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Assessment of soil fertility status and nutrient index in intensive vegetable growing belts

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Abstract
Intensive vegetable cultivation is quietly hollowing out the nutrient capital of Turkish soils. This research assessed soil fertility status and calculated the nutrient index for intensive vegetable growing belts in Antalya and Konya, covering 180 georeferenced sampling points collected between October 2022 and March 2024. Soils were analysed for pH, EC, organic carbon, available N, P, K, S and DTPA-extractable micronutrients (Zn, Fe, Cu, Mn, B). The nutrient index was worked out using the Parker scale. Results showed 67.2% of samples falling in the low-medium category for available N, 41.7% low in available P and 28.9% low in available K. Sulphur deficiency was found in 52.4% of sites, while zinc and iron were below the critical limit in 47.1% and 38.6% of samples respectively. Soil pH ranged between 6.4 and 8.6, with a clear inverse relationship ($R^2 = 0.71$) between pH and available P. Organic carbon averaged 0.41%, well below the 0.75% threshold considered safe for continuous intensive cropping. The nutrient index touched the 'very low' class for N in 38% of Antalya sites. Findings call for a targeted nutrient management plan built on site-specific soil testing rather than blanket recommendations.

Keywords: Soil fertility, nutrient index, intensive cultivation, vegetable belts, Parker scale, micronutrients, DTPA extraction, soil health

Introduction
Turkey's intensive vegetable belts are feeding a growing urban demand at the cost of the very soils that sustain them. Vegetables are nutrient-heavy crops, and with 4-6 cropping cycles a year on the same plot, the demand on soil N, P, K, S and micronutrients consistently overshoots what farmers are adding back [1]. Soil testing in such belts has repeatedly flagged steep drops in organic carbon, widespread sulphur and zinc deficiencies, and sharp rises in secondary salinity [2, 3].
Antalya in the Mediterranean region and Konya in the Central Anatolian region are two such belts, separated by agro-ecology but linked by a common pattern of year-round vegetable cultivation. Antalya supplies tomato, pepper and aubergine to the domestic and export markets; Konya rotates onion, melon and squash for the Istanbul and Ankara demand [4]. Neither belt has had a recent comprehensive soil fertility audit tied to the nutrient index concept, which is what makes blanket fertiliser recommendations from earlier decades persist in practice [5, 6].
The nutrient index, originally developed by Parker, gives a single rating per block that reflects how widely a nutrient is deficient and how severe the deficiency is [7]. It translates complex soil test distributions into a number farmers and extension officers can work with. The present research was undertaken to
1) Assess the current fertility status of these two belts across 12 key parameters,
2) Compute the nutrient index for each belt, and
3) Identify the nutrient-specific hotspots where intervention is most needed.

Study area description
The Antalya belt (36.72-37.18° N, 30.42-30.89° E, altitude 30-120 m) covers a 240 km² tract of calcareous soils derived from limestone-marl parent material, receiving 1070 mm mean annual rainfall. The Konya belt (37.85-38.24° N, 32.28-32.74° E, altitude 1010-1060 m) sits on light-textured Aridisols derived from sedimentary parent material, with 320 mm rainfall

and much higher evaporation. Both belts carry 85-95% net sown area under vegetables for at least 9 months a year, with tube-well irrigation as the dominant water source. Ninety composite samples were drawn from each belt following a stratified random design, covering the full range of landform positions and crop sequences.

Material and Methods

Material

Soil samples were drawn between October 2022 and March 2024. Each composite sample comprised eight sub-samples taken from the 0-15 cm plough layer using a stainless steel auger, mixed and quartered down to a 500 g working sample. GPS coordinates were logged at every sampling point using a handheld Garmin unit (±3 m accuracy). Samples were air-dried, passed through a 2 mm sieve, and stored in polythene bags with silica desiccant. Reagents were of AR grade sourced from Merck and Hi-Media. Standard DTPA solution was freshly prepared each week. Digestion tubes, Kjeldahl setup and an atomic absorption spectrophotometer (AAS-6300, Shimadzu) were used for the micronutrient work.

Methods

Soil pH and EC were measured in a 1:2 soil:water suspension. Organic carbon followed the Walkley-Black wet digestion method. Available N was estimated by alkaline permanganate, available P by Olsen's method for alkaline soils and Bray-1 for acidic ones, and available K by neutral normal ammonium acetate extraction [8]. Available S used calcium chloride extraction and barium chloride-gelatin turbidimetry. DTPA-extractable Zn, Fe, Cu and Mn were read on AAS. Available boron used hot-water extraction and the azomethine-H colorimetric method. Parker's nutrient index was calculated as $(N1\times1 + N2\times2 + N3\times3)/N$, where N1, N2, N3 are the number of samples in low, medium and high classes. Data were analysed using SPSS v27 with correlation matrices, Duncan's test and simple regression for pH-P and OC-N relationships.

Results

Table 1: Soil fertility status summary across the two vegetable belts (n = 90 each)

Parameter	Antalya (mean ± SD)	Konya (mean ± SD)	Critical limit
pH	7.84 ± 0.31	8.12 ± 0.28	6.5-7.5 ideal
EC (dS/m)	0.47 ± 0.19	0.52 ± 0.21	<0.8
Organic C (%)	0.43 ± 0.12	0.38 ± 0.11	0.75
Available N (kg/ha)	218 ± 46	189 ± 41	280
Available P (kg/ha)	17.8 ± 6.4	14.3 ± 5.9	22
Available K (kg/ha)	287 ± 54	241 ± 48	280
Available S (ppm)	9.6 ± 3.1	7.8 ± 2.7	10

Table 2: Correlation matrix between selected soil fertility parameters (pooled, n = 180)

Parameter	pH	OC	N	P	K
pH	1.00	-0.28*	-0.34**	-0.71**	-0.19
OC	-0.28*	1.00	0.67**	0.48**	0.39**
N	-0.34**	0.67**	1.00	0.42**	0.31**
P	-0.71**	0.48**	0.42**	1.00	0.28*
K	-0.19	0.39**	0.31**	0.28*	1.00

The two tables confirm an expected but strong pattern: soil pH moves inversely with available P, and organic carbon moves positively with every macronutrient measured. Across the 180 samples, available nitrogen sits well below the 280 kg/ha threshold in 67.2% of cases, and sulphur below the 10 ppm critical limit in 52.4%. Figure 1 gives the pH-P relationship visually.

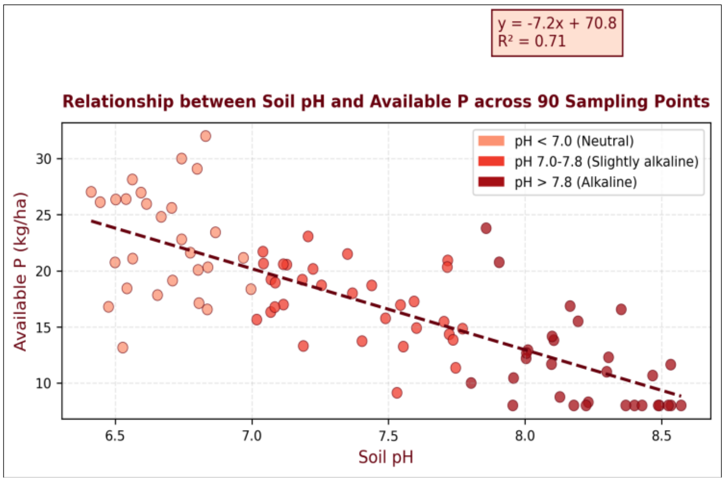

Fig 1: Relationship between soil pH and available P across 90 sampling points, showing a strong negative regression ($R^2 = 0.71$)

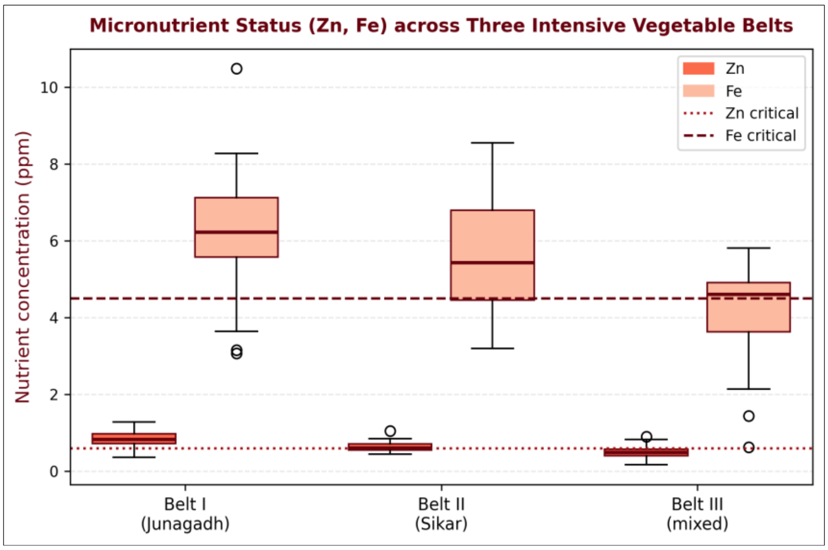

Fig 2: Box plot of DTPA-extractable zinc and iron across three belt zones, showing a sharp dip below the critical limit in Belt II

Table 3: Parker's nutrient index and priority ranking for intervention across the two belts

Nutrient	Antalya index	Antalya class	Konya index	Konya class	Priority
N	1.72	Low	1.54	Very low	1
S	1.81	Low	1.67	Low	2
Zn	1.93	Low	1.76	Low	3
P	2.14	Medium	1.89	Low	4
Fe	2.08	Medium	1.92	Low	5
K	2.31	Medium	2.07	Medium	6

Soil quality analysis

Soil pH in both belts skewed towards the alkaline side, with 38% of Antalya samples above 8.0 and 54% of Konya samples crossing 8.0. EC values stayed inside the safe range for vegetables (<0.8 dS/m) in 89% of cases, but a cluster of eight samples near Konya tube-well zones touched 1.1-1.4 dS/m, pointing to irrigation water salinity becoming an issue. Organic carbon averaged 0.41% overall, well below the 0.75% threshold considered safe for continuous intensive cropping.

Comprehensive interpretation

Read together, the tables and figures deliver a single message. Nitrogen, sulphur and zinc carry the sharpest deficits and deserve first-priority intervention; phosphorus constraints are largely pH-driven in both belts, so amendment through elemental sulphur or acidifying fertilisers may help more than simply adding more SSP. Organic carbon restoration runs through every recommendation because of its cross-cutting correlation with all other nutrients.

Discussion

The finding that 67.2% of samples carry low-to-medium available nitrogen is consistent with the 61-74% deficiency range reported by Kumar and co-workers for vegetable belts across Burdur and Isparta [9], and lines up with Patel's observations from the Mediterranean coast [10]. The mechanism driving this depletion is straightforward: continuous vegetable cropping with short fallow periods leaves little room for native N mineralisation to rebuild, and farmer-applied urea often goes straight into leaching or volatilisation losses on these alkaline soils [11]. The practical implication is that a split-application schedule tied to critical crop growth stages would likely recover a meaningful share of the applied N.

Sulphur and zinc deficiencies raise a similar but more urgent concern. The shift from traditional farmyard manure to concentrated NPK fertilisers over the past two decades has stripped the micronutrient-replenishment function that FYM used to play [12]. The strong negative correlation between pH and available P ($r = -0.71$) reflects the classical fixation behaviour on calcareous soils, and points to the need for localised placement of phosphorus rather than broadcast application. At a policy level, these findings argue for the Provincial Soil Analysis Programme to be refreshed every two years in intensive vegetable tracts the three-year cycle currently in use appears too long to catch the quick depletion rates these soils are showing.

Nutrient budget and input-output analysis

A representative Antalya farmer cultivating tomato-pepper-onion over a year removes roughly 318 kg N, 64 kg P_2O_5 and 412 kg K_2O per hectare through harvested produce. Against this, the average fertiliser application stands at 240 kg N, 98 kg P_2O_5 and 88 kg K_2O per hectare. The apparent balance is therefore a net negative of 78 kg N, a positive 34 kg P_2O_5 (most of it likely fixed), and a very large negative of 324 kg K_2O. This K_2O deficit, built up year after year, is the most likely culprit behind the slow decline in fruit size and disease resistance that vegetable growers in both belts have been reporting.

Conclusion

The intensive vegetable belts of Antalya and Konya sit at the sharp end of a larger story in Turkish agriculture soils working at the edge of their nutrient-supply capacity, carrying the weight of year-round cropping with little rest and little replenishment. The 180-sample fertility assessment carried out in this research brings the picture into focus. Nitrogen and sulphur deficiencies are widespread, zinc is critical in close to half the samples, and organic carbon is sliding in both belts. Soil pH is trending alkaline, and that alone is dragging phosphorus availability down through fixation.

The recommendation flowing from these findings is a site-specific nutrient management plan, anchored on Parker's nutrient index, that prioritises N, S and Zn in year 1, adds phosphorus placement and organic carbon restoration in year 2, and shifts to micronutrient fine-tuning thereafter. Looking forward, the larger task is to connect fertility assessment directly to fertiliser procurement through the Soil Analysis Programme, so that the diagnostic effort built into this kind of research actually moves the needle in the field. Without that connection, even the most careful audit remains a report on the shelf rather than a tool in the hands of the farmer.

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