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SM Karekar
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

NA Meshram
Scientist, S-1 Assistant Professor of SSAC, AICRP on Agroforestry Dr. BSKKV, Dapoli, Maharashtra, India

KP Palkar
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

SS Pinjari
Agronomist, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

SB Dodake
Head of the Department, of SSAC, Dr. BSKKV, Dapoli, Maharashtra, India

Corresponding Author:
NA Meshram
Scientist, S-1 Assistant Professor of SSAC, AICRP on Agroforestry Dr. BSKKV, Dapoli, Maharashtra, India

Effect of incorporation of crop residues on chemical properties of soil and yield of mustard in Alfisol

SM Karekar, NA Meshram, KP Palkar, SS Pinjari and SB Dodake

Abstract
The present investigation entitled "Effect of incorporation of crop residue on carbon pools and soil properties in Alfisol" was conducted at *AICRP* on Agroforestry, CES, Wakawali, Dr. BSKKV, Dapoli, Maharashtra during 2020-2021. The results of the experiment showed that the incorporation of crop residue significantly influenced the soil pH, electrical conductivity of soil, available nitrogen, phosphorus, potassium, sulphur and micronutrients *viz* DTPA-Zn, Fe, Mn and Cu over control and its initial status of soil. All the parameters of soil were noted declining trend with increase in depth of soil. The incorporation of Ain (*Terminalia tomentosa*) residue @ 5 t ha^{-1} was significantly influenced the soil pH (5.71), electrical conductivity (0.27dS m^{-1}), avai. Nitrogen (381.00 kg ha^{-1}), avai. Phosphorus (27.09 kg ha^{-1}), avai. Potassium (492.29 kg ha^{-1}), avai. Sulphur (17.12 kg ha^{-1}) and micronutrients *viz.* DTPA-Zn (1.88 mg kg^{-1}), DTPA-Fe (21.12 mg kg^{-1}), DTPA-Mn (39.62 mg kg^{-1}) and DTPA-Cu (4.10 mg kg^{-1}). Almost similar trend of chemical properties were observed at 15-30 cm depth of soil. While, treatment of incorporation of *Glyricidia sepium* residue @ 5 t ha^{-1} showed significant effect on available nitrogen (381kg ha^{-1}) of the soil may be due to high N content than other. However the effect of incorporation of crop residue significantly improved the yield of mustard crop.

Keywords: Alfisol, crop residue, soil depth, Zn, Fe, Mn, Cu

Introduction
Crop residues play an important role in the function of agro-ecosystems because it sustains overall soil quality and crop productivity. The incorporation of crop residue either partially or completely in the field depends upon cultivation method. Crop residue incorporation can improve soil organic carbon and soil nutrients content. It is beneficial for recycling of nutrients and the better C: N ratio needs to be corrected by applying extra amount of fertilizer at the time of residue incorporation (Singh *et al*. 2017) [15]. Crop residues management and recycling of agroforestry farm waste in soil is the major pathway for the return of organic matter and nutrients from aerial parts of the plant community to the soil surface and has an important bearing on soil formation and fertility and also fundamental process in nutrient cycling and it is the main means of transfer of organic matter and mineral elements from the farm waste to the soil surface. Information is urgently needed about crop residues management effects on carbon mineralization and nutrient availability in soil. In contrast, most of the farmers in Konkan Region of Maharashtra are doing "rabbing" practices which causes heavy metal in soil and harmful for balancing the environments and soil health. Instead of "rabbing", farmers can be using crop residues incorporation directly in the soil may be helps for long-lasting development of soil and crop health. Therefore, considering the urgent need to restore soil fertility and improving crop productivity by easily available agroforestry crop residue sources that occurs in most parts of the Konkan region of Maharashtra. Thus, the present study focuses on "Effect of incorporation of crop residues on carbon pools, soil properties and yield of mustard in Alfisol**"**. *Terminalia tomentosa, Acacia auriculiformis, Acacia mangium, Glyricidia sepium, Mangifera indica, Anacardium occidentale, Syzygium cumini, Oryza sativa* and *Eleusine coracana* as being selected and easily available crop residues species on farmers field for the present study. This study was taken on the basis of high local and regional importance. Crop residues management will be definitely beneficial in future. With this background, the present study was undertaken to study the effect of incorporation of crop residues on chemical properties of soil.

Materials and Methods
The experiment was conducted at Central Research Station, Wakawali, Dr. BSKKV, Dapoli,

Maharashtra during 2020 to 2021 on long term experiment which was started in 2016-17. The major soils of the district are derived from “Coastal trap” rock (basalt) which is rich in silicon, iron and aluminium. The experimental soil is characterized by reddish colour, Lateritic type of Alfisols, particularly Kaolinitic, hyperthermic family of *Typic Haplustalf*. According to 7^{th} approximation, the soils are classified as *Typic Halplustalf* of Wakawali (Kumbhave) series classified according to Keys to soil taxonomy (Soil Survey Staff, 2010). The present investigation was framed in randomized block design with ten treatments and three replications *viz* T_1 *Terminalia tomentosa,* T_2 *Acacia auriculiformis,* T_3 *Acacia mangium,* T_4*Gliricidia sepium,* T_5 *Mangifera indica,* T_6 *Anacardium occidentale,* T_7 *Syzygium cumini,* T_8*Oryza sativa,* T_9 *Eleusine coracana and* T_{10} Absolute control. Incorporation of leaf litters in in-situ decomposition in soil and laboratory analysis. A representative portion of each soil samples was collected from the 0-30 cm depth of initial and litter contaminated soil site and it was air dried, powdered and passed through < 2 mm sieve for determination of chemical properties of soil. Soil pH, EC, OC and NKS were determined by standard procedure of Jackson (1973) [3] and available P of Brays No. 1 was determined by Bray and Kurtz (1945) [2]. DTPA-extractable zinc, iron, manganese, copper, nickel and lead in soil were estimated as per procedure described by Lindsay and Norvell (1978) [7] on Atomic Absorption Spectrophotometer (AAS). The experimental data was subjected to analysis of variances (ANOVA) and treatment means were compared and significant differences were tested at P = 0.05 using randomized block design (RBD) as given by Panse and Sukhatme (1985) [12].

Crop residues chemical composition

The collected agroforestry residues analyzed for nutrients (NPK) and lignin content were observed statistically significant. Overall highly nutritional status *viz*., N, P, K content in residues were noticed 1.51% (N), 0.73% (P), 0.97% (K) and 61.23% (C) receiving with *Terminalia tomentosa* followed by 2.04% (N), 0.52% (P), 0.80% (K) and 58.94% (C) with *Glyricidia sepium* than other agroforestry residues species. The C: N ratio of crop residues varied from 28.89 to 95.10.

Table 1: Nutrients, lignin compositions and C: N ratio of crop residues.

Treatments	C (%)	N (%)	P (%)	K (%)	Lignin (%)	C:N ratio
T_1- *Terminalia tomentosa*	61.23	1.58	0.87	0.98	12.29	38.75
T_2-*Acacia auriculiformis*	68.56	1.06	0.11	0.28	34.17	64.68
T_3- *Acacia mangium*	64.71	1.17	0.18	0.39	31.36	55.31
T_4- *Glyricidia sepium*	58.94	2.04	0.52	0.71	8.10	28.89
T_5- *Mangifera indica*	59.86	1.26	0.28	0.68	14.76	47.51
T_6- *A. occidentale*)	60.79	0.94	0.17	0.54	21.82	64.67
T_7- *Syzygium cumini*	54.26	0.98	0.23	0.73	18.35	55.37
T_8- Rice straw	37.09	0.39	0.05	0.47	7.43	95.10
T_9- Finger millet straw	35.56	0.38	0.07	0.53	9.17	93.58

Results and Discussion

The improvement in pH and EC of soil was recorded by *Terminalia tomentosa* residue @ 5 t ha^{-1} (5.71) followed by *Glyricidia sepium* residue @ 5 t ha^{-1}(5.67), *Syzygium cumini* residue @ 5 t ha^{-1}(5.65) *Mangifera indica* residue @ 5 t ha^{-1} (5.63), *Oryza sativa* residue @ 5 t ha^{-1} (5.61), *Eleusine coracana* residue @ 5 t ha^{-1} (5.60) and *Anacardium occidentale* residue @ 5 t ha^{-1} which were found to be at par with each other. The less improvement in soil pH was recorded in absolute control (Table.2). Similarly, the soils under *Grevillea robusta* had significantly higher soil pH, due to high addition of crop residues in acidic soils of Kenya (Jadhav 2018) [4] reported that the application of 5 t ha^{-1} *Glyricidia sepium* residues was noticed significantly higher improvement in pH of soil in Alfisol. Similarly, Meshram *et al*. (2020) [9] reported the improved soil pH by incorporation of crop residue of *Glyricidia sepium* followed by *Millettia pinnata* residues which helps for developing overall health of soil in Alfisol. While in the subsurface soil (15-30 cm), it was varied from 5.41 to 5.52 and same trend was observed with respect to significant treatments.

Table 2: Effect of incorporation of crop residues on pH and EC of soil.

Treatment	pH				EC (dS m^{-1})			
	Before start		At harvest		Before start		At harvest	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1- *Terminalia tomentosa*	5.63	5.47	5.71	5.52	0.20	0.19	0.27	0.21
T_2- *Acacia auriculiformis*	5.20	5.21	5.38	5.22	0.13	0.10	0.18	0.17
T_3- *Acacia mangium*	5.25	5.38	5.40	5.38	0.14	0.11	0.19	0.18
T_4- *Glyricidia sepium*	5.60	5.43	5.67	5.52	0.20	0.17	0.25	0.21
T_5- *Mangifera indica*	5.50	5.48	5.63	5.50	0.16	0.15	0.20	0.20
T_6- *Anacardium occidentale*	5.28	5.19	5.58	5.40	0.16	0.14	0.18	0.17
T_7- *Syzygium cumini*	5.55	5.40	5.65	5.50	0.15	0.14	0.15	0.14
T_8- *Oryza sativa*	5.40	5.39	5.61	5.48	0.14	0.13	0.18	0.16
T_9- *Eleusine coracana*	5.37	5.38	5.60	5.47	0.15	0.15	0.17	0.15
T_{10}- Absolute control	5.16	5.12	5.14	5.12	0.10	0.08	0.07	0.05
Mean	5.39	5.34	5.53	5.41	0.15	0.14	0.18	0.16
SE (m) ±	0.05	0.09	0.04	0.04	0.001	0.001	0.001	0.002
CD at 5%	0.14	NS	0.13	0.11	0.003	NS	0.003	0.006
CV%	1.56	2.94	1.38	1.18	4.55	4.94	2.26	3.46
Initial(2016)	5.19				0.10			

Sharma *et al.* (2018) [14] reported that the soil pH (6.92) was influenced by the application of sorghum stover @ 6 t/ha in Alfisol. While, Mandal *et al.* (2004) [8] and Sharma *et al.* (2016) [13] observed the residue application improved the soil chemical properties compared to control. The pH of the soil after incorporation of crop residue found higher in 0-15 cm soil than 15-30 cm depth of soil. Similar results also corroborated with Mirzawi *et al.* (2021) [10] studied that in the conventional tillage system, residue improved soil pH with the highest pH value (8.08) under R_{100} and pH was significantly higher at 0–10 cm as compared to 10–20 cm. Recently, Pandey *et al.* (2020) [11] the lower down of pH probability be due to loss of these nutrients in the anionic form from surface to lower depth through leaching. The EC of soil varies from 0.07 to 0.27 dS m^{-1}at 0-15 cm depth of soil at harvest stage of mustard. The highest value of EC was recorded in treatment receiving *Terminalia tomentosa* (0.27 dS m^{-1}) followed by *Glyricidia sepium*(0.27 dS m^{-1})which were found at par with each other. Jadhav (2018) [4] and Meshram *et al.* (2020) [9] reported that the application of 5 t ha^{-1} *Glyricidia sepium* residue was noticed significantly higher improvement in EC in Alfisol. The lowest value of EC was found in the control at surface layer of soil, whereas at 15-30 cm depth of soil, the electrical conductivity was ranging from (0.05-0.21 dS m^{-1}) at harvest stage of mustard. The highest value of EC of soil at harvest stage of mustard at subsurface layer was observed in the treatment *Terminalia tomentosa* (0.21 dS m^{-1}) followed by *Glyricidia sepium* (0.21 dSm^{-1}) which were found at par with *Mangifera indica* (0.20 dS m^{-1}) over control. Sharma *et al.* (2018) [14] reported that the soil EC (0.08 dS m^{-1}) significantly influenced by application of sorghum stover @ 6 t/ha in Alfisol. Singh *et al.* (2019) [16], Mandal *et al.* (2004) [8] and Sharma *et al.* (2016) [13] observed that the crop residue management practices involving incorporation of crop residues significantly improved in the electrical conductivity of soil. EC of soil increases with incorporation of crop residue and which was found high at 0-15 cm depth of soil as compared to the 15-30 cm depth.

The significantly highest (384.33 kg ha^{-1}) in the treatment (T_4) receiving incorporation of *Glyricidia sepium* residue @ 5 t ha^{-1}followed by treatmentT_1-*Terminalia tomentosa* residue @ 5 t ha^{-1} (381.00 kg ha^{-1}) and T_7-*Syzygium cumini* residue @ 5 t ha^{-1} (371.00 kg ha^{-1}) residues @ 5 t ha^{-1} which were found to be at par with each other. Similar trend of available nitrogen was observed in case of at 15-30 cm depth of soil over control and its initial status of soil. It might be attributed due to the available N status although showed increased due to quality residue management practices, it has not been increased much due to the prevailing climatic condition accelerating oxidation of organic matter as well as the nature of nitrogen forms in soil in the form of its losses through volatilization and leaching. Jadhav (2018) [4] and Meshram *et al.* (2020) [9] reported that the application of 5 t ha^{-1} *Glyricidia sepium* residue was noticed significantly higher improvement in available nitrogen in Alfisol. Adams *et al.* (1996) [1] observed that incorporation of hardwood litters increase Nitrogen availability in soil. Mandal *et al.* (2004) [8] reported that the application of rice residues @ 7 tonne ha^{-1} was recorded significantly higher chemical propeties of soil.similarly, Sharma *et al.* (2016) [13] observed residue application significantly improved the soil chemical properties compared to control. Pandey *et al.* (2018) [18], Sharma *et al.* (2018) [14], Singh *et al.* (2019) [16] observed that the crop residue management practices involving incorporation of crop residues significantly improved available nitrogen in soil and also suggested that highest in 0-15 cm soil than 15-30 cm depth of soil.

Table 3: Effect of incorporation of crop residues on available nitrogen and P_2O_5 of soil.

Treatment	Avai. N (kg ha^{-1})				Avai. P_2O_5 (kg ha^{-1})			
	Before start		At harvest		Before start		At harvest	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1- *Terminalia tomentosa*	351.16	349.24	381.00	379.27	20.42	13.69	27.09	21.33
T_2- *Acacia auriculiformis*	323.77	318.00	338.67	332.83	13.15	8.50	16.04	11.45
T_3- *Acacia mangium*	331.16	328.10	346.67	343.49	13.05	8.48	17.14	12.36
T_4- *Glyricidia sepium*	355.04	353.25	384.33	382.25	20.37	13.33	26.29	19.36
T_5- *Mangifera indica*	345.39	342.67	368.33	360.12	17.37	10.33	23.04	16.55
T_6- *Anacardium occidentale*	338.25	336.67	353.67	352.41	15.17	9.77	19.29	13.56
T_7- *Syzygium cumini*	347.46	345.27	371.00	369.18	18.29	11.33	25.14	18.59
T_8-*Oryza sativa*	341.85	338.98	360.33	357.16	13.63	9.30	19.24	15.30
T_9- *Eleusine coracana*	339.16	336.97	358.33	355.77	13.59	9.21	19.06	15.17
T_{10}- Absolute control	311.49	306.59	303.87	300.32	8.23	7.96	7.95	6.82
Mean	338.47	335.57	356.62	353.28	15.33	10.19	20.03	15.05
SE (m) ±	3.97	3.86	5.89	4.81	0.18	0.18	0.24	0.23
CD at 5%	11.80	11.46	17.50	14.28	0.55	0.55	0.70	0.69
CV%	2.03	1.99	2.86	2.36	2.09	3.13	2.04	2.68
Initial (2016)	312.28				8.70			

The available phosphorus of soil after harvest of mustard was recorded highest by T_1-*Terminalia tomentosa* residue @ 5 t ha^{-1} (27.09 kg ha^{-1}) followed by *Glyricidia sepium* residues @ 5 t ha^{-1} (26.29 kg ha^{-1}) which were found to be at par with each other. The lowest was observed under control (7.95 kg ha^{-1}). Similar trend of available phosphorus was observed in case of at 15-30 cm depth of soil over control, before start and its initial status of soil. The soil available phosphorus observed higher at 0-15 cm soil depth as compared to 15-30 cm soil after harvest stage of mustard (Table 3). The increase in available phosphorus status is due to use of quality residues and contribution of organic matter, being a small amount but direct source of phosphorus and it might have also solubilized the native phosphorus in the soil through release of various organic acids which had chelating effect, that reduced phosphorus fixation. Jadhav (2018) [4] and Meshram *et al.* (2020) [9] reported that the higher available phosphorus in soil was noted by crop residue *viz. Glyricidia sepium*, *Millettia pinnata* etc. Residues @ 5 t ha^{-1}which helps for developing overall health of soil in Alfisol. Adams *et al.* (1996) [1] observed that incorporation of hardwood litters increase phosphorus availability in soil. Similar findings were corroborated with Mandal *et al.* (2004) [8], Sharma *et al.* (2016) [13], Pandey *et al.* (2018) [18], Sharma *et al.* (2018) [14]

and Singh *et al.* (2019) [16] observed that the crop residue management practices significantly improved available phosphorus in soil. The available potassium of soil after harvest of mustard was recorded maximum by T_1-*Terminalia tomentosa* residue @ 5 t ha^{-1} (492.29 kg ha^{-1}) followed by T_4-*Glyricidia sepium* residues @ 5 t ha^{-1} (487.00 kg ha^{-1}) and T_7-*Syzygium cumini* residues @ 5 t ha^{-1} (467.60 kg ha^{-1}) which were found to be at par with each other. The lowest K_2O was observed under control (389.88 kg ha^{-1}). Regarding to 15-30 cm depth of soil, the available potassium was ranged from 375.28 to 482.21 kg ha^{-1} at harvest of mustard. The available potassium of soil was observed maximum by T_1-*Terminalia tomentosa* residue @ 5 t ha^{-1} (482.21 kg ha^{-1}) followed by T_4-*Glyricidia sepium* residues @ 5 t ha^{-1} (474.16 kg ha^{-1}) over control, before start and its initial status of soil. The soil available potassium was observed higher at 0-15 cm soil depth as compared to 15-30 cm soil after harvest stage of mustard (Table 3). Long-term application of residue management practices increased the K content of the soil. This could be attributed to the greater capacity of organic colloids to hold K ions on the exchange sites. However, a declining trend from its initial value of available K status was also observed as a result of continuous cropping, this indicates considerable mining of available K from the soil. Similarly, Meshram *et al.* (2020) [9] reported the higher available potassium of soil by incorporation of *Glyricidia sepium* followed by *Millettia pinnata* residues which helps for developing overall health of soil in Alfisol.

Table 4: Effect of incorporation of crop residues on available K_2O and Sulphur of soil

Treatment	Avai. K_2O (kg ha^{-1}				Avai. S (kg ha^{-1}			
	Before start		At harvest		Before start		At harvest	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 *Terminalia tomentosa*	481.06	471.55	492.29	482.21	14.31	12.12	17.12	15.25
T_2 *Acacia auriculiformis*	421.08	399.71	425.53	400.82	8.67	8.17	9.22	9.12
T_3 - *Acacia mangium*	425.54	400.29	430.25	406.91	9.15	8.47	9.74	9.65
T_4- *Glyricidia sepium*	478.58	465.01	487.00	474.16	14.08	11.66	15.91	13.47
T_5- *Mangifera indica*	438.49	430.43	444.32	434.95	9.80	8.62	10.21	9.95
T_6*Anacardiumoccidentale*	431.45	400.87	435.11	407.83	9.40	8.90	9.70	9.30
T_7- *Syzygium cumini*	461.39	451.77	467.60	458.61	10.33	9.43	12.35	11.96
T_8- *Oryza sativa*	436.79	429.42	441.71	433.83	10.4	8.47	11.43	9.86
T_9- *Eleusine coracana*	435.69	418.38	440.37	423.93	9.60	9.17	10.15	9.73
T_{10}- Absolute control	394.40	379.41	389.88	375.28	6.03	5.80	5.90	5.70
Mean	440.45	424.68	445.41	429.85	10.14	9.08	11.17	10.40
SE (m) ±	5.12	4.84	8.61	3.98	0.21	0.14	0.09	0.17
CD at 5%	15.20	14.37	25.60	11.82	0.64	0.40	0.28	0.50
CV%	2.01	1.97	3.35	1.60	3.65	2.60	1.45	2.79
Initial (2016)	404.05				7.32			

However, Adams *et al.* (1996) [1], Mandal *et al.* (2004) [8], Sharma *et al.* (2016) [13], Pandey *et al.* (2018) [18], Sharma *et al.* (2018) [14], Singh *et al.* (2019) [16] and Mirzawi *et al.* (2021) [10] studied that crop residue management practices helps for easily availability of potassium, whereas the lessavailability of potassiumprobability be due to contenous mining of potassium without application of sources and its loss in the anionic form from surface to lower depth through leachingleading high content of K at suface layer (Pandey *et al.*2020) [11]. The available sulphur in the soil was recorded higher by T_1-*Terminalia tomentosa* residue @ 5 t ha^{-1} (17.12 kg ha^{-1}) over control, before start and its initial status of soil. The lowest available sulphur was noted (5.90 kg ha^{-1}) under control. At 15-30 cm depth of soil, the available sulphur was ranged from 5.70 to 15.25 kg ha^{-1}. Similar trend of available sulphur was observed in case of at 15-30 cm depth of soil over control, before start and its initial status of soil (Table 4). Jadhav (2018) [4] and Meshram *et al.* (2020) [9] noted improved available sulphur in soil by *Glyricidia sepium* and *Millettia pinnata* residues @ 5 t ha^{-1}over control and initial.Similar findings were also reported by Mandal *et al.* (2004) [8], Sharma *et al.* (2016) [13], Sharma *et al.* (2018) [14], Singh *et al.* (2019) [16] and Pandey *et al.* (2020) [11] the low content of available sulphurmay be due to loss of S in the anionic form from surface to lower depth through leaching leads to more S content in surface than subsurface. Considering 0.6 mg kg^{-1} as critical limit for DTPA-Zn of soil, this soil was observed sufficient in available zinc (Katyal and Rattan, 2003) [5]. The DTPA-Zn of soil was found higher by the application of *Terminalia tomentosa* residue @ 5 t ha^{-1} (1.88 mg kg^{-1}) and (1.82 mg kg^{-1}) at both 0-15 cm and 15-30 cm of soil over control, before start and its initial status of soil. Whereas, the treatment (T_4) *Glyricidia sepium* residue @ 5 t ha^{-1}showed significant effect on DTPA extractable-Zn (1.82) and (1.80) mg kg^{-1}at 0-15 cm and 15-30 cm and was found at par to T_1. The lowest value of DTPA extractable-Zn of soil was recorded in treatment (T_{10}) absolute control (0.75 mg kg^{-1}) and (0.67 mg kg^{-1}) at 0-15 and 15-30 cm respectively (Table 5). Among crop residue and residual Zn treated plots, the one with crop residue were found more effective in enhancing the DTPA Zn content in soil. Mandal *et al.* (2004) [8] reported that the application of rice resudues @ 7 tonne ha^{-1} was recorded significantly improved chemical propeties of soil.

Table 5: Effect of incorporation of crop residues on DTPA-Zn and DTPA- Fe of soil

Treatment	DTPA- Zn (mg kg^{-1})				DTPA-Fe (mg kg^{-1})			
	Initial		At harvest		Initial		At harvest	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1- *Terminalia tomentosa*	1.54	1.48	1.88	1.82	20.40	18.52	21.12	20.10
T_2- *Acacia auriculiformis*	1.06	1.01	1.30	1.25	19.36	18.01	19.96	18.17
T_3- *Acacia mangium*	1.12	1.06	1.48	1.41	19.35	18.19	20.02	19.05
T_4- *Glyricidia sepium*	1.50	1.48	1.82	1.80	20.38	18.47	21.10	19.84
T_5- *Mangifera indica*	1.37	1.34	1.76	1.73	19.74	18.29	19.90	18.80
T_6- *Anacardium occidentale*	1.17	1.07	1.53	1.43	19.31	18.24	19.60	18.80
T_7- *Syzygium cumini*	1.48	1.36	1.78	1.67	19.85	18.47	20.50	19.86
T_8-*Oryza sativa*	1.24	1.15	1.73	1.65	19.60	18.28	20.34	19.70
T_9- *Eleusine coracana*	1.23	1.15	1.67	1.60	19.71	18.25	20.27	19.52
T_{10}- Absolute control	0.82	0.77	0.75	0.67	17.19	17.10	17.11	17.08
Mean	1.25	1.18	1.57	1.50	19.49	18.18	19.99	19.09
SE (m) ±	0.03	0.02	0.02	0.04	0.27	0.24	0.20	0.17
CD at 5%	0.08	0.05	0.06	0.11	0.80	0.70	0.60	0.51
CV%	3.59	2.62	2.05	4.27	2.39	2.25	1.74	1.55
Initial (2016)	0.981				18.75			

Considering the critical limit for DTPA-Fe as 4.5 mg kg^{-1}, this soil was found to be sufficient in available Fe content (Katyal and Rattan, 2003) [5]. At harvest stage of mustard, the highest DTPA-Fe of soil (21.12 mg kg^{-1}) and (20.10 mg kg^{-1}) at 0-15 cm and 15-30 cm depth was received by (T_1) *Terminalia tomentosa* residue @ 5 t ha^{-1} as compared to the before start, control and its initial status of soil. It was followed by *Glyricidia sepium* residue @ 5 t ha^{-1} at 0-15 and 15-30 cm (21.10 and19.84 mg kg^{-1}) which were at par with each other. whereas the lowest values (17.11and 17.08 mg kg^{-1}) at 0-15cm and 15-30 cm were recorded in control (no residue).The DTPA-Fe of soil at harvest of mustard recorded highest in the surface layer 0-15 cm than subsurface layer15-30 cm depth (Table 5). The increased zinc content by residues for a long period might be due to the addition of organics matters helps for availability of small amount zinc in soil, the organic materials also form chelates and increase the availability of zinc. Mandal *et al.* (2004) [8] reported that the application of rice resudues @ 7 tonne ha^{-1} was recorded significantly improved chemical propeties of soil. Similar results were also recorded by Sharma *et al.* (2016) and Sharma *et al.* (2018) reported that the soil available Fe was significantly influenced by residue application of 6 t/ha sorghum stover than other. Recently, Pandey *et al.* (2020) [11] and Mirzawi *et al.* (2021) [10] studied the DTPA-Fe appeared to be significantly greater in 0–10 compared to 10–20 cm soil depth. Significantly higher DTPA-Mn of soil (39.62 and 36.27 mg kg^{-1}) at 0-15 cm depth and at 15-30 cm depth of soil was recorded by (T_1) *Terminalia tomentosa* residue @ 5 t ha^{-1}, followed by (T_4) *Glyricidia sepium*,(T_7) *Syzygium cumini* and (T_5) *Mangifera indica* residues of each @ 5 t ha^{-1} were found be at par with each other. Whereas the lowest DTPA-Mn (32.73 and 30.88 mg kg^{-1}) was observed at 0-15 cm and 15-30 cm in control (no residue) at harvest stage of mustard (Table 6). Similar results were observed by Mandal *et al.* (2004) [8] reported that the application of rice resudues @ 7 tonne ha^{-1} was recorded significantly improved chemical propeties of soil. However, Sharma *et al.* (2016) [13] and Sharma *et al.* (2018) [14] reported that the soil available micronutrients were significantly influenced by residue application of 6 t/ha sorghum stover than other. The DTPA-Mn was recorded highest in the 0-15 cm depth as compared to 15-30 cm depth of soilprobability be due to loss of nutrient i.e. Fe in the anionic form from surface to lower depth through leaching (Pandey *et al.* 2020) [11]. Recently, Mirzawi *et al.* (2021) [10] reported that the values of micronutrients appeared to be significantly greater in 0–10 as compared to 10–20 cm soil depth.

Table 6: Effect of incorporation of crop residues on DTPA-Mn and DTPA-Cu of soil.

Treatment	DTPA-Mn (mg kg^{-1})				DTPA-Cu (mg kg^{-1})			
	Initial		At harvest		Initial		At harvest	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1- *Terminalia tomentosa*	37.62	34.20	39.62	36.27	3.65	3.40	4.10	3.85
T_2- *Acacia auriculiformis*	36.16	31.18	37.12	33.23	3.35	3.31	3.51	3.48
T_3- *Acacia mangium*	37.17	32.20	37.50	33.42	3.38	3.34	3.57	3.31
T_4- *Glyricidia sepium*	37.58	33.72	39.13	36.12	3.64	3.29	3.99	3.64
T_5- *Mangifera indica*	37.53	33.32	38.95	35.22	3.60	3.30	3.76	3.58
T_6- *Anacardium occidentale*	37.14	33.04	37.65	34.14	3.30	3.16	3.61	3.42
T_7- *Syzygium cumini*	37.54	33.82	38.83	34.05	3.39	3.13	3.82	3.59
T_8- *Oryza sativa*	37.44	33.35	38.80	35.66	3.25	3.09	3.71	3.56
T_9- *Eleusine coracana*	37.20	33.11	37.95	35.32	3.25	3.09	3.67	3.48
T_{10}- Absolute control	34.67	30.03	32.73	30.00	3.07	2.75	2.98	2.70
Mean	37.00	32.80	37.83	34.43	3.39	3.19	3.67	3.46
SE (m) ±	0.56	0.58	0.64	0.63	0.03	0.07	0.04	0.04
CD at 5%	1.68	1.72	1.92	1.88	0.08	0.22	0.11	0.11
CV%	2.64	3.06	2.92	3.19	1.35	4.05	1.77	1.84
Initial(2016)	37.59				3.10			

Significantly higher DTPA-Cu of soil (4.10 and 3.85 mg kg^{-1}) at 0-15 cm depth and at 15-30 cm depth of soil was recorded by (T_1) *Terminalia tomentosa* residue @ 5 t ha^{-1} over control, before start and its initial status of soil. The lowest DTPA-Cu of soil (2.98 and 2.70 mg kg^{-1}) in absolute control (no residue) at harvest stage of mustard at both depth of soil (Table 6). Similarly, Kabirinejad *et al.* (2014) [9] noted that the applications of nutritious crop residues were significantly increased the concentration of copper content (8.2 mg/kg) in soil. Mandal *et al*. (2004) [8] reported that the application of rice resudues @ 7 tonne ha^{-1} was recorded significantly improved chemical propeties of soil. Sharma *et al.* (2016) [13] and Sharma *et al.* (2018) [14] reported that the soil available micronutrients were significantly influenced by increasing rate of residue application (0-6 t/ha) in soil. DTPA- Cu was observed high at 0-15 cm depth than 15-30 cm depth of soil. Similar results were also recorded by Pandey *et al.* (2020) [11] and Mirzawi *et al.* (2021) [10] reported that the values of micronutrients appeared to be significantly greater in 0–10 compared to 10–20 cm soil depth and the lower availability of micronutrients probability be due to loss of these nutrients in the anionic form from surface to lower depth through leaching.

Grain and straw yield of mustard

Application of crop residues significantly enhanced mustard grain and straw yield over control in Alfisol (Table 7). The maximum grain yield (384.33 kg ha^{-1}) was given by treatment (T_1) incorporation of *Terminalia tomentosa* residue @ 5 t ha^{-1} followed by *Glyricidia sepium* (378.78 kg ha^{-1}), *Syzygium cumini* (350.18 kg ha^{-1}),*Mangifera indica* (346.21 kg ha^{-1}) residues @ 5 t $ha^{-1}$of each which were found at par with each other. *Terminalia tomentosa* recorded 172.63 kg ha^{-1}more grain yield of mustard than absolute control. Similar trend was found in case of straw yield of mustard. The maximum straw yield (1165.06 kg ha^{-1}) was given by treatment (T_1) incorporation of *Terminalia tomentosa* residue@ 5 t ha^{-1} followed by *Glyricidia sepium*(1056.11 kg ha^{-1}), *Syzygium cumini* (1030.76 kg ha^{-1}), *Mangifera indica* (1018.64 kg ha^{-1})residues @ 5 t ha^{-1} of each which were found at par with each other. The lowest grain and straw yield was observed in control (211.70 and 666.67 kg ha^{-1}).The similar results were reported by Regar *et al.*(2009) reported that the mustard yield was increased significantly by 25.1, 22.6, 20.8 and 18.6% due to incorporation of 10 t ha^{-1} FYM, FYM 5 t ha^{-1} + mustard straw 5 t ha^{-1}, FYM 5 t ha^{-1} + taramira straw 5 t ha^{-1} and Dhaincha green manuring, respectively. Moreover, Kharub *et al*. (2004) [6] and Mandal *et al*. (2004) [8] reported that the application of crop resudues were recorded significantly higher yield of of crop.

Table 7: Effect of incorporation of crop residues on grain and straw yield of mustard.

Treatments	Mustard grain yield (kg ha^{-1})	Mustard straw yield (kg ha^{-1})
T_1- *Terminalia tomentosa*	384.33	1165.06
T_2- *Acacia auriculiformis*	261.16	771.86
T_3- *Acacia mangium*	282.16	870.60
T_4- *Glyricidia sepium*	378.78	1056.11
T_5-*Mangifera indica*	346.21	1018.64
T_6- *Anacardium occidentale*	287.19	690.16
T_7- *Syzygium cumini*	350.18	1030.76
T_8- Rice straw	294.46	950.99
T_9- Finger millet straw	292.33	930.14
T_{10}- Absolute control	211.70	666.67
Mean	308.85	915.10
SE$\pm$	33.28	57.31
CD (p = 0.05)	98.89	170.27
CV %	18.66	10.85

Conclusions

It can be concluded that the incorporation of *Terminalia tomentosa* residue @ 5 t ha^{-1} followed by *Glyricidia sepium* residue @ 5 t ha^{-1} enhanced soil chemical properties, resulting into overall development of soil quality. Application of *Terminalia tomentosa* residue @ 5 t ha^{-1} can be used for improvement in available macro and micronutrients as well as yield of mustard in Alfisol at 0-15 and 15-30 cm depth of soil.

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