www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(11): 716-719

www.thepharmajournal.com
Received: 14-08-2023
Accepted: 29-09-2023

Gugulothu Sumitra
Ph.D. Scholar, Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Rajkumara S
Professor, Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Kumar D Lamani
Principal Scientist, Department of Agronomy, AICRP on Wheat and Barley, MARS, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Corresponding Author:
Gugulothu Sumitra
Ph.D. Scholar, Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Effect of tillage practices and residue mulch on soil chemical properties in wheat

Gugulothu Sumitra, Rajkumara S and Kumar D Lamani

Abstract
An experiment was conducted to evaluate the effect of tillage practices and residue mulch application on soil pH, EC and availability of N, P and K during *rabi* season of 2020-21 and 2021-22 at AICRP on wheat improvement, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka. The experiment was in split plot design with three replications, examining two main tillage practices (conventional and minimum tillage) and residue mulch application (no residue, soybean, maize, groundnut and glyricidia mulch at 3 t/ha) along with a weed free check (control). The results indicated that minimum tillage is associated with lower soil pH (7.37) and EC (0.24 dS/m) levels but higher available N (186.3 kg/ha), P (30.2 kg/ha), K (274.0 kg/ha) and organic carbon (0.56%), while conventional tillage results in higher soil pH (7.43) and EC (0.26dS/m) but lower available N (178.2 kg/ha), P (27.1 kg/ha), K (270.1 kg/ha) and organic carbon (0.53%) status. Among residue mulch applications, glyricidia mulch recorded lower soil pH (7.29), EC (0.24dS/m) and higher soil organic carbon (0.59%), available N (192.2 kg/ha), P (33.0 kg/ha) and K (278.0 kg/ha) in soil after harvest of the wheat crop. The interaction of minimum tillage with glyricidia mulch showed superior effects on soil properties.

Keywords: Available of N, P, K, glyricidia, minimum tillage

Introduction

Wheat (*Triticum aestivum* L.) ranks among the world's most vital staple crops, playing a pivotal role in global food security. As the global population continues to grow, the demand for wheat and the need to sustainably increase its production have never been more critical. Achieving this objective necessitates a comprehensive understanding of soil management practices, particularly the choice of tillage methods and the management of crop residues, which together exert a profound influence on soil properties and the overall productivity of wheat.

A significant component influencing the qualities of soil is soil tillage. Among the crop production factors, tillage contributes up to 20% and affects the sustainable use of soil resources through its influence on soil properties (Khurshid *et al*., 2006) [6]. Minimum tillage improves the soil physical properties as it improves the soil structure. Conservation tillage with maintenance of crop residue cover on 30 percent of the soil surface is soundly based within the frame work of conservation of natural resources and sustained production. Conservation tillage involving reduced tillage with mulching/residue management practices aims at preventing soil erosion, providing favourable soil and micro-climatic environment, reducing risks of pollution and minimizing environmental hazards. Conventional tillage includes ploughing twice or thrice, followed by harrowing and planking. It damages the soil structure and leaves no residues on the field. Minimum tillage is disturbing the soil to the minimum extent necessary so only primary tillage is done. In most cases, minimum tillage reduces soil loss by 30-40% over conventional tillage (Ngullie *et al.*, 2022) [11].

Crop residues have a lot of potential to improve the physical, chemical, and biological status of soil, but they are frequently regarded as being of little to no value. They are valuable resources when returned to soil. Surface retention of residues from previous crop without incorporation helps in protecting the fertile surface soil against wind and water erosion. Residues decompose slowly on the surface, increases the organic carbon and total N in the surface soil, while protecting the soil from erosion and temperature fluctuations. Retention of residues on the surface increased soil NO_3- concentration by 46%, N uptake by 29%, and yield by 37% compared to burning (Ramteke *et al*., 2018) [14].

This study aimed to investigate the impact of tillage practices combined with residue mulch application on soil chemical properties in wheat crop.

Materials and Methods

A field experiment was conducted at AICRP on wheat improvement, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka) on loamy soil during *rabi* season of 2020-21 and 2021-22. The experiment was laid out in split plot design. The soil of experimental field was neutral (7.4) with normal electrical conductivity (0.25 dS/m), low in organic carbon content (0.47%), very low in available nitrogen (158.41 kg/ha) and medium in available phosphorous (32.15 kg/ha) and potassium (291.52 kg/ha). the wheat variety 'UAS 334'. The experiment was laid out in split plot design with tillage (conventional and minimum) in main and residue mulch (soybean, maize, groundnut and glyricidia residue at 3 t/ha) in subplots with three replications. The recommended dose of fertilizer were applied at the rate of 120:60:40:20:20N, P_2O_5, K_2O, $ZnSO_4$, $FeSO_4$ kg/hain the form of urea, di-ammonium phosphate (DAP), muriate of potash (MOP), zinc sulphate and ferrous sulphate, respectively. At the time of sowing half dose of nitrogen, full dose of phosphorous, potassium, zinc and sulphur were applied as basal dose. Basal application was done in lines 5 cm below the seed rows. The remaining 50 percentof nitrogen was top dressed at 30 days after sowing.

To assess the various treatment effects, soil sample were collected after harvest of the crop from each plot. The collected samples were shade dried, powdered and sieved through 0.5 mm sieve. The soil samples were analysed and the methods adopted for soil pH and EC (Sparks, 1996) [16], bulk density and porosity (Piper, 2002) [13], soil organic carbon (Walkley and Black method, 1934) [18], available N (Subbaiah and Asija, 1956) [17], available P and K (Jackson, 1967) [5].

The experimental data obtained were subjected to statistical analysis by adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984) [4]. The level of significance used in 'F' test was at 5 per cent. The mean value subjected to Duncan's multiple range test (DMRT) using the corresponding mean sum of square and degree of freedom values.

Results and Discussion

Soil pH

The soil pH differed significantly due to tillage practices and residue mulch application during the individual years as well as pooled data are presented in Table 1. Significantly higher soil pH was recorded in conventional tillage (7.43) compared to minimum tillage (7.37). Significantly higher soil pH was recorded with no residue (7.52) treatment compared to residue application treatments. The lower pH in minimum tillage was attributed to accumulation of organic matter in the upper few centimeters under minimum tillage soil causing increases in the concentration of electrolytes and reduction in pH (Busaria *et al*., 2015) [3]. In crop residue application, significantly higher pH was recorded in maize residue (7.44) and was on par with groundnut residue (7.40) treatment. Significantly lower pH was recorded in glyricidia (7.29) compared to other treatments. Continuous inclusion of incorporation of green leaf manure into the soil may be the reason for decline. Conventional tillage with no residue (7.54) recorded significantly higher pH as compared to the other interactions and was on par with T_2M_1. Significantly lower soil pH was recorded in minimum tillage with glyricidia residue (7.26) and was on par with T_2M_2 treatment. Weed free check (7.58) recorded significantly higher pH compared to all the interactions.

Electrical conductivity (EC)

The soil EC significantly varied due to tillage practices after harvest of crop during the individual years as well as pooled data are presented in Table 1. Minimum tillage (0.24 dS/m) recorded significantly lower soil EC compared to conventional tillage (0.26 dS/m). Significantly higher soil EC was recorded with no residue (0.27 dS/m) treatment. Significantly lower EC was found in glyricidia (0.24 dS/m) compared to maize (0.26 dS/m) and no residue (0.27 dS/m) treatment except soybean (0.24 dS/m) and groundnut residue (0.25 dS/m) treatment. The soil EC was significantly higher in conventional tillage with no residue (0.27 dS/m) compared to other treatments and this was followed by T_2M_1, T_1M_3 and T_1M_4 treatments. Minimum tillage with glyricidia (0.23 dS/m) recorded lower soil EC compared to rest of the treatments except T_2M_4, T_2M_2, T_1M_5, T_2M_3 and T_1M_2 with which it was on par.Weed free check (0.27 dS/m) recorded significantly higher soil EC compared to all treatment combinations except T_1M_1 (0.27 dS/m), T_2M_1 (0.26 dS/m), T_1M_3 (0.26 dS/m) and T_1M_4 (0.26 dS/m) with which it was on par.

Soil organic carbon

Significant difference was observed with respect to soil organic carbon due to tillage practices during the individual years as well as pooled data are presented in Table 1. Significantly higher soil organic carbon was recorded in minimum tillage (0.56%) compared to conventional tillage (0.53%). The higher soil organic carbon content in the plots under minimum tillage than conventional tillage plots might be attributed in part to less disruption of soil structure and aggregates (Patel*et al.*, 2020) [12]. Significantly higher soil organic carbon was recorded with glyricidia residue (0.59%) compared to no residue (0.48%) and maize residue (0.52%) treatments and was on par with soybean (0.57%) and groundnut residue (0.54%) treatments. Beedya *et al.* (2010) [2] reported that glyricidia residue recorded 12% higher soil organic carbon compared to maize residue. The interaction effect due to tillage and crop residue application differed significantly with soil organic carbon. Significantly higher soil organic carbon was recorded in minimum tillage with glyricidia residue (0.61%) compared to other treatments except T_2M_2, T_1M_5, T_2M_4 and T_1M_2 with which it was on par. Significantly lower soil organic was recorded in conventional tillage with no residue (0.47%) compared to other treatment combinations and was on par with T_2M_1, T_1M_3 and T_1M_4 treatments. Weed free check (0.43%) recorded significantly lower soil organic carbon compared to all interactions.

Available soil nitrogen

The tillage practices had significant effect on available soil nitrogen after harvest of wheat during the individual years as well as pooled data are presented in Table 2. Minimum tillage (186.3 kg/ha) recorded significantly higher available soil nitrogen as compared to conventional tillage (178.2 kg/ha) practices. The increase in total nitrogen in no tillage is generally due to the absence of soil disturbance and to crop residue retention, which increases the soil organic matter and microbial activity linked to nitrogen fixation (Malobane *et* *al.*,2020) [10]. Significance difference was observed with respect to available soil nitrogen was recorded in glyricidia residue (192.2 kg/ha) compared to no residue (171.9 kg/ha), maize (177.7 kg/ha), groundnut (182.5 kg/ha) and soybean residue (186.8 kg/ha) treatments. No residue (171.9 kg/ha) treatment was recorded significantly lower available soil nitrogen compared to all other crop residue application. Significant difference was noticed with respect to available soil nitrogen due to the interaction of tillage and crop residue application. Minimum tillage with glyricidia residue (197.5 kg/ha) recorded significantly higher available soil nitrogen as compared to all other treatment combinations. Significantly lower available soil nitrogen was recorded in conventional tillage with no residue (169.2 kg/ha) compared to all other treatments. Weed free check (167.3 kg/ha) recorded significantly lower available soil nitrogen compared to all other interactions except T_1M_1 (169.2 kg/ha) with which it was on par.

Available soil phosphorus

The available soil phosphorus differed significantly due to tillage practices during the individual years as well as pooled data are presented in Table 2. Significantly higher available soil phosphorus was recorded in minimum tillage (30.2 kg/ha) as compared to conventional tillage (27.1 kg/ha). Saurabh *et al.* (2021) [15] found that higher concentration of available P in reduced tillage treatment in the top soil layers as compared to conventional tillage. Whereas, significant difference was observed with respect to available soil phosphorus due to crop residue application. Glyricidia residue (33.0 kg/ha) recorded significantly higher available soil phosphorus compared to all other treatments. Significantly lower available soil phosphorus was recorded in no residue (23.7 kg/ha) treatment compared to all other crop residue application. Among interaction, significantly higher available soil phosphorus was recorded in minimum tillage with glyricidia residue (34.5 kg/ha) compared to the rest of the treatment combinations. Available soil phosphorus was in minimum tillage with soybean residue (32.8 kg/ha) was on par with T_1M_5 treatment. Significantly lower available soil phosphorus was recorded in conventional tillage with no residue (22.4 kg/ha) compared to all other treatments. Weed free check (19.3 kg/ha) recorded significantly lower available soil phosphorus compared to all other interactions.

Available soil potassium

The available soil potassium differed significantly with respect to tillage practices, crop residue application and their interaction during the individual years as well as pooled data are presented in Table 2. Minimum tillage (274.0 kg/ha) was recorded in significantly higher available soil potassium compared to conventional tillage (270.1 kg/ha). Glyricidia residue (278.0 kg/ha) recorded significantly higher available soil potassium compared to all other crop residue application. Available soil potassium was recorded in soybean (274.6 kg/ha) residue was on par with groundnut (272.5 kg/ha) residue treatment. No residue (265.7 kg/ha) treatment was recorded significantly lower available soil potassium compared to all other treatments. Alharbi (2015) [1] found that application of mulch increased the available potassium in organic palm farming. Significantly higher available soil potassium was recorded in minimum tillage with glyricidia residue (279.9 kg/ha) compared to other interactions. The next best treatment was conventional tillage with glyricidia residue (276.2 kg/ha) and was on par with T_2M_2 and T_2M_4 treatments. Significantly lower available soil potassium was recorded in weed free check (257.2 kg/ha) as compared to all other interactions.

Table 1: Soil pH, electrical conductivity and soil organic carbon after harvest of wheat as influenced by tillage and crop residue application

Treatment	pH			EC (dS/m)			Soil organic carbon (%)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Tillage									
T_1: Conventional tillage	7.45^{a}	7.41^{a}	7.43^{a}	0.26^{a}	0.25^{a}	0.26^{a}	0.49^{b}	0.55^{b}	0.53^{b}
T_2: Minimum tillage	7.39^{b}	7.35^{b}	7.37^{b}	0.25^{b}	0.23^{b}	0.24^{b}	0.54^{a}	0.57^{a}	0.56^{a}
S.Em. ±	0.005	0.009	0.008	0.002	0.002	0.002	0.01	0.003	0.001
Residue mulch									
M_1: No residue	7.53^{a}	7.51^{a}	7.52^{a}	0.27^{a}	0.26^{a}	0.27^{a}	0.46^{c}	0.51^{c}	0.48^{c}
M_2: Soybean residue	7.38^{c}	7.32^{cd}	7.35^{c}	0.25^{b}	0.23^{c}	0.24^{c}	0.54^{ab}	0.58^{ab}	0.57^{ab}
M_3: Maize	7.47^{b}	7.41^{b}	7.44^{b}	0.26^{a}	0.25^{b}	0.26^{b}	0.49^{bc}	0.54^{bc}	0.52^{bc}
M_4: Groundnut	7.42^{bc}	7.37^{bc}	7.40^{bc}	0.25^{b}	0.24^{c}	0.25^{c}	0.52^{a-c}	0.56^{a-c}	0.54^{a-c}
M_5: Gliricidia	7.31^{d}	7.27^{d}	7.29^{d}	0.24^{b}	0.23^{c}	0.24^{c}	0.57^{a}	0.62^{a}	0.59^{a}
S.Em. ±	0.008	0.005	0.006	0.002	0.002	0.002	0.002	0.003	0.002
Interaction									
T_1M_1	7.54^{a}	7.53^{a}	7.54^{a}	0.27^{a}	0.26^{a}	0.27^{a}	0.44^{e}	0.49^{e}	0.47^{e}
T_1M_2	7.42^{cd}	7.36^{cd}	7.39^{de}	0.26^{a-c}	0.23^{b-d}	0.25^{b-d}	0.52^{b-d}	0.57^{a-d}	0.55^{a-d}
T_1M_3	7.50^{ab}	7.44^{b}	7.47^{bc}	0.27^{ab}	0.25^{ab}	0.26^{a-c}	0.48^{de}	0.53^{c-e}	0.50^{de}
T_1M_4	7.46^{bc}	7.41^{bc}	7.43^{cd}	0.26^{a-c}	0.24^{a-c}	0.26^{a-c}	0.50^{cd}	0.55^{b-e}	0.53^{b-e}
T_1M_5	7.35^{ef}	7.29^{e}	7.33^{fg}	0.25^{cd}	0.23^{cd}	0.24^{d}	0.55^{a-c}	0.61^{ab}	0.58^{ab}
T_2M_1	7.52^{a}	7.49^{a}	7.51^{ab}	0.26^{a-c}	0.25^{ab}	0.26^{a-c}	0.48^{de}	0.52^{de}	0.50^{de}
T_2M_2	7.34^{f}	7.28^{ef}	7.31^{gh}	0.24^{d}	0.23^{cd}	0.24^{d}	0.57^{ab}	0.59^{ab}	0.58^{ab}
T_2M_3	7.43^{cd}	7.39^{b-d}	7.41^{de}	0.25^{cd}	0.24^{a-c}	0.25^{b-d}	0.51^{b-d}	0.55^{b-e}	0.53^{b-d}
T_2M_4	7.39^{de}	7.34^{de}	7.37^{ef}	0.25^{cd}	0.23^{cd}	0.24^{d}	0.54^{a-d}	0.58^{a-c}	0.56^{a-c}
T_2M_5	7.28^{g}	7.24^{f}	7.26^{h}	0.24^{d}	0.22^{d}	0.23^{d}	0.59^{a}	0.62^{a}	0.61^{a}
S.Em. ±	0.01	0.01	0.01	0.003	0.003	0.003	0.01	0.004	0.002
Control (WFC)	7.59	7.56	7.58	0.27	0.26	0.27	0.42	0.43	0.43
S.Em. ±	0.01	0.01	0.01	0.003	0.003	0.003	0.005	0.01	0.005
CD at 5%	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.03	0.02
Initial values	7.4			0.25			0.47		

Note: Means followed by the same alphabet (s) within a column are not significantly differed by DMRT (P = 0.05)

Table 2: Effect of tillage and residue mulch on available soil nitrogen, phosphorus and potassium after crop harvest

Treatment	Nitrogen (kg/ha)			Phosphorus (kg/ha)			Potassium (kg/ha)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Tillage									
T_1: Conventional tillage	175.3^{b}	181.1^{b}	178.2^{b}	25.6^{b}	28.5^{b}	27.1^{b}	267.3^{b}	273.0^{b}	270.1^{b}
T_2: Minimum tillage	181.0^{a}	191.5^{a}	186.3^{a}	29.1^{a}	31.4^{a}	30.2^{a}	272.2^{a}	275.9^{a}	274.0^{a}
S.Em. ±	0.91	0.69	0.59	0.47	0.27	0.18	0.60	0.32	0.40
Residue mulch									
M_1: No residue	169.1^{d}	174.7^{e}	171.9^{e}	22.9^{e}	24.4^{e}	23.7^{e}	264.1^{c}	267.3^{d}	265.7^{d}
M_2: Soybean residue	181.5^{b}	192.1^{b}	186.8^{b}	29.6^{b}	32.3^{b}	30.9^{b}	272.3^{ab}	276.8^{b}	274.6^{b}
M_3: Maize	175.7^{c}	179.8^{d}	177.7^{d}	25.4^{d}	28.3^{d}	26.9^{d}	267.7^{bc}	271.5^{c}	269.6^{c}
M_4: Groundnut	178.2^{bc}	186.8^{c}	182.5^{c}	26.9^{c}	30.4^{c}	28.7^{c}	270.1^{ab}	274.9^{b}	272.5^{b}
M_5: Glyricidia	186.2^{a}	198.2^{a}	192.2^{a}	31.8^{a}	34.3^{a}	33.0^{a}	274.4^{a}	281.7^{a}	278.0^{a}
S.Em. ±	0.83	0.59	0.44	0.35	0.39	0.31	1.19	0.56	0.57
Interaction									
T_1M_1	167.3^{h}	171^{g}	169.2^{g}	21.7^{g}	23.1^{g}	22.4^{h}	261.0^{e}	264.8^{e}	262.9^{h}
T_1M_2	178de	186.3^{d}	182.1^{d}	27.8^{de}	30.5^{de}	29.2^{de}	270.8^{bc}	275.8^{b}	273.3^{c-e}
T_1M_3	172.7^{fg}	176^{f}	174.3^{f}	23.7^{f}	26.7^{f}	25.3^{g}	264.5^{de}	270.3^{d}	267.4^{g}
T_1M_4	175.3^{ef}	181.7^{e}	178.5^{e}	25.0^{f}	29.1^{e}	27.1^{f}	268.4^{b-d}	273.3^{c}	270.9^{ef}
T_1M_5	183.0^{bc}	190.7^{c}	186.8^{c}	30.0^{bc}	33.1^{bc}	31.6^{bc}	271.5^{bc}	280.8^{a}	276.2^{b}
T_2M_1	171.0^{gh}	178.3^{f}	174.7^{f}	24.2^{f}	25.6^{f}	24.9^{g}	267.2^{cd}	269.7^{d}	268.5^{fg}
T_2M_2	185.0^{b}	198.0^{b}	191.5^{b}	31.5^{b}	34.1^{ab}	32.8^{b}	273.7^{ab}	277.8^{b}	275.8^{bc}
T_2M_3	178.7^{de}	183.7^{e}	181.2^{d}	27.1^{e}	29.8^{e}	28.5^{e}	270.9^{bc}	272.8^{c}	271.9^{de}
T_2M_4	181.0^{cd}	192.0^{c}	186.5^{c}	28.9^{cd}	31.8^{cd}	30.4^{cd}	271.9^{bc}	276.5^{b}	274.2^{b-d}
T_2M_5	189.3^{a}	205.7^{a}	197.5^{a}	33.5^{a}	35.4^{a}	34.5^{a}	277.3^{a}	282.6^{a}	279.9^{a}
S.Em. ±	1.39	1.02	0.81	0.65	0.57	0.43	1.62	0.78	0.83
Control (WFC)	165.0	169.7	167.3	18.6	19.9	19.3	252.6	261.8	257.2
S.Em. ±	1.26	1.31	0.92	0.56	0.55	0.41	1.95	0.76	0.94
CD at 5%	3.73	3.88	2.74	1.65	1.64	1.23	5.78	2.25	2.80
Initial values	158.41			32.15			291.52		

Note: Means followed by the same alphabet (s) within a column are not significantly differed by DMRT (P = 0.05)

Conclusion

From this study it can be concluded that minimum tillage outperforms conventional tillage in enhancing soil nutrient availability. Residue mulch application led to higher levels of soil organic carbon and lower pH and EC, especially in comparison to no residue treatment. Moreover, glyricidia mulch exhibited superior nutrient availability (nitrogen, phosphorus, and potassium) when compared with no residue, maize, groundnut, and soybean residue mulch.

References

1. Alharbi A. Effect of mulch on soil properties under organic farming conditions in centre of Saudi Arabia. Journal of American Science. 2015;11(1):108-115.
2. Beedya TL, Snapp SS, Akinnifesi FK, Sileshi GW. Impact of *Gliricidia sepium* intercropping on soil organic matter fractions in a maize-based cropping system. Agriculture, Ecosystems and Environment. 2010;38(3-4):139-146.
3. Busaria MA, Singh KS, Kaur A, Bhatt R, Dulazi AA. Conservation tillage impacts on soil, crop and the environment. International Soil and Water Conservation Research. 2015;3:119-129.
4. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. 2nd Ed. John Willy and Sons, New York (USA); c1984. p. 639.
5. Jackson ML. Soil Chemical Analysis, Prentice Hall of India (Pvt.) Ltd., New Delhi, 1967, p. 67-214.
6. Khurshid KM, Iqbal M, Arif S, Nawaz A. Effect of tillage and mulch on soil physical properties and growth of maize. International Journal of Agriculture and Biology. 2006;8:593-596.
7. Malobane ME, Nciizah AD, Mudau FN, Wakindiki IC. Tillage, crop rotation and crop residue management effects on nutrient availability in a sweet sorghum-based cropping system in marginal soils of South Africa. Agronomy. 2020;10(6):1-13.
8. Ngullie HK, Dutta M, Jamir A, Patton S, Ram S. Effect of tillage and mulching on the performance and status of some important soil properties on cultivating pigeon pea (*Cajanus cajan* L.). The Pharma Innovation Journal. 2022;11(9):1259-1263.
9. Patel VK, Pathak RK, Kumar A, Singh A, Samiksha, Patel A. Effect of tillage and weed management practices on soil physico-chemical characteristics and wheat economics. International Journal of Current Microbiology and Applied Sciences. 2020;9(4):2096-2102.
10. Piper CS. Soil and Plant Analysis, Hans publishers, Bombay, India, 2002.
11. Ramteke PR, Patle PN, Navnage NP. Efficient management of crop residue for optimum soil physical properties and their manipulations. Journal of Pharmacognosy and Phytochemistry. 7(4):2919-2922.
12. Saurabh K, Rao KK, Mishra JS, Kumar R, Poonia SP, Samal SK, *et al*. Influence of tillage based crop establishment and residue management practices on soil quality indices and yield sustainability in rice-wheat cropping system of Eastern Indo-Gangetic Plains. Soil & Tillage Research. 2021;206:1-9.
13. Sparks. Methods of Soil Analysis Part-3: Chemical Methods. Soil Science Society America, USA. 1996.
14. Subbiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soils. Current Science. 1956;25(8):259-260.
15. Walkley A, Black CA. An estimation of the method for determination of soil organic matter and a proposed modification of chromic acid titration method. Soil Science. 1934;37:29-39.