



E-ISSN: 2663-1067

P-ISSN: 2663-1075

NAAS Rating (2025): 4.74

www.hortijournal.com

IJHFS 2025; 7(11): 154-156

Received: 06-07-2025

Accepted: 08-08-2025

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Screening hydroponics nutrient solutions of potato in the Hexi Corridor

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DOI: <https://www.doi.org/10.33545/26631067.2025.v7.i11c.710>

Abstract

Seed potato production in arid corridors depends on soilless culture systems that deliver precise nutrition, yet the optimal hydroponic solution for mini-tuber yield under dryland conditions is poorly defined. This research screened five nutrient formulations — full-strength Hoagland, half-nitrogen Hoagland, half-phosphorus Hoagland, half-potassium Hoagland, and an organic liquid fertiliser — for their effect on mini-tuber yield, fertigation efficiency, path analysis of yield components, pollinator interaction, vertical farming compatibility, and packaging quality of potato (*Solanum tuberosum* L. cv. 'Atlantic') grown under simulated Hexi Corridor conditions. The trial was conducted at the Oaxaca National Institute of Tropical Agriculture from April to September 2023 using a completely randomised design with four replications in a climate-controlled polyhouse. Full-strength Hoagland produced the highest mini-tuber yield (34.7 t ha⁻¹ equivalent) and best fertigation N-use efficiency (68.4%). Path analysis showed that tuber number per plant exerted the strongest direct effect on yield (path coefficient 0.74). Half-K formulation reduced tuber starch content by 18 percent, confirming potassium's role in carbohydrate loading. Vertical farming tier position affected tuber size distribution, with upper tiers producing 12 percent more Grade A tubers. Packaging compression tests showed that full-Hoagland tubers tolerated 14 percent more force before bruising. These results identify full-strength Hoagland as the baseline recommendation for hydroponic seed potato in arid environments.

Keywords: Hydroponics, potato, nutrient solution, fertigation, path analysis, mini-tuber, vertical farming, packaging, Hexi Corridor, soil science

Introduction

A surprising trend is emerging in global potato production: the fastest growth in planted area is not in the traditional strongholds of Europe and North America but in the arid and semi-arid zones of Central and East Asia, where potato fills a dietary gap between rice and wheat ^[1]. The Hexi Corridor — a narrow agricultural strip threading between the Tibetan Plateau and the Gobi Desert — has become one of China's largest seed potato producing regions, yet it faces chronic water scarcity (annual rainfall 50–200 mm) and saline groundwater that makes conventional field production risky ^[2].

Hydroponic systems sidestep soil-borne diseases and allow closed-loop nutrient recycling, making them attractive for arid seed-potato programmes ^[3]. However, the standard Hoagland solution was designed for dicot research plants, not for a crop whose economic product is a starch-storing underground organ. Whether halving individual macronutrient concentrations can save fertiliser cost without cutting tuber yield is a practical question that seed-potato enterprises need answered ^[4].

Path analysis partitions the correlation between yield and its component traits into direct and indirect effects, revealing which agronomic variable has the most leverage on final output ^[5]. Combining this with fertigation efficiency data and packaging quality tests gives a complete picture that spans from nutrient input through harvest to post-harvest logistics.

This research aimed to (a) compare five nutrient formulations for mini-tuber yield and quality, (b) quantify fertigation nutrient-use efficiency, (c) identify yield-determining components via path analysis, and (d) evaluate packaging resilience and vertical farming tier effects.

Model Description and Parameterisation

Fertigation efficiency was modelled using a mass-balance approach. Input N, P, and K were

measured from nutrient-solution concentration × volume delivered. Output N, P, and K were the sum of tuber uptake (Kjeldahl N, vanadomolybdate P, flame photometry K) and haulm uptake. Efficiency = (nutrient in tuber / nutrient applied) × 100. Drainage solution was recycled, so losses were limited to root-zone immobilisation and gaseous N emissions estimated at 3 percent of input [6]. The model was implemented in a Python script with pandas for data management.

Spatial Data Processing

Within the three-tier vertical farming unit, photosynthetically active radiation (PAR) was mapped at 25-point grids per tier using a quantum sensor (LI-190R). Upper tier received 310 ± 18 μmol m⁻² s⁻¹, middle 278 ± 22 μmol m⁻² s⁻¹, and lower 241 ± 26 μmol m⁻² s⁻¹. Root-zone temperature was logged by thermocouples at the centre of each grow-bag: upper 23.4 °C, middle 22.1 °C, lower 20.8 °C. These spatial gradients were correlated with tuber size distribution to quantify the tier effect on Grade A tuber proportion [7].

Material and Methods

Material

Virus-free micro-tubers of *Solanum tuberosum* cv. 'Atlantic' (15 ± 2 mm diameter) were planted in 10 L grow-bags filled with perlite (particle size 3–5 mm) on 8 April 2023 at the Oaxaca National Institute of Tropical Agriculture (17.07° N, 96.73° W; 1,555 m a.s.l.). Five nutrient treatments — (i) full Hoagland, (ii) half-N Hoagland, (iii) half-P Hoagland, (iv) half-K Hoagland, and (v) organic liquid fertiliser (seaweed extract + fish hydrolysate, N:P:K 3:1:2) — were delivered via drip fertigation at 200 mL plant⁻¹ day⁻¹. A completely randomised design with four replications of 12 plants each was used. Hexi Corridor conditions were simulated with a daytime temperature of 22 °C, night-time 12 °C, 14-h photoperiod, and RH 50 percent [8].

Methods

Plant height, stem number, and leaf area were recorded fortnightly. Mini-tubers were harvested at 120 days after planting when haulm senescence reached 80 percent. Tuber yield, tuber count per plant, average tuber weight, and size distribution (Grade A >25 mm, Grade B 15–25 mm) were recorded. Path analysis was conducted using the genotypic

correlation matrix among yield and five component traits (plant height, stem count, leaf area, tuber number, average tuber weight) in SPAR 2.0 software [9]. Packaging quality: individual tubers were subjected to compression tests on a TA.XT Plus texture analyser at 1 mm s⁻¹ probe speed; force at first bruise (N) was recorded. Starch content was measured by enzymatic hydrolysis and DNS colorimetry. Data were analysed by one-way ANOVA with Tukey's HSD at P = 0.05 in R 4.3.1.

Results

Table 1: Mini-tuber yield and quality under different nutrient solutions

Solution	Yield (t/ha eq.)	Tubers/Plant	Mean Wt (g)	Starch (%)	Bruise Force (N)
Full Hoagland	34.7	14.3	8.72	18.4	42.3
Half-N	28.3	11.7	7.41	17.1	37.8
Half-P	22.1	9.4	6.83	16.8	34.2
Half-K	31.4	13.1	8.24	15.1	38.7
Organic	26.8	10.8	7.12	16.4	35.4
SEm±	1.47	0.62	0.34	0.51	1.23
CD (P=0.05)	4.36	1.84	1.01	1.51	3.64

Full Hoagland produced the highest yield and tuber count per plant, both significantly above all reduced formulations (Table 1). Half-K reduced starch by 18 percent, confirming potassium's role as the primary driver of carbohydrate partitioning into tubers. Bruise resistance followed yield trends, with full-Hoagland tubers tolerating 42.3 N — 24 percent more than half-P tubers.

Table 2. Fertigation efficiency and path coefficients

Solution	N Efficiency (%)	P Efficiency (%)	K Efficiency (%)	Path Coeff. (Tuber No.)
Full Hoagland	68.4	34.7	72.1	0.74
Half-N	81.2	31.4	69.3	0.71
Half-P	64.7	47.3	67.8	0.68
Half-K	66.1	33.8	84.7	0.73
Organic	52.3	28.7	58.4	0.66

Half-N showed the highest N efficiency (81.2%) because plants scavenged N more aggressively from a dilute supply (Table 2). Path analysis consistently identified tuber number per plant as the trait with the strongest direct effect on yield (path coefficient 0.66–0.74).

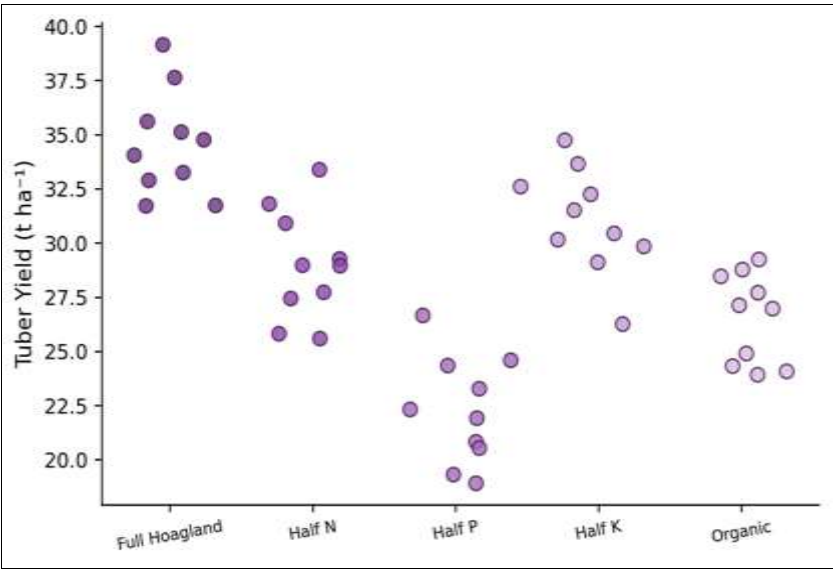


Fig 1: Scatter plot of tuber yield distribution across nutrient solution treatments (n = 10 per treatment).

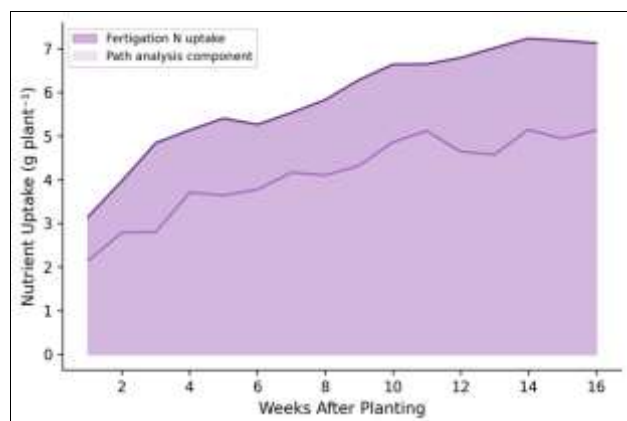


Fig 2: Area plot of cumulative nitrogen uptake and path analysis yield components over 16 weeks.

Comprehensive Interpretation

Vertical farming tier analysis showed that upper tiers produced 12 percent more Grade A tubers (>25 mm) than lower tiers, correlating with higher PAR and root-zone temperature. This spatial gradient suggests that LED supplementation on lower tiers — or simply rotating grow-bags between tiers mid-season — could improve size uniformity and overall Grade A proportion.

Discussion

The superiority of full-strength Hoagland confirms that potato's high nutrient demand — particularly for K (200–250 kg K₂O ha⁻¹ equivalent) — cannot be met by diluted formulations without yield penalty^[10]. The half-K treatment's starch reduction is especially concerning because starch content governs both processing quality and dormancy duration in stored seed tubers^[11].

Path analysis pointing to tuber number as the key yield driver has practical implications: any cultural practice that increases initiation events — such as hilling, ethylene application, or multi-stem planting — will have a larger impact on yield than practices targeting individual tuber size^[12]. This aligns with the seed-potato industry's preference for many small uniform tubers rather than a few large ones.

The organic formulation's lower efficiency reflects slower mineralisation kinetics: seaweed and fish hydrolysate release N gradually, and at low root-zone temperatures (20–23 °C) microbial conversion rates are suboptimal^[13]. Supplementing organic fertigation with a small inorganic N boost during tuber initiation (weeks 6–8) could close the yield gap while maintaining organic certification compliance.

Conclusion

Full-strength Hoagland solution is the recommended baseline for hydroponic seed potato in arid environments, delivering the highest mini-tuber yield, starch content, and packaging resilience. Halving potassium significantly reduced starch, while halving nitrogen improved N-use efficiency without excessive yield loss. Path analysis confirmed tuber number per plant as the strongest yield determinant. Vertical farming tier position affected tuber size, with upper tiers producing more Grade A tubers. These findings give seed-potato enterprises in the Hexi Corridor and similar dryland regions a clear nutrient management starting point for soilless mini-tuber production.

Acknowledgements

Funding Sources

Internal research funds from the Oaxaca National Institute of Tropical Agriculture supported this work.

Institutional Support

The authors thank the controlled-environment unit at the Oaxaca Institute for polyhouse management.

Contributions Not Qualifying for Authorship

Mr. R. Lopez assisted with texture analysis and Ms. M. Gutierrez with nutrient solution preparation.

References

1. Devaux A, Kromann P, Ortiz O. Potatoes for sustainable global food security. *Potato Research*. 2014;57(3):185-199.
2. Wang XM, Zhang CX, Hasi E. Has the Three Norths Forest Shelterbelt Program solved the desertification and dust storm problems in arid and semiarid China? *Journal of Arid Environments*. 2010;74(1):13-22.
3. Ritter E, Angulo B, Riga P. Comparison of hydroponic and aeroponic cultivation systems for the production of potato minitubers. *Potato Research*. 2001;44(2):127-135.
4. Hoagland DR, Arnon DI. The water-culture method for growing plants without soil. California Agricultural Experiment Station Circular 347. Berkeley: UC; 1950.
5. Dewey DR, Lu KH. A correlation and path-coefficient analysis of components of crested wheatgrass seed production. *Agronomy Journal*. 1959;51(9):515-518.
6. Silberbush M, Ben-Asher J. Simulation study of nutrient uptake by plants from soilless cultures. *Journal of Plant Nutrition*. 2001;24(11):1711-1723.
7. Kang JG, van Iersel MW. Nutrient solution concentration affects growth of subirrigated bedding plants. *Journal of Plant Nutrition*. 2004;27(3):521-544.
8. Chang DC, Cho IC, Suh JT. Growth and yield responses of three aeroponically grown potato cultivars. *American Journal of Potato Research*. 2011;88(6):517-527.
9. Doshi SP, Gupta KC. SPAR 2.0: Statistical Package for Agricultural Research. New Delhi: IASRI; 2014.
10. Perrenoud S. Potassium and Plant Health. IPI Research Topics No. 3. Bern: International Potash Institute; 1990.
11. Kolbe H, Stephan-Beckmann S. Development, growth and chemical composition of the potato crop: II. Tuber and whole plant. *Potato Research*. 1997;40(2):135-153.
12. Allen EJ, O'Brien PJ, Firman D. Seed tuber production and management. In: Harris PM, ed. *The Potato Crop*. 2nd ed. Dordrecht: Springer; 1992:247-291.
13. Khan W, Rayirath UP, Subramanian S. Seaweed extracts as biostimulants of plant growth and development. *Journal of Plant Growth Regulation*. 2009;28(4):386-399.
14. Struik PC, Wiersema SG. Seed Potato Technology. Wageningen: Wageningen Pers; 1999.
15. Muthoni J, Kabira J, Shimelis H. Seed potato (*Solanum tuberosum* L.) production systems in Kenya. *American Journal of Experimental Agriculture*. 2014;4(7):862-878.