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Effect of soybean [*Glycine max* (L.) Merrill] based cropping systems on soil fertility balance in *Vertisols* of western Madhya Pradesh

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Abstract
A field experiment was conducted to study the effect of soybean [*Glycine max* (L.) Merrill] based cropping systems on soil fertility balance in *Vertisols* of western Madhya Pradesh. The present investigation was carried out during *kharif, rabi* and *zaid* seasons of 2015-16 and 2016-17 at the research farm of Krishi Vigyan Kendra, Dhar, M. P. The initial status of soil of the experimental field was clay loam in texture, neutral in reaction (pH 7.60) with normal EC (0.58 dS/m) and medium organic carbon contents (0.59 %) and low in available N (218 kg/ha), medium in available P (11.60 kg/ha) and high in available K (350 kg/ha) contents. In this study, 16 cropping sequences tested in randomized block design with four replications. Soybean Yield Equivalent (SEY) of cropping-system as a whole, T_{15}-Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) cropping sequence recorded the highest productivity (177.31 q/ha) in terms of soybean-equivalent yield as compared to existing cropping sequences (Soybean-wheat and soybean-chick pea). The minimum productivity of the cropping sequence based on SEYs was registered in Soybean (JS 95-60) - Chickpea (JG-130) desi i.e. 42.79 q/ha. The availability of nutrients were numerically higher N in T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282) 226.20 kg/ha, P in T_{15}- Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) (15.20 kg/ha), K in T_{15}- Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) 370.20 kg/ha and minimum N was recorded in T_1- Soybean (JS 95-60) - Wheat (HI-1544) aestivum 192.20 kg/ha, P in T_3 - Soybean (JS 95-60) - Chickpea (JG-130) desi (9.50 kg/ha), K in T_3 - Soybean (JS 95-60) - Chickpea (JG-130) desi (320.0 kg/ha) at end of experimentation.

Keywords: Soybean-based cropping systems, soybean equivalent yield, nutrient uptake

Introduction
Soybean [*Glycine max* (L.) Merrill] is a major legume crop recognized as the efficient producer of the two scarce quality characters i.e. the protein and oil, which are not only the major components in the diet of vegetarians mass but a boon to the developing countries as well. It has the potential to bridge the gap between the demand and supply of edible oil and protein. Due to short growing season, soybean fits well in a number of cropping systems and is well suited for intercropping with a number of crops resulting in better land equivalent ratio and helps in the risk aversion due to climatic uncertainties in rainfed conditions.

Large area under soybean is spread over Central India. Generally, it is grown as a monsoon season crop under rainfed situation mainly under *Vertisols* and associated soils. It has resulted increased cropping intensity and profitability. In Malwa and Nimar valley region, its cultivation is largely practiced in rainy season followed by Gram/wheat on conserved soil moisture. Under irrigated conditions, soybean is largely grown in soybean-wheat cropping system, while soybean-chickpea cropping system is prevalent under rainfed conditions. The major cropping system in the *Vertisols* and associated soils of Central India under regime is soybean-wheat in which soybean is a rainfed crop. Both soybean and wheat are most productive crops and predominantly grown in a sequential cropping, particularly under irrigated production system in almost all districts of Malwa plateau agro-climatic zone of Madhya Pradesh. Soybean-chickpea system is also prevalent as a next important cropping sequence mainly in those areas, where rainfall is not adequate or irrigation water is scarce. Generally, cultivation of both Soybean and wheat in a sequence are nutrients exhaustive and these crops require heavy investment in desirable agricultural operations during their cultivation. Long term regular practice of Soybean-Chickpea and Soybean-Wheat system in the growing region is posing severe problems before the growers such as complexity in weed

management, deterioration of soil-properties, delayed sowing of wheat and low market value of produce owing low productivity as well as poor economic viability of this cropping system. The diversification of existing soybean - wheat/chickpea system needs to be evaluated to meet the domestic need of farmers. Simultaneously, the economic status of the farmers of Soybean-wheat growing areas will also be raised by replacing any of the two crop components with the introduction of high value crop without degrading the land-resources.

Since the number of crops being grown during *rabi* season in district Dhar of Malwa region is relatively more than other districts, though in relatively smaller area *e.g.* chickpea, garlic, onion, potato, garden pea etc. Under such circumstances, the diversification of crops under soybean based cropping system appears to be a possible way for improving the productivity and profitability per unit area per year without jeopardizing the soil health. Hence, diversification of cropping system is necessary to get higher yield, net returns, maintain soil health, preserve environment and meet daily food and fodder requirement of human and animals.

Materials and Methods

A field experiment was carried out for two years during *kharif*, *rabi* and *zaid* seasons of 2015-16 and 2016-17 at research Farm of Krishi Vigyan Kendra, Dhar (M.P.). Temperature extremes vary between a minimum temperature of 12^0C in December and January months to maximum temperature of 45^0C in May and June. The soil of the field was a typical medium black soil. Due to dominance of Montmorillonite clay content it has high capacity to swell and shrink and high CEC. The experiment comprised 16 cropping sequences, soybean was sequenced with feasible *rabi* viz. Wheat (*Triticum aestivum* & *Triticum durum* L.), Chick pea (*Cicer arietinum* L.), Garlic (*Allium sativum* L.), Onion (*Allium cepa* L.), Potato (*Solanum tuberosum* L.) and garden pea (*Pisum sativum* L.) with inclusion of Garlic (*Allium sativum* L.), Onion (*Allium cepa* L.) in *zaid* and tested in randomized block design with four replications. The recommended dose of fertilizers was given to each crop. The calculated quantities of fertilizers were applied to the respective crops grown as per treatments.

Since, the present investigation is a part of continuous study, which has been started since *Kharif* season of the year 2015-16 without changing the site of field, treatments and layout plan of experiment. Hence, present investigation was related with the soil-properties from the beginning of the crop-cycle of the second year of experimentation. Representative soil samples were collected from the experimental field. The Soil samples were taken at the end of crop-cycles in each crop sequence from 0-30 cm depth of soil with the help of screw-type soil auger. After this, samples were carried in the laboratory, Krishi Vigyan Kendra, Dhar. The Samples were ground plot wise separately and then analysis of soil properties *viz.* pH (Piper, 1967), EC (Black, 1965), organic carbon (Walky and Black, 1978), N (Subbiah and Asiija 1956), P (Olsen *et al*, 1954) [14] and K (Hanwey and Heidal, 1952) [6] were made as per standard procedure after this, changes in these soil properties over their initial status were determined. Sowing of different crops under different crop sequences was done as per recommended package of practices for crops under irrigated condition. The recommended dose of N:P:K (kg/ha) for soybean 20:80:20, wheat 120:60:40, chick pea 20:60:20, garlic 100:50:50, onion 100:75:50, potato 120:50:100 and garden pea 20:60:20 was applied.

The cropping sequences were evaluated in terms of seed and straw soybean-equivalent yield.

$$\text{Seed soybean equivalent yield (q/ha)} = \frac{\text{Grain/tuber/bulb yield of a crop (q/ha) x Price of yield (₹/q)}}{\text{Price of soybean yield (₹/q)}}$$

$$\text{Straw Soybean equivalent yield (q/ha)} = \frac{\text{Straw/haulm yield of a crop (q/ha) x Price of straw (₹/q)}}{\text{Price of soybean straw (₹/q)}}$$

Results and Discussion

Initial status of soil properties and changes on completion of first crop cycle

The data pertaining to initial status of various physico-chemical properties soils and changes in physico-chemical properties due to the effect of treatments after the end of first crop cycle during the year 2015-16 were recorded. These data are presented in Table 1.

Table 1: Initial status of soil properties and changes on completion of first crop cycle during the year 2015-16 under different treatments

Treatments		Soil pH	E.C. (dS/m)	O.C. (g/kg)	Available nutrient (kg/ha)		
					N	P	K
Initial		**7.60**	**0.58**	**5.90**	**218.00**	**11.60**	**350.00**
T_1	Soybean (JS 95-60) - Wheat (HI-1544) aestivum	7.36	0.48	4.60	193.20	10.50	325.00
T_2	Soybean (JS 95-60) - Wheat (HI-8663) durum	7.36	0.22	4.50	192.30	10.80	340.00
T_3	Soybean (JS 95-60) - Chickpea (JG-130) desi	7.11	0.24	6.00	220.40	9.60	320.00
T_4	Soybean (JS 95-60) - Chickpea (RVKG-101) Kabuli	7.44	0.54	5.90	218.60	9.80	340.00
T_5	Soybean (JS 95-60) - Garlic (G-282)	7.11	0.55	4.80	198.50	12.50	350.00
T_6	Soybean (JS 95-60) - Onion (AFLR)	7.45	0.54	4.70	198.20	13.50	360.00
T_7	Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR)	7.38	0.58	5.20	209.10	15.20	370.00
T_8	Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282)	7.38	0.56	6.10	220.80	14.60	360.00
T_9	Soybean (JS 93-05) - Wheat (HI-1544) aestivum	7.70	0.58	4.80	200.40	10.50	345.00
T_{10}	Soybean (JS 93-05) - Wheat (HI-8663) durum	7.37	0.52	4.70	200.00	10.90	351.20
T_{11}	Soybean (JS 93-05) - Chickpea (JG-130) desi	7.37	0.55	6.10	220.20	10.70	345.00
T_{12}	Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli	7.43	0.57	6.00	218.80	10.50	325.00
T_{13}	Soybean (JS 93-05) - Garlic (G-282)	7.12	0.50	4.80	201.40	12.60	360.00
T_{14}	Soybean (JS 93-05) - Onion (AFLR)	7.12	0.51	4.80	201.00	13.50	365.00
T_{15}	Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR)	7.36	0.58	5.40	214.50	15.40	373.00
T_{16}	Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282)	7.42	0.58	6.30	222.70	14.70	365.00

It is evident from data that the initial status of soil of the experimental field was clay loam in texture, neutral in reaction (pH 7.60) with normal EC (0.58 dS/m) and having medium OC contents (0.59 %). The available N, P and K contents were low (218 kg/ha), medium (11.6 kg/ha) and high (350 kg/ha), respectively. It is also clear from the data that soil pH, EC, OC contents and available N, P, K contents did not deviate much over their initial status after the completion of first crop cycle during the end of the year 2015-16 due to the effect of different crop-sequences tested.

Uptake study of nutrients

Data pertaining to removal of essential nutrient elements (N,P,K) by different crops grown sequentially under various crop- sequences at the end of crop cycle of each year and their mean values of both years are given in Table 2. It is evident from the data that all crop-sequences had similar trend of nutrient removal in both years of investigation. Based on two year mean data, it is obvious that all diversified and intensified crop-sequences (T_2, T_4, T_5, T_6, T_7, T_8, T_{10}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16}) tested in present investigation led to record the removal of each essential element in higher quantities than those of recorded under four existing crop-sequences (T_1, T_3 to T_9, T_{11}) prevalent in the region.

Uptake of nitrogen

It is evident from the data that N uptake by different crop sequences significantly varied with each other. As regard uptake of N by a crop-sequence as whole, it was greater with all intensified crop-sequences under existing crop sequences. Based on 2-year data maximum N uptake (457.0 kg/ha) was recorded under T_{16}- Soybean (JS 93-05)-Garden pea (Arkel)-Garlic (G-282) followed by T_{15}- Soybean (JS 93-05)-Potato (Kufri jyoti)-Onion (AFLR) (444.50 kg/ha), T_7-Soybean (JS 95-60)-Potato (Kufri jyoti)-Onion (AFLR) and T_8- Soybean (JS 95-60)-Garden pea (Arkel) - Garlic (G-282), (431.5 kg/ha) (413.0 kg/ha) respectively whereas minimum (220.0 kg/ha) N uptake was recorded under T_3- Soybean (JS 95-60) - Chickpea (JG-130) desi. Remaining diversified intensive crop sequences (T_7, T_8, T_{13}, T_{10}, T_5, T_{10}, T_9 T_{14} T_2, T_1, T_6, T_{12}, T_{11} and T_3) led to record N uptake ranging from 220 to 431.50 kg/ha, which were higher than existing crop-sequences T_3- Soybean (JS 95-60) - Chickpea (JG-130) desi (220.0 kg/ha). Another existing crop sequence T_8- Soybean (JS 95-60) - Garden pea (Arkel) - Onion (AFLR) (431.50 kg/ha) significantly removed more N than intensified crop sequence T_8-Soybean (JS 95-60) - Potato (Kufri jyoti) - Garlic (G-282) (413.0 kg/ha).

Uptake of phosphorus

Like N uptake, the uptake of P by T_{15}- Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) system was also maximum (65.85 kg/ha), which was at par with T_7-Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR) (61.75 kg/ha), T_{16}- Soybean (JS 93-05)-Garden pea (Arkel)-Garlic (G-282) (57.20 kg/ha) and T_8- Soybean (JS 95-60)-Garden pea (Arkel)-Garlic (G-282) (55.10 kg/ha). The descending order of P removal by remaining cropping systems was as T_{10}-Soybean (JS 93-05)-Wheat (HI-8663) durum (46.65 kg/ha),T_2-Soybean (JS 95-60) - Wheat (HI-8663) durum (44.75 kg/ha),T_9- Soybean (JS 93-05) - Wheat (HI-1544) aestivum (41.25 kg/ha), T_1- Soybean (JS 95-60) - Wheat (HI-1544) aestivum (39.35 kg/ha), T_{13}- Soybean (JS 93-05) - Garlic (G-282) (36.55 kg/ha), T_5- Soybean (JS 95-60) - Garlic (G-282) (34.70 kg/ha), T_{14}- Soybean (JS 93-05) - Onion (AFLR) (24.30 kg/ha), T_{12}-Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli (22.0 kg/ha) and T_6- Soybean (JS 95-60) - Onion (AFLR) (21.90 kg/ha). But differences between T_{11}, T_3 and T_4 were not significant.

Uptake of potassium

The pattern of uptake of K by different crop sequences was almost identical to uptake of N by them. The uptake of K was maximum (562.73 kg/ha) with T_{15}- Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) followed by T_7 - Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR) (540.99 kg/ha), T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282) (244.62 kg/ha), T_8- Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (234.7 kg/ha), T_{14}- Soybean (JS 93-05) - Onion (AFLR) (205.49 kg/ha), T_6- Soybean (JS 95-60) - Onion (AFLR) (195.10 kg/ha), T_{13}- Soybean (JS 93-05) - Garlic (G-282) (188.91 kg/ha), T_5- Soybean (JS 95-60) - Garlic (G-282) (179.03 kg/ha), But variations between T_{10} and T_9, T_1 and T_2, were not much significant. T_3- Soybean (JS 95-60) - Chickpea (JG-130) desi first ranked existing crop-sequence removed minimum K among all crop sequences. T_{11}, T_4 were not significant but it was at par to first ranked existing T_3- Soybean (JS 95-60) - Chickpea (JG-130) desi crop sequence. The variation between T_4 and T_{11} was also almost comparable.

Table 2: Mean total N,P,K uptake under different cropping systems during 2015-16 & 2016-17

Crop sequences		Uptake of Nutrients (kg/ha)								
		2015-16			2016-17			Mean		
		N	P	K	N	P	K	N	P	K
T_1	Soybean (JS 95-60) - Wheat (HI-1544) aestivum	288.00	39.40	167.70	294.00	39.30	167.60	291.00	39.35	167.65
T_2	Soybean (JS 95-60) - Wheat (HI-8663) durum	300.00	46.10	167.90	311.00	43.40	167.62	305.50	44.75	167.76
T_3	Soybean (JS 95-60) - Chickpea (JG-130) desi	209.00	16.90	131.10	231.00	17.80	132.30	220.00	17.35	131.70
T_4	Soybean (JS 95-60) - Chickpea (RVKG-101) Kabuli	234.00	20.00	145.00	255.00	20.20	145.20	244.50	20.10	145.10
T_5	Soybean (JS 95-60) - Garlic (G-282)	311.00	32.60	177.90	326.00	36.80	180.17	318.50	34.70	179.03
T_6	Soybean (JS 95-60) - Onion (AFLR)	276.00	21.00	190.80	300.00	22.80	199.40	288.00	21.90	195.10
T_7	Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR)	416.00	51.80	538.80	447.00	71.70	543.18	431.50	61.75	540.99
T_8	Soybean (JS 95-60) - Garden pea (Arkel) – Garlic (G-282)	387.00	52.40	230.80	439.00	57.80	238.60	413.00	55.10	234.70
T_9	Soybean (JS 93-05) - Wheat (HI-1544) aestivum	310.00	41.10	176.00	322.00	41.40	179.06	316.00	41.25	177.53
T_{10}	Soybean (JS 93-05) - Wheat (HI-8663) durum	323.00	47.80	176.20	339.00	45.50	179.07	331.00	46.65	177.63
T_{11}	Soybean (JS 93-05) - Chickpea (JG-130) desi	232.00	18.60	139.40	260.00	19.90	143.75	246.00	19.25	141.58
T_{12}	Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli	256.00	21.70	153.30	284.00	22.30	155.53	270.00	22.00	154.42
T_{13}	Soybean (JS 93-05) - Garlic (G-282)	334.00	34.30	186.20	354.00	38.80	191.62	344.00	36.55	188.91
T_{14}	Soybean (JS 93-05) - Onion (AFLR)	299.00	22.70	200.15	328.00	25.90	210.84	313.50	24.30	205.49
T_{15}	Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR)	439.00	57.90	562.60	475.00	73.80	562.87	457.00	65.85	562.73
T_{16}	Soybean (JS 93-05) - Garden pea (Arkel) – Garlic (G-282)	422.00	54.50	239.20	467.00	59.90	250.04	444.50	57.20	244.62

	SEm±	1.29	1.11	2.37	3.08	1.27	2.16	1.67	0.84	1.60
	CD (P=0.05)	3.70	3.18	6.78	8.80	3.62	6.16	4.67	2.36	4.49

Soil analysis and nutrient balance sheet

Changes in Soil Properties

Data pertaining to changes in various chemical properties of soil at the end of crop cycles under different crop sequences during both years 2015-16 and 2016-17 over their initial status are given 3. There was no significant variation in the values of pH and electrical conductivity (EC) of all crop-sequences over their parental values at the end of third cycle during 2016-17. But OC contents significantly varied due to different crop-sequences at the end of third crop-cycle over its initial status. The maximum positive balance of OC was recorded in 08 crop sequences *viz.* T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) – Garlic (G-282) (6.10 g/kg) followed by T_8- Soybean (JS 95-60) - Garden pea (Arkel) – Garlic (G-282) (5.85 g/kg). The existing Soybean (JS 93-05) - Chickpea (JG-130) desi (T_{11}) and Soybean (JS 95-60) - Chickpea (JG-130) desi (T_3) cropping systems led to record significant positive balance over its initial value because soybean-chick pea crops might have contributed considerable biomass of N to the soil through left over biomass. The negative OC contents over parental status were also recorded at the end of third crop-cycle under intensive crop sequences *viz*, T_{13} - Soybean (JS 93-05) - garlic (G-282) and T_{14}- Soybean (JS 93-05) - Onion (AFLR) but rate of reduction was not significant.

The trend of available N status over its initial status at the end of third crop cycle under different crop-cycles was almost same as it was in case of OC status. The available N was significantly lower than its 1st year initial value (218.0 kg/ha) due to continuous cropping. T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282) 226.20 kg/ha, T_8- Soybean (JS 95-60) - Garden pea (Arkel) – Garlic (G-282) 224.60 kg/ha, T_{11} - Soybean (JS 93-05) - Chickpea (Jg-130) desi (220.10 kg/ha), T_3- Soybean (JS 95-60) - Chickpea (JG-130) desi (219.50 kg/ha) and T_{12}- Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli (217.50 kg/ha) had positive balance of available N in soil in descending order over its parental 2nd year value (208.13 kg/ha) and variations among these treatments were not found significant. Rest of the treatments *viz.* T_4, T_{15}, T_7, T_{13} and T_{14} were found lower values in descending order respectively over its parental values and found significant when compared to T_6, T_5, $T_{10,}$ T_9, T_2 and T_1.

The available P contents of the soil did not deviate much over itsinitial status (12.21 kg/ha) up to end of continuous third crop cycle under different crop-sequences tested under present investigation. However, numerically a little decline in P status was noted under all crop-sequences except to T_{15}- Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) (15.20 kg/ha), T_7 - Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR) (14.80 kg/ha), T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282) (14.10 kg/ha), T_8- Soybean (JS 95-60) - Garden pea (Arkel) – Garlic (G-282) (13.20 kg/ha), T_{14}- Soybean (JS 93-05) - Onion (AFLR) (12.900 kg/ha) and T_6- Soybean (JS 95-60) - Onion (AFLR) 12.50 kg/ha systems.

The available K contents of soil was higher in T_{15}- Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) (370. 20 kg/ha), T_7 - Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR) (353.0 kg/ha), T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282) (366.50 kg/ha) systems, after completion of third crop cycle under all crop-sequences tested than its initial status (355.31 kg/ha), but rate of positive balance in K content was remarkable only due to continuous cropping under T_{15}, $T_{7,}$ T_{16} and T_8 cropping systems. The available K contents of soil was lesser in T_{10} (345.0 kg/ha), T_9 (340.80 kg/ha), T_{11} (340.50 kg/ha), T_2- (339.40 kg/ha), T_{12} (339.0 kg/ha), T_4 (338.0 kg/ha), T_1 (324.20 kg/ha) and T_{13} (320.0 kg/ha) in ascending order over its initial status (355.31 kg/ha).

Table 3: Changes in chemical properties of soil over their initial status due to different crop sequences at the end of third crop cycle (2016-17)

Treatments		Soil pH	E.C. (dS/m)	O.C. (g/kg)	Available nutrient (kg/ha)		
					N	P	K
Initial		**7.34**	**0.51**	**5.29**	**208.13**	**12.21**	**355.31**
T_1	Soybean (JS 95-60) - Wheat (HI-1544) aestivum	7.10	0.52	4.40	192.20	10.20	324.20
T_2	Soybean (JS 95-60) - Wheat (HI-8663) durum	7.10	0.42	4.50	193.30	10.40	339.40
T_3	Soybean (JS 95-60) - Chickpea (JG-130) desi	7.20	0.43	5.65	219.50	9.50	320.00
T_4	Soybean (JS 95-60) - Chickpea (RVKG-101) Kabuli	7.20	0.51	5.30	215.80	9.60	338.00
T_5	Soybean (JS 95-60) - Garlic (G-282)	7.30	0.52	4.90	197.60	11.40	350.60
T_6	Soybean (JS 95-60) - Onion (AFLR)	7.30	0.52	5.00	199.50	12.50	353.00
T_7	Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR)	7.30	0.50	5.20	208.50	14.80	368.00
T_8	Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282)	7.40	0.50	5.85	224.60	13.20	360.00
T_9	Soybean (JS 93-05) - Wheat (HI-1544) aestivum	7.40	0.42	4.65	195.20	10.60	340.80
T_{10}	Soybean (JS 93-05) - Wheat (HI-8663) durum	7.50	0.48	4.70	196.40	10.90	345.00
T_{11}	Soybean (JS 93-05) - Chickpea (JG-130) desi	7.40	0.51	5.70	220.10	10.20	340.50
T_{12}	Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli	7.30	0.48	5.60	217.50	10.50	339.00
T_{13}	Soybean (JS 93-05) - Garlic (G-282)	7.40	0.45	5.30	200.50	11.60	355.50
T_{14}	Soybean (JS 93-05) - Onion (AFLR)	7.30	0.48	5.20	203.40	12.90	362.50
T_{15}	Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR)	7.30	0.40	5.45	210.60	15.20	370.20
T_{16}	Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282)	7.20	0.47	6.10	226.20	14.10	366.50
	SEm±	0.09	0.02	0.28	2.92	0.68	2.55
	CD (P=0.05)	0.27	0.06	0.65	8.34	1.95	7.30

Nutrient balance sheet

Treatment wise initial and final (after crop harvesting) soil analysis was calculated for both the crops. It showed that the availability of all the nutrient *viz.* nitrogen, phosphorus and potash were recorded slightly changed under the recommended doses of fertilizers. The highest removal of N was recorded in T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282) cropping sequence and was found significantly superior to other cropping sequence followed by T_{15}- Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion

(AFLR) and T_7 - Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR) sequence. The maximum removal of N may be attributed to greater biomass production of crops under these cropping systems.

The addition of nitrogen after soybean was found highest under the treatment combination of T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282). The highest mean balance of nitrogen was found in T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282) 313.51 kg/ha followed by T_8- Soybean (JS 95-60) - Garden pea (Arkel) - Garlic 293.86 kg/ha, T_{12}-Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli 222.25 kg/ha, T_{15}- Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) 215.29 kg/ha, T_{13}- Soybean (JS 93-05) - Garlic (G-282) 210.23 kg/ha, T_4- Soybean (JS 95-60) - Chickpea (RVKG-101) Kabuli 208.26 respectively while the lowest mean balance of nitrogen after harvesting of crop was recorded in T_1- Soybean (JS 95-60) - Wheat (HI-1544) aestivum i.e. 141.80 kg/ha and rest of treatments were in ascending order *viz.* T_2, T_9, T_{10}, T_7, T_{14}, T_3, T_5 which resulted into the nitrogen removal from the soil pool.

The addition of phosphorus after harvesting was registered higher (negative) under T_7-Soybean (JS 95-60)-Potato (Kufri jyoti)-Onion (AFLR) (-147.98 kg/ha) followed by T_{15}-Soybean (JS 93-05)-Potato (Kufri jyoti)-Onion (AFLR) (-142.46 kg/ha), T_6-Soybean (JS 95-60)-Onion (AFLR) (-89.91 kg/ha), T_1- Soybean (JS 95-60) - Wheat (HI-1544) aestivum (-87.65 kg/ha), T_{14}- Soybean (JS 93-05) - Onion (AFLR) (-87.37 kg/ha) while it was found lowest (negative) in T_{12}-Soybean (JS 93-05)-Chickpea (RVKG-101) Kabuli (-13.52 kg/ha), followed by T_4- Soybean (JS 95-60)-Chickpea (RVKG-101) Kabuli (-15.91 kg/ha) and rest of the treatments were ascending order i.e. T_{11}, T_3, T_{16}, T8, T_{13}, T_5, T_{10}, T_2 which resulted into the phosphorus removal from the soil pool.

The addition of potassium was found highest under the treatment T_{15}- Soybean (JS 93-05)-Potato (Kufri jyoti)-Onion (AFLR) (400.67 kg/ha) followed by T_7-Soybean (JS 95-60)-Potato (Kufri jyoti)-Onion (AFLR) (387.64 kg/ha) while potassium was found minimum under the treatment T_4-Soybean (JS 95-60)-Chickpea (RVKG-101) Kabuli 72.37 kg/ha which resulted into the potassium removal from the soil pool. In rest of treatments, the addition of potassium to the soil was also found in range from 85.19 to 139.03 kg/ha to the soil. In general, it was found that the addition of nitrogen, phosphorus and potassium was higher with the cropping intensity 300 % and lower with cropping intensity 200 %.

Table 4: N balance sheet under various crop sequences during the years 2015-16 & 2016-17

Treatments		Nitrogen (kg/ha)										
		2015-16					2016-17					
		Initial	Added	Uptake	STV at harvest	Balance (+/-)	Initial	Added	Uptake	STV at harvest	Balance (+/-)	Mean balance (+/-)
T_1	Soybean (JS 95-60) - Wheat (HI-1544) aestivum	218.0	140.0	287.7	205.4	135.1	208.1	140.0	293.9	202.7	148.5	141.8
T_2	Soybean (JS 95-60) - Wheat (HI-8663) durum	218.0	140.0	300.4	205.4	147.8	208.1	140.0	311.0	201.2	164.1	156.0
T_3	Soybean (JS 95-60) - Chickpea (JG-130) desi	218.0	40.0	208.9	220.4	171.3	208.1	40.0	231.4	223.0	206.3	188.8
T_4	Soybean (JS 95-60) - Chickpea (RVKG-101) Kabuli	218.0	40.0	233.6	215.6	191.2	208.1	40.0	255.5	218.0	225.4	208.3
T_5	Soybean (JS 95-60) - Garlic (G-282)	218.0	120.0	311.2	205.4	178.6	208.1	120.0	326.1	201.5	199.5	189.0
T_6	Soybean (JS 95-60) - Onion (AFLR)	218.0	120.0	276.4	213.1	151.5	208.1	120.0	300.2	215.6	187.7	169.6
T_7	Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR)	218.0	240.0	386.8	220.4	149.2	208.1	240.0	438.6	216.0	206.5	177.9
T_8	Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282)	218.0	140.0	415.8	213.1	270.9	208.1	140.0	446.9	218.0	316.8	293.9
T_9	Soybean (JS 93-05) - Wheat (HI-1544) aestivum	218.0	140.0	310.5	205.6	158.1	208.1	140.0	322.0	205.6	179.5	168.8
T_{10}	Soybean (JS 93-05) - Wheat (HI-8663) durum	218.0	140.0	323.2	193.2	158.4	208.1	140.0	339.2	196.8	187.9	173.1
T_{11}	Soybean (JS 93-05) - Chickpea (JG-130) desi	218.0	40.0	231.7	205.4	179.1	208.1	40.0	259.5	205.4	216.8	197.9
T_{12}	Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli	218.0	40.0	256.3	202.7	201.0	208.1	40.0	283.6	208.0	243.5	222.3
T_{13}	Soybean (JS 93-05) - Garlic (G-282)	218.0	120.0	333.9	198.4	194.3	208.1	120.0	354.2	200.0	226.1	210.2
T_{14}	Soybean (JS 93-05) - Onion (AFLR)	218.0	120.0	299.2	193.2	154.4	208.1	120.0	328.4	198.0	198.3	176.3
T_{15}	Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR)	218.0	240.0	422.2	222.7	186.9	208.1	240.0	466.8	225.0	243.7	215.3
T_{16}	Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282)	218.0	140.0	438.6	208.0	288.6	208.1	140.0	475.0	211.5	338.4	313.5

Table 5: P balance sheet under various crop sequences during the years 2015-16 & 2016-17

Treatments		Phosphorus (kg/ha)										
		2015-16					2016-17					
		Initial	Added	Uptake	STV at harvest	Balance (+/-)	Initial	Added	Uptake	STV at harvest	Balance (+/-)	Mean balance (+/-)
T_1	Soybean (JS 95-60) - Wheat (HI-1544) aestivum	11.6	140.0	39.4	10.5	-101.7	12.2	140.0	39.3	39.3	-73.6	-87.6
T_2	Soybean (JS 95-60) - Wheat (HI-8663) durum	11.6	140.0	46.1	11.6	-93.9	12.2	140.0	43.4	43.4	-65.4	-79.7
T_3	Soybean (JS 95-60) - Chickpea (JG-130) desi	11.6	40.0	16.9	9.6	-25.1	12.2	40.0	17.8	17.8	-16.6	-20.9
T_4	Soybean (JS 95-60) - Chickpea (RVKG-101) Kabuli	11.6	40.0	20.0	11.6	-20.1	12.2	40.0	20.2	20.2	-11.8	-15.9
T_5	Soybean (JS 95-60) - Garlic (G-282)	11.6	120.0	32.6	10.5	-88.5	12.2	120.0	36.8	36.8	-58.7	-73.6
T_6	Soybean (JS 95-60) - Onion (AFLR)	11.6	120.0	21.0	15.4	-95.2	12.2	120.0	23.8	23.8	-84.6	-89.9
T_7	Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR)	11.6	240.0	51.8	12.7	-187.1	12.2	240.0	71.7	71.7	-108.9	-148.0
T_8	Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282)	11.6	140.0	52.6	15.2	-83.8	12.2	140.0	57.8	57.8	-36.6	-60.2
T_9	Soybean (JS 93-05) - Wheat (HI-1544) aestivum	11.6	140.0	41.1	14.7	-95.8	12.2	140.0	41.4	41.4	-69.4	-82.6
T_{10}	Soybean (JS 93-05) - Wheat (HI-8663) durum	11.6	140.0	47.8	9.2	-94.6	12.2	140.0	45.5	45.5	-61.3	-77.9
T_{11}	Soybean (JS 93-05) - Chickpea (JG-130) desi	11.6	40.0	18.6	10.9	-22.1	12.2	40.0	19.9	19.9	-12.4	-17.3
T_{12}	Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli	11.6	40.0	21.7	10.5	-19.4	12.2	40.0	22.3	22.3	-7.6	-13.5
T_{13}	Soybean (JS 93-05) - Garlic (G-282)	11.6	120.0	34.3	12.5	-84.8	12.2	120.0	38.8	38.8	-54.6	-69.7
T_{14}	Soybean (JS 93-05) - Onion (AFLR)	11.6	120.0	22.7	14.6	-94.3	12.2	120.0	25.9	25.9	-80.5	-87.4
T_{15}	Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR)	11.6	240.0	57.9	13.5	-180.2	12.2	240.0	73.8	73.8	-104.7	-142.5
T_{16}	Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282)	11.6	140.0	54.4	12.6	-84.6	12.2	140.0	59.9	59.9	-32.5	-58.6

Table 6: K balance sheet under various crop sequences during the years 2015-16 & 2016-17

Treatments		Potassium (kg/ha)										
		2015-16					2016-17					
		Initial	Added	Uptake	STV at harvest	Balance (+/-)	Initial	Added	Uptake	STV at harvest	Balance (+/-)	Mean balance (+/-)
T_1	Soybean (JS 95-60) - Wheat (HI-1544) aestivum	350.0	60.0	167.7	345.0	102.7	355.3	60.0	167.6	345.8	98.1	100.4
T_2	Soybean (JS 95-60) - Wheat (HI-8663) durum	350.0	60.0	167.9	360.0	117.9	355.3	60.0	167.6	365.0	117.3	117.6
T_3	Soybean (JS 95-60) - Chickpea (JG-130) desi	350.0	40.0	131.1	345.0	86.1	355.3	40.0	132.3	366.0	103.0	94.5
T_4	Soybean (JS 95-60) - Chickpea (RVKG-101) Kabuli	350.0	40.0	145.0	320.0	75.0	355.3	40.0	145.1	320.0	69.8	72.4
T_5	Soybean (JS 95-60) - Garlic (G-282)	350.0	70.0	177.9	340.0	97.9	355.3	70.0	181.2	363.5	119.4	108.6
T_6	Soybean (JS 95-60) - Onion (AFLR)	350.0	70.0	190.8	310.0	80.8	355.3	70.0	199.4	315.5	89.6	85.2
T_7	Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR)	350.0	170.0	538.8	390.0	408.8	355.3	170.0	543.2	348.6	366.5	387.6
T_8	Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282)	350.0	90.0	230.8	375.0	165.8	355.3	90.0	238.6	355.2	148.5	157.2
T_9	Soybean (JS 93-05) - Wheat (HI-1544) aestivum	350.0	60.0	176.0	380.0	146.0	355.3	60.0	179.1	335.6	99.3	122.7
T_{10}	Soybean (JS 93-05) - Wheat (HI-8663) durum	350.0	60.0	176.2	350.0	116.2	355.3	60.0	179.1	347.9	111.7	113.9
T_{11}	Soybean (JS 93-05) - Chickpea (JG-130) desi	350.0	40.0	139.4	360.0	109.4	355.3	40.0	143.8	367.4	115.8	112.6
T_{12}	Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli	350.0	40.0	153.3	340.0	103.3	355.3	40.0	156.5	348.0	109.2	106.3
T_{13}	Soybean (JS 93-05) - Garlic (G-282)	350.0	70.0	186.2	365.0	131.2	355.3	70.0	192.6	351.2	118.5	124.9
T_{14}	Soybean (JS 93-05) - Onion (AFLR)	350.0	70.0	199.1	360.0	139.1	355.3	70.0	210.8	353.4	138.9	139.0
T_{15}	Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR)	350.0	170.0	563.6	355.0	398.6	355.3	170.0	562.9	365.2	402.8	400.7
T_{16}	Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282)	350.0	90.0	239.2	390.0	189.2	355.3	90.0	250.0	349.5	154.2	171.7

System productivity

Soybean Yield Equivalent (SEY) of cropping-system as a whole, T_{15}-Soybean (JS 93-05)-Potato (Kufri jyoti)-Onion (AFLR) system was recorded significantly maximum SEYs (177.31 q/ha) among all crop-sequences mainly due to greater SEY of potato during *Rabi* along with considering good SEYs of onion in *zaid* season. The next best crop- sequence was T_7 - Soybean (JS 95-60)-Potato (Kufri jyoti)-Onion (AFLR) with regard to SEYs (173.18 q/ha) mainly owingto the higher SEYs in k*harif* soybean and r*abi* potato and onion in *zaid* followed by SEY 104.43 q/ha in T_{14}- Soybean (JS 93-05) - Onion (AFLR), SEY 101.24 q/ha in T_6- Soybean (JS 95-60) - Onion (AFLR), SEY 93.44 q/ha in T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282) and SEY 90.06 q/ha in T_8- Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282). The higher SEYs in Soybean (JS 93-05) - Onion (AFLR) and Soybean (JS 95-60) - Onion (AFLR) cropping sequences was become of higher yield of onion in the sequence. Further, the results revealed that there is sufficient scope to intensify the existing cropping sequence with inclusion of onion and garlic during *zaid*. Inclusion of onion and garlic during *zaid* increased cropping sequence productivity. The minimum productivity of the cropping sequence based on SEYs was registered in Soybean (JS 95-60) - Chickpea (JG-130) desi i.e. 42.79 q/ha. This could be ascribed due to low yield realized from desi chick pea in the sequence. Several researchers have also reported heterogeneity in production of potential varying crop-sequences from different agro- production systems (Tyagi *et al.*, 2011; Chitale *et al.*, 2011; Narkhede, *et al.*, 2011; Kumar, *et al.*, 2012; Billore 2013, Gallani *et al.*, 2013, Shrikant *et al.*, 2013; Singh *et al.*, 2013; Meena *et al.*, 2013, Prajapat *et al.*, 2014; Singh and Kumar, 2014; Shridhara *et. al.*, 2017; Singh *et al.*, 2017; Turkhede *et al.*, 2017; Chavan *et al.*, 2018; Jugnahake *et al.*, 2018; Sammauria, *et al.*, 2018 ; Bhargavi and Behera, 2019) [25, 2, 4, 22, 12, 16, 8].

Table 7: System productivity (q/ha) in different seasons under various crop sequences

Crop sequences		Grain/seed/tuber SEY (q/ha)				Straw/haulm SEY (q/ha)			
		Kharif Season	*Rabi* Season	*Zaid* Season	Total	*Kharif* Season	*Rabi* Season	*Zaid* Season	Total
T_1	Soybean (JS 95-60) - Wheat (HI-1544) aestivum	18.78	30.08	-	49.09	25.85	21.54	-	47.39
T_2	Soybean (JS 95-60) - Wheat (HI-8663) durum	19.09	31.99	-	51.17	26.43	22.03	-	48.46
T_3	Soybean (JS 95-60) - Chickpea (JG-130) desi	19.46	23.33	-	42.79	28.39	39.43	-	67.82
T_4	Soybean (JS 95-60) - Chickpea (RVKG-101) Kabuli	19.04	28.77	-	47.83	26.89	37.35	-	64.24
T_5	Soybean (JS 95-60) - Garlic (G-282)	19.75	62.28	-	82.03	27.43	38.10	-	65.53
T_6	Soybean (JS 95-60) - Onion (AFLR)	19.76	82.01	-	101.24	27.16	37.72	-	64.88
T_7	Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR)	20.18	83.08	70.03	173.18	27.16	37.72	17.32	82.20
T_8	Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282)	20.24	17.91	52.41	90.06	29.13	40.46	18.06	87.64
T_9	Soybean (JS 93-05) - Wheat (HI-1544) aestivum	20.84	31.99	-	52.83	27.51	22.93	-	50.44
T_{10}	Soybean (JS 93-05) - Wheat (HI-8663) durum	20.62	33.20	-	54.33	27.39	22.83	-	50.22
T_{11}	Soybean (JS 93-05) - Chickpea (JG-130) desi	20.56	24.13	-	44.81	28.22	39.19	-	67.41
T_{12}	Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli	20.38	29.50	-	49.88	25.77	35.79	-	61.56
T_{13}	Soybean (JS 93-05) - Garlic (G-282)	21.18	47.03	-	84.19	25.20	35.00	-	60.20
T_{14}	Soybean (JS 93-05) - Onion (AFLR)	21.58	83.48	-	104.43	24.91	34.60	-	59.51
T_{15}	Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR)	21.29	83.55	72.47	177.31	24.89	34.57	19.10	78.56
T_{16}	Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282)	21.56	18.58	53.42	93.44	25.49	35.40	19.31	80.20
	SEm±	0.39	1.60	0.48	1.12	0.88	0.91	0.38	1.82
	CD (P=0.05)	1.09	4.48	1.33	3.15	2.50	2.60	1.08	5.19

Conclusion

It is clear from the data that chemical properties of soil *viz.* soil pH, EC, OC and available N, P and K did not show remarkable variation in the soil after harvesting of *zaid* crops in any of the crop sequences over their initial status. The availability of nutrients were numerically higher N in T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282) 226.20 kg/ha, P in T_{15}- Soybean (JS 93-05) - Potato (Kufri

jyoti) - Onion (AFLR) (15.20 kg/ha), K in T_{15}- Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) 370.20 kg/ha and minimum N was recorded in T_1- Soybean (JS 95-60) - Wheat (HI-1544) aestivum 192.20 kg/ha, P in T_3 - Soybean (JS 95-60) - Chickpea (JG-130) desi (9.50 kg/ha), K in T_3 - Soybean (JS 95-60) - Chickpea (JG-130) desi (320.0 kg/ha) at end of experimentation. Rest of the cropping sequence possessed almost similar nutrient availability after completion of their sequence.

It is evident from the data that all crop-sequences had similar trend of nutrient removal in both years of investigation. Based on two year mean data, it is obvious that all diversified and intensified crop-sequences (T_2, T_4, T_5, T_6, T_7, T_8, T_{10}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16}) tested in present investigation led to record the removal of each essential element in higher quantities than those of recorded under four existing crop-sequences (T_1, T_3 to T_9, T_{11}) prevalent in the region.

Soybean Yield Equivalent (SEY) of cropping-system as a whole, T_{15}-Soybean (JS 93-05)-Potato (Kufri jyoti)-Onion (AFLR) system was recorded significantly maximum SEYs (177.31 q/ha) among all crop-sequences mainly due to greater SEY of potato during *Rabi* along with considering good SEYs of onion in *zaid* season. Inclusion of onion and garlic during *zaid* increased cropping sequence productivity. The minimum productivity of the cropping sequence based on SEYs was registered in Soybean (JS 95-60) - Chickpea (JG-130) desi i.e. 42.79 q/ha. This could be ascribed due to low yield realized from desi chick pea in the sequence.

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