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Different Cropping System Effects of Depth-Wise Distribution of Available NPKS in an *Inceptisol* of Southern Telangana Zone

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Authors' contributions

This work was carried out in collaboration among all authors. Author KN performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SHKS and AAQ managed the analyses of the study. Author CPK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The present study was undertaken in the ongoing long-term experiment initiated during 2017 at the experimental farm of College of Agriculture, Rajendranagar, Hyderabad. Soil samples were collected from two depths (0–15 and 15–30 cm) and analysed for soil fertility parameters namely: available N, P, K and S. The results indicated that the different cropping systems had positive influence on improving the nutrient status (i.e., available N, P and K) significantly over the initial soil values (N: 112.20, P: 23.40 and K: 170.30 kg ha^{-1}, respectively). Interestingly, it was noticed that improved availability of nutrients (N, P, K and S) was more profound in the upper soil layer (0–15 cm) compared to lower depth (15–30 cm) in all the cropping systems (CS). The CS: Bt cotton + Greengram – Groundnut had recorded high nitrogen (N=221.60 $kg^{-}1$), CS: Fodder maize – Lucerne recorded high in available P (P=49.13 kg^{-1}) and CS: Fodder sorghum + Fodder cowpea – Horsegram – Sunhemp recorded high in K and S (K=208.10 kg^{-1}, S= 172.0 kg S ha^{-1}) after kharif

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season. While, CS: Pigeon pea + Greengram – Sesame showed high for N (N=228.57 kg^{-1}), CS: Fodder maize – Lucerne for high P (P=48.27 kg^{-1}) and Rice – Maize recorded high for K and S (K=207.63 kg^{-1} and S= 95.40 kg S ha^{-1}) in top soil layer (0–15 cm) after harvest of *rabi* compared to lower soil depth (15–30 cm).

Keywords: Available N; P; K; S; cropping system; season; legumes; soil depth.

1. INTRODUCTION

Rice, maize and Bt cotton are the predominant crops which are either grown solely or in rotation with other crops in Telangana state. As all these crops are exhaustive, non–leguminous in nature and their continuous cultivation over long period may lead to fast soil degradation [1].

Therefore, a major agricultural research priority is needed to sustain soil productivity by including legume component in present cropping systems of Telangana. Cropping system is an important component of a farming system representing a cropping pattern adopted on a farm, which is supposed to maintain and enhance soil health [2]. The effect of cropping systems on soil properties provide an opportunity to evaluate sustainability of Agro-ecosystems and thus the effect on basic processes of soil degradation in relation to agricultural use [3]. The sustainability of Indian agriculture is being threatened by sharp declining factor productivity due to deteriorating soil quality, imbalanced use of fertilizers, mismatch between nutrient additions and removal by crops and escalating cost of production [4]. The food production must keep pace with the country's increasing population, demanding not only the food security but also nutritional security [5]. Therefore, to achieve sustainable fertility and productivity, efforts must be focused on reversing the trend in soil degradation by adopting efficient cropping systems and soil health management. Soil is the mainstay of agriculture and resource base of food production [6]. Hence, sustainable increase in crop yields is needed to ensure food security in India. Increasing population and shrinking land resources are exerting considerable pressure on land resource due to intensive cultivation. Over exploitation of land resources is leading to degradation of soil rapidly. It is also a fact that highly productive lands have been diverted from agriculture to infrastructural development, urbanization, and other related activities. Under these circumstances, the only viable option is to enhance the productivity vertically to meet the production goals. Therefore, there is an urgency to maintain soil health for sustaining productivity of land.

Adopting different inter-cropping systems is the fastest way of restoring the nutrient depletion, yet ever increasing energy costs, limited input availability, and rising fertilizer prices that hinder the farmers from using these inputs to a required level [7]. Consequently, continuous imbalanced use of fertilizers has led to deterioration of soil health and reduction in productivity. Over dependence on existing Rice-maize cropping has encouraged the process of land degradation and is badly affecting production potential of crops. Hence, most of the productive soils are becoming unproductive due to cultivation of cereal crops. The area under maize and wheat in the state is 292.14 and 371.06 thousand hectares, respectively [8].

The importance of long-term experiments in studying the effects of continuous cropping on soil fertility and sustenance of crop production is widely recognized [9,10]. Interest in long-term field experiments as the suitable indicators of sustainability of agriculture has increased during past few decades worldwide. The long-term experiments provide an ideal base to assess the effect of nutrient management practices involving different fertilizers and amendments on changes in soil quality and crop productivity. Therefore, the present study was undertaken to investigate the effect of different cropping systems on nutrient availability and depth-wise distribution of available nutrients and productivity under different cropping systems in sandy loam soils.

2. MATERIALS AND METHODS

This experiment was carried out in the ongoing project of the All India Coordinated Research Project on Integrated Farming Systems Unit, college farm, college of Agriculture, Rajendranagar, Hyderabad to study the effect of different cropping systems on depth-wise distribution of available NPKS in sandy loam soils belonging to *Inceptisol* soil order of Southern Telangana zone. Different cropping systems are being maintained in fixed plots since 2017-18. The observations and results for third year study was taken up for both *kharif* and *rabi*, 2019-2020. The experimental site was located at 17°32' North latitude and 78°40' East longitude and at altitude of above 451m. The location has average maximum temperature of 32.33°C and average minimum temperature of 18.46°C, the annual rainfall is 797mm and its major portion (about 80%) is received during June to September. Soil reaction is alkaline (pH 7.68), low in soil organic carbon (0.41%), low in electrical conductivity (0.40 ds m^{-1}), low in available nitrogen (191.65 kg ha^{-1}), medium in available phosphorus (38.50 kg ha^{-1}), medium in available potassium (194.79 kg ha^{-1}) and high in available sulphur (78.58 mg S kg^{-1}).

The experiment was laid out in randomized block design comprising of 10 treatments (cropping systems) *viz*., T_1: Rice – Maize, T_2: Bt cotton – Fallow, T_3: Bt cotton + Greengram(1:3) – Groundnut, T_4: Pigeon pea + Greengram (1:3) – Sesame, T_5: Maize + Pigeon pea (1:3) – Groundnut, T_6 : Pigeon pea + Groundnut (1:7) – Ragi, T_7: Fodder sorghum + Fodder cowpea (1:2) – Horsegram – Sunhemp, T_8: Fodder maize – Lucerne, T_9: Sweet corn – Vegetables (Tomato) and T_{10}: Bhendi – Marigold – Beetroot during *kharif* – *rabi* seasons, respectively. Each treatment was allocated randomly initially and replicated three times.

All the crops in different cropping systems were raised in accordance with recommended package of practices. Available NPKS, and NPKS uptake have been reported and discussed. Soil samples collected from a depth of 0–15 and 15–30cm after the harvest of various crops (2019–2020) during *kharif* and *rabi* were used for determination of various chemical parameters. Three composite soil samples from all the depths were also drawn each plot. The soil samples were air dried, processed and passed through 2 mm sieve and properly stored in polythene bags. The processed soil samples were analysed for available nitrogen, phosphorus, potassium and sulphur by adopting standard procedures as given below.

2.1 Available Nitrogen

Available nitrogen in the soil was determined by alkaline permanganate method as described by [11]. and expressed as kg ha^{-1}.

2.2 Available Phosphorus

Available phosphorus was extracted from soil by Olsen's reagent as described by [12]. The blue colour was developed following ascorbic acid method and the intensity of blue colour was measured at 660nm wavelength by using Spectrophotometer (Elico SL – 177). The available phosphorus content was calculated and expressed as kg P ha^{-1}.

2.3 Available Potassium

Available potassium was extracted from soil using neutral normal ammonium acetate [13] and was determined by using Flame photometer (Elico CL 361) as described by [14] and expressed as kg K ha^{-1}.

2.4 Available Sulphur

Available sulphur was extracted from the soil by employing 0.15 per cent $CaCl_2.2H_2O$ solution [15]. using 1:5 soil to solution ratio. The S content in the extracts was determined by the turbidimetric method of [16].

2.5 Data Analysis and Statistics

The experimental data were analysed by adopting RBD statistical tool and analysis of variance was worked out as suggested by [17].

3. RESULTS AND DISCUSSION

3.1 Effect of Different Cropping Systems on Available Nutrients (N, P, K and S)

3.1.1 Available nitrogen

Our results indicated that the available nitrogen in soil after harvest in different cropping systems ranged from 156.90 to 221.60 kg ha^{-1} by soil depths during both *kharif* and *rabi.* The minimum available soil nitrogen was 112.20 kg ha^{-1} at 0-15 cm soil depth. The maximum (221.60 and 221.57 kg ha^{-1}) more soil available nitrogen was obtained in Pigeon pea + Greengram (1:3) – Sesame in 0-15 cm soil depth during *kharif* and *rabi* respectively. The results of the study are in line with those of [18-21] who conducted studies in the semi-arid tropics of India and the results revealed that the addition of pigeon pea, as a sole crop or as an intercrop in a cropping system, not only helps in improving soil N fertility, but also makes more phosphorus reserves available for subsequent crops. Highest available nitrogen under Pigeon pea + Greengram (1:3) – Sesame after harvest of *kharif* might be attributed to addition of pigeon pea in intercropping.

Highest available soil nitrogen (221.60 kg ha^{-1} and 204.46 kg ha^{-1}) was recorded in Pigeon pea + Greengram (1:3) – Sesame at both 0-15 cm and 15-30 cm after *kharif.* Fodder sorghum + Fodder cowpea (1:2) – Horsegram – Sunhemp gave (217.40 kg ha^{-1} and 189.30 kg ha^{-1}) of nitrogen in comparison with soil depths i.e in 0-15 cm and 15-30 cm respectively while available nitrogen (209.10 kg ha^{-1} and 196.53 kg ha^{-1}) in Fodder maize – Lucerne was statistically on par with Bt cotton + Greengram (1:3) – Groundnut (209.00 kg ha^{-1}) and (198.70 kg ha^{-1}) at 0-15 cm and 15-30 cm soil depths after *kharif* respectively. This might be due to inclusion of leguminous crops in the system. also reported that the inclusion of leguminous crops in the cropping system improved soil available nitrogen status (Table 1).

The available N in soil decreased with increasing in soil depths having maximum (221.60 kg ha^{-1}) soil available N at 0-15 cm in both cropping seasons, comparing to 15-30 cm depth. The maximum available N was found in surface (0-15 cm) layer after *kharif* and *rabi*. The lowest available N was recorded in the lowest soil depth of 15-30 cm irrespective of the cropping systems. The available N decreased with depth in all the cropping systems under study. This might be due to the higher pH, which declined organic matter status by fast degradation, which reflected low status of available nitrogen. Similar results were recorded by [22] from Shevaon Tehsil of Ahmednagar district.

All the cropping systems enhanced soil available nitrogen over the initial in both *kharif* and *rabi*. The marginal increase in crops or cropping systems which include leguminous crops in the system might be due to the fact that legumes have ability to access atmospheric nitrogen through symbiosis with a group of soil bacteria (rhizobia) and so require minimal N fertilizer inputs. Similar findings were reported by [23]

3.1.2 Available phosphorus

The results showed that the available phosphorus in soil after harvest in different cropping systems ranged from 23.98 to 48.27 kg ha^{-1} by soil depths during both *kharif* and *rabi*. Available phosphorus after *kharif* was found higher in Fodder maize – Lucerne (48.27 kg ha^{-1} and 44.33kg ha^{-1}), followed by Maize + Pigeon pea (1:3) – Groundnut (47.33 kg ha^{-1} and 42.30 kg ha^{-1}) , Pigeon pea + Greengram (1:3) – Sesame (45.07 kg ha^{-1} and 39.30 kg ha^{-1}), Bt cotton + Greengram (1:3) – Groundnut (43.33 kg ha^{-1} and 39.20 kg ha^{-1}), Fodder sorghum + Fodder cowpea (1:2) – Horsegram – Sunhemp (41.23 kg ha^{-1} and 29.48 kg ha^{-1}), Pigeon pea + Groundnut (1:7) – Ragi (40.23 kg ha^{-1} and 28.73 kg ha^{-1}), Bhendi – Marigold – Beetroot (39.07 kg ha^{-1}) and (27.53 kg ha^{-1}), Rice – Maize (37.30 kg ha^{-1} and 26.60 kg ha^{-1}), Sweet corn – Vegetables (Tomato) (35.70 kg ha^{-1} and 24.50 kg ha^{-1}), Bt cotton – Fallow (32.97 kg ha^{-1}) and (23.98 kg ha^{-1}) in both 0-15 cm and 15-30 cm soil depth respectively. The decrease in available phosphorus with soil depth in all the cropping systems during *kharif* might be attributed to alkaline in reaction (7.68) and high content of $CaCO_3$ (0.96 %) in the soil.

Data pertaining to available phosphorus in soil after *rabi* revealed that higher available phosphorus was registered in Fodder maize – Lucerne (48.27 kg ha^{-1} and 46.43 kg ha^{-1}). It has increased in these sequence, Pigeon pea + Maize (1:3) – Groundnut (47.33 kg ha^{-1} and 45.50 kg ha^{-1}), Pigeon pea + Greengram (1:3) – Sesame (45.07 kg ha^{-1}) and (43.23 kg ha^{-1}), Bt cotton + Greengram (1:3) – Groundnut (43.33 kg ha^{-1} and 41.50 kg ha^{-1}), Fodder sorghum + Fodder cowpea (1:2) – Horsegram – Sunhemp (41.23 kg ha^{-1} and 39.40 kg ha^{-1}), Pigeon pea + Groundnut (1:7) – Ragi (40.23 kg ha^{-1} and 38.40 kg ha^{-1}), Bhendi – Marigold – Beetroot (39.37 kg ha^{-1}) and (37.53 kg ha^{-1}), Rice – Maize (37.30 kg ha^{-1} and 35.47 ha^{-1}), Sweetcorn – Vegetables (Tomato) (35.37 kg ha^{-1} and 33.87 kg ha^{-1}) and Bt cotton – Fallow (32.97 kg ha^{-1} and 31.13 kg ha^{-1}) in both 0-15cm and 15-30 cm soil depth after *rabi*. All the cropping systems have increased available phosphorus in the soil during both kharif and *rabi* over the initial (Table 1).

3.1.3 Available potassium

The data on available potassium after harvest ranged from 126.23 to 207.63 kg ha^{-1} in *kharif* and *rabi* by soil depths. Increase in available potassium was in the order after *kharif*; Rice – Maize (207.63 kg ha^{-1} and 206.01 kg ha^{-1}), followed by Fodder maize – Lucerne (205.50 kg ha^{-1} and 203.07kg ha^{-1}), Pigeon pea + Greengram – Sesame (1:3) (204.33 kg ha^{-1} and 202.88 kg ha^{-1}), Maize + Pigeon pea (1:3) – Groundnut (202.50 kg ha^{-1} and 196.90), Bt cotton + Greengram (1:3) – Groundnut (199.50 kg ha^{-1} and 195.07 kg ha^{-1}), Pigeon pea + Groundnut (1:7) – Ragi (198.53 kg ha^{-1} and 184.78kg ha^{-1}), Bt cotton – Fallow (196.53 kg ha^{-1} and 192.49 kg ha^{-1}), Fodder sorghum + Fodder

Table 1. Effect of different cropping systems on available nitrogen, phosphorus, potassium and sulphur at two depths

	Avaialble nutrients after *kharif*							
Treatment (Cropping system: *kharif* - *rabi*)	**Avail N kg ha^{-1}**		**Avail P kg P ha^{-1}**		**Avail K kg K ha^{-1}**		**Avail S mg kg^{-1}**	
	0-15 cm	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**
Initial	112.20		23.40		170.30			
Rice – Maize	179.80	173.63	39.39	26.60	204.23	206.01	83.833	69.50
Bt cotton – Fallow	163.00	156.90	30.91	23.98	189.53	192.49	78.00	40.83
Bt cotton + Greengram – Groundnut	209.00	198.70	41.15	39.20	202.23	195.07	84.08	58.17
Pigeon pea + Greengram - Seasame	221.60	204.46	42.07	39.30	201.43	202.88	109.42	77.00
Maize + Pigeon pea - Groundnut	196.50	184.93	48.64	42.30	200.65	196.90	114.58	69.25
Pigeon pea + Groundnut – Ragi	192.30	177.40	44.65	28.73	193.58	184.78	85.33	53.75
Fodder sorghum+ Fodder cowpea–Horsegram-Sunhemp	217.40	189.30	43.56	29.48	198.00	183.31	172.00	101.58
Fodder maize – Lucerne	209.10	196.53	49.13	44.33	208.10	203.07	83.00	52.25
Sweet corn – Vegetables (tomato)	188.10	176.90	33.75	24.50	183.76	176.83	149.67	89.00
Bhendi – Marigold + Beetroot	171.40	169.20	40.38	27.53	178.76	156.23	123.08	98.08
SEM (±)	18.72	9.80	1.36	6.40	9.52	17.96	11.18	7.56
CD (at 5%)	NS	NS	4.08	NS	NS	NS	33.46	22.63
	Available nutrients after *rabi*							
Treatment (Cropping system: kharif - rabi)	**Avail N kg ha-1**		**Avail P. kg ha-1**		**Avail K. kg ha^{-1}**		**Avail S. kg ha^{-1}**	
	0 -15 cm	**15 -30 cm**	**0 -15 cm**	**15 -30 cm**	**0 -15 cm**	**15 -30 cm**	**0 -15 cm**	**15 -30 cm**
Rice – Maize	182.07	179.09	37.30	35.47	207.63	206.90	95.40	85.03
Bt cotton – Fallow	169.13	162.35	32.97	31.13	196.53	195.80	47.08	47.55
Bt cotton + Greengram – Groundnut	212.23	208.35	43.33	41.50	199.50	198.77	59.92	46.40
Pigeon pea + Greengram – Seasame	228.57	220.09	45.07	43.23	204.33	203.60	56.99	43.88
Maize + Pigeon pea – Groundnut	188.37	195.79	47.33	45.50	202.50	201.77	59.10	52.73
Pigeon pea + Groundnut – Ragi	199.30	191.62	40.23	38.40	198.53	197.80	81.79	65.28
Fodder sorghum+Fodder cowpea–Horsegram–Sunhemp	215.43	216.75	41.23	39.40	192.00	191.27	95.27	67.59
Fodder maize – Lucerne	209.07	208.39	48.27	46.43	205.50	204.77	90.38	78.69
Sweet corn – Vegetables (tomato)	180.45	187.45	35.70	33.87	186.67	185.93	69.28	63.76
Bhendi – Marigold + Beetroot	176.43	170.75	39.37	37.53	183.90	183.17	75.58	68.83
SEM (±)	20.23	18.73	1.45	1.55	10.00	10.00	10.87	10.74
CD (at 5%)	NS	NS	4.35	NS	NS	NS	32.55	NS

cowpea (1:2) – Horsegram– Sunhemp (192.00 kg ha^{-1} and 183.31 kg ha^{-1}) , Sweet corn – Vegetables (Tomato) (186.67 kg ha^{-1} and 176.83 kg ha^{-1}), Bhendi (183.90 kg ha^{-1} and 126.23 kg ha^{-1}) in both 0-15 cm and 15-30 cm depths respectively.

During *rabi*, Maize registered higher available potassium (207.63 and 206.01 kg ha^{-1}), followed by Lucerne (205.50 kg ha^{-1} and 204.77 kg ha^{-1}). It has increased in these sequence, T_4 Sesame (204.33 kg ha^{-1} and 203.60 kg ha^{-1}), Groundnut (202.50 kg ha^{-1} and 196.90 kg ha^{-1}), Groundnut (199.50 kg ha^{-1} and 198.77 kg ha^{-1}), Ragi (198.53 kg ha^{-1} and 197.80 kg ha^{-1}), Fallow (196.53 kg ha^{-1}) and (195.80 kg ha^{-1}), Horsegram – Sunhemp (192.00 kg ha^{-1} and 191.27kg ha^{-1}), Vegetables (Tomato) (186.67 kg ha^{-1} and 185.93 kg ha^{-1}) and Bhendi – Marigold – Beetroot (183.90 kg ha^{-1} and 183.17kg ha^{-1}) in 0-15 cm and 15-30 cm respectively. However, all the cropping systems in both seasons were not significant.

All the cropping systems increased available potassium status of the soil over the initial by depths in both *kharif* and *rabi* except Bhendi– Marigold – Beetroot (126.23 kg ha^{-1}) in 15-30 cm depth after harvest. The available potassium decreased with depth in all the cropping systems. This might be due to dissolution and diffusion of K from internal crystal lattice of silicate clay minerals and high clay content and montmorillonite. [24] reported similar trends (Table 1).

3.1.4 Available sulphur

The results on available sulphur in soil as influenced by different cropping systems is presented in Table 1. The content of available sulphur in soil was high in all the cropping systems.

Amount of available-S is directly related to crop growth and yield. It varied from 78.00 to 172 mg kg^{-1} in surface soil (0-15 cm) and 40.83 to 101.58 mg kg^{-1} in sub-surface soil (15-30 cm) after *kharif*. Highest content of available S (172 mg kg^{-1} in surface soil and 101.58 mg kg^{-1} in subsurface soil) was recorded under Fodder sorghum + Fodder cowpea – Horse gram – Sunhemp followed by Sweet corn – vegetable (149.67 mg kg^{-1} in surface soil). Available sulphur in these two treatments was significantly higher than in all other treatments. Lowest content of available S was observed in Bt cotton – Fallow (78.00 mg kg^{-1} in surface soil and 40.83 mg kg^{-1} in subsurface soil).

Content of available sulphur ranged from 47.08 to 95.40 mg kg^{-1} in surface soil (0-15 cm) and 43.88 to 85.03 mg kg^{-1} in sub-surface soil (15-30 cm) after *rabi*. Highest content of available S (95.40 mg kg^{-1} in surface soil and 85.03 mg S kg^{-1} in subsurface soil) was recorded under Rice – Maize and Fodder sorghum + cowpea – Horsegram – Sunhemp. Lowest content of available S was observed in Bt cotton – Fallow (47.08 mg S kg^{-1} in surface soil and 43.88 mg S kg^{-1} in subsurface soil). Available sulphur content after *rabi* was not significantly influenced by different cropping systems. The available sulphur decreased with the depth in all the cropping systems under study. This might be due to greater plant and microbial activities and mineralization of organic matter in the surface layer. Similar results were reported by [25] who reported that higher values of available sulphur were found in surface soil than in the subsurface soils of Kalhapur district.

4. CONCLUSION

Diversification of existing cropping systems with legume based cropping systems and rice- based cropping systems have improved all the soil available nutrients as compared to initial value(s) (N=112.20, P= 23.40 and K=170.30 kg^{-1}). Long term field experiment on different cropping systems increased available NPKS at all the depths. There was a decrease in available NPK and S with increase in soil depth. Monoculture cropping and continuous cereal- based cropping systems had an adverse effect on soil properties and crop productivity. Continuous omission of legume and vegetable based cropping systems resulted in significant decrease in soil properties among other crops within the system. Therefore, different cropping systems which involve legumes are essential to improve soil health.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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