RESEARCH ARTICLE   Indian Journal of Agricultural Research, Volume 55 Issue 6: 733-738 (December 2021)

Effect of Different Crop Sequences on Soil Nutrient Status, Nutrient Uptake and Crop Yield in Western Himalayas of India

Akashdeep Singh, Pawan Pathania, Tarun Sharma, Sanjay Sharma[1]

10.18805/IJARe.A-5774

ABSTRACT

Background: The field experiment was conducted during 2018-19 experimental farm of Department of Agronomy, College of Agriculture, CSK HPKV, Palampur (H.P.), India. The experiment comprised of ten treatments (maize-wheat, maize-wheat + gobhi sarson, dhaincha-cabbage-frenchbean, sunhemp-vegetable pea-frenchbean, maize + soybean chickpea + linseed, rice-wheat + gram, hybrid sorghum + hybrid bajra-oats + sarson (hybrid), hybrid sorghum + hybrid bajra-ryegrass + berseem, babycorn-broccoli-frenchbean and okra-turnip-tomato) which was laid out in randomized block design with three replications.

Methods: The present investigation was conducted during October 2018-October 2019 (*Kharif* and *Rabi* seasons) at an elevation of 1100 m amsl at a latitude of 32°04′N and longitude of 76°35′E at Bhadiarkar Experimental Farm, Department of Agronomy, CSK HPKV, Palampur, Kangra district of Himachal Pradesh, India. The soil of the experimental area falls in the order of Alfisols with Paleudalf as the great group as per the Udic Moisture Regime. During kharif and rabi season the crop varieties were applied with the recommended dose of N, P_2O_5 and K_2O (kg ha^{-1}). The source of nitrogen (N), phosphorus (P) and potassium (K) were urea, single super phosphate and muriate of potash.

Result: In terms of food for human consumption, highest yield was obtained under the okra-turnip-tomato cropping sequence followed by dhaincha-cabbage-frenchbean and sunhemp-vegetable pea-frenchbean. While in terms of fodder yield, highest was obtained under hybrid sorghum + hybrid bajra-oats + sarson (hybrid) cropping sequence followed by hybrid sorghum + hybrid bajra-ryegrass + berseem. Highest maize grain equivalent yield was obtained with okra-turnip-tomato crop sequence. All other treatments remained superior in comparison to the maize-wheat crop sequence. Maize + soybean-chickpea + linseed emerged to be the best treatment with the highest benefit cost ratio. The treatment comprising okra-turnip-tomato sequence also proved to be the second-best treatment followed by hybrid sorghum + hybrid bajra-oats + sarson (hybrid). Sunhemp-vegetable pea-frenchbean recorded the highest uptake of the available nutrients from soil which was followed by babycorn-broccoli-frenchbean. There was net loss of available nutrients although the loss was less in the sequences with multiple crops during the year. The treatments had no significant effect on the pH and organic carbon content of the soil.

Key words: Crop sequences, Cereal, Diversification, Economics, Fodder, Nutrient uptake, Oilseeds, Pulses.

INTRODUCTION

In India, a large number of crops are grown due to diverse agro-climatic conditions. At present, among cereal-based cropping systems, rice-wheat, rice-rice, pearl millet-wheat, maize-wheat and sorghum-wheat are the major cropping systems and occupy 85 per cent area. The continuous cultivation of these existing cropping systems resulted in reduced soil fertility and predominance of specific weeds (Katyal, 2003). Under the evolving agricultural scenario, crop diversification emerges as a major component for the sustainable production. In the peri-urban interface, the inclusion of high-value crops into the maize-based intercropping or sequential cropping systems proved to be profitable and remunerative (Singh, 2006).

Cropping systems, including crop diversification, intercropping *etc.* greatly impact soil health and quality. Usually cropping systems are designed to maximise yield putting strain on the available soil resources, but modern agriculture has become increasingly concerned about the sustainability of the system in order to attain long-term stable productivity (Vukicevich *et al*., 2016; Farigone *et al.,* 2018). Since Indian agriculture seems to be influenced by the economic factors therefore to increase the income of the small households, to stabilize farm income and to conserve the natural resource-base, diversification of the existing systems is recommended. Sharma *et al*. (2012) and Mandal *et al*. (2016) have also reported that planting of suitable crop types in a system helps improve the soil nutrient status and also the microbial population. The selection of the crops needs

Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062, Himachal Pradesh, India.
[1]Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062, Himachal Pradesh, India.

Corresponding Author: Akashdeep Singh, Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062, Himachal Pradesh, India. Email: sjsuh@knu.ac.kr

How to cite this article: Singh, A., Pathania, P., Sharma, T. and Sharma, S. (2021). Effect of Different Crop Sequences on Soil Nutrient Status, Nutrient Uptake and Crop Yield in Western Himalayas of India. Indian Journal of Agricultural Research. 55(6): 733-738. DOI: 10.18805/IJARe.A-5774.

Submitted: 24-03-2021 **Accepted:** 02-07-2021 **Online:** 04-08-2021

to be planned to utilize the synergism among crops towards the efficient utilization of resources and to stabilise overall productivity, profitability and soil quality. Keeping this in view, the field study was conducted to assess the effect of different crop sequences on soil organic carbon, available N, P and K, nutrient uptake and crop yield.

MATERIALS AND METHODS

Experimental site climate and soil type

In the present investigation, a field experiment was conducted during October 2018-October 2019 (*Kharif* and *Rabi* seasons) at an elevation of 1100 m amsl at a latitude of 32°04′ N and longitude of 76°35′ E at Bhadiarkar Experimental Farm, Department of Agronomy, CSK HPKV, Palampur, Kangra District of Himachal Pradesh, India. The soil of the experimental area falls in the order of Alfisols with Paleudalf as the great group as per the Udic Moisture Regime.

Treatment details

There were ten intensified cropping sequences examined under randomized block design with three replications *viz.,* maize-wheat (T_1), maize-gobhi sarson + toria (T_2), dhaincha-cabbage-french bean (T_3), sunhemp-vegetable pea-french bean (T_4), maize + soybean-chickpea + linseed (T_5), rice-wheat + gram (T_6), hybrid sorghum + hybrid bajra-oats + aarson (hybrid) (T_7), hybrid sorghum + hybrid bajra-ryegrass + berseem (T_8), babycorn-broccoli-french bean (T_9), okra-turnip-tomato (T_{10}). During *kharif* and *rabi* season the crop varieties were applied with the recommended dose of N, P_2O_5 and K_2O (Kg ha^{-1}). The source of nitrogen (N), phosphorus (P) and potassium (K) were urea, single super phosphate and muriate of potash.

Analysis of soil and plant samples

A composite sample (0-15 cm) of the experimental field was collected before the initiation of the field experiment for analysis. In order to study the chemical changes in the soil due to the cropping sequences, soil samples were collected from each plot after the harvest of the *kharif* and *rabi* season crops. The soil collected was then air dried, grounded and sieved through 2 mm sieve, labelled and stored for further analysis. The organic carbon was estimated by Chromic Acid Wet Digestion (Walkley and Black, 1934), available N by Alkaline potassium permanganate (Subbiah and Asija, 1956), available P by Olsen's (Olsen *et al*., 1954) and available K by Ammonium acetate method (Metson, 1956). Plant samples were also analysed for N content using micro-kjeldahl method (AOAC, 1995), P and K content using wet digestion method (Koenig and Johnson, 1942; Black 1965, respectively). Analysis of soil for various physico-chemical properties in the sample collected before sowing have shown that soil was having Silty clay loam texture, soil being slightly acidic (pH 5.30), electrical conductivity 0.072 dS/m, status for organic carbon as 1.37 mg/kg, for available nitrogen 276.58 kg/ha, available phosphorus 34.28 kg/ha and available potassium 132.45 kg/ha.

Statistical analysis

In order to determine the effect of different cropping sequences on the soil nutrient status and yield analysis of variance (ANOVA) was used. The means were separated and compared through critical difference at 5 per cent level of significance under RBD.

RESULTS AND DISCUSSION

Economic and maize grain equivalent yield

The crops in most of the treatments produced lower yields (Table 1) corresponding to their reported yields in the region except for maize, wheat, sorghum, bajra and linseed. The yield of the diverse vegetable crops supplanting the maize in kharif and wheat in *rabi viz*., okra, cabbage, vegetable pea, broccoli, turnip, frenchbean and tomato fluctuated from low to very low. The central reason for low yield in case of okra is the very high rainfall before and immediately after the sowing resulting in fluctuations in temperature. Similar trends were observed for seed germination in okra at high or low temperature conditions by Yusuf *et al*. (2001). The higher maize grain equivalent yield of 33,376 kg/ha was achieved under okra-turnip-tomato cropping sequence

Table 1: Yield of individual crops under different treatments.

Treatment	Economic yield (kg ha^{-1})				
	Kharif	*Kharif* Intercrop	*Rabi*-I	*Rabi*-I Intercrop	*Rabi*-II
T_1	4015	-	2525	-	-
T_2	5429	-	1326	227	-
T_3	11111	-	13131		4407
T_4	12247	-	6692	-	4583
T_5	5069	400	110	1263	-
T_6	3535	-	2399	66	-
T_7	22980	-	35732	-	-
T_8	23232	-	34091	-	-
T_9	6402	-	7449	-	4520
T_{10}	1263	-	17803	-	10732

which was tailgated by baby corn-broccoli-frenchbean cropping sequence (25,375 kg/ha). Maize-wheat cropping sequence produced the lowest equivalent yield of 7,719 kg/ha. Okra-turnip-tomato gave 4.32 times higher equivalent yield in contrast to the traditional cropping system. The higher equivalent yields were owing to more tonnage of vegetable crops substituting the traditional crop (Table 2). The vegetables have a higher market price than the cereal crops which ended in higher equivalent yield as opposed to the cereal-cereal crop sequence. Mukherjee (2016) and Singh *et al.* (1979) observed similar trend for the equivalent yield in multiple cropping system over the traditional cropping system.

Effect on pH, electrical conductivity and organic carbon

Soil under different cropping sequences was analysed for their soil properties (Table 3) and no significant differences were observed in pH and organic carbon content. Electrical conductivity in surface soil ranged from 0.050-0.108 dS/m. The conventional cropping sequence, maize-wheat (T_1), resulted in the highest electrical conductivity (0.108 dS/m) while the lowest electrical conductivity (0.050 ds/m) was recorded under Maize-gobhi sarson + toria cropping sequence (T_2). Smaller amounts of soluble salts may be attributed to excessive leaching in lower soil profiles. EC in the normal range (0.05-0.70 dS/m) have also been reported by Loria *et al.* (2015) in Shiwalik hills.

Effect on available NPK

Soil samples were analysed to determine the initial as well as final nutrient status of the system and increase in available soil nutrients under the influence cropping sequence was recorded. In soil, mean values of available N, P and K ranged from 319.19-376.86 kg/ha, 40.56-48.57 kg/ha and 129.44-185.68 kg/ha (Table 4). The order of available nitrogen as affected by cropping systems was 376.86 kg ha^{-1} under dhaincha-cabbage-frenchbean sequence followed by sunhemp-vegetable pea-frenchbean (371.27 kg ha^{-1}) and hybrid sorghum + hybrid bajra-ryegrass + berseem (369.59 kg ha^{-1}). Lowest available nitrogen of 319.19 kg ha^{-1} was reported under rice-wheat + gram cropping sequence followed by the traditional cropping sequence, maize-wheat (320.45 kg/ha). Available phosphorous followed the order, Babycorn-broccoli-frenchbean sequence (48.47 kg/ha) followed by a hybrid sorghum + hybrid bajra-ryegrass + berseem sequence (46.81 kg/ha) of available phosphorus. The lowest available phosphorus of 40.56 kg/ha under maize-gobhi sarson + toria followed by maize + soybean-chickpea + linseed (41.33 kg/ha). Maize-wheat and rice-wheat + gram sequences showed almost similar available phosphorus (42.60 and 42.80, respectively) after the completion of experiment. Available potassium followed the order, 185.68 kg/ha under okra-turnip-tomato sequence followed by hybrid sorghum + hybrid bajra-oats + sarson (hybrid)(163.04 kg/ha) and babycorn-broccoli-frenchbean (154.57 kg/ha) sequence. The lowest available potassium was reported with dhaincha-cabbage-frenchbean and rice-wheat + gram, 129.44 and 132.91 kg/ha, respectively. Comparatively higher nutrient status was observed in soils under vegetable cropping sequence which may be attributed to regular additions of NPK fertilizers and organic manures. Higher status of phosphorus status may be attributed to the fact the soils are slightly acidic in nature there by increasing

Table 2: pH, EC and OC under different treatments.

Treatment	pH	Electrical conductivity (d Sm^{-1})	Organic carbon (%)
T_1	5.47	0.108	1.21
T_2	5.44	0.050	1.01
T_3	5.39	0.090	1.08
T_4	5.47	0.072	1.17
T_5	5.28	0.075	1.15
T_6	5.42	0.071	1.03
T_7	5.48	0.066	1.00
T_8	5.35	0.061	1.11
T_9	5.29	0.072	1.25
T_{10}	5.27	0.073	1.12
SEm±	0.07	0.003	0.07
CD	NS	0.009	NS

Table 3: Effect of different treatments on available nitrogen, phosphorus and potassium in soil.

Treatment	After *Kharif* 2019		
	Nitrogen	Phosphorus	Potassium
T_1	320.45	42.60	140.24
T_2	335.21	40.56	139.48
T_3	376.86	44.45	129.44
T_4	371.27	45.00	139.55
T_5	369.29	41.33	144.60
T_6	319.19	42.80	132.91
T_7	363.88	43.45	163.04
T_8	369.59	46.81	143.19
T_9	344.82	48.47	154.57
T_{10}	335.63	46.58	185.68

Table 4: Total nutrient uptake under different treatments.

Treatment	Total uptake (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
T_1	60	43	50
T_2	106	23	134
T_3	112	44	231
T_4	199	51	335
T_5	123	29	72
T_6	83	22	83
T_7	95	21	54
T_8	60	36	69
T_9	146	60	265
T_{10}	177	70	197
SEm±	6.5	2.3	7.5
CD	19.3	6.9	22.2

the phosphorus reserves and making it available gradually. An intensive cropping system results in removal of nutrients from soil.

Effect on the uptake of nutrients

Nitrogen

Among cropping sequences (Table 4) sunhemp-vegetable pea-frenchbean recorded the highest uptake of the nitrogen (199 kg/ha) which was followed by okra-turnip-tomato cropping sequence (177 kg/ha) and babycorn-broccoli-frenchbean (146 kg/ha). The traditional cropping system, maize-wheat, showed the lowest uptake of nitrogen (59 kg/ha) followed by hybrid sorghum + hybrid bajra-ryegrass + berseem (60 kg/ha) sequence.

Phosphorus

Okra-turnip-tomato cropping sequence showed significantly highest uptake of phosphorus (70 kg/ha) which was tailgated by babycorn-broccoli-frenchbean and sunhemp-vegetable pea-frenchbean with 60 and 51 kg/ha, respectively. While the traditional cropping sequence, maize-wheat was at par with dhaincha-cabbage-frenchbean sequence in terms of the uptake with 44 kg/ha. The lowest uptake of the nutrient 21 kg/ha, was registered with the hybrid sorghum + hybrid bajra-oats + sarson (hybrid) while maize-gobhi sarson + toria and rice-wheat+gram cropping sequences were at par with each other with 22 kg/ha.

Potassium

The higher potassium uptake of 334 kg/ha was registered under sun hemp-vegetable pea-frenchbean which was followed by 265 kg/ha under babycorn-broccoli-frenchbean, dhaincha-cabbage-frenchbean (230 kg/ha) and okra-turnip-tomato (197 kg/ha) cropping sequences. The conventional cropping sequence, maize-wheat recorded the lowest potassium uptake of 50 kg/ha followed by 54 kg/ha under hybrid sorghum+hybrid bajra-oats+sarson (hybrid) sequence.

Balance sheet of nitrogen

All cropping sequences showed considerable loss in the available nitrogen (Table 5) except for the cropping sequence which included sunhemp-vegetable pea-frenchbean. The said sequence saw an increase of 166.37 kg/ha which might be due to the inclusion of green manuring crop followed by the leguminous crops in the subsequent seasons. The highest loss of available nitrogen to the tune of 247.49 kg/ha was recorded under maize-gobhi sarson + toria cropping sequence which was followed by rice-wheat + gram (195.93 kg/ha) and babycorn-broccoli-frenchbean (175.36 kg/ha) cropping sequence. Maximum removal of nitrogen may be attributed to greater production of biomass. Higher amounts of nitrogen fertilizer doses are to expect from the sequences which have net loss in the available nitrogen.

Table 5: Balance sheet of available nitrogen in soil.

Treatment	Amount added	Initial	Total	Cumulative uptake	Expected balance	Actual balance	Net gain /loss
T_1	354.00	273.59	627.59	59.65	567.94	320.45	-247.49
T_2	295.50	277.86	573.36	106.35	467.01	335.21	-131.80
T_3	253.60	272.57	526.17	111.54	414.63	376.86	-37.77
T_4	128.60	275.23	403.83	198.93	204.90	371.27	166.37
T_5	250.50	274.67	525.17	123.03	402.14	369.29	-32.85
T_6	324.00	273.82	597.82	82.70	515.12	319.19	-195.93
T_7	334.00	285.36	619.36	94.68	524.68	363.88	-160.80
T_8	279.00	279.34	558.34	59.81	498.53	369.59	-128.94
T_9	390.50	276.11	666.61	146.43	520.18	344.82	-175.36
T_{10}	285.25	277.24	562.49	177.40	385.09	335.63	-49.46

Table 6: Balance sheet of available phosphorus in soil.

Treatment	Amount added	Initial	Total	Cumulative uptake	Expected balance	Actual balance	Net gain /loss
T_1	126.00	31.87	157.87	43.39	114.48	42.60	-71.88
T_2	109.50	33.22	142.72	22.97	119.75	40.56	-79.19
T_3	104.40	32.57	136.97	43.90	93.07	44.45	-48.62
T_4	89.40	35.81	125.21	51.29	73.92	45.00	-28.92
T_5	99.50	35.35	134.85	28.50	106.35	41.33	-65.02
T_6	116.00	33.05	149.05	21.54	127.51	42.80	-84.71
T_7	111.00	34.76	145.76	21.02	124.74	43.45	-81.29
T_8	121.00	37.43	158.43	36.40	122.03	46.81	-75.22
T_9	147.50	33.53	181.03	60.11	120.92	48.47	-72.45
T_{10}	119.75	35.21	154.96	69.72	85.24	46.58	-38.66

Table 7: Balance sheet of available potassium in soil.

Treatment	Amount added	Initial	Total	Cumulative uptake	Expected balance	Actual Balance	Net Gain/Loss
T_1	202.00	118.73	320.73	49.91	270.82	140.24	-130.58
T_2	165.80	120.54	286.34	133.76	152.58	139.48	-13.10
T_3	142.80	119.54	262.34	230.74	31.60	129.44	97.84
T_4	167.80	140.79	308.59	334.61	-26.02	139.55	165.57
T_5	169.00	135.64	304.64	72.17	232.47	144.60	-87.87
T_6	202.00	132.98	334.98	83.40	251.58	132.91	-118.67
T_7	212.00	150.78	362.78	54.17	308.61	163.04	-145.57
T_8	172.00	139.99	311.99	68.66	243.33	143.19	-100.14
T_9	229.00	134.78	363.78	265.08	98.70	154.57	55.87
T_{10}	219.50	130.71	350.21	196.76	153.45	185.68	32.23

Table 8: Effect of different treatments on yield and economics.

Treatments	Maize grain equivalent yield	Cost of Cultivation	Gross returns	Net returns	B:C
T_1	7719	121813.27	155025.25	33211.98	0.56
T_2	9570	128967.58	189393.94	60426.86	0.79
T_3	19789	267552.71	329892.67	62339.96	0.56
T_4	25000	280953.43	459564.39	202053.63	2.28
T_5	11572	140212.71	221726.01	81514.29	4.9
T_6	8653	140373.24	166051.14	25678.4	-0.05
T_7	23485	119639.64	352272.73	232633.09	3.87
T_8	22929	124801.11	343939.39	219138.29	3.47
T_9	25375	308590.36	452929.3	145383.93	1.84
T_{10}	33376	227849.81	566919.19	339069.37	4.84
SEm±	662.4	9252.6	12059	8537.1	0.13
CD	1968.1	27492	35830.5	25366	0.37

Balance sheet of phosphorus

There was a net loss of available phosphorus in all of the cropping sequences (Table 6). The highest loss of available phosphorus amounting to 84.71 kg/ha was recorded with rice-wheat + gram followed by 81.29 kg/ha under hybrid sorghum + hybrid bajra-oats + sarson (hybrid) and maize-gobhi sarson + toria (79.19 kg/ha) sequences. Besides the lowest decline was recorded under sunhemp-vegetable pea-frenchbean sequence (28.92 kg/ha) followed by okra-turnip-tomato sequence (38.66 kg/ha) which might be due to the multiple crops in the sequence.

Balance sheet of potassium

There was a net loss of available potassium in most of the cropping sequences (Table 7) except for those which had vegetable crops in their sequence. The maximum loss of 145.57 kg/ha was recorded under hybrid sorghum + hybrid bajra-oats + sarson (hybrid) sequence followed by maize-wheat (130.58 kg/ha) sequence. The sequence with a maximum gain was recorded under sunhemp-vegetable pea-frenchbean (165.57 kg/ha) sequence. This was followed by dhaincha-cabbage-frenchbean (97.84 kg/ha) and babycorn-broccoli-frenchbean (55.87 kg/ha) sequences.

Economics under different sequences

Cost of cultivation

Babycorn-broccoli-frenchbean with ₹ 308590.36 ha^{-1} was the sequence with the highest cost of cultivation followed by sunhemp-vegetable pea-frenchbean, dhaincha-cabbage-frenchbean and okra-turnip-tomato sequences (₹ 280953.43 ha^{-1}, ₹ 267552.71 ha^{-1} and ₹ 227849.81 ha^{-1} respectively) (Table 8). Hybrid sorghum + hybrid bajra-oats + sarson (hybrid) recorded the lowest cost of cultivation (₹ 119639.64 ha^{-1}).

Gross and net returns

The highest gross returns of ₹ 566919.19 was recorded under okra-turnip-tomato cropping sequence. The lowest gross returns were recorded with the traditional cropping sequence *viz.*, maize-wheat (₹ 155025.25 ha^{-1}). Okra-turnip-tomato recorded the highest net returns of ₹ 339069.37 ha^{-1}. The lowest net returns were recorded under rice-wheat + gram sequence (₹ 25678.40 ha^{-1}). Mukherjee (2016) observed similar trends under cereal-vegetable cropping system.

Benefit cost ratio

Maize + soybean-chickpea + linseed cropping sequence recorded the highest BC ratio of 4.9 followed by 3.92 under okra-turnip-tomato and 3.87 under hybrid sorghum + hybrid bajra-oats + sarson (hybrid) sequences. The lowest of the ratio was recorded under the traditional cropping sequence *viz.*, rice-wheat + gram (-0.05) followed by dhaincha-cabbage-frenchbean (0.56) which was at par with maize-wheat sequence (0.56). The intercropping in the sequences improved the BC ratio of some of sequences.

CONCLUSION

In terms of food for human consumption, highest yield was obtained under the okra-turnip-tomato cropping sequence followed by dhaincha-cabbage-frenchbean and sunhemp-vegetable pea-frenchbean. While in terms of fodder yield, highest was obtained under hybrid sorghum + hybrid bajra-oats + sarson (hybrid) cropping sequence followed by hybrid sorghum + hybrid bajra-ryegrass + berseem. Highest maize grain equivalent yield was obtained with okra-turnip-tomato crop sequence. All other treatments remained superior in comparison to the maize-wheat crop sequence. Maize + soybean-chickpea + linseed emerged to be the best treatment with the highest benefit cost ratio. The treatment comprising okra-turnip-tomato sequence also proved to be the second-best treatment followed by hybrid sorghum + hybrid bajra-oats + sarson (hybrid). Sunhemp-vegetable pea-frenchbean recorded the highest uptake of the available nutrients from soil which was followed by babycorn-broccoli-frenchbean. There was net loss of available nutrients although the loss was less in the sequences with multiple crops during the year. The treatments had no significant effect on the pH and organic carbon content of the soil.

Disclosure statement

No potential conflict of interest was reported by the author(s).

REFERENCES

AOAC. (1995). Official Methods of Analysis. Association of Official Analytical Chemists, 16th Edition, Washington, DC.

Black C.A. (1965). Method of Soil Analysis Part 2: Chemical and Microbiological Properties. American Society of Agronomy, Madison, Wisconsin USA.

Farigone, J.E., Bassett, S., Boucher, T., Bridgham, S.D., Conant, R.T. *et al.* (2018). Natural climate solutions for the United States. Science Advances. 4(11): DOI: 10.1126/sciadv.aat1869.

Katyal, J.C. (2003). Soil fertility management-A key to prevent desertification. Journal of Indian Society of Soil Science. 51: 378-87.

Koenig, R.A. and Johnson, C.R. (1942). Colorimetric determination of Phosphorus in biological materials. Industrial and Engineering Chemistry, Analytical Edition. 14: 155-156.

Loria, N., Verma, K.S., Bhardwaj, S.K. and Brahmi, M.K. (2015). Impact of catchment land use on water quality of Pong wetland of Himachal Pradesh. Indian Journal of Ecology. 42(1): 21-26.

Mandal, B., Majumder, B., Bandopadhyay, P.K. (2007). The potential of cropping systems and soil amendments for carbon sequestration in soils under long-term experiments in subtropical India. Global Change Biology. 13: 357-369.

Metson, A.J. (1956). Methods of Chemical Analysis for Soil Survey Samples. New Zealand Soil Bureau, Bulletin No. 12.

Mukherjee, D. (2016). Evaluation of different crop sequence production potential, economics and nutrient balance under New Alluvial situation of NEPZ. International Journal of Horticulture and Agriculture. 1(1): 1-5.

Olsen, S.R., Cole, C.V., Watanabe F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular 939, United States Department of Agriculture. pp. 1-19.

Sharma, K.L., Mandal, B., Venkateswarlu, B. (2012). Soil Quality and Productivity Improvement under Rainfed Conditions-Indian Perspectives. In: Resource Management for Sustainable Agriculture. InTech, India. pp. 203-238.

Singh, G., Sandhu, H.S., Brar, S.S. and Gill, G.S. (1979). Studies on multiple cropping: Crop yield and production potential of different crop rotations. Indian Journal of Agronomy. 24(3): 310-314.

Singh, P. (2006). Alternate Cropping Systems in Peri-Urban Areas in PDCSR Annual Report 2005-06 (ICAR-IIFSR). pp. 11.

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the determination of available nitrogen in soil. Current Science. 25: 259-260.

Vukicevich, E., Lowery, T., Bowen, P., Urbez-Torres, J.R. and Hart, M. (2016). Cover crops to increase soil microbial diversity and mitigate decline in perennial agriculture. A Review. Agronomy for Sustainable Development. 36: 48. DOI: 10.1007/s13593-016-0385-7.

Walkley, A.J. and Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid Titration method. Soil Science. 37: 29-38.

Yusuf, K.O., Iyanada, M.O. and Olayiwola, T.E. (2001). Determination of optimum temperature and moisture content for crop germination. Journal of Agricultural Research and Development. 3: 39-49.