Andhra Pradesh J Agril. Sci : 11(1): 31-38, 2025

ASSESSMENT OF SOIL MAJOR NUTRIENTS IN SCARCE RAINFALL ZONE OF ANDHRA PRADESH

M. RAMA TULASI*, CH. BHARGAVA RAMI REDDY, K.V. NAGA MADHURI, Y. PAVAN KUMAR REDDY AND M.V.S. NAIDU

Department of Soil Science, S.V. Agricultural College, ANGRAU, Tirupati-517 502.

Date of Receipt: 21-02-2025 Date of Acceptance: 03-03-2025

ABSTRACT

Six prominent cropping systems in scarce rainfall zone of Andhra Pradesh *viz*., groundnut-horsegram, cotton-fallow, fallow-bengalgram, groundnut monocropping, paddy-paddy and paddy-groundnut cropping systems were selected to study the chemical properties of soils. Twenty soil samples from each cropping system were collected at 0-15 cm (surface soil) and 15-30 cm (sub-surface soil) depth. The soils were processed and analysed for their chemical properties. The available nitrogen (206 and 180 kg ha^{-1}) and available phosphorus (63.10 and 43.51 kg ha^{-1}) were highest in paddy-groundnut cropping system in both surface and sub-surface soils, respectively. While the lowest available nitrogen (159 and 130 kg ha^{-1}) and available phosphorus (45.59 and 32.22 kg ha^{-1}) were observed in cotton-fallow cropping system in both surface and sub-surface soils, respectively. The highest available K (216 and 148 mg kg^{-1}) was recorded under paddy-paddy cropping system in both surface and sub-surface soils. However, the lowest available K (122 and 92 mg kg^{-1}) was recorded under groundnut monocropping system in both surface and sub-surface soils.

KEYWORDS: Scarce rainfall zone, Prominent cropping systems, Surface and Sub-surface soils.

INTRODUCTION

Soil is an exhaustible storehouse of plant nutrients. The successful agriculture requires the sustainable use of soil resources, because soil easily lose their quality and quantity within short period of time. Due to increasing population and acquisition of fertile land for urbanization the cultivable land for agriculture land is decreased day by day (Kumar *et al*., 2023). Therefore, assessment of nutrient constraints of soils being intensively cultivated with high yielding crops need to be carried out (Patil *et al*., 2016). Scarce rainfall zone of Andhra Pradesh faces significant challenges in agricultural productivity due to low and erratic rainfall, leading to soil moisture stress and reduced crop yields. It has been documented very well that dry land soils are not only thirsty but hungry too (Wani, 2008). However, intensive cropping systems and inadequate nutrient management practices have led to soil nutrient depletion, further exacerbating the challenges faced by farmers in these regions. Nitrogen, phosphorus and potassium are the major nutrients required by all the crops for their growth (Borkar *et al*., 2018). Understanding the soil nutrient content at different depths of soil is one of the most important aspects of crop management and information about the soil nutrient status of study area is very important for nutrient management programs (Amgain *et al*., 2023). Supplement of balanced nutrition is one of the important factors to improve the crop productivity.

MATERIAL AND METHODS

The present study was carried out in scarce rainfall zone of Andhra Pradesh. Scarce rainfall zone of Andhra Pradesh lies in between the northern latitudes of $13^{0}40'$ to $16^{0}18'$ and eastern longitudes of $76^{0}47'$ to $79^{0}34'$. The geographical area of Scarce rainfall zone 36,788 km^2. Out of 40 lakh ha of rainfed area, about 45% area is in scarce rainfall zone of Andhra Pradesh. The scarce rainfall zone of Andhra Pradesh received total annual rainfall during the year 2023-24 is 201.45 mm. Twenty soil samples at 0-15 cm (surface soil) and 15-30 cm (sub-surface soil) depth from each cropping system were collected from the scarce rainfall zone of Andhra Pradesh *viz*., groundnut-horsegram, cotton-fallow, fallow-bengalgram, groundnut monocropping, paddy-paddy and paddy-groundnut cropping systems. The collected soil samples were air dried in shade, ground with a wooden hammer, passed through the sieves of 2 mm and used for determination of various soil properties by following standard procedures.

Available nitrogen was determined by alkaline permanganate (0.32% $KMnO_4$) method (Subbiah and Asija, 1956); Available phosphorus was determined by extracting the soil P with 0.5 M $NaHCO_3$ from alkaline soil at pH 8.5. (Olsen *et al*., 1954); Available potassium was estimated by using neutral-normal-ammonium acetate (NH_4OAc, pH 7.0) (Jackson 1973).

*Corresponding author, E-mail: mopideviramatulasi500@gmail.com

RESULTS AND DISCUSSION

Available nitrogen

The available nitrogen (Table 1) in surface soils varied from 103 kg ha^{-1} in cotton-fallow cropping system to 286 kg ha^{-1} in paddy-groundnut cropping system with mean values of 159 and 206 kg ha^{-1}, respectively. The available nitrogen of soils in groundnut-horsegram, cotton-fallow, fallow-bengalgram, groundnut monocropping, paddy-paddy and paddy-groundnut cropping systems was ranged from 125-165, 103-259, 116-263, 124-276, 111-262 and 127-186 kg ha^{-1}, respectively with mean values of 198, 159, 195, 202, 179 and 206 kg ha^{-1} respectively. The available nitrogen in surface soils varied from low to medium in status.

In sub-surface soils available nitrogen varied from 75 kg ha^{-1} in cotton-fallow cropping system to 276 kg ha^{-1} in paddy-groundnut cropping system with mean values of 130 and 180 kg ha^{-1}, respectively. The available nitrogen of soils in groundnut-horsegram, cotton-fallow, fallow-bengalgram, groundnut monocropping, paddy-paddy and paddy-groundnut cropping systems was ranged from 96-232, 75-206, 88-216, 105-236, 85-212 and 112-276 kg ha^{-1}, respectively with mean values of 161, 130, 151, 164, 140 and 180 kg ha^{-1}, respectively.

The maximum available nitrogen was observed in soils of paddy- groundnut cropping system in both surface and sub-surface soils. The minimum available nitrogen was observed in cotton-fallow cropping system in both the surface and sub-surface soils.

The available nitrogen of soils under paddy-groundnut cropping system and legume-based cropping systems was higher than that of other cropping systems. Several other workers have reported that legumes have the ability to fix and store more atmospheric N through their symbiotic association with rhizobium bacteria resulted more available nitrogen in soils (Kumar *et al*., 2020).

Regarding depth, available N decreased with increasing depth in all cropping systems. The increase in available nitrogen in surface soil is due to higher quantity of residue additions and their slow decomposition due to less soil disturbance might have caused higher available nitrogen concentrations in the surface layer (Du *et al*., 2010 and Dikgwatlhe *et al*., 2014).

Available Phosphorus

The available phosphorous (Table 2) in surface soils ranged from 15.48 kg ha^{-1} in cotton-fallow cropping system to 80.10 kg ha^{-1} in paddy-groundnut cropping system with mean values of 45.59 and 63.10 kg ha^{-1}, respectively. The available phosphorus of soils in groundnut-horsegram, cotton-fallow, fallow-bengalgram, groundnut monocropping, paddy-paddy and paddy-groundnut cropping systems was ranged from 32.40-74.26, 15.48-66.85, 25.49-72.45, 34.60-76.93, 25.44-68.43 and 35.67-80.10 kg ha^{-1}, respectively with mean values of 55.42, 45.59, 53.10, 57.27, 49.31 and 63.10 kg ha^{-1} respectively.

Available phosphorus in sub-surface soils ranged from 12.39 kg ha^{-1} in cotton-fallow cropping system to 68.23 kg ha^{-1} in paddy-groundnut cropping system with mean values of 32.22 and 43.51 kg ha^{-1}, respectively. The available phosphorus of soils in groundnut-horsegram, cotton-fallow, fallow-bengalgram, groundnut monocropping, paddy-paddy and paddy-groundnut cropping systems was ranged from 17.70-57.64, 12.39-52.56, 16.54-54.16, 18.42-57.99, 12.83-52.68 and 19.30-68.23 kg ha^{-1}, respectively with mean values of 38.00, 32.22, 34.61, 40.18, 33.85 and 43.51 kg ha^{-1}, respectively.

The maximum available phosphorus was recorded in soils of paddy-groundnut cropping system and the minimum available phosphorus was recorded in cotton-fallow cropping system in both surface and sub-surface soils. These soils were low to high in available phosphorus.

The available phosphorus of soils under paddy-groundnut cropping system was higher than that of other cropping systems. Crop rotations with legumes, can increase root colonization by mycorrhizae. Mycorrhizal associations have the greatest impact on increasing P availability in soils by colonizing root. This may be also due to higher available N in paddy-groundnut cropping system with BNF causes positive interaction between available N and P. The results are in accordance with the findings of Newton *et al*. (2011) and Smith *et al*. (2011).

The data further revealed that the soil available phosphorus decreased with increasing depth in all cropping systems. The increase in available phosphorus in surface soil which might be due to higher residue retention and higher organic carbon content that leads to favourable conditions for increasing nutrient availability

Table 1. Available nitrogen (kg ha^{-1}) of soils under prominent cropping systems in scarce rainfall zone of Andhra Pradesh

S. No.	Groundnut-Horsegram		Cotton-Fallow		Fallow-Bengalgram		Groundnut monocropping		Paddy-Paddy		Paddy-Groundnut	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	196	187	124	107	138	125	248	231	148	100	188	151
2	154	151	103	75	176	151	124	106	126	118	138	113
3	176	148	125	120	195	125	135	105	111	100	163	138
4	246	128	138	100	159	138	254	232	113	88	176	163
5	158	147	151	125	176	112	219	141	138	113	151	125
6	138	113	138	113	151	138	147	121	116	85	127	112
7	125	96	151	125	116	88	138	125	151	125	138	125
8	215	138	165	108	154	108	151	125	138	113	151	148
9	235	125	113	75	138	117	262	150	151	113	176	138
10	265	210	138	121	151	125	235	183	138	125	176	136
11	238	232	163	125	226	201	213	188	259	188	276	251
12	226	213	176	151	213	188	163	138	183	168	238	226
13	188	176	151	138	263	168	151	123	206	119	268	243
14	264	188	188	163	257	151	163	125	232	186	258	189
15	176	142	151	125	188	176	201	163	224	198	263	226
16	201	164	229	185	248	169	263	231	168	156	201	176
17	188	158	201	176	256	138	276	236	262	148	238	201
18	163	138	151	100	263	216	251	196	213	136	276	251
19	201	176	259	206	213	184	213	168	257	212	238	213
20	213	191	176	163	226	201	238	188	238	201	286	276
Min	**125**	**96**	**103**	**75**	**116**	**88**	**124**	**105**	**111**	**85**	**127**	**112**
Max	**265**	**232**	**259**	**206**	**263**	**216**	**276**	**236**	**262**	**212**	**286**	**276**
Mean	**198**	**161**	**159**	**130**	**195**	**151**	**202**	**164**	**179**	**140**	**206**	**180**
S. D	**40**	**35**	**38**	**35**	**47**	**35**	**51**	**44**	**53**	**40**	**54**	**52**
C.V	**20.12**	**21.96**	**23.82**	**26.66**	**24.28**	**23.48**	**25.12**	**27.15**	**29.61**	**28.56**	**26.27**	**29.00**

Table 2. Available phosphorus- P_2O_5 (kg ha^{-1}) of soils under prominent cropping systems in scarce rainfall zone of Andhra Pradesh

S. No	Groundnut-orsegram		Cotton-Fallow		Fallow-Bengalgram		Groundnut monocropping		Paddy-Paddy		Paddy-Groundnut	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	58.36	55.17	20.52	14.56	48.62	20.52	46.21	25.65	35.13	28.47	41.04	19.30
2	32.40	30.78	15.48	12.39	25.49	19.90	35.91	25.65	34.27	12.83	39.45	20.52
3	74.26	52.14	22.18	19.48	51.30	21.70	46.17	34.78	34.16	15.39	46.17	26.10
4	48.27	31.09	38.25	22.60	48.27	27.59	34.60	18.42	42.54	30.27	52.47	46.01
5	66.76	31.70	47.21	25.65	57.54	49.63	48.66	34.24	62.45	41.63	67.72	39.18
6	46.17	35.91	58.23	32.54	40.36	16.54	67.47	57.99	62.34	42.56	35.67	19.60
7	41.80	17.70	18.14	13.26	27.44	20.54	51.73	46.17	45.05	30.17	67.45	54.23
8	70.73	48.16	16.28	12.47	36.58	21.74	48.19	28.53	68.43	42.27	80.10	56.66
9	41.04	36.20	47.86	24.84	46.60	32.85	64.12	31.77	40.54	29.27	72.56	65.12
10	62.40	32.66	66.51	24.37	72.45	24.57	57.66	38.49	58.75	37.99	62.45	40.49
11	48.66	36.80	58.92	48.56	41.49	35.72	58.24	57.36	63.55	47.52	74.76	58.74
12	64.88	57.64	42.64	38.36	56.33	33.50	72.54	45.32	48.51	46.84	60.44	55.47
13	42.57	30.50	66.85	47.56	69.56	48.66	58.32	42.68	25.44	14.55	78.59	34.65
14	70.46	55.60	66.56	51.27	54.16	38.27	66.52	27.30	53.66	35.68	69.88	68.23
15	43.22	28.42	49.58	38.45	66.50	52.37	59.88	49.27	48.27	22.54	77.63	43.52
16	54.46	32.18	66.45	52.56	71.50	38.24	64.10	48.40	48.10	33.49	71.72	39.57
17	64.27	49.20	56.34	34.13	70.45	47.12	74.68	55.60	46.28	34.10	63.94	42.75
18	69.53	32.50	47.45	50.45	58.46	40.28	47.98	45.62	37.86	26.04	58.75	54.18
19	52.48	30.28	59.43	42.72	68.74	54.16	65.44	56.67	62.45	52.64	65.10	47.65
20	55.67	35.43	46.86	38.10	50.15	48.26	76.93	33.69	68.40	52.68	76.16	38.23
Min	**32.40**	**17.70**	**15.48**	**12.39**	**25.49**	**16.54**	**34.60**	**18.42**	**25.44**	**12.83**	**35.67**	**19.30**
Max	**74.26**	**57.64**	**66.85**	**52.56**	**72.45**	**54.16**	**76.93**	**57.99**	**68.43**	**52.68**	**80.10**	**68.23**
Mean	**55.42**	**38.00**	**45.59**	**32.22**	**53.10**	**34.61**	**57.27**	**40.18**	**49.31**	**33.85**	**63.10**	**43.51**
S. D	**12.13**	**10.97**	**18.06**	**13.96**	**14.25**	**12.46**	**12.08**	**12.03**	**12.70**	**11.95**	**13.62**	**14.54**
C.V	**21.89**	**28.87**	**39.61**	**43.33**	**26.84**	**36.00**	**21.09**	**29.94**	**25.76**	**35.30**	**21.58**	**33.42**

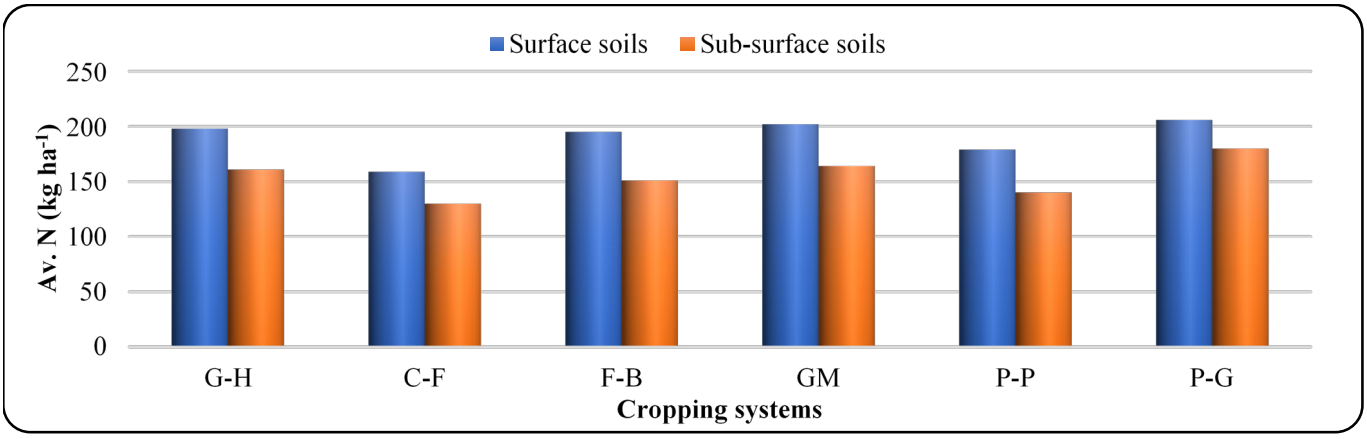

Fig. 1. Available nitrogen (kg ha^{-1}) status of soils under prominent cropping systems in scarce rainfall zone of Andhra Pradesh.

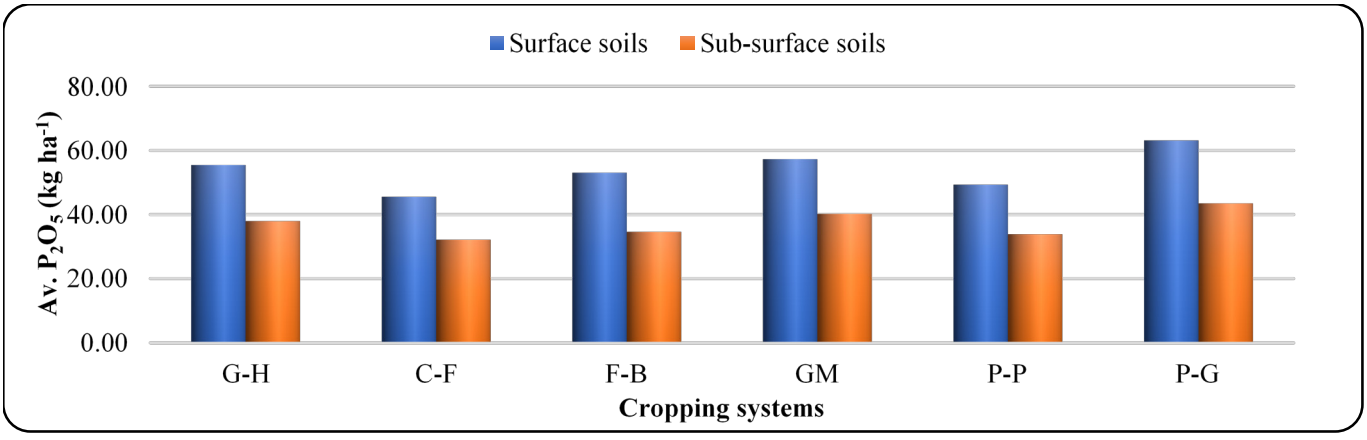

Fig. 2. Available phosphorus (kg ha^{-1}) status of soils under prominent cropping systems in scarce rainfall zone of Andhra Pradesh.

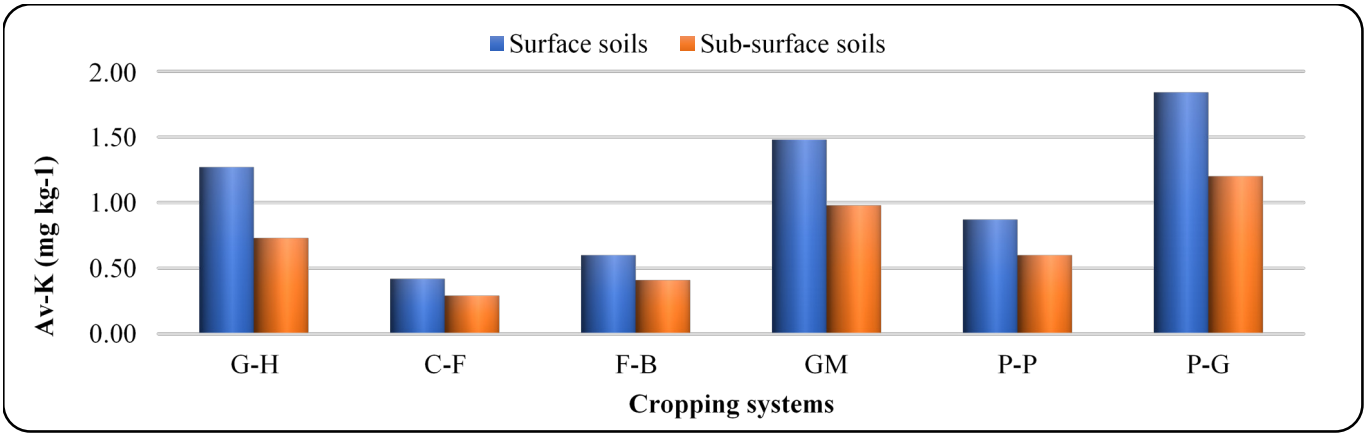

Fig. 3. Available K (mg kg^{-1}) status of soils under prominent cropping systems in scarce rainfall zone of Andhra Pradesh.

Note: G-H: Groundnut-Horsegram; C-F: Cotton-Fallow; F-B: Fallow-Bengalgram; GM: Groundnut Monocropping; P-P: Paddy-Paddy; P-G: Paddy-Groundnut

Table 3. Distribution of available potassium (mg kg^{-1}) under prominent cropping system in scarce rainfall zone of Andhra Pradesh

S. No	Groundnut-Horsegram		Cotton-Fallow		Fallow-Bengalgram		Groundnut monocropping		Paddy-Paddy		Paddy-Groundnut	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	156	130	85	70	197	134	147	104	229	189	127	112
2	140	125	152	132	149	112	76	61	161	143	279	150
3	108	98	145	66	152	118	108	101	208	168	282	130
4	122	114	123	109	135	122	73	66	118	89	113	72
5	128	108	135	122	173	137	113	64	143	120	146	77
6	82	60	108	80	153	126	138	104	256	244	101	92
7	134	96	136	63	167	133	80	72	241	138	284	226
8	121	59	154	76	183	126	113	73	191	129	160	129
9	85	69	85	67	145	122	141	83	127	122	134	85
10	93	80	118	123	139	117	83	58	268	142	110	74
11	147	66	224	150	143	116	84	68	201	110	230	124
12	135	124	237	146	189	130	191	128	289	172	272	146
13	157	126	191	161	153	141	125	134	273	156	247	166
14	188	125	157	87	156	114	91	59	203	121	200	117
15	177	130	278	125	98	70	134	112	217	136	220	176
16	167	108	149	62	249	140	82	74	274	166	206	166
17	143	112	145	128	213	131	184	134	230	176	234	125
18	182	92	223	166	282	210	131	69	205	145	246	158
19	213	146	246	184	174	132	175	144	263	153	249	184
20	152	112	264	150	157	139	179	133	220	150	219	176
Min	**82**	**59**	**85**	**62**	**98**	**70**	**73**	**58**	**118**	**89**	**101**	**72**
Max	**213**	**146**	**278**	**184**	**282**	**210**	**191**	**144**	**289**	**244**	**284**	**226**
Mean	**141**	**104**	**168**	**113**	**170**	**128**	**122**	**92**	**216**	**148**	**203**	**134**
S. D	**35**	**26**	**58**	**39**	**41**	**25**	**39**	**30**	**50**	**33**	**63**	**42**
C.V	**24.82**	**25.00**	**34.52**	**34.51**	**24.12**	**19.53**	**31.97**	**32.61**	**23.15**	**22.30**	**31.03**	**31.34**

at the surface layers (Jat *et al*., 2018 and Kavitha *et al*., 2019).

Available Potassium

The available potassium (Table no.3) content of surface soils varied from 73 mg kg^{-1} in groundnut monocropping system to 289 mg kg^{-1} in paddy- paddy cropping sytem with mean values of 122 and 216 mg kg^{-1}, respectively. The available potassium of soils in groundnut-horsegram, cotton-fallow, fallow-bengalgram, groundnut monocropping, paddy-paddy and paddy-groundnut cropping systems was ranged from 82-213, 85-278, 98-282, 73-191, 118-289 and 101-284 mg kg^{-1}, respectively with mean values of 141, 168, 170, 122, 216 and 203 mg kg^{-1}, respectively. The available potassium content in surface soils was varied from medium to high in status.

In sub-surface soils available potassium content varied from 58 mg kg^{-1} in groundnut monocropping system to 244 mg kg^{-1} in paddy- paddy cropping sytem with mean values of 92 and 148 mg kg^{-1}, respectively. The available potassium of soils in groundnut-horsegram, cotton-fallow, fallow-bengalgram, groundnut monocropping, paddy-paddy and paddy-groundnut cropping systems was ranged from 59-146, 62-184, 70-210, 58-144, 89-244 and 72-226 mg kg^{-1}, respectively with mean values of 104, 113, 128, 92, 148 and 134 mg kg^{-1}, respectively. The available potassium content in sub-surface soils was varied from medium to high in status.

The highest available potassium was observed in soils of paddy- paddy cropping system in both surface and sub-surface soils due to continuous application of potassic fertilizers. The lowest available potassium was recorded in groundnut monocropping system in both surface and sub-surface soils possibly due to less application of potassic fertilizers than crop needed or imbalanced fertilization in crop nutrition caused mining of its native pools (Charankumar *et al*., 2022).

The data further revealed that highest available potassium was observed in surface soils than in sub-surface soils in all cropping systems, which might be attributed to presence of vegetation or upward translocation of K from lower layers through capillary rise or ground water. (Lungmuana *et al*., 2014).

The results of this study indicated that the soils under prominent cropping systems in scarce rainfall zone of Andhra Pradesh were low to medium in available nitrogen, low to high in available phosphorus and medium to high in available potassium. In both surface and sub-surface soils, the available nitrogen and available phosphorus content in the prominent cropping systems were in the order of paddy-groundnut > groundnut monocropping > groundnut-horsegram > fallow-bengalgram > paddy-paddy > cotton-fallow. The available K in the prominent cropping systems waas in the order of paddy-paddy > paddy-groundnut > fallow-bengalgram > cotton-fallow > groundnut-horsegram > groundnut monocropping in both surface and sub-surface soils. Paddy-groundnut cropping system was found to be maintain sustainable soil health leading to improved crop productivity and profitability.

ACKNOWLEDGEMENT

The authors are sincerely thankful to the Acharya N.G. Ranga Agricultural University, S.V. Agricultural College, Tirupati, Department of Soil Science, ANGRAU, India for providing infrastructure and financial support.

LITERATURE CITED

Amgain, R., Khadka, D and Joshi, S. 2023. Soil macronutrient status in different depths after wheat harvest in the paddy-wheat cropping system of Rupandehi District of Nepal. *Nepal Agriculture Research Journal*. 15(1): 46-54.

Borkar, V.S., Gokhale, N.B., Dhopavkar, R.V., Khobragade, N.H., More, S.S and Kasture, M.C. 2018. Distribution of nutrients in different soil types in Konkan region of Maharashtra. *International Journal of Chemical Studies*. 6(1): 275-279.

Charankumar, G.R., Munaswamy, V., Krishna, T.G and Subramanyam, D. 2022. Dynamics of soil potassium under different cropping systems in YSR Kadapa district of Andhra Pradesh. *Environment and Ecology*. 40(2): 425-431.

Dikgwatlhe, S.B., Chen, Z., Lal, R., Zhang, H and Chen, F. 2014. Changes in soil organic carbon and nitrogen as affected by tillage and residue management under wheat–maize cropping system in the North China Plain. *Soil Tillage Research*. 144: 110-118.

Du, Z., Ren, T and Hu, C. 2010. Tillage and residue removal effects on soil carbon and nitrogen storage in the North China Plain. *Soil Science Society of America Journal*. 74(1): 196-202.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Oxford IBH Publishing House, Bombay. 38.

Jat, H.S., Datta, A., Sharma, P.C., Kumar, V., Yadav, A.K., Choudhary, M., Choudhary, V., Gathala, M.K., Sharma, D.K., Jat, M.L and Yaduvanshi, N.P.S. 2018. Assessing soil properties and nutrient availability under conservation agriculture practices in a reclaimed sodic soil in cereal-based systems of North-West India. *Archives of Agronomy and Soil Science*. *64*(4): 531-545.

Kavitha, M., Vajantha, B., Naidu, M.V.S and Reddi Ramu, Y. 2019. Delineation and geographic information system (GIS) mapping of soil macronutrients status in sugarcane growing tracts of prudential sugar factory zone in Chittoor district, Andhra Pradesh. *International Journal of Chemical Studies*. 7(6): 11-16.

Kumar, A., Kumar, S., Gaur, A.S., Kumar, A., Singh, A and Prajpati, D. 2023. Effect of Physico-Chemical Properties of Soil under Various Depths on Different Cropping Systems in Ayodhya, India. *International Journal of Plant and Soil Science*. 35(18): 1484-1490.

Kumar, V., Singh, S.K., Singh, P., Tiwari, S., Nand, M.M., Chiranjeeb, K and Majhi, M. 2020. Effects of Cropping Systems on Soil Properties and Enzymatic Activities in Calcareous Soil. *International Journal of Current Microbiology and Applied Sciences*. 9(4): 2020.

Lungmuana., Bose, A., Ghosh, I., Ghosh, S.K and Patra, P.K. 2014. Distribution and variation of potassium in rice growing soils of red and laterite zone of West Bengal. *Journal of the Indian Society of Soil Science*. 62(1): 84-87.

Newton, Z.L., Kennedy, A.N and Chirwa, R.M. 2011. Grain legume impacts on soil biological processes in sub-Saharan Africa. *African Journal of Plant Science*. 5(1): 1-7.

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 of United States Department of Agriculture*. 939.

Patil, P.L., Kuligod, V.B., Gundlur, S.S., Katti, J., Nagaral, I.N., Shikrashetti, P., Geetanjali, H.M and Dasog, G.S. 2016. Soil fertility mapping in Dindur sub-watershed of Karnataka for site specific recommendations. *Journal of the Indian Society of Soil Science*. 64(4): 381-390.

Smith, S.E., Jakobsen, I., Gronlund, M and Smith, F.A. 2011. Roles of arbuscular mycorrhiza as in plant phosphorus nutrition: interactions between pathways of phosphorus uptake in arbuscular mycorrhizal roots have important implications for understanding and manipulating plant phosphorus acquisition. *Plant Physiology*. 156(3): 1050-1057.

Subbiah, B.V and Asija, C.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science*. 25: 32.

Wani, S.P. 2008. Taking soil science to farmers' doorsteps through community watershed management. *Journal of the Indian Society of Soil Science*. 56(4): 367-377.