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Evaluation of soil physical and chemical properties in the vegetable growing areas of Shivalik hills of Himachal Pradesh, India

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Abstract
The study was conducted in the months of February and March, 2020 in the tomato growing areas of Sirmour district of Himachal Pradesh, India to study the physical properties of the soil. In this study, 50 randomly selected sampling locations within vegetable growing areas of Sirmour district were used to collect 100 representative soil samples from two depths (0-15 cm and 15-30 cm). These samples were analyzed for various soil physical properties like soil texture, bulk density, particle density, porosity, and water holding capacity. The soils were found to range from sandy loam to loamy sand, characteristics common to the region. Results indicated that both bulk density and particle density increased with depth, while porosity and water holding capacity declined. In the surface layer, bulk density ranged from 1.13 to 1.34 Mg m^{-3}, particle density from 2.01 to 2.46 Mg m^{-3}, porosity from 39.90% to 50.00%, and water holding capacity from 41.74% to 66.03%. In the sub-surface, these parameters shifted to 1.18-1.41 Mg m^{-3}, 2.04-2.47 Mg m^{-3}, 38.32-48.99%, and 48.45-50.98% respectively. Correlation analysis revealed that higher sand content significantly increased bulk and particle densities while reducing water holding capacity, with silt showing variable depth-dependent relationships and clay exhibiting no significant correlations. These findings highlighted the significant depth-related variability in soil physical properties, providing valuable insights for improved soil management in vegetable farming.

Keywords: Soil texture, bulk density, particle density, porosity, water holding capacity

1. Introduction

Soil physical properties are fundamental determinants of soil quality and directly influence the productivity of vegetable crops (Doran *et al*., 2018) [8]. In vegetable production, characteristics such as soil texture, bulk density, particle density, porosity, and water holding capacity are critical because they regulate water availability, root penetration, aeration, and overall nutrient uptake (Sung *et al*., 2017) [36]. The evaluation of these properties is particularly important in regions like the Sirmour district of Himachal Pradesh, where varied agro-climatic conditions and diverse soil types can significantly affect crop performance. This study aims to assess the soil physical properties in vegetable growing areas of Sirmour, providing insights that are crucial for optimizing management practices and ensuring sustainable production.

Soil textureis the proportions of sand, silt, and clay which influences water retention and drainage capabilities (Paltseva, 2024) [29]. Sandy soils, for instance, are known for their rapid drainage and low water retention (Huang and Hartemink, 2020) [16], while clayey soils exhibit high water holding capacity than sand (Herawati*et al*. 2021) [15] but may restrict root growth due to their compact nature (Tracy *et al*., 2011) [39]. The vegetable crops, which generally require well-drained soils with moderate water retention (Yadav *et al*., 2023) [41], thrive in textures that strike a balance between these extremes. Evaluating soil texture can help in recommending appropriate amendments and irrigation practices tailored to the specific needs of vegetable crops. Bulk density is another critical parameter as it reflects the degree of soil compaction (Udom and Ehilegbu, 2018) [40], affecting root growth and the soil's ability to store water and air (Nawaz *et al*., 2013) [27].

Lower bulk density generally indicates a more porous soil with better aeration and water movement, which are essential for healthy vegetable production. Conversely, higher bulk density can hinder root expansion and reduce the efficiency of water uptake (Ren *et al*. 2018) [32]. Therefore, understanding the bulk density variations in the region which indicates compaction can guide farmers in implementing practices that mitigate compaction, such as organic matter incorporation or reduced tillage (Yang *et al*. 2022) [42]. Closely related to bulk density is particle density, which provides information about the intrinsic density of soil particles independent of pore space. Although, particle density plays an important role in calculating soil porosity, the fraction of soil volume that is occupied by air and water. Porosity is crucial because it influences the soil's water holding capacity and gas exchange (Regelink *et al*., 2015) [31], both of which are vital for sustaining the biological activity necessary for nutrient cycling in vegetable crops. High porosity facilitates effective root respiration and microbial activity, promoting a healthy soil ecosystem (Kravchenko and Guber, 2017) [22]. Water holding capacity, the ability of soil to retain water after the excess water is drained out (Abdallah *et al*., 2021) [1], is a pivotal factor in vegetable farming, particularly in regions prone to irregular rainfall. Adequate water holding capacity ensures that plants have access to sufficient moisture during dry periods (Gavrilescu, 2021) [10], thereby reducing the need for frequent irrigation and enhancing water use efficiency. In vegetable production, where water availability directly impacts yield and quality (Liliane and Charles, 2020) [24], understanding and managing water holding capacity can lead to improved crop resilience and productivity.

This research addresses the evaluation of these soil physical properties in the vegetable growing areas of Sirmour district. By systematically analyzing soil texture, bulk density, particle density, porosity, and water holding capacity, this study not only highlights the inherent variability within the region but also provides a scientific basis for improved soil management practices. Ultimately, the findings aim to support sustainable vegetable production by guiding farmers and policymakers in optimizing soil conditions to enhance crop performance and resource use efficiency.

2. Materials and Methods

The study was conducted in the months of February and March, 2020 in the tomato growing areas of Sirmour district of Himachal Pradesh, India. The survey was conducted in the tomato growing regions of Sirmour district, Himachal Pradesh, India covering the blocks of Nahan, Pachhad, Rajgarh, Sangrah, and Shillai. Sirmour lies between 30°22′30″ and 31°01′20″ North latitude and 77°01′12″ to 77°49′40″ East longitude, with elevations ranging from 300 to 3000 meters above sea level, making it the southeasternmost district of the state. Covering 2,825 square kilometers—approximately 5.07% of Himachal Pradesh's total area—the district is predominantly mountainous, situated within the Shivalik ranges. It receives an average annual rainfall of about 1405 mm, with 90% falling during the monsoon months of July to September, and experiences three main seasons: winter (November to February), summer (March to June), and monsoon (July to October). Soil types vary widely from thin, barren soils on high mountains to deep, fertile alluvial soils in the valleys, with hilly areas characterized by brown hill soils and the southern parts featuring shallow black, brown, and alluvial soils.A preliminary survey was carried out to collect essential information on the area and vegetable production, which led to the selection of tomato as the crop of interest. Fifty farmers cultivating tomatoes on plots exceeding 1 Bigha (800 m²) were chosen for the study, and the locations are depicted in Table 1. The sampling sites ranged from 30°38′19″ to 30°54′10″ North latitude, 77°11′48″ to 77°39′14″ East longitude, and 762 to 1522 meters in altitude. From each site, two representative soil samples were collected: one from the surface layer (0-15 cm) and one from the sub-surface (15-30 cm), using stainless steel augers and spades to avoid contamination. The samples were then air-dried in the shade, ground with a wooden pestle and mortar, and sieved through a 2 mm mesh before being stored in cloth bags for laboratory analysis. These processed samples were analyzed for key soil physical properties including texture, bulk density, particle density, porosity, and water holding capacity using standard methods as detailed in table 2. For chemical properties, soil pH was estimated by Potentiometric method (Jackson 1973), electrical conductivity by Conductimetric method (Jackson 1973) and organic carbon by Rapid titration method (Walkley and Black 1934). Descriptive statistics, including ranges, means, standard errors, and coefficients of variation, were calculated for each property. Additionally, simple correlation analysis was employed to assess the relationships between soil physical characteristics with each other, following the methodology described by Gomez and Gomez (1984) [11].

3. Results and Discussion

3.1 Soil texture

A scrutiny of data presented in table 3 revealed that the soils of the studied area varied in texture. The sand, silt and clay content in the surface layer (0-15 cm) varied from 56.78 to 88.34, 8.00 to 32.00 and 2.57 to 13.80% with the mean values of 73.93, 18.70 and 7.39%, respectively. The CV of 8.98, 33.43 and 31.64% for sand, silt and clay, respectively indicates that these varied spatially in surface depths. The highest (88.34%) and lowest (56.75%) content of sand was recorded in Gavahi village of Sangrah block and Banogta village of Nahan block, respectively. The lowest (8.00%) silt content in the surface layer was observed in Raasat village of Shillai block and Nahog and Gavahi villages of Sangrah block. Whereas, the highest (32.00%) silt content in the surface layer was found in Banogta and Bechar Kabag villages of Nahan block. The clay content was observed to be highest (13.80%) in Laja-Manal village of Shillai block and lowest (2.57%) in Salana village of Rajgarh block.The sand, silt and clay content in the soils of sub-surface layer (15-30 cm) varied from 52.70 to 80.36, 10.00 to 37.00 and 3.21 to 15.65% with the mean values of 67.75, 22.62 and 9.63%, respectively as shown in table 4.1. Ghil Pabiyana and Rohnat villages of Rajgarh and Shillai block recorded the highest (80.36%) and lowest (52.70%) sand contents in sub-surface soil, respectively.The highest (37.00%) and lowest (10.00%) silt contents in sub-surface soil were found in Rohnat and Gavahi villages of Shillai and Sangrahblock, respectively.Narag and Salana villages of Pachhad and Rajgarh block recorded highest (15.75%) and lowest (3.21%) contentsof clay in sub-surface soil, respectively. The CV of 10.02, 26.69 and 28.66% for sand, silt and clay, respectively indicates that it varied spatially in sub-surface depths. The cumulative range data showed gradual increase in the percentage of silt and clay in the lower depths. Sand percentage showed the opposite distribution tendency which indicated the migration processes of finer soil particles to lower depths as the result of the climatic conditions of the region. Jamio (2014) [18], Kaur (2017) [19], Chandel (2020) [5] and Zhou *et al*. (2020) [43] also reported the same trend of decline in the sand percentage and increase in the silt and clay percentages with increase in the soil depth.

The figure 1 shows that in overall, 86.00% of the surface soil samples were found to have sandy loam texture. Remaining 14.00% were loamy sand in texture and this textural class was found in the Arka Bardhyog village of Pachhad block, Ghil Pabiyana, Kotli and Salana villages of Rajgarh block and Nahog, Rerli and Gavahi villages of Sangrah block. In sub-surface soils, 92.00% of soil samples were sandy loam in texture except Ghil Pabiyana, Kotli and Salana villages of Rajgarh block and Rerli village of Sangrah block (Figure 2). The results corroborate the findings of Kumari *et al*. (2018) [23], Suri (2018) [37] and Thakur and Bisht (2020) [38] also reported that most of the soils of Sirmour district have sandy loam texture.

3.2 Bulk density

The data pertaining to the status of bulk density is depicted in table 4 showed that the bulk density of the surface soil (0-15 cm) and sub-surface (15-30 cm) varied from1.13 to 1.34 and 1.18 to 1.41 Mg m^{-3} with the mean values of 1.22 and 1.28 Mg m^{-3}, respectively. For surface and sub-surface soils, the highest values (1.34 and 1.41 Mg m^{-3}, respectively) of bulk density were recorded in Manal village of Shillai block and lowest values (1.13 and 1.18 Mg m^{-3}) were recorded in Mewag jon village of Rajgarh block. The bulk density in the surface and sub-surface depths spatially as indicated by the CV values of 4.47 and 4.43%, respectively. The data also showed that the bulk density of soil increased with increase in soil depth at all the sampling sites.The increase in bulk density with increase in soil depths may be attributed to the high organic matter content in the surface layer. Arshad (2020) [2], Chandel (2020) [5] and Thakur and Bisht (2020) [38] also showed the similar trend of increase in bulk density. Sharma (2005) [34-35] reported that the bulk density values varied from 1.22 to 1.42 and 1.22 to 1.44 Mg m^{-3} in surface and sub-surface soils, respectively and Chandel (2013) [4] also revealed that the bulk density values ranged from 1.04 to 1.74 g cm^{-3} in the vegetable growing soils of Sirmour district. Fayed and Rateb (2013) [9], Gyawali*et al*. (2016) [14] and Nkwopara *et al*. (2021) [28] also found the similar trend of increase in bulk density with depth in their studies.

3.3 Particle density

Thedata presented in table 4 revealed that the particle densityof the surface soil (0-15 cm) and sub-surface soil (15-30 cm) varied from 2.01 to 2.46and 2.04 to 2.47 Mg m^{-3} with the mean values of 2.22 and 2.27 Mg m^{-3}, respectively. The highest values for surface (2.46 Mg m^{-3}) and sub-surface soils (2.47 Mg m^{-3}) were observed in Methli village of Sangrah block, whereas, Bhelan village of Pachhad block recorded the lowest value in surface (2.01 Mg m^{-3}) and sub-surface (2.04 Mg m^{-3}) layers. The CV of 4.80 and 4.62% for particle density in the surface and sub-surface depths respectively indicated the spatial variability. It is also observed from the data (Table 4) that the particle density increased with increase in soil depth in all the sampling sites. The trend of increase in particle density with increase in soil depth is ascribed to low content of organic matter in the sub-surface layers. The result trend was in line with the findings of Mahajan *et al*. (2007) [25] and Chandel (2013) [4] (Table 4).

3.4 Porosity

An appraisal ofthe data presented in table 4 revealed that the porosity in surface (0-15 cm) and sub-surface (15-30 cm) soil ranged from 39.90 to 50.00 and 38.32 to 48.99% with mean values of 44.89 and 43.66%, respectively. In surface and sub-surface layer, the highest (50.00 and 48.99%, respectively) and lowest (39.90 and 38.32%, respectively) values of porosity were found in Methli and Khano Khanani villages of Sangrah and Nahan block, respectively. The CV of 4.99 and 5.13% for porosity in the surface and sub-surface layers, respectively showed that it varied spatially. In all the sampling sites, decrease in porosity was observed with the increase in soil depth. The decrease in porosity decreased with increase in soil depths is attributed to the higher level of organic matter content in the surface depths ashigher organic matter content have positive effect on porosity. The trend of the results is in accordance with the findings of Salve and Bhardwaj (2020) [33] and Nkwopara*et al*. (2021) [28]. The results get strength from the findings of Chandel (2013) [4] who also observed that the porosity values in vegetable cultivated areas of Sirmour district ranged from 23.61 to 52.68%.

3.5 Water holding capacity

The data with respect to the water holding capacity of the soils of the Sirmour district is enumerated in table 5. The data reveals that the water holding capacity ranged from 41.74 to 66.03 and 38.92 to 62.02% with mean values of 50.98 and 48.45% in surface (0-15 cm) and sub-surface (15-30 cm) soil, respectively. Nehar Sawar village of Nahan block recorded the highest values for both the surface (66.03%) and sub-surface (62.02%) depths. Whereas, the lowest values for surface (41.74%) and sub-surface (38.92%) soils was registered in Rerli village of Sangrah block. The water holding capacity in the surface and sub-surface depths varied spatially as indicated by CV values of 12.41 and 12.23%, respectively.It was observed that water holding capacity decreased with increase in soil depths. This may be because of the reason that water holding capacity depends on the accumulation of organic matter which is comparatively more in the surface soil layers as compared to sub-surface layers. Similar trend was also reported by Naskar*et al*. (2010) [26] andRavikumar and Somashekar (2014) [20]. Thakur and Bisht (2020) [38] observed that the mean values of water holding capacity in different forest sites of Sirmour district varied from 85.19 to 113.91%. They also revealed that loam soils can hold a significant quantity of water, and as shown in table 4.1, all samples from the sampling sites had a sandy loam and loamy sand texture (Table 5).

3.6 Soil pH

The data presented in table 6 on soil pH indicates that it ranged from 6.61 to 7.45 and 6.63 to 7.49 with a mean value of 7.20 and 7.26 in the surface (0-15 cm) and sub-surface (15-30 cm) soils, respectively. The CV of 3.83 and 3.82 percent for soil pH showed that, it varied spatially in both the surface and sub-surface depths, respectively. The lowest soil pH in the surface soil (0.61) was recorded in Raasat village of Shillai block, whereas, in the case of sub-surface layer the lowest pH (6.63) was observed in Gavahi village of Sangrah block and Raasat village of Shillai block. The highest soil pH values were recorded in Bhulti village of Sangrah block in both surface (7.45) and sub-surface (7.49) depths. The data showed that the soil pH increased with increase in the soil depth. This might be due to the increase in the alkalinity with the increase in soil depth and leaching because of the deposition of the basic salts by the elluviation process and irrigation. Similar trend of increase in soil pH with increase in soil depth was reported by Fayed and Rateb (2013) [9], Khajuria *et al*. (2015) [21], Gupta and Arora (2017) [12] and Chandel (2020) [5]. A critical appraisal of the data also indicates that the overall soil pH of the study areas was neutral (6.6-7.3) to slightly alkaline (7.4-7.8) in reaction which may be due to the location of the district which is at relatively lower altitude. The soil reaction of most of the soils was neutral, which is ideal for the availability of various mineral nutrients. Chandel (2013) [4] also revealed that the soil pH varied from 6.1 to 7.9 in the soils of Sirmour district.

3.7 Electrical conductivity

The electrical conductivity of the studied soil samples ranged from 0.11 to 0.27 and 0.10 to 0.22 dS m^{-1} with the mean values of 0.17 and 0.14 dS m^{-1} in surface (0-15 cm) and sub-surface (15-30 cm) soils, respectively (Table 6). The EC varied spatially in both surface and sub-surface depths as indicated by CV values of 22.59 and 22.36 percent, respectively. For surface and sub-surface soils, the highest EC values (0.27 and 0.22 dS m^{-1}, respectively) were found in the Dhanech village of Rajgarh block and lowest EC values (0.11 and 0.10 dS m^{-1}, respectively) were observed in Narag village of Pachhad block. The results showed that there was decrease in electrical conductivity values of the soil with increase in depth. The probable reason of decline may be the rise up of soluble salts by capillary action of soils (Gyawali *et al*. 2016) [14] due to the climate of the study area. It was observed from the results that the electrical conductivity values of all the soil samples were under normal range i.e. < 0.8 dS m^{-1} which is safe for suitable growth and development of the crop. The soils of the study region are responsive to the fertilizer application as these soils are free from soluble salts. These results are in agreement with those obtained by Sharma (2005) [34-35], Chandel (2013) [4], Chauhan (2018) [6] and Suri (2018) [37] who revealed the EC in normal range in the soils of the Sirmour district.

3.8 Organic carbon content

The data on the status of organic carbon have been enumerated in table 6 revealed that the organic carbon content in the surface and sub-surface soil varied from 05.70 to 22.50 and 05.10 to 21.00 g kg-1 with overall mean values of 13.44 and 11.97 g kg-1, respectively. Parara village of Nahan block showed the highest organic carbon content in surface (22.50 g kg-1) and sub-surface (21.00 g kg-1) layer. Katyana Serta village of Pachhad block showed the lowest organic carbon content in surface (5.70 g kg-1) and sub-surface (5.10 g kg-1) layer. The organic carbon content in the surface and sub-surface depths varied spatially as signified by the CV values of 36.38 and 37.40 percent, respectively. The high organic carbon content was found in the surface layers as compared to sub-surface layers, which shows that the organic carbon decreased with increase in the soil depth. This might be due to the increased proportion of slower cycling of soil organic carbon (SOC) pool at the lower depth (Jobbagy and Jackson 2000) and litter fall on the surface of the soil. A similar decreasing trend of soil organic carbon with soil depth was also reported by Mahajan *et al*. (2007) [25], Jamaluddin *et al*. (2013) [17], Gyawali *et al*. (2016) [14], Chandel (2020) [5] and Salve and Bhardwaj (2020) [33]. The overall results showed that the soils of the studied region were in medium to high categories with regard to organic carbon content. This might be because of the management practices and addition of farm yard manure in the soil by the farmers of the vegetable growers of the studied area. In the Sirmour soils, Chauhan (2018) [6] reported that the organic carbon content ranged from 10.45 to 21.85 g kg-1 in the surface and sub-surface soils.

3.9 Correlation analysis

Correlation analysis was computed between various physical properties and at both surface (0-15 cm) and sub-surface (15-30 cm) depths, sand content was significantly and positively associated with both bulk density and particle density. In contrast, sand was significantly negatively correlated with silt, clay, and water holding capacity. At the surface level, silt content showed a significant negative correlation with particle density, but it was significantly and positively correlated with both bulk density and water holding capacity. Conversely, in the sub-surface, silt exhibited a significant negative relationship with bulk density and a significant positive relationship with water holding capacity. No significant correlations were observed for clay content at either depth. Additionally, bulk density demonstrated significant negative correlations with both porosity and water holding capacity, while particle density was significantly positively correlated with porosity and significantly negatively correlated with water holding capacity (Table 7 and 8).

Table 1: List of sampling sites

Sr. No.	Block	Village	Latitude	Longitude	Altitude
1	Nahan	Banogta	30º38′19″ N	77º20′20″ E	805 m
2		Mahipur	30º38′56″ N	77º20′41″ E	1072 m
3		Bechar Kabag	30º39′48″ N	77º21′36″ E	1515 m
4		Kandal	30º39′50″ N	77º21′36″ E	1522 m
5		Parara	30º40′38″ N	77º21′25″ E	1478 m
6		Mehdon Patarag	30º40′37″ N	77º21′34″ E	1438 m
7		Panyali	30º41′18″ N	77º20′59″ E	1288 m
8		Khano Khanani	30º39′44″ N	77º20′43″ E	1446 m
9		Nehar Sawar	30º40′32″ N	77º19′26″ E	1357 m
10		Runja Chanar	30º40′27″ N	77º18′25″ E	1107 m
11	Pachhad	Paprana	30º42′58″ N	77º19′37″ E	917 m
12		Lana Bhalta	30º43′44″ N	77º19′13″ E	1160 m
13		Baru Sahib	30º45′33″ N	77º17′42″ E	925 m
14		Lana Machher	30º45′7″ N	77º18′33″ E	875 m
15		Lana Marag 1	30º46′9″ N	77º17′57″ E	762 m
16		Lana Marag 2	30º46′13″ N	77º17′57″ E	784 m
17		Katyana Serta	30º41′8″ N	77º18′88″ E	1085 m
18		Lana Baka	30º41′43″ N	77º17′47″ E	1109 m
19		Arka Bardhyog	30º41′23″ N	77º17′41″ E	1119 m
20		Bhelan	30º45′9″ N	77º12′4″ E	1460 m
21		Malhog Lal Tikker	30º47′33″ N	77º11′52″ E	1311 m
22		Pajopad	30º47′33″ N	77º11′52″ E	1308 m
23		Narag	30º49′23″ N	77º11′48″ E	1285 m
24	Rajgarh	Mariog	30º52′21″ N	77º12′44″ E	915 m
25		Karganu	30º54′10″ N	77º13′14″ E	858 m
26		Dhanech	30º53′15″ N	77º14′6″ E	1126 m
27		Batol	30º53′18″ N	77º14′6″ E	1121 m
28		Ghil Pabiyana	30º51′56″ N	77º16′19″ E	1501 m
29		Kotli	30º51′29″ N	77º17′38″ E	1440 m
30		Salana	30º49′55″ N	77º17′46″ E	1449 m
31		Mewag jon	30º49′34″ N	77º17′47″ E	1420 m
32		Kot	30º47′56″ N	77º18′15″ E	1094 m
33		Dimbar	30º47′5″ N	77º17′40″ E	1089 m
34		Reri Gausan	30º48′7″ N	77º17′41″ E	1083 m
35		Thor Kolan	30º48′6″ N	77º17′19″ E	914 m
36		Kheri Chowki	30º47′20″ N	77º17′40″ E	876 m
37	Sangrah	Bhulti	30º45′58″ N	77º21′19″ E	916 m
38		Pharog	30º44′58″ N	77º21′33″ E	960 m
39		Methli	30º43′54″ N	77º19′32″ E	1191 m
40		Nahog	30º43′41″ N	77º20′32″ E	1154 m
41		Rerli	30º41′02″ N	77º24′34″ E	1119 m
42		Gavahi	30º43′07″ N	77º20′38″ E	1109 m
43		Kuftu	30º45′28″ N	77º20′31″ E	1047 m
44	Shillai	Panog	30º45′14″ N	77º36′51″ E	1244 m
45		Gumrah	30º46′26″ N	77º38′24″ E	1210 m
46		Raasat	30º45′18″ N	77º38′54″ E	1117 m
47		Balh-Behral	30º45′1″ N	77º39′14″ E	1257 m
48		Manal	30º44′36″ N	77º37′51″ E	1194 m
49		Laja-Manal	30º44′37″ N	77º37′32″ E	1123 m
50		Rohnat	30º46′8″ N	77º39′8″ E	919 m

Table 2: Analytical methods used for soil physical properties analysis

Sr. No.	Soil Property	Method Followed	References
Physical properties			
1	Bulk density	Pycnometer method	Chopra and Kanwar (2011) [7]
2	Particle density	Pycnometer method	Gupta and Dhakshinamoorthy (1980) [13]
3	Porosity	Empirical method	Gupta and Dhakshinamoorthy (1980) [13]
4	Soil texture	Hydrometer method	Bouyoucos (1962) [3]
5	Water holding capacity	Keen’s method	Keen and Raczkowski (1921) [20]

Table 3: Status of soil texture in the soils of tomato growing areas of Sirmour district

Site No.	Block	Village	% Sand		% Silt		% Clay		Textural Class	
			Soil depth (cm)							
			0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	Nahan	Banogta	56.78	53.10	32.00	33.00	11.22	13.90	sl	sl
2		Mahipur	64.99	62.27	27.00	28.00	08.01	09.73	sl	sl
3		Bechar Kabag	60.78	58.78	32.00	32.00	07.22	09.22	sl	sl
4		Kandal	65.92	62.27	23.00	24.00	11.08	13.73	sl	sl
5		Parara	70.29	66.92	24.00	26.00	05.71	07.08	sl	sl
6		Mehdon Patarag	69.79	56.98	25.00	28.00	05.21	15.02	sl	sl
7		Panyali	70.29	58.27	26.00	32.00	03.71	09.73	sl	sl
8		Khano Khanani	63.34	59.34	29.00	32.00	07.66	08.66	sl	sl
9		Nehar Sawar	64.27	60.34	26.00	26.00	09.73	13.66	sl	sl
10		Runja Chanar	79.34	71.55	10.00	16.00	10.66	12.45	sl	sl
11	Pachhad	Paprana	70.20	64.98	23.00	26.00	06.80	09.02	sl	sl
12		Lana Bhalta	77.06	72.98	16.00	18.00	06.94	09.02	sl	sl
13		Baru Sahib	71.26	67.78	22.00	24.00	06.74	08.22	sl	sl
14		Lana Machher	69.78	62.92	25.00	30.00	05.22	07.08	sl	sl
15		Lana Marag 1	70.58	59.78	22.00	30.00	07.42	10.22	sl	sl
16		Lana Marag 2	74.98	67.35	20.00	24.00	05.02	08.65	sl	sl
17		Katyana Serta	76.29	69.86	15.00	18.00	09.71	12.14	sl	sl
18		Lana Baka	72.79	71.79	18.00	18.00	09.21	10.21	sl	sl
19		Arka Bardhyog	79.29	74.36	15.00	19.00	05.71	06.64	ls	sl
20		Bhelan	78.79	72.50	12.00	16.00	09.21	11.50	sl	sl
21		Malhog Lal Tikker	76.93	72.93	15.00	17.00	08.07	10.07	sl	sl
22		Pajopad	70.79	63.65	24.00	28.00	05.21	08.35	sl	sl
23		Narag	73.86	63.35	16.00	21.00	10.14	15.65	sl	sl
24	Rajgarh	Mariog	74.29	64.79	20.00	26.00	05.71	09.21	sl	sl
25		Karganu	76.36	71.78	18.00	22.00	05.64	06.22	sl	sl
26		Dhanech	77.86	74.50	14.00	16.00	08.14	09.50	sl	sl
27		Batol	76.29	70.65	16.00	20.00	07.71	09.35	sl	sl
28		Ghil Pabiyana	82.58	80.36	12.00	14.00	05.42	05.64	ls	ls
29		Kotli	78.79	74.58	18.00	22.00	03.21	03.42	ls	ls
30		Salana	78.43	74.79	19.00	22.00	02.57	03.21	ls	ls
31		Mewag jon	73.86	71.86	21.00	21.00	05.14	07.14	sl	sl
32		Kot	69.93	63.93	19.00	24.00	11.07	12.07	sl	sl
33		Dimbar	70.34	65.99	24.00	27.00	05.66	07.01	sl	sl
34		Reri Gausan	77.77	74.34	13.00	15.00	09.23	10.66	sl	sl
35		Thor Kolan	76.49	70.85	16.00	21.00	07.51	08.15	sl	sl
36		Kheri Chowki	75.77	65.99	18.00	27.00	06.23	07.01	sl	sl
37	Sangrah	Bhulti	77.17	70.34	16.00	22.00	06.83	07.66	sl	sl
38		Pharog	76.34	67.48	17.00	24.00	06.66	08.52	sl	sl
39		Methli	77.77	70.85	12.00	18.00	10.23	11.15	sl	sl
40		Nahog	86.99	75.77	08.00	16.00	05.01	08.23	ls	sl
41		Rerli	84.85	78.34	09.00	15.00	06.15	06.66	ls	ls
42		Gavahi	88.34	79.86	08.00	10.00	03.66	10.14	ls	sl
43		Kuftu	77.77	67.48	14.00	22.00	08.23	10.52	sl	sl
44	Shillai	Panog	76.70	65.77	16.00	26.00	07.30	08.23	sl	sl
45		Gumrah	70.20	62.17	22.00	25.00	07.80	12.83	sl	sl
46		Raasat	82.34	77.99	08.00	11.00	09.66	11.01	sl	sl
47		Balh-Behral	78.34	72.20	14.00	18.00	07.66	09.80	sl	sl
48		Manal	77.78	71.48	12.00	16.00	10.22	12.52	sl	sl
49		Laja-Manal	62.20	56.85	24.00	28.00	13.80	15.15	sl	sl
50		Rohnat	62.70	52.70	30.00	37.00	07.30	10.30	sl	sl
Range			56.78-88.34	52.70-80.36	8.00-32.00	10.00-37.00	02.57-13.80	03.21-15.65		
Mean			73.93	67.75	18.70	22.62	7.39	9.63		
SE±			0.77	0.83	1.45	1.27	0.86	0.89		
CV (%)			8.98	10.02	33.43	26.69	31.64	28.66		

sl: Sandy loam, ls: Loamy sand

Table 4: Status of bulk density (Mg m^{-3}), particle density (Mg m^{-3}) and porosity (%) in the soils of tomato growing areas of Sirmour district

Site No.	Block	Village	Bulk density (Mg m^{-3})		Particle density (Mg m^{-3})		Porosity (%)	
			Soil depth (cm)					
			0-15	15-30	0-15	15-30	0-15	15-30
1	Nahan	Banogta	1.22	1.28	2.17	2.22	43.78	42.34
2		Mahipur	1.14	1.21	2.15	2.19	46.98	44.75
3		Bechar Kabag	1.15	1.21	2.13	2.19	46.01	44.75
4		Kandal	1.20	1.27	2.13	2.21	43.66	42.53
5		Parara	1.14	1.19	2.17	2.21	47.93	46.15
6		Mehdon Patarag	1.17	1.22	2.22	2.26	47.30	46.02
7		Panyali	1.15	1.20	2.21	2.24	47.96	46.43
8		Khano Khanani	1.25	1.32	2.08	2.14	39.90	38.32
9		Nehar Sawar	1.16	1.21	2.10	2.16	44.49	43.59
10		Runja Chanar	1.26	1.32	2.27	2.34	44.49	43.59
11	Pachhad	Paprana	1.15	1.21	2.17	2.23	47.00	45.74
12		Lana Bhalta	1.25	1.28	2.21	2.24	43.44	42.86
13		Baru Sahib	1.28	1.34	2.17	2.22	41.01	39.64
14		Lana Machher	1.27	1.33	2.33	2.39	45.49	44.35
15		Lana Marag 1	1.27	1.31	2.27	2.32	44.05	43.53
16		Lana Marag 2	1.24	1.27	2.38	2.40	47.90	47.08
17		Katyana Serta	1.27	1.33	2.38	2.42	46.64	45.04
18		Lana Baka	1.19	1.25	2.17	2.22	45.16	43.69
19		Arka Bardhyog	1.21	1.26	2.22	2.27	45.50	44.49
20		Bhelan	1.14	1.19	2.01	2.04	43.28	42.16
21		Malhog Lal Tikker	1.18	1.23	2.08	2.12	43.27	41.98
22		Pajopad	1.23	1.29	2.10	2.14	41.43	39.72
23		Narag	1.22	1.25	2.27	2.31	46.26	45.89
24	Rajgarh	Mariog	1.20	1.26	2.08	2.15	42.31	41.40
25		Karganu	1.22	1.25	2.27	2.29	46.26	45.41
26		Dhanech	1.14	1.19	2.13	2.17	46.48	45.16
27		Batol	1.23	1.28	2.27	2.31	45.81	44.59
28		Ghil Pabiyana	1.20	1.24	2.31	2.35	48.05	47.23
29		Kotli	1.14	1.20	2.11	2.15	45.97	44.19
30		Salana	1.23	1.29	2.33	2.38	47.21	45.80
31		Mewag jon	1.13	1.18	2.04	2.08	44.61	43.27
32		Kot	1.21	1.26	2.27	2.33	46.70	45.92
33		Dimbar	1.25	1.29	2.23	2.26	43.95	42.92
34		Reri Gausan	1.33	1.40	2.33	2.38	42.49	41.18
35		Thor Kolan	1.27	1.33	2.30	2.36	44.78	43.64
36		Kheri Chowki	1.24	1.31	2.38	2.44	47.90	46.31
37	Sangrah	Bhulti	1.26	1.30	2.10	2.13	40.00	38.97
38		Pharog	1.21	1.27	2.28	2.33	46.93	45.49
39		Methli	1.23	1.26	2.46	2.47	50.00	48.99
40		Nahog	1.27	1.32	2.22	2.26	42.79	41.59
41		Rerli	1.31	1.36	2.31	2.35	43.29	42.13
42		Gavahi	1.33	1.38	2.32	2.34	42.67	41.03
43		Kuftu	1.23	1.28	2.21	2.26	44.34	43.36
44	Shillai	Panog	1.18	1.23	2.03	2.08	41.87	40.87
45		Gumrah	1.23	1.30	2.33	2.38	47.21	45.38
46		Raasat	1.29	1.35	2.33	2.37	44.64	43.04
47		Balh-Behral	1.29	1.34	2.30	2.34	43.91	42.74
48		Manal	1.34	1.41	2.38	2.44	43.70	42.21
49		Laja-Manal	1.21	1.26	2.13	2.19	43.19	42.47
50		Rohnat	1.21	1.26	2.18	2.22	44.50	43.24
Range			1.13-1.34	1.18-1.41	2.01-2.46	2.04-2.47	39.90-50.00	38.32-48.99
Mean			1.22	1.28	2.22	2.27	44.89	43.66
SE±			0.05	0.05	0.07	0.07	0.34	0.34
CV (%)			4.47	4.43	4.80	4.62	4.99	5.13

Table 5: Status of water holding capacity (%) in the soils of tomato growing areas of Sirmour district

Site No.	Block	Village	Water holding capacity (%) Soil depth (cm)	
			0-15	15-30
1	Nahan	Banogta	54.38	49.98
2		Mahipur	56.21	53.06
3		Bechar Kabag	57.76	55.69
4		Kandal	51.17	51.12
5		Parara	64.57	59.81
6		Mehdon Patarag	52.62	48.04
7		Panyali	54.60	52.32
8		Khano Khanani	43.05	41.17
9		Nehar Sawar	66.03	62.02
10		Runja Chanar	50.27	44.49
11	Pachhad	Paprana	57.45	54.77
12		Lana Bhalta	51.86	51.05
13		Baru Sahib	52.70	50.43
14		Lana Machher	52.21	47.19
15		Lana Marag 1	49.24	45.70
16		Lana Marag 2	44.98	42.49
17		Katyana Serta	44.93	43.26
18		Lana Baka	56.94	55.01
19		Arka Bardhyog	45.32	44.57
20		Bhelan	58.53	57.24
21		Malhog Lal Tikker	47.92	45.78
22		Pajopad	50.45	42.59
23		Narag	46.68	46.04
24	Rajgarh	Mariog	57.14	55.37
25		Karganu	54.01	50.93
26		Dhanech	52.00	48.88
27		Batol	47.21	46.74
28		Ghil Pabiyana	50.60	50.30
29		Kotli	63.56	60.78
30		Salana	48.25	46.45
31		Mewag jon	55.67	54.99
32		Kot	50.15	45.61
33		Dimbar	53.63	48.77
34		Reri Gausan	45.05	48.76
35		Thor Kolan	44.10	41.10
36		Kheri Chowki	46.40	46.36
37	Sangrah	Bhulti	44.44	41.18
38		Pharog	44.57	44.00
39		Methli	54.80	50.96
40		Nahog	48.43	45.94
41		Rerli	41.74	38.92
42		Gavahi	42.01	41.52
43		Kuftu	42.28	40.89
44	Shillai	Panog	62.48	60.09
45		Gumrah	46.74	43.63
46		Raasat	42.57	41.41
47		Balh-Behral	45.04	41.13
48		Manal	42.36	41.66
49		Laja-Manal	56.80	49.47
50		Rohnat	57.14	52.84
Range			41.74-66.03	38.92-62.02
Mean			50.98	48.45
SE±			0.89	0.85
CV (%)			12.41	12.23

Table 6: Status of soil pH, electrical conductivity (dS m^{-1}) and organic carbon (g kg^{-1}) in the soils of tomato growing areas of Sirmour district

Site No.	Block	Village	Soil pH		Electrical Conductivity (dS m^{-1})		Organic carbon (g kg^{-1})	
			Soil depth (cm)					
			0-15	15-30	0-15	15-30	0-15	15-30
1	Nahan	Banogta	7.40	7.41	0.17	0.16	12.20	10.20
2		Mahipur	7.41	7.47	0.18	0.18	10.80	10.10
3		Bechar Kabag	7.15	7.28	0.21	0.19	19.50	17.20
4		Kandal	7.35	7.37	0.16	0.15	15.30	11.30
5		Parara	7.08	7.16	0.14	0.11	22.50	21.00
6		Mehdon Patarag	6.93	6.99	0.20	0.15	18.60	15.30
7		Panyali	7.27	7.29	0.16	0.15	20.70	17.90
8		Khano Khanani	7.03	7.04	0.18	0.15	19.70	19.10
9		Nehar Sawar	7.10	7.18	0.25	0.14	20.10	18.80
10		Runja Chanar	7.30	7.48	0.14	0.12	07.35	07.20
11	Pachhad	Paprana	7.41	7.48	0.18	0.17	20.30	19.80
12		Lana Bhalta	7.42	7.45	0.15	0.15	21.80	19.80
13		Baru Sahib	7.21	7.42	0.14	0.11	18.50	16.20
14		Lana Machher	7.41	7.48	0.15	0.14	16.50	15.80
15		Lana Marag 1	7.43	7.48	0.18	0.12	09.50	08.90
16		Lana Marag 2	7.12	7.32	0.14	0.13	07.40	06.50
17		Katyana Serta	7.42	7.44	0.16	0.15	05.70	05.10
18		Lana Baka	7.43	7.44	0.24	0.20	12.90	11.00
19		Arka Bardhyog	7.36	7.36	0.19	0.16	13.80	10.40
20		Bhelan	7.41	7.47	0.25	0.20	09.50	08.70
21		Malhog Lal Tikker	7.40	7.45	0.16	0.12	12.00	10.00
22		Pajopad	7.42	7.47	0.22	0.20	17.30	14.90
23		Narag	7.42	7.47	0.11	0.10	09.10	08.20
24	Rajgarh	Mariog	7.44	7.48	0.25	0.17	13.90	10.50
25		Karganu	6.75	6.92	0.14	0.12	09.20	08.40
26		Dhanech	7.43	7.45	0.27	0.22	16.20	15.80
27		Batol	6.62	6.66	0.17	0.15	14.30	12.90
28		Ghil Pabiyana	6.63	6.66	0.14	0.11	20.10	16.80
29		Kotli	6.83	6.91	0.18	0.15	19.20	18.00
30		Salana	6.64	6.67	0.14	0.12	10.50	09.30
31		Mewag jon	7.38	7.40	0.24	0.21	22.10	19.50
32		Kot	7.17	7.19	0.16	0.11	09.50	08.40
33		Dimbar	7.01	7.14	0.13	0.12	17.10	14.90
34		Reri Gausan	7.40	7.47	0.23	0.20	07.20	06.50
35		Thor Kolan	6.96	6.99	0.13	0.11	06.80	06.00
36		Kheri Chowki	7.44	7.48	0.22	0.12	06.80	06.20
37	Sangrah	Bhulti	7.45	7.49	0.20	0.18	14.30	12.20
38		Pharog	7.35	7.43	0.15	0.12	12.20	11.90
39		Methli	7.43	7.45	0.17	0.14	11.40	10.20
40		Nahog	7.38	7.43	0.16	0.14	15.30	13.50
41		Rerli	7.30	7.44	0.14	0.11	10.80	10.50
42		Gavahi	6.62	6.63	0.16	0.11	09.50	08.60
43		Kuftu	7.38	7.47	0.15	0.12	12.80	12.20
44	Shillai	Panog	7.14	7.31	0.14	0.12	16.40	14.80
45		Gumrah	7.44	7.47	0.21	0.20	06.80	06.40
46		Raasat	6.61	6.63	0.15	0.12	06.90	06.50
47		Balh-Behral	6.64	6.68	0.12	0.12	10.50	09.90
48		Manal	7.17	7.24	0.13	0.11	08.10	06.80
49		Laja-Manal	7.21	7.22	0.15	0.13	09.50	07.10
50		Rohnat	7.43	7.48	0.19	0.15	13.50	11.40
Range			6.61-7.45	6.63-7.49	0.11-0.27	0.10-0.22	05.70-22.50	05.10-21.00
Mean			7.20	7.26	0.17	0.14	13.44	11.97
SE±			0.10	0.10	0.09	0.09	1.33	1.29
CV (%)			3.83	3.82	22.59	22.36	36.38	37.40

Table 7: Correlation coefficient (r) between different soil physical characterstics of surface (0-15 cm) soil

	% Sand	% Silt	% Clay	Bulk density	P.D	Porosity	Water holding capacity
% Sand	1						
% Silt	-0.937**	1					
% Clay	-0.332*	-0.018	1				
Bulk density	0.393*	0.447**	0.088	1			
Particle density	0.361*	-0.377**	-0.005	0.623**	1		
Porosity	-0.005	0.051	-0.115	-0.372**	0.492**	1	
Water holding capacity	-0.451**	0.479**	0.010	-0.733**	-0.561**	0.149	1

Table 8: Correlation coefficient (r) between different soil physical characterstics of sub-surface (15-30 cm) soil

	% Sand	% Silt	% Clay	Bulk density	P.D	Porosity	Water holding capacity
% Sand	1						
% Silt	-0.914**	1					
% Clay	-0.460**	0.060	1				
Bulk density	0.271	-0.327*	0.048	1			
Particle density	0.233	-0.278	0.035	0.611**	1		
Porosity	-0.020	0.026	-0.010	-0.399*	0.480**	1	
Water holding capacity	-0.233	0.293*	-0.067	-0.709**	-0.543**	0.159	1

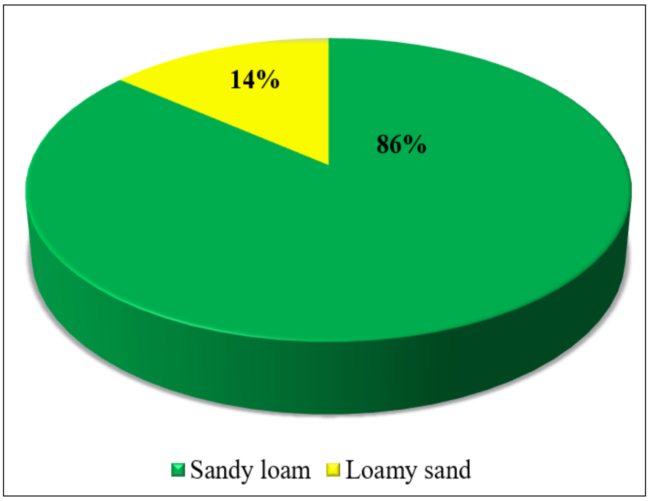

Fig 1: Percentage distribution of textural classes in surface soils (0 to 15 cm)

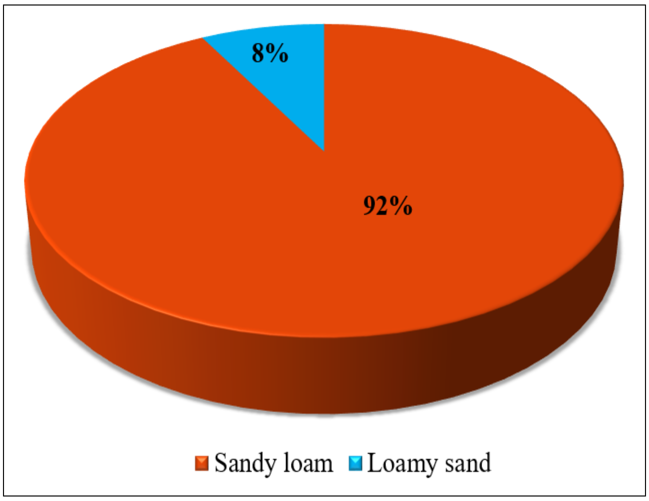

Fig 2: Percentage distribution of textural classes in sub-surface soils (15 to 30 cm)

4. Conclusion
This study on soil physical properties in Sirmour's vegetable-growing areas highlighted significant depth-wise variation, with sandy loam to loamy sand textures. Bulk and particle densities increased with depth, while porosity and water holding capacity were higher at the surface. Sand content correlated with higher densities and lower retention, whereas silt and clay showed variable trends. These findings emphasized the need for depth-specific soil management to improve structure, water use, and nutrient uptake, supporting sustainable vegetable cultivation and long-term soil health.

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6. Conflict of Interest
The authors declare that they have no conflict of interest.

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