International Journal of Agriculture and Plant Science
www.agriculturejournal.in
Online ISSN: 2664-7664, Print ISSN: 2664-7656
Received: 15-12-2024, Accepted: 14-01-2025, Published: 29-01-2025
Volume 7, Issue 1, 2025, Page No. 83-89

Soil fertility status of tomato (kashi aman) growing soils of U.P.

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Abstract
Aims: To assess the soil fertility status under continuous growing tomato fields in U.P.
Methodology: Composite soil samples in surface (0-15 cm) and subsurface (15-30 cm) were collected from 100 locations by following random sampling technique in intensively growing tomato fields of Jaisinghpur block during 2020 by considering their physiographic units to estimate various physico-chemical properties. Kashi Aman tomato variety procured from ICAR-IIVR, Varanasi, U.P.
Results: Samples were analyzed for texture, BD and MWHC as physical properties. Results revealed that both surface and subsurface soils were comprised of sandy loam texture, as depth increases there was increased BD and decreased MWHC. The soils were slightly acidic and non-saline in nature, the extent of deficiency of organic carbon content increased with increasing depth (0.51 and 0.34 g/cc) but CEC varied from surface (9.44 meq/ 100g) to subsurface (10.04 meq/ 100g). Soils were deficient in available N (175.54 and 117.67 N kg ha^{-1}) and moderate in available K content (290.64 and 227.45 K_2O kg $ha^{1)}$ in both the depths, but available phosphorous found at varied levels in soil (39.31 and 26.70 P_2O_5 kg ha^{-1}) and sufficient quantity of secondary nutrients were found in the soil. DTPA extractable Zn, Fe and Mn showed decreasing trend but Cu and hot water-soluble B showed increasing trend with increased depth. Correlation of nutrients indicate its variation in availability and also the relationship among various nutrients.
Conclusion: Low organic carbon and nutrients in soils were attributed to low application of recommended dose of organic manures, high temperature and imbalanced application of fertilizers, especially in dry zone areas. Hence, availability of nutrients in soil influenced by amount and type of fertilizers application, cropping system and management practices followed by the farmers.

Keywords: Soil properties, fertility status, intense tomato growing soils, surface and subsurface soils

Introduction

Agricultural production majorly depends on the quality and fertility status of the soil and it will act as a backbone for building the high input agricultural production system (Parnes, 2013) [15] and helpful for improving soil physical condition and nutrient availability in turn influences the plant growth and development. Thus, understanding its soil fertility status becomes the fundamental objective to know the optimum condition for the soil growth (Amgain *et al* 2020) [1]. The most critical concern associated with the depletion of soil fertility lies in its enduring consequences. Soil loses a considerable quantity of nutrients each year due to factors such as leaching, erosion and intensive cropping system. When crops are grown consistently without replenishing these nutrients, soil fertility declines, resulting in reduced crop yields. Poor soil fertility gives rise to sparse vegetation cover, which, in turn, heightens vulnerability to erosion (Srinivasan *et al*, 2023). While, soil testing is a valuable tool for assessing the nutrient content of soil, aiding in the determination of appropriate fertilizer recommendations. While the focus is often on analysing the nutrient status of the topsoil, it's important to recognize that plants also extract nutrients from deeper layers of the soil. The days of single fertilizers are numbered due to reduced availability and there is an over dependence of complex fertilizers, DAP and there is hardly any addition of farm yard manures (FYM) and other organics leading to nutrient mining. This is further accentuated due to the fact that there are very few tasks of nutrient application based on soil tests which ideally would have addressed imbalance in soil fertility. Yield plateau is an issue directly related to soil fertility reports of response to balanced nutrient addition. Therefore, understanding the vertical distribution of nutrients is of utmost significance when making recommendations for effective soil management practices (Sanker *et al*.,2009). Various processes, including leaching, weathering, dissolution, and atmospheric deposition, contribute to distinct patterns of nutrient distribution in the vertical direction of the soil profile (Mandal *et al*. 2021) [11]. Hence, the present study was undertaken to know the vertical distribution of fertility status of nutrients in the tomato growing soils.

Material and Methods

1. Location of sampling sites

The annual rain fall ranged from 850 to 1089 mm and more than 50 per cent is received during *kharif* season. The soils are grey-yellowish sandy loam in major areas, lateritic in pockets. Soil samples were collected from Jaisinghpur block situated in the Sultanpur district of U.P. and falls in the tropical type of climatic region of India. The climate here moderately hot and dry. The months of March to June of the summer season are very hot with temperature of around 35^0C - 45^0C. Large percentage of cultivated land is mainly under tomato, which was cultivating intensively with application of high analysis fertilizers over the years.

2. Soil sampling procedure and laboratory analysis

One hundred surface (0-15 cm) and subsurface (15-30 cm) soil samples (n=200) were collected from intense tomato growing soils of the said block of Sultanpur by using random soil survey method. The samples were collected air dried, passed through 2.0 mm sieve and stored in cloth bags in readiness for laboratory analysis for its physical and chemical properties. Standard Methods as described by Jackson, 1973 [8] were adopted for the analysis of the soil samples. Particle sizes distribution was determined by Bouycous hydrometer method (Bouyoucos GJ., 1936) [2], Bulk density and moisture content by gravimetric method (as expressed by the weight of the soil before and after over-dried and the volume of the soil), by keen's box method (Piper CS.., 1966) [16]. The soil pH in water (1:2.5) was determined using potentiometric analysis using glass electrode pH meter. Conductivity cell is used for estimation of EC of soil water suspension, Organic matter content was determined by (Walkley A. and Black CA.,1934) [28] wet chromic acid digestion method. The available N of soil was distilled with 25 mL of 0.32% $KMnO_4$ and 25 mL of 2.5% sodium hydroxide (NaOH). The liberated ammonia was trapped in 4% H_3BO_3 containing bromo-cresol green and methyl red mixed indicator and titrated against standard sulfuric acid (Subbaiah BV. and Asija GL., 1956) [23], available P_2O_5 in soil samples were extracted with Bray's-1 (NH_4F+HCl) and Olsen's Method (0.5 M $NaHCO_3$). Phosphorus content in the extract was determined by ascorbic acid–molybdate complex method and the blue colour intensity was recorded at 660 nm using spectrophotometer (Jackson ML., 1973) [8]. The exchangeable cations were extracted with 1M NH_4OAC (pH 7.0) to determine K using flame photometer and exchangeable Ca and Mg by ion complex with EDTA solution while available sulphur was estimated by using Turbidometry method. Micronutrient cations (Fe, Mn, Cu and Zn) are extracted with DTPA and estimated by atomic absorption spectrophotometer (Lindsay WL. and Norvell WA.,1978) [10] and hot water-soluble boron was estimated by colour development with azomethane-H and intensity was recorded at 430 nm using spectrophotometer (Jackson ML., 1973) [8].

Results and Discussion

1. Effect of intense tomato growing on physical properties of soil

The mean values of soil texture (Relative proportion of sand, silt and clay particles) of the study area indicated that soils consistently maintained a sandy loam texture, extending from surface to deeper layers of the soil profile. Majority of the surface soil samples had sandy loam texture while subsurface soils had loamy sand texture (Table 1) but as the depth increases clay content increases because the study area originated from coarser parent material (granite, gneiss and feldspar) tend to have a notable proportion of sand in their surface layers. Additionally, they tend to accumulate clay and silt particles in the subsurface due to the finer particle size (Chaithra BK., *et al*. 2019) [3].

Bulk density (BD) and maximum water holding capacity (MWHC) varied with depth and observed with high BD, low MWHC with the mean values of 1.43 g/ cc and 1.58 g/ cc, 37.09% and 30.69% in surface and subsurface soils respectively (Fig. 2 and 3). Majority of the surface soil samples had higher bulk density ranged between 1.25-1.50 g/ cc, while subsurface had lower BD (1.00-1.25 g/ cc). Similarly, majority of soil samples at both the depth observed with range of 30-50% MWHC. Lower BD due to stable aggregate formation and presence of organic matter in surface soils (Prathibha KS., Hebbara M. and Patil PL., 2019) [17] and (Tumbal P. and Patil PL., 2015) [25], but as depth increases increased BD was observed due to continuous growing of high yielding crop with higher rate uses of heavy implements and mechanized cultivation of crops also illuviation (Washing in of finer particles) and dispersion of clay particles, causes clogging the soil pores in subsurface resulting in increased bulk density (Nagendra BR. and Patil PL., 2015) [13] as WHC is inversely related to BD and directly to pore space more WHC observed in surface soils.

2. Effect of intense tomato growing on Chemical properties of the soil

The effect of tomato growing on chemical properties was indicated in Table 2. Soils of the study area was slightly acidic in nature with a mean value of 6.52 ± 0.79 and 6.50 ± 0.74 with a low soluble salt concentration 0.86 ± 0.41 dS m^{-1} and 0.76 ± 0.36 dS m^{-1} and observed with low organic matter content 0.51 ± 0.22 % and 0.34 ± 0.15 % in both surface and subsurface soils respectively, also CEC showed increasing trends with increased depth. Here, soil pH, electrical conductivity (EC) and organic carbon (OC) decreased with increasing depth of the soils due to various factors such as application of acid forming fertilizers such as ammonical and amide form of chemical fertilizers, these practices resulted in accumulation of hydrogen ions in the soil also increases the soluble salt concentration in soil (Chang EH., Chung R. and Tsai YW., 2007 [4] and Pal DK., *et al*. 2009) [14] highlighted that climate and vegetation are the major factors influencing the change in soil organic carbon content which was found to be higher in surface soils compared to subsurface due to application of farm yard manure (FYM) accumulation and decomposition of plant and animal residues in surface soil are affected by microbial activity, as evidenced by the studies conducted by (Dhumgond P., *et al*, 2012 [6] and Veeresha K. and Patil PL., 2019) [27].

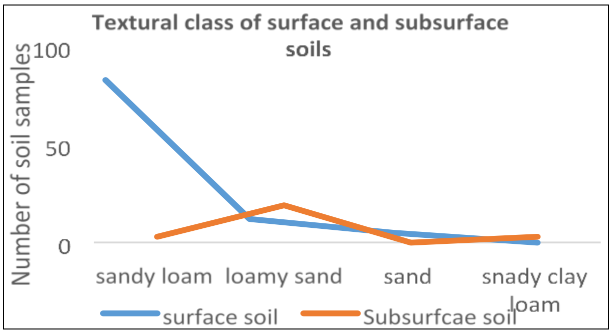

Fig 1: Textural class of Surface and Subsurface soils

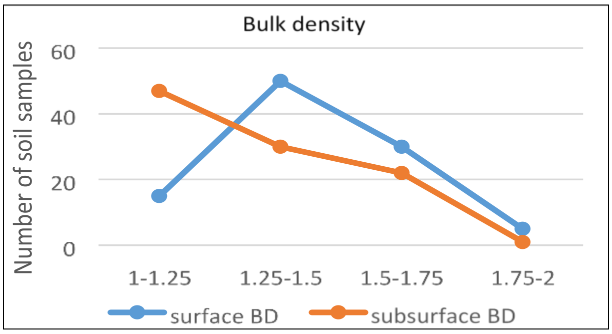

Fig 2: Bulk density of surface and subsurface soils

Table 1: Changes in physical properties of surface and subsurface soils due to intense tomato cultivation

Parameter	Surface soil (0-15 cm)		Subsurface soils (15-30 cm)	
	Mean ± SD	Range	Mean ± SD	Range
Sand (%)	76.24	64.5 - 90.24	72.62	60.45 - 87.56
Silt (%)	11.44	4.00 - 18.76	13.87	5.98 - 20.05
Clay (%)	11.84	3.88 - 18.95	13.94	4.08 - 21.42
Textural class	Sandy loam		Sandy loam	
Bulk density (g/cc)	1.43 ± 0.17	1.14 - 1.93	1.58 ± 0.22	1.25 - 2.53
Maximum water holding capacity (%)	37.09 ± 9.76	17.00 - 64.50	30.69 ± 10.70	13.76 - 51.78

Table 2: Changes in chemical properties of surface and subsurface soils due to intense tomato cultivation

Parameter	Surface soil (0-15 cm)		Subsurface soils (15-30 cm)	
	Mean ± SD	Range	Mean ± SD	Range
pH	6.52 ± 0.79	3.78-8.33	6.50 ± 0.74	3.95-8.33
Electrical conductivity (dS m^{-1})	0.86 ± 0.41	0.14-2.09	0.76 ± 0.36	0.21-2.38
Organic carbon (%)	0.51 ± 0.22	0.09-1.06	0.34 ± 0.15	0.06-0.72
Cation exchange capacity (meq/ 100g soils)	9.44 ± 3.29	4.97-23.14	10.04 ± 3.02	4.86-23.42

3. Effect of intense tomato growing on soil nutrient status

Effect of intense tomato growing on major, secondary and micronutrients status data were indicated in Table 3 and Table 4.

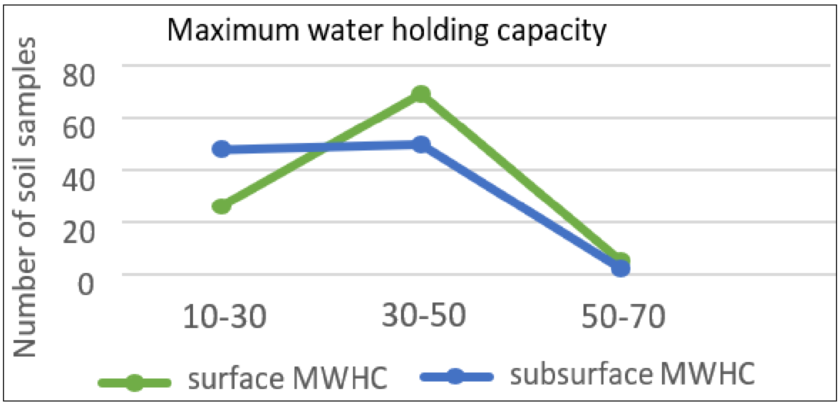

Fig 3: Maximum water holding capacity of surface and subsurface subsurface soils

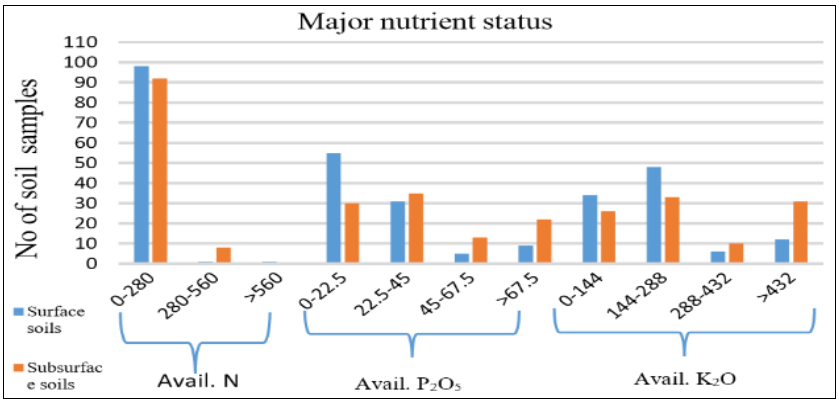

Fig 4: Major nutrient status of surface and soils

3.1. Available N, P_2O_5 and K_2O:

Nutrient status of the tomato growing soils of study area was found to be low in available N content, available P_2O_5 and medium available K_2O content with a mean values of 175.54 and 117.67 N kg ha^{-1}, 39.31 and 26.70 P_2O_5 kg ha^{-1}, 290.64 and 227.45 K_2O kg ha^1 in surface and sub-surface soils respectively and the classification of major nutrients based on LMH approach (Fig. 4) indicated that most of the collected soil samples contained low quantity of available N (0-280 kg ha^{-1}), medium content of available K_2O (144-288 kg ha^{-1}) both in surface and sub-surface soils except phosphorous, low available P_2O_5 (0-22.5 kg ha^{-1}) in surface soils and medium content of P_2O_5 (22.5-45 kg ha^{-1}) in sub-surface soil due to losses of available form of nutrients through leaching, run- off, fixation by basic cations, low vegetation cover and low organic matter leads to low availability of nitrogen and fixation of phosphorous by clay particles, iron, aluminium, also with the higher concentration of Zn had antagonistic interaction with phosphorus reduced its availability in soil (Chaithra BK., 2019 [3] and Veeresha K. and Patil PL., 2019) [27]. The available potassium content in the soil exhibited a wide range, from low to very high levels, which can be attributed to the continuous application of potassic fertilizers, the prevalence of micaceous feldspar parent material in the study area and the release of readily available potassium from organic residues (Amgain R., Khadka D., Sushila J. and Rajan M.,2020 [1] and Harsha BR. and Jagadeesh BR.,2017) [7].

3.2. Secondary nutrient status (Ca, Mg and S)

Secondary nutrient status indicate the presence of sufficient concentration of exchangeable calcium, magnesium and available sulphur in intense tomato growing soils with the mean values of 4.87 and 4.80 meq/100g, 4.07 and 4.74 meq/100g and 15.17 and 11.13 mg kg^{-1} in surface and subsurface soils respectively. As per the LMH classification, around 98% and 97% of the soil samples comes under >2.5 meq/100g of soil of exch. Ca. Around 97% and 98% of the soils had >1.5 meq/100g of exch. Mg. whereas, around 99% of the soils had avail. S content ranged between 0-20 mg kg^{-1} (Fig. 5) in both the depth of the soil. As mobility of the Mg was more compare to Ca and adsorption onto the clay particles more in subsurface soils but clay particles also have strong association with Ca hence, with increasing depth Exch. Ca content decreases but Exch. Mg content increases (Pulakeshi HBP., Patil PL. and Dasog GS., 2014 [18] and Siddharam PKS., Anil Kumarand Eresha., 2015) [21]. Available Sulphur showed decreasing trends with increased depth, due to consistent incorporation of farm residues, organic manures and sulphur-containing fertilizers, a substantial concentration of available sulphur was detected in the uppermost layer of the soil profile (Khanday MUDD., Ram D., Wani JA. and Ali T., 2017) [9].

Table 3: Changes in major and secondary nutrient status of surface and subsurface soils due to tomato cultivation

Parameter	Surface soil (0-15 cm)		Subsurface soils (15-30 cm)	
	Mean ± SD	Range	Mean ± SD	Range
Available N (kg ha^{-1})	175.54 ± 70.01	62.72-398.78	117.67 ± 67.49	37.63-583.29
Available P_2O_5 (kg ha^{-1})	39.31 ± 26.25	7.14-132.82	26.70 ± 21.32	4.06-120.30
Available K_2O (kg ha^{-1})	290.64 ± 183.78	83.44-709.36	227.45 ± 146.96	79.43-709.77
Exchangeable Ca (meq/ 100g soils)	4.87 ± 2.43	2.25-15.90	4.80 ± 2.27	1.13-15.95
Exchangeable Mg (meq/ 100g soils)	4.07 ± 1.61	1.25-8.13	4.74 ± 1.86	1.03-9.72
Available S (mg kg^{-1})	15.17 ± 2.76	5.11-24.14	11.63 ± 2.63	5.11-20.07

3.3. Soil micronutrient status

DTPA extractable micronutrients (Fe, Mn, Zn and Cu) content of the intense tomato growing area showed decreasing trend with increased depth except Cu with a mean value of 15.50, 18.56, 1.52 and 1.61 mg kg-1 in surface soils respectively, similarly in subsurface soils had mean values of 14.16, 17.85, 1.43 and 1.63 mg kg-1 respectively. The availability of micronutrients of as per the critical limits showed in Fig.6 indicated that majority of the soil samples had higher concentration of micronutrients in soil, due to varying intensity of pedogenic process, formation of chelation with organic matter, will prevent the micronutrient from oxidation and precipitation, with the increase in microbial activity influences the release of micronutrient into soil solution (Sathish S., Naidu MVS. And Ramana KV., 2018 [20], Nagarjuna V. and Naidu MVS., 2021 [12] and Srinivasan R., Natarajan A., Kumar KSA. and Kalaivanan D., 2013) [22] and increased Cu content due to its complexation with clay in subsurface soils showed increasing trend of Cu availability (Udeigwe KT., Eichmann M., Eze NP., Ogendi MG., Morris NM. and Riley RM., 2016) [26]. Hot water soluble Boron status of intense tomato growing soils has a range of 0.01-1.02 and 0.01-1.97 mg kg-1 in surface and subsurface respectively, indicated increasing trend with increased depth of soil and most of the soil samples comes under 0-0.5 mg kg-1 classification of LMH and boron availability majorly depends on the pH of the soil and with increase in clay content will contributes for the adsorption and desorption kinetics in soil (Tlili A., Dridi I., Attaya R. and Gueddari M.,2019) [24].

Table 4: Changes in micronutrient status of surface and subsurface soils due to intense tomato cultivation

Parameter	Surface soil (0-15 cm)		Subsurface soils (15-30 cm)	
	Mean ± SD	Range	Mean ± SD	Range
DTPA extractable Zn (mg kg^{-1})	1.52 ± 1.26	0.03-7.58	1.43 ± 0.72	0.36-4.34
DTPA extractable Cu (mg kg^{-1})	1.61 ± 0.66	0.04-4.34	1.63 ± 0.69	0.36-3.93
DTPA extractable Fe (mg kg^{-1})	15.50 ± 9.01	4.38-44.66	14.16 ± 8.15	1.55-37.42
DTPA extractable Mn (mg kg^{-1})	18.56 ± 7.48	0.25-40.44	17.85 ± 5.48	2.94-31.52
Hot water-soluble B (mg kg^{-1})	0.25 ± 0.21	0.01-1.02	0.33 ± 0.39	0.01-1.97

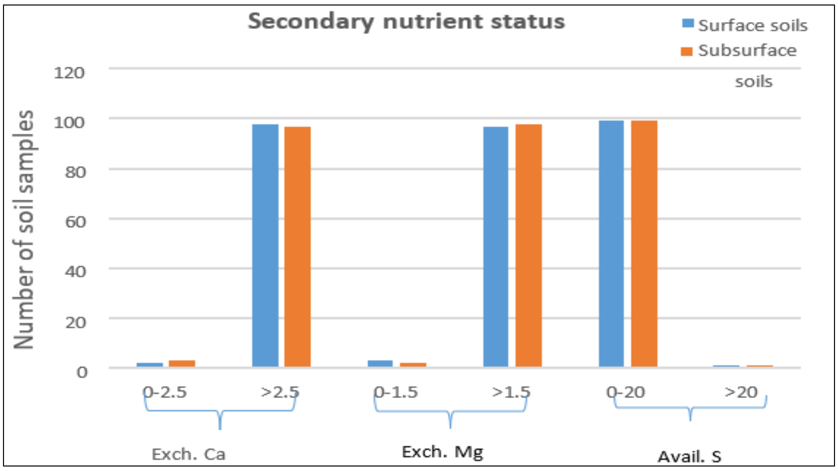

Fig 5: Secondary nutrient status of Surface and Subsurface soils

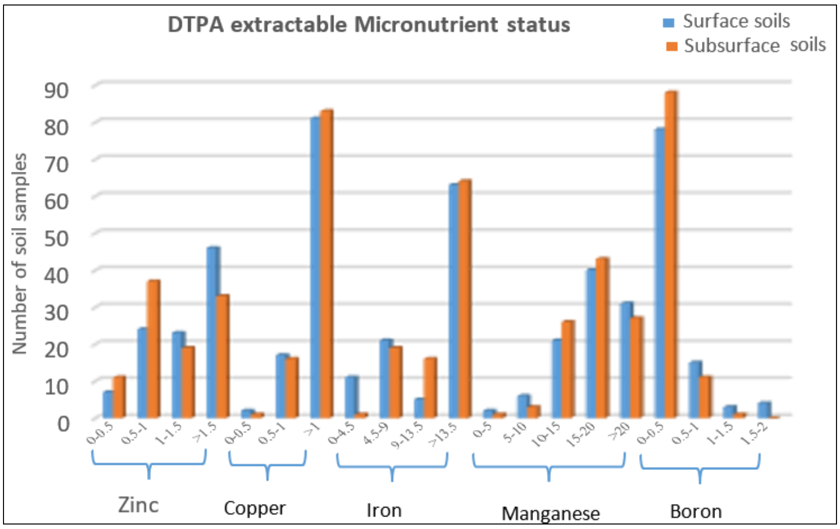

Fig 6: DTPA extractable micronutrient status in soils

3.4. Correlation of chemical properties and nutrient status of surface and subsurface soils due to tomato cultivation in the study area

The table 5 and 6 showed that the surface soils showed variation in their relation with the nutrients present in the soil, pH was positively and significantly correlated with available phosphorous, exchangeable calcium and magnesium, whose availability was more in neutral condition. Whereas, calcium showed significantly negative relation with available nitrogen indicates calcium induced nitrogen deficiency in soil in surface soil.

Organic carbon positively and significantly related with available phosphorous and sulphur, due to increased mineralization of organic matter and Zn had negative correlation with available phosphorous in subsurface soil by forming chelation decreases the phosphorous availability in soil.

Table 5: Correlation of chemical properties and nutrient status of surface soils due to intense tomato cultivation

	pH	EC	OC	N	P	K	Ca	Mg	S	Zn	Cu	Fe	Mn	B
pH	1													
EC	0.955**	1												
OC	0.215*	0.240*	1											
N	-0.788**	-0.787**	-0.143	1										
P	0.798**	0.825**	0.165	-0.613**	1									
K	-0.606**	-0.613**	-0.071	0.557**	-0.495**	1								
Ca	0.861**	0.868**	0.186	-0.705**	0.706**	-0.539**	1							
Mg	0.263**	0.352**	0.053	-0.264**	0.221*	-0.147	0.394**	1						
S	-0.903**	-0.889**	0.207*	0.698**	-0.731**	0.594**	-0.767**	-0.268**	1					
Zn	0.910**	0.926**	0.280**	-0.717**	-0.728**	-0.556**	0.818**	0.394**	-0.890**	1				
Cu	0.150	0.244*	0.040	-0.219*	0.219*	-0.068	0.279**	0.446**	-0.140	0.184	1			
Fe	-0.642**	-0.651**	-0.263**	0.508**	-0.559**	0.413**	-0.576**	-0.217*	0.644**	-0.624**	-0.223*	1		
Mn	-0.119	-0.027	-0.117	0.079	0.051	0.091	-0.034	-0.008	0.063	-0.024	0.287**	0.078	1	
B	0.852**	0.875**	0.244*	-0.696**	0.633**	-0.546**	0.805**	0.349**	-0.818**	0.867**	0.256*	-0.590**	0.011	1

*indicates significance at 0.05

** indicates significance at 0.01

Table 6: Correlation of chemical properties and nutrient status of subsurface soils due to intense tomato cultivation

	pH	EC	OC	N	P	K	Ca	Mg	S	Zn	Cu	Fe	Mn	B
pH	1	0.600**	0.139	-0.641**	0.214*	-0.590**	0.125	-0.080	-0.459**	0.428**	0.201*	-0.496**	-0.102	0.329**
EC		1	0.226*	-0.819**	0.205*	-0.663**	0.252*	0.168	-0.545**	0.570**	0.120	-0.607**	-0.120	0.330**
OC			1	-0.222*	0.346**	-0.127	0.093	0.339**	0.141**	0.123	0.065	-0.137	-0.111	0.133
N				1	-0.209*	0.686**	-0.260**	-0.036	0.696**	-0.560**	-0.033	0.565**	0.131	-0.460**
P					1	-0.127	0.227*	0.013	-0.079	-0.055	-0.033	-0.142	-0.179	0.140
K						1	-0.254*	0.024	0.699**	-0.598**	0.022	0.833**	0.098	-0.552**
Ca							1	0.058	-0.164	0.247*	-0.007	-0.287**	-0.086	0.105
Mg								1	0.187	-0.053	0.115	-0.046	-0.033	-0.065
S									1	-0.525**	0.044	0.548**	0.088	-0.484**
Zn										1	-0.095	-0.525**	0.059	0.437**
Cu											1	-0.026	-0.140	-0.186
Fe												1	0.062	-0.547**
Mn													1	0.154
B														1

*indicates significance at 0.05
** indicates significance at 0.01

Conclusion

The fertility status of intensively cultivated tomato soils of Sultanpur U.P., reveals certain key characteristics. The study area falls under sandy loam textural class with increased bulk density and reduced maximum water holding capacity with increasing depth. They tend to have slightly acidic pH and low organic carbon content. The availability of nutrient status indicated, low availability of Nitrogen, medium availability of P_2O_5, and K_2O content at various depth. Furthermore, the sufficient content of exchangeable cations like Ca, Mg and available S also DTPA-extractable micronutrients were found in soil at both the depths, but hot water-soluble B found to be deficient. From this study displayed that, nutrient dynamics are significantly influenced by the type and quantity of fertilizers applied, the adoption of management strategies, cropping intensity, cropping pattern and the presence of organic residues within the soil, by adopting crop rotation with balanced application of organic manure with inorganic fertilizers can balances the nutrient status and improves the soil health.

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