Original Research Article

Impression of different agroforestry system on Physical properties of soil

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ABSTRACT

This study is associated with the difference between agroforestry systems and their impact on soil over long durations. This investigation interpreted the changes between two years. This study was analyzed by the RBD (Randomized Block Design) with 5 treatments (agroforestry systems) and 4 replications. This investigation was run in the existing systems planted at Forestry Reasech Farm, Department of Forestry, JNKVV, Jabalpur conducted during *the Rabi* season of 2021-22 and 2022-23. The soil collection was done in the 0-15 cm depth of soil under different agroforestry systems; after that, the soil was tested in the department of agricultural chemistry and soil science under different methodologies. The result revealed that the data of sand silt percentage maximum was obtained in the *Acacia nilotica*-wheat agroforestry system, and the sand value was found in the *Dalbergia sissoo-wheat based* system. *A. Nilotica-wheat based* intercropping agroforestry system shows the highest bulk density and lowest water holding capacity. The pH of soil under investigation was found to be slightly acidic; soil ranges from 6.20 to 6.51, and EC was obtained from 0.20 to 0.26 dsm^{-1} in the two years of the experiment, with cation exchange capacity (CEC) noted from 22.55 to 35.57 C mol kg^{-1} between 2021-22 and 2022-23 respectively. The above investigation *of D. sissoo–wheat-based* agroforestry system was found to be the best treatment. This research was important for the scientific community due to this study's focus on agroforestry systems that have to change the soil's physical properties in long-term scenarios.

Keywords: Bulk density, pH, D. sissoo, A. nilotica, G.arborea, M. indica, M. pinnata Agroforestry systems etc.

1. INTRODUCTION

Physical properties of soil include color, texture, structure, porosity, density, consistence, aggregate stability, and temperature. These properties affect processes such as infiltration, erosion, nutrient cycling, and biologic activity. Different factors affecting physical properties of matter, are the solubility, boiling point, density, melting point, reactivity, and temperature of soil. Soil physical properties define movement of air and water/dissolved chemicals through soil, as well as conditions affecting germination, root growth, and erosion processes. Soil physical properties form the foundation of several chemical and biological processes, which may be further governed by climate, landscape position, and land use. Thus, a range of soil physical properties when altered by climate change can trigger a chain reaction that leads to soil environment, which may greatly influence growth and production of crops including wheat. Some key soil physical indicators in relation to climate change include soil structure, water infiltration rate, bulk density, rooting depth, and soil surface cover (Mangi *et al.,* 2018). The physical properties are main point to effect the cropping pattern of crops. Agroforestry system (AFS) is a land use system in which perennial trees/ plants are integrated with arable crops (grasses, other crops) with or without livestock either in rotation or not associated with ecological and environmental benefits among tree and non-tree components (Lundgren and Raintree 1982).

Agroforestry systems contribute to the physical properties of the soil by improving soil aggregates, bulk density, water holding capacity, etc. Manures applied in these systems provide soil surface coverage while minimizing evaporation, runoff, soil loss, soil compaction, etc. improving water infiltration and moisture retention. Soil aggregate stability is a powerful indicator of soil degradation. Agroforestry systems improve soil compaction through fallen debris and renewal of root biomass. The addition of organic matter to the soil thus provides better soil structural stability, improves the distribution of soil aggregates and water-resistant aggregates, thereby reducing soil erosion. Tree-based agroforestry systems help retain more moisture in the soil profile. Perennial tree crops improve the supply of organic matter, reduce soil moisture loss, and prevent erosion in the agroecosystem. Another important physical property is bulk density, an indicator of soil health, influenced by management practices. Bulk density affects soil moisture content, infiltration, porosity, and directly affects biochemical processes in the soil. Planting trees at high densities increases litter supply and organic matter content, thereby reducing bulk density. Thus, the inclusion of various multipurpose tree species (MPT) in the agroecosystem improves various hydro-physical properties of the soil, thus acting as a barrier against soil erosion rates, improving macro-aggregation and infiltration capacity, reducing losses. Furthermore, the agroforestry system practiced with reduced or no-till reduces soil erosion, provides additional soil surface cover with litter fall, minimal disturbance and crop diversification.

2. MATERIAL AND METHODS

The experimental trail carried out in agroforestry field of Forestry Research Farm, Department of Forestry, JNKVV, Jabalpur. These studies conducted during *Rabi* season of 2021-22 and 2022-23.

Table 1. Physical and chemical properties of experimental soil (0-15 cm)

A. Physical Properties	
Sand (%), Silt (%), and Clay (%)	International pipette method (Piper, 1967)
Bulk density (g cm^{-3})	Oven dry method (Black, 1965)
Water holding capacity (%)	Oven dry method (Black, 1965)
Soil pH	Solo-bridge method (Black, 1965)
Electrical conductivity (dS m^{-1})	Solo-bridge method (Black, 1965)

2.1 Physical analysis

2.1.1 Bulk density

Soil bulk density is the ratio of dry soil mass to bulk soil volume (including pore spaces). The unit for density is mega grams per cubic meter (Mg/m^3), which is numerically equivalent to grams per cubic centimeter.

$$\text{Soil bulk density (g cm}^{-1}\text{)} = \frac{\text{Weight of Oven dry soil (g)}}{\text{Volume of the soil in the core sampler(cm}^3\text{)}}$$

2.1.2 Water Holding Capability (%)

Water holding capacity is the ability of a certain soil texture to physically hold water against the force of gravity. It is important to know the WHC of the soil to determine how much water storage. The texture, composition, and volume of organic materials in the grow medium determine how much water it can hold. Keen boxes were used to measure the water holding capacity. To allow soil to absorb water to the point of saturation, keen boxes were entirely filled with air-dried soil samples and placed in plastic trays that had some water in them. The formula below is used to estimate water holding capacity:

$$\% \text{ WHC} = \frac{\text{Wet weight} - \text{Oven Dry weight}}{\text{Wet weight}} \times 100$$

2.1.3 Soil pH

In order to determine of soil pH, 1:2.5 soil water extract was prepared by taking 20 g soil and 50 ml of distilled water in 100 ml of beaker. Subsequently the extract was mixed with a glass rod. The pH meter was calibrated by Immersing the electrodes in different buffer solution of pH 4.0, 7.0 and 9.2 Electrodes were placed into beaker containing the soil extract and recorded the reading displayed by the pH meter. After each determination, the electrodes were thoroughly washed by distilled water and wiped out by ordinary tissue paper.

2.1.4 Electrical conductivity

Soil water extract was prepared by 20 g soil sample and 50 ml distilled water (1:2.5 ratio) beaker cup of 100 ml and extract was mixed with the help of glass rod. The electrical conductivity meter was adjusted conductivity 1.41 dSm^{-1} at 25^0C at temperature and calibrated with the standard solution 0.01 N KCl. Before proceeding the samples, washed the conductivity cell for avoiding error.

3. RESULTS AND DISCUSSION

The data present in Table 2, i.e., sand, silt, and clay of soil, were the data in table sand and clay percent significantly differing in agroforestry systems soil, but in the case of silt percent, it was found non-significantly under different systems.

3.1 Sand, silt and clay (%)

The sand percent T_4–A. *nilotica*-wheat (23.50, 23.74, and 23.62%) and T_5–*M. indica-linseed* (24.47, 25.30, and 24.89%) were significantly higher than T_1–D. *sissoo*-wheat (20.44, 20.72, and 20.58%), T_2–*G. arborea-mustard* (20.13, 20.30, and 20.21%), and T_3–M. *pinnata*-wheat (21.10, 20.72, and 20.91%) in the 2021-22, 2022-23, and pooled data, respectively. Whereas T_4—*A. nilotica*-wheat was at par with T_5—*M. indica*-linseed in both years as well as the pooled mean. Moreover, between the years, the percentage was found to be non-significant. The silt percent in soil was non-significantly found. The maximum silt percentage was estimated in T_4—*A. nilotica*-wheat (23.99, 21.28, and 22.64%) followed by T_2—*G. arborea-mustard* (21.32, 20.88, and 21.10%) and the minimum under T_5—*M. indica-linseed* (18.74, 19.76, and 19.25%) in the first year, second year, and pooled data, respectively. Moreover, the data in the respective year show no significant variation found.

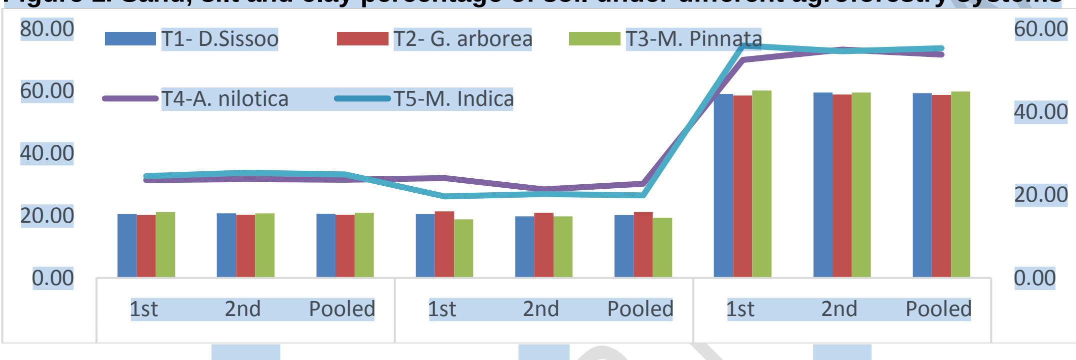
Table 2. Sand, silt and clay percentage of soil under different agroforestry systems

Treatments	Sand %			Silt %			Clay %		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1- D.Sissoo-Wheat	20.44	20.72	20.58	20.49	19.75	20.12	59.07	59.53	59.30
T_2- G. arborea-Mustard	20.13	20.30	20.21	21.32	20.88	21.10	58.55	58.83	58.69
T_3-M. Pinnata-Wheat	21.10	20.72	20.91	18.74	19.76	19.25	60.16	59.53	59.84
T_4-A. nilotica-Wheat	23.50	23.74	23.62	23.99	21.28	22.64	52.51	54.98	53.74
T_5-M. Indica-Linseed	24.47	25.30	24.89	19.57	20.16	19.86	55.96	54.54	55.25
Mean	**21.93**	**22.15**	**22.04**	**20.82**	**20.36**	**20.59**	**57.25**	**57.48**	**57.37**
SEm±	0.41	0.51	0.29	1.93	1.50	1.09	1.99	1.45	1.10
CD(P<0.05)	1.52	1.88	1.14	7.19	5.57	4.29	7.40	5.38	4.32
SEm±(Year)	0.21			0.77			0.78		
CD(Year) (P<0.05)	0.81			3.04			3.05		
SEm±(YXT)	0.46			1.73			1.74		
CD(YXT) (P<0.05)	1.81			6.79			6.83		

The clay per cent in soil under different agroforestry systems was noted minimum and maximum range 52.51 to 60.16 % in first year (2021-22). During second year (2022-23) it was recorded minimum and maximum range 54.54 to 59.53%. There cumulative effect (pooled) minimum to maximum varies from 53.74 to 59.84 %. Whereas the data in first year second year were fond non-significant difference but cumulative effect founds significant *i.e.* T_1-

D.sissoo- wheat (59.30 %), T_2- *G. arborea* - mustard (58.69 %) and T_3 - *M. Pinnata*- wheat (59.84 %) were significant to T_4 – *A. nilotica*- wheat (53.74%) and T_5- *M. indica* - linseed (55.25 %), however the data was found partly between T_1 T_2 and T_3. The above result is highly correlated with Kinyili et. al. (2024), who found that sand was significantly higher among non-adopters compared to adopters, while silt and bulk density were significantly higher among the adopters compared to the non-adopters. Sand levels decreased while silt and bulk density significantly increased with increasing agroforestry stand age. The result was similar; the decline in sand proportion in Acacia nilotica agroforestry was attributed to the protection of soil from the impact of raindrops, which would otherwise increase the deflocculating effects. The increased proportion of silt in soil where agroforestry is practiced has been widely reported (Bhaduri et al., 2017; Deng et al., 2017; and Dhaliwal et al., 2019).

Figure 1. Sand, silt and clay percentage of soil under different agroforestry systems



3.2 Bulk density

The data revealed that bulk density is presented in Table 3 and Fig. 2. The data was non-significantly found in both years and pooled. The bulk density was noted to be in the minimum and maximum range of 1.25 to 1.41 g/cm³ during 2021-22, while in the year of 2022-23, the minimum and maximum were between 1.26 and 1.41 g/cm³, and the pooled minimum and maximum range was 1.25 to 1.41 g/cm³. Whereas the maximum T_4–A. *nilotica*-wheat (1.41, 1.41, and 1.41 g/cm³) and T_1-D.*issoo-wheat* (1.25, 1.26, and 1.25 g/cm³) are both the year and pooled. Moreover, in the year, data was found to have non-significant differences. There was a significant difference in mass density according to the age of agroforestry practice. The result of bulk density of soil was higher in adopters than in non-adopters and increased with the age of agroforestry adoption. These studies are consistent with those of (Silva *et al.,* 2011; Chaudhari *et al.,* 2013 and Sharma *et al.,* 2022) The lower bulk density under the canopies might be due to higher soil organic matter accumulation under canopies of the tree through litter fall and root turnover that improves soil aggregate stability (Brady and Weil, 2002). The result was almost augmented with Singh *et al.,* (2018), and Musongora *et al.*, (2023)

3.3 Water Holding Capacity (WHC)

The data shown in Table 3 and Fig. 2. found that in 2021-22 the water holding capacity (WHC) was found non –significant.The maximum water holding capacity found in T_3 - *M. Pinnata*- wheat (84.39 %) and minimum was found in T_4 – *A. nilotica*- wheat (70.51%) based agroforestry system.In 2022-23 WHC in the T_1- *D.Sissoo* – wheat (82.88 %) and T_3 - *M. Pinnata*- wheat (82.86 %) were significantly higher to T_2- *G. arborea* - mustard (81.18 %), T_4 – *A. nilotica*- wheat (71.21 %) and T_5- *M. indica* - linseed (75.89 %). Whereas, the T_1 was at par with T_3. While in the cumulative (pooled) data T_1- *D.Sissoo* – wheat (82.32 %) and T_3 - *M. Pinnata*- wheat (83.85 %) T_2- *G. arborea* - mustard (80.85 %) were significantly maximum to T_4 – *A. nilotica*- wheat (70.86 %) and T_5- *M. indica* - linseed (74.64 %) whereas, T_1, T_2, T_3 found partly in the different agroforestry systems. This effect was produced due to bulk density and the clay percent in soil increase. In the multi-use tree species, water-stable aggregates (>0.25 mm) showed significant increases, but soil erodibility was significantly reduced compared to control (Saha et al., 2007). This finding are similar with Ferrant *et al.,*2016 and Ferrant *et al.,*2011.

Table 3 Bulk density and water holding capacity of soil in different agroforestry system

Treatments	Bulk density (g cm^3)			Water Holding Capacity(%)		
	2021-22	**2022-23**	**Pooled**	**2021-22**	**2022-23**	**Pooled**
T_1- D.Sissoo-Wheat	1.25	1.26	1.25	81.77	82.88	82.32
T_2- G. arborea-Mustard	1.27	1.27	1.27	80.52	81.18	80.85
T_3-M. Pinnata-Wheat	1.30	1.27	1.29	84.39	82.86	83.62
T_4-A. nilotica-Wheat	1.41	1.41	1.41	70.51	71.21	70.86
T_5-M. Indica-Linseed	1.36	1.35	1.35	73.40	75.89	74.64
Mean	**1.32**	**1.31**	**1.31**	**78.12**	**78.80**	**78.46**
SEm±	0.07	0.06	0.04	3.83	2.81	2.13
CD(P<0.05)	0.27	0.21	0.16	14.25	10.46	8.35
SEm±(Year)	0.03			1.50		
CD(Year) (P<0.05)	0.11			5.90		
SEm(YXT)	0.06			3.36		
CD(YXT) (P<0.05)	0.25			13.20		

3.4 pH

The data in Table 4 and Fig. 3 revealed that pH and EC were found to be non-significant in the different agroforestry systems in both years as well as pooled data. The maximum to minimum pH was found in the T_4–A. *nilotica*-wheat (6.49, 6.51, and 6.50), followed by T_5–*M. indica*-linseed (6.48, 6.45, and 6.46), after that T_1–D.*issoo*-wheat (6.47, 6.41, and 6.44), then T_2–*G. arborea*-mustard (6.23, 6.23, and 6.23), and the minimum pH was found in the T_3–M. *Pinnata*-wheat (6.20, 6.23, and 6.21) in the 2021-22 (first year), 2022-23 (second year), and pooled data, respectively. This might also be due to the leaching of soluble salts from the surface to the deeper layers of soil. Similar results and trends of variation in soil pH under agroforestry systems in comparison to crop fields has been reported by Newaj et al., 2007 and Rawat et al., 2018

3.5 Electrical conductivity (EC)

Table 4, Fig. 3, presented that EC was found to be non-significant in the different agroforestry systems in both years as well as pooled data. The result noted that electrical conductivity was minimum and maximum, ranging from 0.20 to 0.25 dSm^{-1} during 2021-22, where maximum EC was found in T_4—*A. nilotica*-wheat and T_3—M. *pinnata*-wheat. While minimum and maximum ranged 0.21 to 0.26 dSm^{-1} during 2022-23. Their maximum observed in T_6 and T_1 treatments and minimum found in T_3. Moreover, the pooled data ranged from 0.20 to 0.25 dSm^{-1}. Tomar *et al.* 2004 and Tomar *et al.* 1986 reported the soil amelioration in terms of reduction in soil pH and improvement in organic matter and available nitrogen contents under the agri-horticultural system. The EC was higher under T. grandis as compared to the agriculture field which could be due to enrichment of soil mineral basic salts through addition and decomposition of litter. Similar results and reasons have been reported by (Newaj et al., 2007; and Fahad *et al.,* 2022)

Table 4 pH and EC of soil under different agroforestry systems

Treatments	pH			EC (dSm^{-1})		
	2021-22	**2022-23**	**Pooled**	**2021-22**	**2022-23**	**Pooled**
T_1- D.Sissoo-Wheat	6.47	6.41	6.44	0.24	0.26	0.25
T_2- G. arborea-Mustard	6.23	6.23	6.23	0.23	0.24	0.23
T_3-M. Pinnata-Wheat	6.20	6.23	6.21	0.20	0.21	0.20
T_4-A. nilotica-Wheat	6.49	6.51	6.50	0.25	0.25	0.25
T_5-M. Indica-Linseed	6.48	6.45	6.46	0.25	0.26	0.25
Mean	**6.37**	**6.36**	**6.37**	**0.23**	**0.24**	**0.24**

SEm±	0.10	0.11	0.07	0.01	0.01	0.01
CD(P<0.05)	0.37	0.40	0.26	0.05	0.05	0.03
SEm± (Year)	0.05			0.01		
CD(Year) (P<0.05)	0.18			0.02		
SEm± (YXT)	0.10			0.01		
CD(YXT) (P<0.05)	0.41			0.05		

Figure 2. Bulk density and water holding capacity under different agroforestry systems

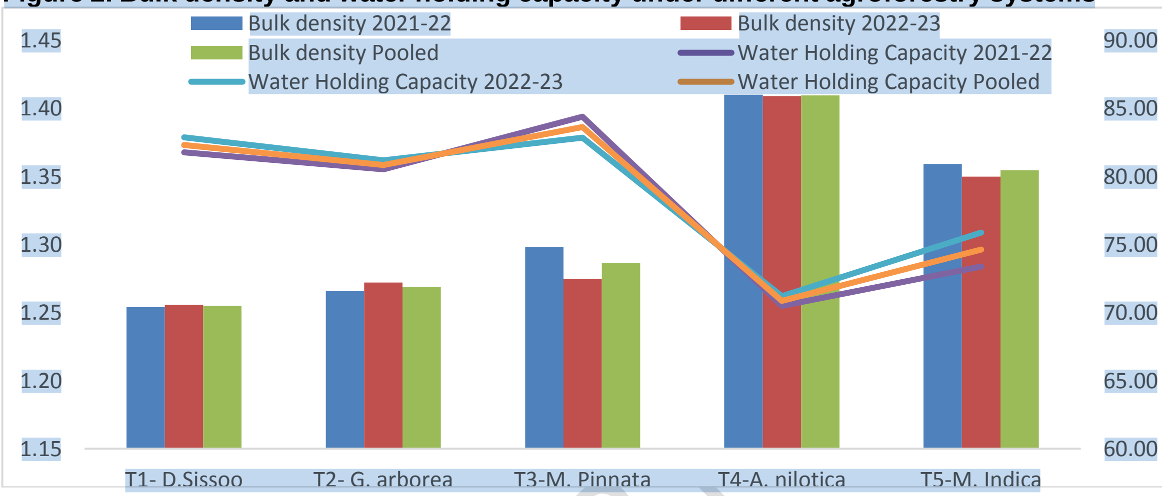
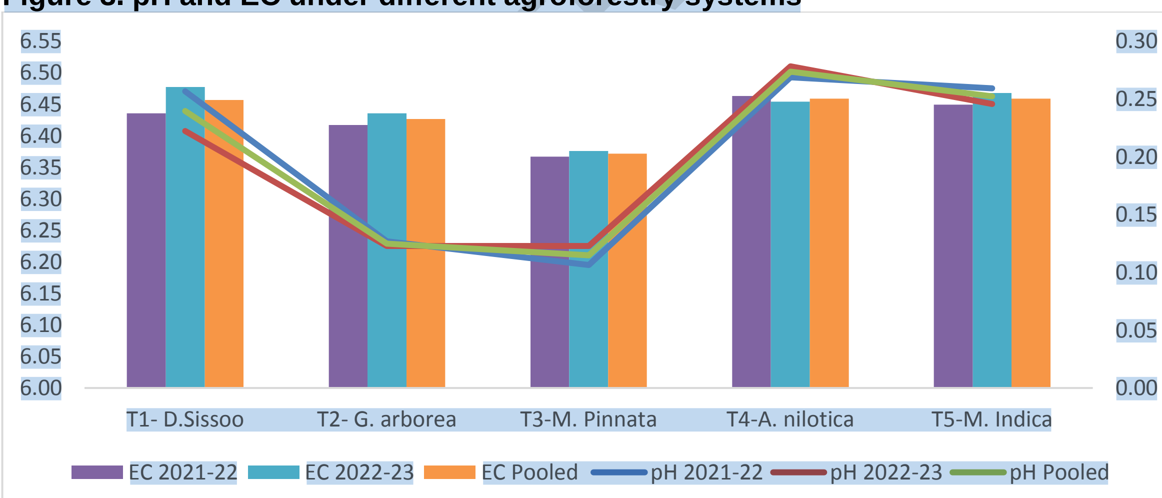


Figure 3. pH and EC under different agroforestry systems



3.6 Cation exchange capacity (CEC) of soil under different agroforestry systems

The observation revealed that in Table 5 the cation exchange capacity was recorded. T_1- *D. sissoo*—wheat (35.37, 35.47, and 35.42 C mol kg^{-1}) and T_2- *G. arborea*—mustard (34.95, 35.57, and 35.26 C mol kg^{-1}) were highly significant to T_3 - *M. pinnata*—wheat (28.05, 28.56, and 28.30 C mol kg^{-1}), T_5- *M. indica*—linseed (29.70, 29.90, and 29.80 C mol kg-1), and T4—*A. nilotica*—wheat (22.55, 22.56, and 22.55 C mol kg^{-1}) in the first year (2021-22), the second year (2022-23), and pooled data, respectively. Whereas T_1 was at par with T_2. While T_3 - *M. pinnata*-wheat and T5 - *M. indica*-linseed were significant to T4 - *A. nilotica*-wheat in both years and pooled data, respectively. Between the years, the data was found non-significant. The CEC of agroforestry systems shows non-significant differences between the years, but on a long-term basis, it was continuously changing year to year. The CEC depends on the pH, EC, as well as bulk density. Soil electrical conductivity (EC) is a measurement related to soil properties that affect plant productivity, including soil structure, cation exchange capacity (CEC), drainage conditions, material-level organic matter, soil salinity, and subsoil characteristics that was reported by Rawat et.al., 2018.

Table 5 Cation exchange capacity (CEC) of soil under different agroforestry systems

Treatments	**CEC (C mol kg^{-1})**		
	2021-22	**2022-23**	**Pooled**
T_1- D.Sissoo-Wheat	35.37	35.47	35.42
T_2- G. arborea-Mustard	34.95	35.57	35.26
T_3-M. Pinnata-Wheat	28.05	28.56	28.30
T_4-A. nilotica-Wheat	22.55	22.56	22.55
T_5-M. Indica-Linseed	29.70	29.90	29.80
Mean	**30.12**	**30.41**	**30.27**
SEm±	1.28	1.47	0.87
CD (P<0.05)	4.76	5.48	3.43
SEm± (Year)	0.62	**SEm± (YXT)**	1.38
CD(Year)	2.42	**CD(YXT)**	5.42

4. CONCLUSION

From the above investigation, it may be concluded that sand and clay percentages under different agroforestry systems were shown to be significantly different; the data on bulk density, water holding capacity, pH, EC, and CEC between years (2021-22 to 2022-23) were found to have no significant difference. Under different agroforestry systems. The best treatments under the agroforestry system were noted to be on the basis of the percentage of sand, silt, and clay (20.58, 20.12, and 59.30, respectively), bulk density (1.25 g cm^3), pH (6.44), EC (0.25 dsm^{-1}), CEC (35.42 C mol kg^{-1}),*he D. sissoo-wheat-based* agroforestry system on behalf of pooled analysis ($P < 0.05$).

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ABBREVIATIONS

Dalbergia sissoo = D. sissoo, Millettia pinnata = M. pinnata, Gmelina arborea = G. arborea, Acacia nilotica = A. nilotica, CEC = Cation exchange capacity