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Different Cropping System's Effect on Available NPK Post-harvest and their Uptake on Sandy Loam Soil of Southern Telangana Zone, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author CPK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MG and GKR managed the analyses of the study. Authors KN, SHKS, AAQ, MA and KC 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 experimental farm, College of Agriculture, Rajendranagar, Hyderabad. Soil samples collected from a depth of 0–15 cm was analysed for soil fertility parameters namely: available N, P and K. 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). These ten cropping systems were grouped in to five categories *viz*., pre-dominant cropping systems of the zone, ecological cropping systems, household nutritional security giving cropping systems, fodder security giving cropping systems and cropping systems involving high value crops. So that from each category, best cropping system can be identified and can be suggested to different integrated farming systems models. The maximum (221.60 and

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221.57 kg ha^{-1}) soil available nitrogen was obtained in Pigeon pea + Greengram (1:3) – Sesame after harvest of *kharif* and *rabi*, available phosphorus builds up was profound in Fodder maize – Lucerne (48.27 kg ha^{-1}) and available K (207.63 kg ha^{-1}) was higher in Rice –Maize cropping system after harvest. Fodder crops recorded significantly higher NPK uptake over other cropping systems.

Keywords: Available NPK; NPK uptake and cropping system; soil fertility.

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. Therefore, a major agricultural research priority is needed to sustain soil fertility by including legume component in present cropping systems of Telangana [1]. 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 [2]. The food production must keep pace with the country's increasing population, demanding not only the food security but also nutritional security. 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. Over exploitation of land resources is leading to degradation of soil rapidly.

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. Consequently, continuous imbalanced use of fertilizers has led to deterioration of soil health and reduction in productivity. Over dependence on existing cereal based 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 importance of long-term experiments in studying the effects of continuous cropping on soil fertility and sustenance of crop production is widely recognized [3,4]. 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 and amendments on changes in soil quality. It is essential to identify cropping systems which could aid in improving productivity and soil health without deteriorating the soil. Therefore, the present study was undertaken to investigate the effect of different cropping systems on nutrient availability and their uptakes post-harvest in sandy loam soils.

2. MATERIALS AND METHODS

The study on effect of different cropping systems on available NPK and their uptake by different crops in sandy loam soils belonging to *Inceptisol* soil order of Southern Telangana zone was conducted in the ongoing project of the All India Coordinated Research Project on Integrated Farming Systems Unit, college farm, college of Agriculture, Rajendranagar, Hyderabad. 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 is located at 17°32' North latitude and 78°40' East longitude and at altitude of above 451 m. The location has average maximum temperature of 32.33°C and average minimum temperature of 18.46°C, the annual rainfall is 797 mm 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 low in available sulphur (3.10 mg kg^{-1}).

The experiment was laid out in randomized block design comprising of 10 treatments (cropping systems). Each treatment was allocated randomly initially and replicated three times. The ten combinations of cropping systems tested were grouped in to five subsets. They are pre-dominant cropping systems of the region (T1and T2), T1: rice -maize, T2: Bt cotton, second sub set (T3and T4) included ecological cropping systems for improving soil health viz., T3: Bt cotton + greengram (1:3) -groundnut, T4: pigeonpea + greengram (1:6) -sesame, under cropping systems to meet the household nutritional security (T5 and T6) T5 : pigeonpea + maize (1:3)-groundnut, T6: pigeonpea + groundnut (1:7) -ragi, within cropping systems for round the year green fodder production (T7 and T8) T7: fodder sorghum + fodder cowpea (1:2) –horsegram -sunhemp,T8: fodder maize - lucerne, under cropping systems involving vegetables and other high value crops for income enhancement (T9 & T10) T9 : sweet corn - vegetables (tomato),T10: okra –marigold – beetroot.

All the crops in different cropping systems were raised in accordance with recommended package of practices. Available NPK and NPK uptake have been reported and discussed. Soil samples collected from a depth of 0–15 cm after the harvest of various crops (2019–20) during *kharif* and *rabi* were used for determination of various chemical parameters. The processed soil samples were analysed for available nitrogen, phosphorus, and potassium by adopting standard procedures.

Grain and straw/stover yield of different crops were recorded after the harvest of each crop in both *kharif* and *rabi.* The plant samples (grain and straw/stover) were collected and dried in an oven at 65°C. Grounded samples were analysed for total N by micro-Kjeldahl method [5]. In diacid digested samples, P content was estimated by vanado-molybdo-phosphoric acid method [5] and K content by flame photometer method [6]. The nutrient uptake was calculated by multiplying percent content of a particular nutrient with grain and straw yields. The uptake with respect to grain and straw were summed up to compute the amount of total nutrient removed by each crop.

2.1 Data Analysis and Statistics

The experimental data was analysed by adopting RBD statistical tool and analysis of variance was worked out as suggested by Rao [7].

3. RESULTS AND DISCUSSION

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

3.1.1 Available nitrogen

Our results indicated that the available nitrogen in soil after harvest in different cropping systems ranged from 163.00 to 221.60 kg ha^{-1} b after harvest of *kharif* and *rabi.* The minimum available soil nitrogen was 112.20 kg ha^{-1}. The maximum (221.60 and 221.57 kg ha^{-1}) soil available nitrogen was obtained in Pigeon pea + Greengram (1:3) – Sesame after harvest of *kharif* and *rabi* respectively. The results of the study are in line with those of Ae et al. [8] 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.

Fodder sorghum + Fodder cowpea (1:2) – Horsegram – Sunhemp gave (217.40 kg ha^{-1}) of nitrogen while available nitrogen (209.10 kg ha^{-1}) in Fodder maize – Lucerne was statistically on par with Bt cotton + Greengram (1:3) – Groundnut (209.00 kg ha^{-1}) after *kharif* respectively. This might be due to inclusion of leguminous crops in the system. Subbian and Palaniappan [9], Porpavia et al. [10] and Ali et al. [11] also reported that the inclusion of leguminous crops in the cropping system improved soil available nitrogen status (Table 1).

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 van et al. [12].

3.1.2 Available phosphorus

The results showed that the available phosphorus in soil after harvest in different cropping systems ranged from 32.97 in Bt cotton – Fallow to 48.27 kg ha^{-1} in Fodder maize – Lucerne after *kharif* and *rabi*. Available phosphorus after *kharif* was found higher in Fodder maize – Lucerne (48.27 kg ha^{-1}), followed by Maize + Pigeon pea (1:3) – Groundnut (47.33 kg ha^{-1}) and Pigeon pea + Greengram (1:3) – Sesame (45.07 kg ha^{-1}).

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}). All the cropping systems have increased available phosphorus after *kharif* and *rabi* over the initial (23.40 kg ha^{-1}) as indicated in Table 1.

3.1.3 Available potassium

The data on available potassium after harvest ranged from 183.90 in Bhendi – Marigold – Beetroot to 207.63 kg ha^{-1} in Bt cotton – Fallow after *kharif* and *rabi* respectively. During *rabi*, Rice – Maize registered higher available potassium (207.63), followed by Fodder maize – Lucerne (205.50 kg ha^{-1}). 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 value (170.30 kg ha^{-1}) after *kharif* and *rabi*. (Table 1).

3.2 Nitrogen Uptake

During *kharif* 2019, among the crops and cropping systems, fodder crops were found to be more exhaustive (Table 2). Out of the two fodder crops/cropping systems, fodder sorghum + fodder Cow pea (1:2) fodder system removed maximum nitrogen (312.9 kg ha^{-1}) and was followed by fodder maize (201.0 kg ha^{-1}). Among the ecological cropping systems involving pulses/green manures and other crops for improving soil health, nitrogen removal by both the systems were statistically on par. However, Bt cotton + Greengram (1:3) cropping system removed slightly higher quantities of nitrogen (102.2 kg ha^{-1}) than Pigeon pea + Greengram (1:3) cropping system (96.1 kg ha^{-1}). Out of the two systems tested to meet the household nutritional security involving cereals / pulses / oilseeds, both Pigeon pea + Maize (1:3) and Pigeon pea + Groundnut (1:7) systems removed almost at par quantities of nitrogen with 138.5 and 148.0 kg ha^{-1} respectively. However, Pigeon pea + Maize (1:3) removed lesser than and Pigeon pea + Groundnut (1:7). Sweet corn and Okra were tested under cropping systems involving vegetables and other high value crops for income enhancement and sweet corn was found to be more exhaustive with 177.1 kg ha^{-1} nitrogen removal than Bhendi (42.8 kg ha^{-1}). Rice and Bt cotton were tested as pre-dominant cropping system of the region and nitrogen removal by both the crops was at par.

During *rabi* and summer 2019-20 (Table 3), Marigold-Beetroot removed maximum nitrogen (286.7 kg ha^{-1}) and was closely followed by Lucerne crop (213.0 kg ha^{-1}). Lowest nutrient uptake was observed with Sesame (31.6 kg ha^{-1}). In terms of system uptake (Table 8), Rice-Maize and Bt cotton were tested as pre-dominant cropping systems (Check) of the region and nitrogen removal by Rice-Maize was higher (162.7 kg ha^{-1}). The system nitrogen uptake out of the two fodder crops/cropping systems was maximum with Fodder sorghum + Fodder cowpea (1:2) – Horsegram - Sunhemp fodder system (481.3 kg ha^{-1}) and was followed by Fodder maize - Lucerne system (414.1 kg ha^{-1}). Among the ecological cropping systems involving pulses/green manures and other crops for improving soil health, nitrogen removal by Bt cotton+ Greengram (1:3)- Groundnut cropping system slightly higher (170.8 kg ha^{-1}) than Pigeon pea + Greengram (1:6) – Sesame cropping system (127.7 kg ha^{-1}). Out of the two systems tested to meet the household nutritional security involving cereals / pulses / oilseeds, both Pigeon pea+ Maize (1:3)-Groundnut and Pigeonpea + Groundnut (1:7) – Ragi systems removed almost similar quantities of nitrogen with 211.0 and 205.8 kg ha^{-1} respectively.

Sweet corn-Vegetables (Tomato) system (358.1 kg ha^{-1}) and Okra – Marigold – Beetroot (329.5 kg ha^{-1}) systems were tested under cropping systems involving vegetables and other high value crops for income enhancement and the former was found to be more exhaustive. Similar results were reported by Kumari et al. [1].

3.3 Phosphorus Uptake

During *kharif* 2019, among the crops and cropping systems tested sweetcorn was found to be more exhaustive with higher phosphorus removal (Table 4). In case of fodder crops/cropping systems, both fodder sorghum + fodder cow pea (1:2) (28.1 kg ha^{-1}) and fodder maize (32.4 kg ha^{-1}) removed on par quantities of phosphorus. Among the ecological cropping systems involving pulses/green manures and other crops for improving soil health, phosphorus removal by both the systems was statistically on par. However, Bt cotton + Greengram (1:3) cropping system removed slightly higher quantities of phosphorus (10.9 kg ha^{-1}) than Pigeon pea + Greengram (1:3) cropping system (10.3 kg ha^{-1}). Out of the two systems tested to meet the household nutritional security involving cereals / pulses / oilseeds, Pigeon pea +

Table 1. Effect of different cropping systems on available nitrogen, phosphorus, potassium after harvest of *kharif-rabi*, 2019-20

(Crop/ Cropping system- *kharif*- *rabi*)	*Kharif*			*rabi*		
	Avail N. kg ha^{-1}	Avail P. kg ha^{-1}	Avail K. kg ha^{-1}	Avail N.kg ha^{-1}	Avail P. kg ha^{-1}	Avail K.kg ha^{-1}
Initial	112.20	23.40	170.30			
Rice – Maize	179.80	37.30	207.63	179.77	37.30	207.63
Bt cotton – Fallow	163.00	32.97	196.53	163.03	32.97	196.53
Bt cotton + Greengram (1:3) – Groundnut	209.00	43.33	199.50	209.03	43.33	199.50
Pigeon pea + Greengram (1:3) – Sesame	221.60	45.07	204.33	221.57	45.07	204.33
Maize + Pigeon pea (1:3) – Grondnut	196.50	47.33	202.50	196.47	47.33	202.50
Pigeon pea + Groundnut (1:7) – Ragi	192.30	40.23	198.53	192.30	40.23	198.53
Fodder sorghum + Fodder cowpea (1:2) – Horsegram – Sunhemp	217.40	41.23	192.00	217.43	41.23	192.00
Fodder maize – Lucerne	209.10	48.27	205.50	209.07	48.27	205.50
Sweet corn	188.10	35.70	186.67	188.13	35.70	186.67
Bhendi – Marigold – Beetroot	171.40	39.37	183.90	171.43	39.37	183.90
SE(m)±	18.72	1.45	10.00	18.73	1.45	10.00
CD @ 5%	NS	4.35	NS	NS	4.35	NS

Table 2. Nitrogen uptake (kg ha^{-1}) by crops in various cropping systems during *kharif*, 2019

Treatment		Grain			Stover			Total
Crop /Cropping System (kharif)		Main crop	Inter crop	Total	Main crop	Inter crop	Total	G+S
T1	Rice	55.4	0.0	55.4	35.4	0.0	35.4	90.8
T2	Bt cotton	33.1	0.0	33.1	49.4	0.0	49.4	82.5
T3	Bt cotton + Greengram (1:3)	30.7	12.5	43.1	48.0	11.0	59.0	102.2
T4	Pigeon pea + Greengram (1:3)	29.9	15.7	45.7	36.3	14.1	50.4	96.1
T5	Pigeon pea + Maize (1:3)	63.9	14.9	78.8	42.6	17.0	59.7	138.5
T6	Pigeon pea + Groundnut (1:7)	31.4	46.2	77.6	38.7	31.7	70.4	148.0
T7	Fodder sorghum + Fodder Cow pea (1:2)	0.0	0.0	0.0	117.8	195.1	312.9	312.9
T8	Fodder maize	0.0	0.0	0.0	201.0	0.0	201.0	201.0
T9	Sweet corn	79.9	0.0	79.9	97.3	0.0	97.3	177.1
T10	Bhendi	38.2	0.0	38.2	4.6	0.0	4.6	42.8
	SE(m)±						SE(m)	9.69
	CD @ 5%						C.D.	29.03
	CV (%)						C.V.	12.06

Table 3. Nitrogen uptake (kg ha^{-1}) by crops in various cropping systems during *rabi and summer*, 2019-20

	Treatment	Grain			Stover			Total
	Crop / CS (Rabi / Summer)	Rabi	Summer	Total	Rabi	Summer	Total	(G+S)
T1	Maize	35.7	0.0	35.7	36.2	0.0	36.2	71.9
T2	Fallow	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T3	Groundnut	53.3	0.0	53.3	15.3	0.0	15.3	68.6
T4	Sesame	17.6	0.0	17.6	14.0	0.0	14.0	31.6
T5	Groundnut	55.9	0.0	55.9	16.6	0.0	16.6	72.5
T6	Ragi	23.9	0.0	24.0	33.8	0.0	33.8	57.8
T7	Horsegram - Sunhemp	0.0	0.0	0.0	34.9	133.6	168.4	168.4
T8	Lucerne	0.0	0.0	0.0	213.1	0.0	213.1	213.1
T9	Tomato	169.5	0.0	169.5	11.5	0.0	11.5	181.0
T10	Marigold-Beetroot	89.4	140.5	229.9	41.2	15.6	56.8	286.7
	SE(m)±							9.07
	CD @ 5%							27.16
	CV (%)							13.64

Table 4. Phosphorus uptake (kg ha^{-1}) by crops in various cropping systems after *kharif*, 2019

Treatment		Grain			Stover			Total
Crop /Cropping System (kharif)		Main crop	Inter crop	Total	Main crop	Inter crop	Total	G+S
T1	Rice	16.5	0.0	16.5	8.3	0.0	8.3	24.7
T2	Bt cotton	4.6	0.0	4.6	3.9	0.0	3.9	8.4
T3	Bt cotton + Greengram (1:3)	4.6	1.5	6.1	3.9	0.9	4.8	10.9
T4	Pigeon pea + Greengram (1:3)	3.7	1.8	5.5	3.6	1.2	4.8	10.3
T5	Pigeon pea + Maize (1:3)	16.8	1.8	18.6	11.5	1.8	13.3	31.9
T6	Pigeon pea + Groundnut (1:7)	3.6	5.0	8.6	4.7	1.9	6.5	15.1
T7	Fodder sorghum + Fodder Cow pea (1:2)	0.0	0.0	0.0	9.3	18.8	28.1	28.1
T8	Fodder maize	0.0	0.0	0.0	32.4	0.0	32.4	32.4
T9	Sweet corn	17.4	0.0	17.4	17.4	0.0	17.4	34.8
T10	Bhendi	7.6	0.0	7.6	1.4	0.0	1.4	9.0
	SE(m)±							1.51
	CD @ 5%							4.52
	CV (%)							12.73

Maize (1:3) system removed significantly higher quantities of phosphorus (31.9 kg ha^{-1}) than Pigeon pea + Groundnut (1:7) system (15.1 kg ha^{-1}). Sweet corn and okra were tested under cropping systems involving vegetables and other high value crops for income enhancement and sweet corn was found to be more exhaustive with nearly four times higher phosphorus removal (34.8 kg ha^{-1}) than Bhendi (9.0 kg ha^{-1}). Rice and Bt cotton were tested as pre-dominant cropping system of the region and phosphorus removal by rice (24.7 kg ha^{-1}) was significantly higher than Bt cotton (8.4 kg ha^{-1}).

During *rabi* and summer 2019-20 (Table 5), Marigold-Beetroot removed maximum phosphorus (48.7 kg ha^{-1}) and was followed by maize crop (30.4 kg ha^{-1}). Lowest nutrient uptake was observed with Sesame (6.8 kg ha^{-1}). In terms of system uptake (Table 8), Rice-Maize and Bt cotton were tested as pre-dominant cropping systems (Check) of the region and phosphorus removal by Rice-Maize was 55.1 kg ha^{-1}. The system phosphorus uptake out of the two fodder crops/cropping systems was Fodder maize - Lucerne system (44.3 kg ha^{-1}) and Fodder sorghum + Fodder cowpea (1:2) – Horsegram - Sunhemp fodder system (42.2 kg ha^{-1}). Among the ecological cropping systems involving pulses/green manures and other crops for improving soil health, phosphorus removal by Bt cotton+ Greengram (1:3)- Groundnut cropping system slightly higher (19.5 kg ha^{-1}) than Pigeon pea + Greengram (1:6) – Sesame cropping system (17.1 kg ha^{-1}) and both were on par. Out of the two systems tested to meet the household nutritional security involving cereals/ pulses / oilseeds, both Pigeonpea+ Maize (1:3)-Groundnut (41.2 kg ha^{-1}) removed significantly more phosphorus than Pigeonpea + Groundnut (1:7) – Ragi system (23.5 kg ha^{-1}). Sweet corn-Vegetables (Tomato) system (58.7 kg ha^{-1}) and Okra – Marigold – Beetroot (57.7 kg ha^{-1}) systems were tested under cropping systems involving vegetables and other high value crops for income enhancement and the former was found to be more exhaustive. These results were supported by Kumari et al. [13].

3.4 Potassium Uptake

During *kharif* 2019, similar to nitrogen removal fodder crops were found to be more exhaustive among the crops and cropping systems with more potassium removal (Table 6). Out of the two fodders crops/cropping systems; fodder maize (376.4 kg ha^{-1}) removed significantly higher potassium than fodder sorghum + fodder Cow pea (1:2) fodder system (173.6 kg ha^{-1}). Among the ecological cropping systems involving pulses/green manures and other crops for improving soil health, Bt cotton + Greengram (1:3) cropping system removed significantly higher quantities of potassium (61.5 kg ha^{-1}) than Pigeon pea + Greengram (1:3) cropping system (47.8 kg ha^{-1}). Out of the two systems tested to meet the household nutritional security involving cereals / pulses / oilseeds, both Pigeon pea + Maize (1:3) removed higher quantities of potassium (106.6 kg ha^{-1}) than Pigeon pea + Groundnut (1:7) system (59.8 kg ha^{-1}). Sweet corn and okra were tested under cropping systems involving vegetables and other high value crops for income enhancement and sweet corn was found to be 3.7 times more exhaustive with 218.4 kg ha^{-1} potassium removal than okra (58.5 kg ha^{-1}). Rice and Bt cotton were tested as pre-dominant cropping system of the region and potassium removal by rice crop (111.4 kg ha^{-1}) was two times higher than Bt cotton (55.8 kg ha^{-1}).

During *rabi* and summer 2019-20 (Table 7), Marigold-Beetroot (177.2 kg ha^{-1}) system removed maximum potassium and was followed by Horsegram - Sunhemp (151.6 kg ha^{-1}). Lowest nutrient uptake was observed with Sesame (13.8 kg ha^{-1}). In terms of system uptake (Table 8), Rice-Maize and Bt cotton were tested as pre-dominant cropping systems (Check) of the region and potassium removal by Rice-Maize was higher (192.8 kg ha^{-1}). The system potassium uptake, out of the two fodder crops/cropping systems was maximum with Fodder maize – Lucerne system (519.5 kg ha^{-1}) and was followed by Fodder sorghum + Fodder cowpea (1:2) – Horsegram - Sunhemp (325.2 kg ha^{-1}). Among the ecological cropping systems involving pulses/green manures and other crops for improving soil health, potassium removal by Bt cotton+ Greengram (1:3)- Groundnut cropping system slightly higher (84.1 kg ha^{-1}) than Pigeon pea + Greengram (1:6) – Sesame cropping system (61.6 kg ha^{-1}). Among the two systems tested to meet the household nutritional security involving cereals / pulses / oilseeds, both Pigeon pea+ Maize (1:3)-Groundnut (130.3 kg ha^{-1}) removed higher quantities of potassium than Pigeonpea + Groundnut (1:7) – Ragi system (80.8 kg ha^{-1}). Sweet corn-Vegetables (Tomato) system (309.3 kg ha^{-1}) and Okra – Marigold – Beetroot (235.7 kg ha^{-1}) systems were tested under cropping systems involving vegetables and other high value crops for income enhancement and the former was found to be significantly more exhaustive.

Table 5. Phosphorus uptake (kg ha^{-1}) by crops in various cropping systems during *rabi and summer*, 2019-20

	Treatment	Grain			Stover			Total (G+S)
	Rabi & summer	Rabi	Summer	Total	Rabi	Summer	Total	
T1	Maize	16.8	0.0	16.8	13.6	0.0	13.6	30.4
T2	Fallow	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T3	Groundnut	6.4	0.0	6.4	2.2	0.0	2.2	8.6
T4	Sesame	2.8	0.0	2.8	4.0	0.0	4.0	6.8
T5	Groundnut	6.3	0.0	6.3	3.0	0.0	3.0	9.3
T6	Ragi	4.7	0.0	4.7	3.7	0.0	3.7	8.4
T7	Horsegram- Sunhemp	0.0	0.0	0.0	6.1	8.0	14.1	14.1
T8	Lucerne	0.0	0.0	0.0	11.9	0.0	11.9	11.9
T9	Tomato	23.1	0.0	23.1	0.8	0.0	0.8	23.9
T10	Marigold-Beetroot	18.7	25.5	44.1	2.5	2.1	4.6	48.7
	SE(m)±							1.387
	CD @ 5%							4.154
	CV (%)							14.816

Table 6. Potassium uptake (kg ha^{-1} by crops in various cropping systems after *kharif*, 2019

Treatment		Grain			Stover			Total
Crop /Cropping System (kharif)		Main crop	Inter crop	Total	Main crop	Inter crop	Total	G+S
T1	Rice	26.9	0.0	26.9	84.4	0.0	84.4	111.4
T2	Bt cotton	14.9	0.0	14.9	41.0	0.0	41.0	55.8
T3	Bt cotton + Greengram (1:3)	14.9	3.8	18.7	38.7	4.1	42.8	61.5
T4	Pigeon pea + Greengram (1:3)	9.3	4.2	13.5	29.4	4.9	34.3	47.8
T5	Pigeon pea + Maize (1:3)	23.2	4.2	27.4	65.8	13.4	79.2	106.6
T6	Pigeon pea + Groundnut (1:7)	9.4	8.3	17.7	33.5	8.6	42.1	59.8
T7	Fodder sorghum + Fodder Cow pea (1:2)	0.0	0.0	0.0	103.0	70.6	173.6	173.6
T8	Fodder maize	0.0	0.0	0.0	376.4	0.0	376.4	376.4
T9	Sweet corn	26.1	0.0	26.1	192.3	0.0	192.3	218.4
T10	Bhendi	49.9	0.0	49.9	8.6	0.0	8.6	58.5
	SE(m)±							13.07
	CD @ 5%							39.14
	CV (%)							17.83

Table 7. Potassium uptake (kg ha^{-1}) by crops in various cropping systems during *rabi and summer*, 2019-20

	Treatment	Grain			Stover			Total (G+S)
	Crop / Crop System	Rabi	Summer	Total	Rabi	Summer	Total	
T1	Maize	27.5	0.0	27.5	53.8	0.0	53.8	81.4
T2	Fallow	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T3	Groundnut	10.3	0.0	10.3	12.3	0.0	12.3	22.6
T4	Sesame	2.3	0.0	2.3	11.6	0.0	11.6	13.8
T5	Groundnut	10.8	0.0	10.8	13.0	0.0	13.0	23.7
T6	Ragi	5.4	0.0	5.4	15.6	0.0	15.6	21.0
T7	Horsegram-Sunhemp	0.0	0.0	0.0	38.1	113.5	151.6	151.6
T8	Lucerne	0.0	0.0	0.0	143.1	0.0	143.1	143.1
T9	Tomato	80.5	0.0	80.5	10.4	0.0	10.4	90.9
T10	Marigold-Beetroot	101.3	42.3	143.6	20.7	12.9	33.6	177.2
	SE(m)±							7.274
	CD @ 5%							21.78
	CV (%)							17.37

Table 8. Nutrient (Nitrogen, Phosphorus and Potassium) uptake by crops in various cropping systems during *kharif*, *rabi and summer*, 2019-20

Treatment		Kharif uptake			Rabi uptake			System uptake		
		N	P	K	N	P	K	N	P	K
T1	Rice – Maize	90.8	24.7	111.4	71.9	30.4	81.4	162.7	55.1	192.8
T2	Bt Cotton – Fallow	82.5	8.4	55.8	0.0	0.0	0.0	82.5	8.4	55.8
T3	Bt cotton+ Greengram (1:3) – Groundnut	102.2	10.9	61.5	68.6	8.6	22.6	170.8	19.5	84.1
T4	Pigeon pea + Greengram (1:6) – Sesame	96.1	10.3	47.8	31.6	6.8	13.8	127.7	17.1	61.6
T5	Pigeon pea+ Maize (1:3) – Groundnut	138.5	31.9	106.6	72.5	9.3	23.7	211.0	41.2	130.3
T6	Pigeonpea + Groundnut (1:7) - Ragi	148.0	15.1	59.8	57.8	8.4	21.0	205.8	23.5	80.8
T7	Fodder sorghum + Fodder cowpea (1:2) – Horsegram – Sunhemp	312.9	28.1	173.6	168.4	14.1	151.6	481.3	42.2	325.2
T8	Fodder maize – Lucerne	201.0	32.4	376.4	213.1	11.9	143.1	414.1	44.3	519.5
T9	Sweetcorn – Vegetables (Tomato)	177.1	34.8	218.4	181.0	23.9	90.9	358.1	58.7	309.3
T10	Okra – Marigold – Beetroot	42.8	9.0	58.5	286.7	48.7	177.2	329.5	57.7	235.7
	SE(m)±	9.69	1.51	13.07	9.07	1.38	7.27	17.40	1.83	16.02
	CD @ 5%	29.03	4.52	39.14	27.16	4.15	21.78	52.11	5.48	47.96
	CV (%)	12.06	12.73	17.83	13.64	14.81	17.37	11.85	8.62	13.90

4. CONCLUSION

Diversification of existing cropping systems with legume based cropping systems have improved all the soil properties as (available NPK) compared to initial value. Under high value crops, sweet corn - vegetable system (tomato), among the ecological cropping systems, pigeonpea + greengram (1:6) – sesame, under the cropping systems for household nutritional security, pigeonpea + maize (1:3) - groundnut system, under two fodder crops/cropping systems, fodder maize – lucerne systems were most profitable and can highly be recommended for different farming systems of Southern Telangana Zone of Telangana.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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