, is a powerhouse, solubilizing phosphorus ions in the soil, forming polymers that diffuse quickly

to roots, and releasing phosphorus ions on demand.

Recirculation of mineral nutrients

The mineral cycle is the backbone of the Earth's ecosystem, orchestrating the flow, distribution, and migration of mineral nutrients across the globe. This intricate process is the linchpin of plant growth, ensuring a steady supply of nutrients to the apical root zones and cushioning crops against fluctuations in external nutrient availability. The mineral cycle also plays a starring role in phloem loading and the export of photosynthates from source leaves. When nutrients are in short supply, the mineral cycle kicks into high gear, redirecting dry matter partitioning between shoots and roots and facilitating the free flow of mineral nutrients from source leaves to roots.

Rhizosphere microbes symbiosis

The rhizosphere is the hub of plant growth, where nutrient dynamics and microbial magic happen. Microbes living in harmony with roots are the unsung heroes, driving plant growth and development. This microbiota powerhouse boosts plant productivity, carbon sequestration, and phytoremediation, with Proteobacteria and Firmicutes forming the backbone of rhizosphere biomass. As plant roots release organic carbon, microbial activity shifts into high gear.

Adaptation strategy in acidic soils

A well-balanced nutrient supply acts as a shield, protecting plants from various stress factors when fertilizers are applied in appropriate doses. Nutrient depletion, loss of soil organic matter, and erosion are major contributors to deficiency. Although nutrient scarcity is an abiotic stress, identifying and

addressing limited nutrient reserves is crucial to prevent restricted availability. This challenge can be managed effectively by maintaining healthy soil condition.

Adaptation strategy in toxic soils

An increase in soil toxicity elevates concentrations of hydrogen ions (H^+), aluminium (Al^{3+}), and manganese (Mn^{2+}), disrupting the plant's nutrient absorption mechanisms. Higher leaching rates further inhibit root development, impairing overall plant function. Additionally, reduced levels of calcium, potassium, and magnesium lead to a decline in cation exchange capacity.

In response, plants develop various tolerance strategies, such as minimizing internal mineral requirements, recycling nutrients, and adapting tissues to withstand elevated toxicity. While tolerance is a key survival mechanism, avoidance strategies also play a vital role in helping plants endure harsh conditions. These include altering root architecture and enhancing mineral nutrient storage to combat deficiencies and toxic stress during nutrient scarcity.

For instance, silicon has been shown to mitigate the harmful effects of heavy metals and bolster resistance to fungal infections by strengthening the structure and function of plant cell walls.

CONCLUSION

Just like a well-oiled machine needs the right fuel, plants thrive when they are fed an optimal dose of nutrients. These nutrients are the lifeblood of growth and development, directly tied to the fruits of labor production and yield. Each nutrient plays its own starring role in the crop's performance, tailored to meet the ever-growing demands of food security. When nutrient levels dip, plants feel

the pinch but with a full pantry of essential elements, those deficiencies can be patched up. It's crucial to strike the right balance; too much or too little, and the whole system goes off-kilter. A well-nourished plant is like a ship with a steady rudder ready to weather any storm. Plants are no strangers to adversity. When the nutrient scales tip in their favour, they pull out all the stops adopting clever survival tactics to push through stress and still deliver the goods. Recognizing the importance of every single nutrient is the key to unlocking peak performance. In the grand symphony of plant growth, nutrients must play in harmony—each one complementing the other, working hand in glove to support robust development and a bountiful harvest.

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