

Impact of diversified cropping system on primary nutrients and crop yield in north-western Himalayas

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Crop diversification manifests great potential in accomplishing the goals of sustainable agricultural development, food security, economic growth and poverty alleviation (Feliciano, 2019). Diversification act as a key component in changing the economy of developing countries like India. It is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops (Khanam *et al.* 2018). A diversified farming system is a stress-defusing practice that helps the farming community in augmenting agricultural productivity, economy and decreasing price risks in the market. Growing a variety of crops suited to a particular agro-ecosystem with different sowing and harvesting times permits farmers to attend to each crop timely while managing large farms.

Intensive cropping systems including cereals often result in more nutrient removal than its replenishment through fertilizers (Dwivedi *et al.*, 2014). Nutrient over-mining needs to be stopped if soil health is to be maintained, which is urgently needed to sustain the nation's food and nutritional security (Kumar *et al.*, 2021). Crop diversification is crucial for strengthening soil health by balancing soil biodiversity, improving soil nutrient use efficiency and lowering soil-borne pathogens in addition to being essential for maximizing crop output (Yang *et al.*, 2020; Barbieri *et al.*, 2019). Health guidelines that urge increasing vegetable consumption have led to a rapid increase in vegetable demand (FAO,

2017). Taking into account the increasing demand for vegetables due to the shift in the consumption pattern and also diverse agro-climatic conditions in India, vegetables can be successfully introduced in cereal-based sequences which will secure farm income and also stabilize the agro-ecosystem by supplying nutrients to the plants. The inclusion of vegetable crops such as pea not only helps in increasing/improving crop productivity but also helps in increasing the nutritional status of the soil. Keeping this in view field study was conducted to find out the impact of different rice-based crop sequences on primary nutrients, their uptake and organic matter.

Material and Methods

Study Area

In 2017-18, a field experiment on the diversified cropping system was conducted at Bhadiarkhar research farm of the Department of Agronomy, CSK HPKV, Palampur under All India Co-ordinated Research Project. The research farm is situated at 32°6' N latitude and 76°3' E longitude at an altitude of 1223.7 m amsl in the Palam Valley of Kangra district of Himachal Pradesh. The soil of the experimental farm is silty clay loam in texture with 22.5% sand, 43.6% silt and 31.7% clay and classified as "Alfisols" with subgroup "Typic Hapludalf". The climate is humid sub-tropical with cool winters and mild summers.



Treatments and Growing System

A randomized block design was used with eight treatments in four replications each in net plots of 4.8-5.5 m. All the crops were grown in accordance with the recommended package of practices. Details of varieties and fertilizer dose is given in table 1. The treatments were-

T₁: Rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L.)

T₂: Rice – pea (*Pisum sativum* L.) – summer squash (*Cucurbita pepo*)

T₃: Okra (*Abelmoschus esculentus*) – radish (*Raphanus sativus*) – onion (*Allium cepa*)

T₄: Turmeric (*Curcuma longa*) – pea – summer squash

T₅: Rice – lettuce (*Lactuca sativa*) – potato (*Solanum tuberosum*)+coriander (*Coriandrum sativum*)

T₆: Rice – palak (*Spinacia oleracea*) – cucumber (*Cucumis sativus*)

T₇: Rice – broccoli (*Brassica oleracea*) – radish

T₈: Colocasia (*Colocasia esculenta*) – pea + coriander

Table 1: Details of varieties and fertilizer dose

Kharif

Crop	Variety	Seed rate (kg ha ⁻¹)	Fertilizer dose		
			N	P ₂ O ₅	K ₂ O
Rice	HPR 2143	15	90	40	40
Rice	HPR 2143	15	90	40	40
Okra	P-8	15	75	55	25
Turmeric	Palam pitamber	2250	30	15	60
Rice	HPR 2143	15	90	40	40
Rice	HPR 2143	15	90	40	40
Rice	HPR 2143	15	90	40	40
Colocasia	Local	2000	75	25	50

Rabi

Crop	Variety	Seed rate (kg ha ⁻¹)	Fertilizer dose		
			N	P ₂ O ₅	K ₂ O
Wheat	HPW-155	100	120	60	30
Pea	Palam priya	75	25	30	60
Radish	Japanese white	8	100	25	35
Pea	Palam priya	75	25	30	60
Lettuce	Avej wonder	0.5	60	20	40
Palak	Pusa harit	30	75	25	30
Broccoli	Palam samridhi	0.5	150	50	55
Pea +	Palam priya	75	25	30	60
Coriander	Local	10	-	-	-

Summer

Summer squash	Pusa alankar	8	100	25	55
Onion	Nasik red	10	125	37.5	60
Summer squash	Pusa alankar	8	100	25	55
Potato + Coriander	Kufri jyoti Local	2250	120	40	60
		10	-	-	-
Cucumber	Palam sanjog	4	100	25	60
Radish	Marvel white	8	100	25	35



Results and Discussion

Rice Grain Equivalent Yield

The diversified cropping system significantly affected rice grain equivalent yield (RGEY). The highest RGEY was reported in rice – palak – cucumber (table 2) which was followed by okra – radish – onion, turmeric – pea – summer squash, rice – lettuce – potato + coriander, colocasia – pea + coriander and rice – broccoli – radish. Higher RGEY in these systems can be attributed mainly to the inclusion of high-value vegetable crops in place of cereals. The lowest RGEY was found in the rice – wheat system. Rice – palak – cucumber was reported to produce about 62% more rice equivalent yield than traditional rice – wheat crop sequence. This corroborates the findings of Sharma *et al.* (2015) who reported that replacing wheat with vegetables resulted in higher RGEY. Upadhaya *et al.* (2022) also reported that diversifying rice – wheat system with high-value crops like vegetables results in the production of higher rice equivalent yield.

Soil Properties

pH and Organic Carbon

The study results (table 2) indicated that diversification of rice – wheat cropping system improved organic carbon (OC) of the soil. Initial soil analysis values of pH and OC were 5.5 and 1.02, respectively. After completion of the crop cycle lowest organic carbon content (0.93%) was reported in rice – wheat and okra – radish – onion. However, turmeric – pea – summer squash, rice – lettuce – potato + coriander, rice – broccoli – radish and colocasia – pea + coriander were reported to have comparatively high organic carbon content (0.97%).

Available Nitrogen, Phosphorus and Potassium

Available nitrogen, phosphorus and potassium differ significantly among eight crop sequences. In all the cropping systems except okra – radish – onion available nitrogen content increased after the harvest of rabi crop compared with kharif crop. This increase might have been due to less nitrogen losses due to leaching in rabi season. After completion of crop cycle higher available nitrogen was recorded in colocasia – pea + coriander as compared to other cropping systems. This might be because of the inclusion of pea which is a legume crop and fixes atmospheric nitrogen and subsequently release it into the soil. However, available nitrogen in this cropping

system was statistically at par with turmeric – pea – summer squash and rice – broccoli – radish. Kumar *et al.* (2021) reported similar results where available nitrogen was improved because of the addition of legume crop in the system.

Rice – palak – cucumber crop sequence resulted in significantly higher available phosphorus which was at the same level with turmeric – pea – summer squash, colocasia – pea + coriander and rice – broccoli – radish. In the case of available potassium, it was significantly higher in turmeric – pea – summer squash which was at par with okra – radish – onion and colocasia – pea + coriander. The lowest available phosphorus and potassium was found in rice – wheat cropping system which can be attributed to the exhaustive nature of cereals. Both phosphorus and potassium status in most of the crop sequences decreased after harvest of rabi crop as compared to kharif crop. The maximum depletion in potassium content in the soil after rabi as compared to kharif was found in rice – wheat (6.7%) and rice – lettuce – potato + coriander (7.8%) crop sequence. This may be attributed to the nutrient exhaustive nature of cereals and high potassium uptake by potato crop. Similar results were reported by Singh *et al.* (2011) showing depletion in potassium content in the soil after completion of the crop cycle.

Nutrient Uptake of Nitrogen, Phosphorus and Potassium

Maximum nutrient uptake was reported in the conventional cereal-based cropping system. Nitrogen uptake was significantly higher in rice – wheat which was followed by rice – lettuce – potato + coriander, rice – broccoli – radish and rice – pea – summer squash. Significantly higher phosphorus uptake was found in rice – wheat which was similar to uptake in rice – broccoli – radish. Lower uptake was recorded in turmeric – pea – summer squash. Potassium uptake was also higher in rice – wheat which was statistically at par with rice – pea – summer squash. Nutrient uptake was found to be more in cropping systems where cereal crop was involved.

Balance Sheet of Available Nitrogen, Phosphorus, and Potassium

Nitrogen

Table 3 indicates the net loss of nitrogen in all the cropping systems. The loss was maximum from rice – broccoli – radish (189.91 kg) which might be because of the high





Table 2: RGEY, pH, OC and available primary nutrient status in soil

Treatment	RGEY	pH	OC (%)	Nitrogen		Phosphorus			Potassium	
				Initial	After Kharif	After Rabi	Initial	After Kharif	Initial	After Kharif
T1 Rice-Wheat	6259	5.45	0.93	265.8	230.7	234.60	72.6	58.08	121.72	112.23
T2 Rice-Pea-Summer squash	13163	5.58	0.95	321.77	293.44	298.07	50.32	63.61	116.35	123.88
T3 Okra-Radish-Onion	14025	5.63	0.93	272.45	300.59	297.92	65.75	67.71	136.5	135.97
T4 Turmeric-Pea-Summer squash	13506	5.55	0.97	281.1	304.71	314.76	91.2	78.5	126.24	136.97
T5 Rice-Lettuce-Potato+Coriander	12547	5.45	0.97	301.62	284.99	297.94	74.35	69.18	116.5	119.67
T6 Rice-Palak-Cucumber	16477	5.63	0.94	304.75	286.06	296.30	77.42	70.02	125.1	120.91
T7 Rice-Broccoli-Radish	7599	5.63	0.97	301.65	296.93	303.76	73.8	62.79	128.65	127.79
T8 Colocasia-Pea+Coriander	10630	5.48	0.97	326.3	305.29	317.62	73.05	77.07	115.24	132.17
SEm±	591	0.22	0.93	-	5.62	5.61	-	5.03	-	5.03
CD (P=0.05)	1737	-	-	7.96	16.54	16.51	7.24	14.81	7.41	18.58

Table 3: Balance sheet of available Nitrogen

Treatment	Amount added	Initial amount	Total amount	Cumulative uptake	Expected balance	Actual balance	Net gain or loss
Rice-Wheat	210	265.8	475.8	194.42	281.38	234.6	-46.78
Rice-Pea-Summer squash	215	321.77	536.77	128.12	408.65	298.07	-110.58
Okra-Radish-Onion	300	272.45	572.45	94.6	477.85	297.92	-179.93
Turmeric-Pea-Summer squash	155	281.1	436.1	96.69	339.41	314.76	-24.65
Rice-Lettuce-Potato+Coriander	270	301.62	571.62	156.07	415.55	297.94	-117.61
Rice-Palak-Cucumber	265	304.75	569.75	100.41	469.34	296.3	-173.04
Rice-Broccoli-Radish	340	301.65	641.65	147.98	493.67	303.76	-189.91
Colocasia-Pea+Coriander	100	326.3	426.3	92.36	333.94	317.62	-16.32

Table 4: Balance sheet of available phosphorus

Treatment	Amount added	Initial amount	Total amount	Cumulative uptake	Expected balance	Actual balance	Net gain or loss
Rice-Wheat	100	72.6	172.6	38	134.6	56.35	-78.25
Rice-Pea-Summer squash	95	50.32	145.32	32.8	112.52	60.93	-51.59
Okra-Radish-Onion	117.5	65.75	183.25	21.7	161.55	63.57	-97.98
Turmeric-Pea-Summer squash	70	91.2	161.2	17.4	143.8	77.43	-66.37
Rice-Lettuce-Potato+Coriander	100	74.35	174.35	32.6	141.75	63.44	-78.31
Rice-Palak-Cucumber	90	77.42	167.42	24.3	143.12	81.07	-62.05
Rice-Broccoli-Radish	115	73.8	188.8	34.7	154.1	72.62	-81.48
Colocasia-Pea+Coriander	55	73.05	128.05	22.6	105.45	73.26	-32.19

Table 5: Balance sheet of available potassium

Treatment	Amount added	Initial amount	Total amount	Cumulative uptake	Expected balance	Actual balance	Net gain or loss
Rice-Wheat	70	121.72	191.72	94.17	97.55	104.75	7.2
Rice-Pea-Summer squash	155	116.35	271.35	85.77	185.58	118.44	-67.14
Okra-Radish-Onion	120	136.5	256.5	50.66	205.84	137.78	-68.06
Turmeric-Pea-Summer squash	175	126.24	301.24	50.38	250.86	139.95	-110.91
Rice-Lettuce-Potato+Coriander	140	116.5	256.5	55.57	200.93	110.31	-90.62



Rice-Palak-Cucumber	130	125.1	255.1	51.73	203.37	117.9	-85.47
Rice-Broccoli-Radish	130	128.65	258.65	69.77	188.88	125.32	-63.56
Colocasia-Pea+Coriander	110	115.24	225.24	31.86	193.38	132.4	-60.98

nitrogen requirement for all three crops viz. broccoli (150 kg), radish (100 kg) and rice (90 kg). Because of the application of the maximum amount of nitrogenous fertilizer in this system proportionate loss can be expected. This was followed by okra – radish – onion (179.93 kg ha⁻¹), rice – palak – cucumber (173.04 kg ha⁻¹), rice – lettuce – potato + coriander (117.61 kg ha⁻¹) and rice – pea – summer squash (110.58 kg ha⁻¹). The minimum loss was observed in colocasia – pea + coriander (16.32 kg ha⁻¹).

Phosphorus

It is evident from table 4 that all the crop sequences resulted in net loss of phosphorus from the soil which may be ascribed to phosphorus fixation in soil. The loss was maximum from okra – radish – onion (97.98 kg ha⁻¹) followed by rice – broccoli – radish (81.48 kg ha⁻¹).

Potassium

There was net loss of potassium (table 5) from the soil in all the crop sequences except rice – wheat system in which net gain of 7.2 kg ha⁻¹ was observed. Maximum loss was reported from turmeric – pea – summer squash (110.91 kg ha⁻¹) followed by rice – lettuce – potato + coriander (90.62 kg ha⁻¹), rice – palak – cucumber (85.47 kg ha⁻¹), okra – radish – onion (68.06 kg ha⁻¹), rice – pea – summer squash (67.14 kg ha⁻¹), rice – broccoli – radish (63.56 kg ha⁻¹) and colocasia – pea + coriander (60.98 kg ha⁻¹).

Conclusion

All the treatments remained superior over rice – wheat in case of rice grain equivalent yield. Rice – wheat also resulted in highest removal of all the primary nutrients from the soil, cereals being the exhaustive crops. Balance sheet of available nutrients in soil indicated net loss of available nitrogen, phosphorus and potassium in all crop sequences.

Author Contributions

AM and SCN prepared the manuscript and preparing the final version of the manuscript and correspond to the journal.

Ethical Approval

This article does not contain any studies involving human or animal participants performed by any of the authors.

Conflicts of Interest:

The authors declare no conflict of interest.

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