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Research article

Effect of different nutrient management practices on productivity, profitability and nutrient dynamics in forage-based cropping systems under mid-hill conditions of north-western Himalayas

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Abstract

A field experiment was conducted at the research farm of Fodder Section, CSKHPKV, Palampur, from *Kharif* 2018 to *Rabi* 2019-20 to study the effect of different nutrient management practices in forage-based cropping systems. Ten nutrient management practices in two cropping systems were tested in randomized block design with three replications. Integrated nutrient management, *i.e.*, 50% recommended N + 10 t/ha FYM + 10% *Jeevamrit* and 50% recommended N+ 10 t/ha FYM + 5% *Jeevamrit* and recommended NPK behaving alike resulted in higher oat green fodder equivalent yield, nutrient uptake (N, P and K) and system productivity of sorghum + pearl millet - oat + *sarson*/wheat cropping systems. An increase in soil organic carbon content was observed with integrated nutrient management (50% recommended N + 10 t/ha FYM + *Jeevamrit*) and organic nutrient management (10 t/ha FYM + *Jeevamrit*) over the initial status at the end of sorghum + pearl millet - oat + *sarson*/wheat cropping systems. Integrated nutrient management improved available soil nitrogen, phosphorus and potassium contents over the initial values. Significantly higher available soil nitrogen, phosphorus and potassium contents were recorded with integrated nutrient management as well as with recommended NPK through inorganic sources over other treatments comprised of organic and natural farming systems of nutrition in both the cropping systems. Recommended NPK proved most profitable with the highest net returns and benefit-cost ratio in sorghum + pearl millet - oat + *sarson*/wheat cropping systems. Sorghum + pearl millet - oat + *sarson* cropping system comprised of all fodder crops resulted in higher productivity and profitability but did not increase soil available nutrient status as compared to sorghum + pearl millet - wheat cropping system comprised of fodder as well as grain crops.

Keywords: Cropping systems**,** Fodder yield, Natural farming, Organic nutrient management

Introduction

Sorghum + pearl millet - oat + *sarson*, a prominent fodder-based cropping system, ensures forage availability for the existing livestock population of 4.41 million (Anonymous, 2019) in mid hills of the north-western Himalayas. However, small land holdings and more preference of farmers for grain crops offer little scope for the cultivation of fodder crops. Therefore, the inclusion of fodder crops in the existing maize/rice-wheat cropping systems appears to be a viable option to meet out the fodder requirement of the existing livestock population in the region without compromising yield of food crops (Kumar *et al.*, 2023). These cereal-cereal-based cropping systems are highly nutrient-demanding and mainly grown under inorganic nutrition conditions. But poor economic conditions of hill farmers and the high price of chemical fertilizers discourage them from meeting the nutritional requirements of crops fully through chemical fertilizers. It has also been established that continuous use of chemical fertilizers leads to deficiency of secondary and micronutrients, soil salinity and environmental pollution (Nandhini *et al.*, 2023).

The role of organic manures in improving soil fertility is well documented. Organic crop production is expected to expand in response to increased demand for organic food (Patel *et al.*, 2014). Organic manures provide a good substrate for the growth of microorganisms, supply both macro and micronutrients and improve soil physical, chemical and biological health (Verma *et al.*, 2018). But limited availability of organics and their lower nutrient contents are the major constraints in use of these alternative sources of plant nutrients. These constraints

can be overcome by the integrated nutrient management (INM) approach, where the application of organic manures and chemical fertilizers in combination holds a great potential to maintain economic crop production and soil fertility on a long-term basis (Singh *et al*., 2018). In recent years, Subash Palekar Natural Farming (SPNF) is admired by different sectors for sustaining crop productivity and improving soil health using inputs like *Beejamrit, Jeevamrit* and *Ghanjeevamrit* (Amareswari and Sujathamma, 2014). But this needs experimental testing on a long term basis. Therefore, an attempt was made to study the comparative effect of different nutrient management in terms of green fodder equivalent yield, system productivity, nutrient uptake (N, P and K), profitability and soil fertility under sorghum + pearl millet – oat + *sarson*/wheat cropping systems.

Materials and Methods

Experimental details: The field experiment was conducted at the Research Farm of Fodder Section, CSKHPKV, Palampur from *Kharif* 2018 to *Rabi* 2019-20. A sub-humid sub-tropical climate in the mid-hill of the north-western Himalayas characterized the experimental site. The soil of the experimental field was acidic in reaction (pH 5.47), medium in organic carbon (0.70%), low in available nitrogen (230 kg/ha), medium in available phosphorus (17.64 kg/ha) and available potassium (168 kg/ha). The experiment was laid out in randomized block design with three replications, consisting of two cropping systems, i.e., sorghum + pearl millet – oat + *sarson* and sorghum + pearl millet – wheat and ten nutrient management treatments i.e. absolute control (T_1), 5% *Jeevamrit* (T_2), 10% *Jeevamrit* (T_3), seed treatment with *Beejamrit* + 5% *Jeevamrit* (T_4), seed treatment with *Beejamrit* + 10% *Jeevamrit* (T_5), 10 t/ha FYM + 5% *Jeevamrit* (T_6), 10 t/ha FYM + 10% *Jeevamrit* (T_7), 50% recommended N + 10 t/ha FYM + 5% *Jeevamrit* (T_8), 50% recommended N + 10 t/ha FYM + 10% *Jeevamrit* (T_9) and recommended dose of NPK through inorganic sources (T_{10}).

Crop management: 'PHS-111' variety of sorghum, 'PG-3545' variety of pearl millet, 'PLP-1' variety of oat, 'FOS-902' variety of *sarson* and 'HPW-236' variety of wheat were grown. During *Kharif* season, the seeds of sorghum and pearl millet hybrids were mixed using 50% recommended seed rate of sorghum (22.5 kg/ha) + 50% recommended seed rate of pearl millet (7.5 kg/ha) and this seed mixture was sown in lines 30 cm apart. During *Rabi* season, the gross plot was divided into two equal parts and each part was used for the sowing of oat + *sarson* and wheat crops separately. Oat and wheat, each at recommended seed rate of 100 kg/ha were sown in lines 20 cm apart; in oat crop, *sarson* was over sown by broadcast using seed rate of 3 kg/ha. Prior to sowing, a full dose of FYM on a dry weight basis was incorporated in the soil in all the treatments comprised of FYM application. Inorganic fertilizers were applied to crops as per treatments. In sorghum + pearl millet and oat + *sarson* crops, a half dose of N as per treatments and a whole of P and K was applied at the time of sowing. The remaining $¼^{th}$ dose of N was top dressed after 30 days of sowing of crop and the remaining $¼^{th}$ was applied after first cut. In wheat, half dose of N as per treatments and whole of P and K was applied at the time of sowing and the remaining half dose of N was top dressed after 30 days of sowing. *Beejamrit* was prepared on the farm using local cow dung (5 kg), local cow urine (5 litres), lime (50 g), soil (0.1 g) and water (20 litres) for treating seeds (100 kg) as per treatments. *Jeevamrit* (2 litres) was also prepared on the farm itself using local cow dung (100 g), local cow urine (100 ml), jaggery (20 g), pulse flour (20 g), soil (0.1 g) and water (2 litres). Both the inputs of natural farming were prepared as per the procedure proposed by Subhash Palekar (Palekar, 2006). After 48 hours of *Jeevamrit* fermentation, two dilutions of 5 and 10% were prepared from the concentrated *Jeevamrit* and used @ 500 l/ha as basal and at 4 weeks intervals after sowing of crop in the respective treatments.

Productivity: For comparison between cropping systems, sorghum + pearl millet green fodder yield and wheat grain yield were converted to oat green fodder equivalent yields. Oat green fodder equivalent yield of sorghum + pearl millet – oat + *sarson* cropping system in respective treatment was computed by summing up the oat green fodder equivalent yield as calculated from sorghum + pearl millet during *Kharif* and green fodder yield of oat + *sarson* during *Rabi* season. Whereas oat green fodder equivalent yield of sorghum + pearl millet – wheat cropping systems in respective treatment was computed by summing up the oat green fodder equivalent yield as calculated from sorghum + pearl millet during *Kharif* and wheat crop during *Rabi* season. System productivity was calculated by dividing the oat green fodder equivalent yield by number of days taken by crop sequence.

Chemical analysis: Plant samples were collected at harvest of each crop for chemical analysis *viz*. nitrogen, phosphorus and potassium content (%) following standard methods of modified Kjeldahl's method (AOAC, 1970), vanado-molybdate phosphoric method (Jackson, 1967) and flame photometer technique (Jackson, 1967), respectively and then the nutrient uptakes (N, P and K) by crops were computed. Soil samples (0-15 cm depth) were also collected from plots of different treatments after completion of each cropping cycle and analyzed for soil chemical properties. The soil pH and organic carbon content were estimated following the methods of Jackson (1967) and Walkley and Black (1934), respectively,

whereas available nitrogen, phosphorus and potassium were determined by the methods described by Subbiah and Asija (1956), Olsen *et al*. (1954) and AOAC (1970), respectively.

Economic analysis: Cost of production (Rs/ha), net returns (Rs/ha) and benefit-cost ratio were calculated on the basis of prevailing market prices, costs of inputs and outputs. The net returns (Rs/ha) were computed treatment-wise by subtracting the cost of cultivation from the gross returns of the respective treatment. The benefit-cost ratio was worked out by using the equation of gross return (Rs/ha)/ cost of cultivation (Rs/ha).

Statistical analysis: The data pertaining to productivity, nutrient uptake, profitability and soil fertility parameters were subjected to statistical analysis as per the procedures suggested by Gomez and Gomez (1984). Wherever present the effect of significance at 5% level of probability and the critical difference (CD) was calculated.

Results and Discussion

Productivity of cropping systems

Green fodder equivalent yield: Productivity of sorghum + pearl millet - oat + *sarson* and sorghum + pearl millet – wheat cropping systems in terms of oat green fodder equivalent yield exhibited significant variation due to different nutrient management practices (Table 1). The better oat green fodder equivalent yield in the sorghum + pearl millet - oat + *sarson* cropping system compared to the sorghum + pearl millet – wheat cropping system might be due to the inclusion of fodder crops during both seasons, which resulted in higher biomass yield with better economic returns and ultimately in more green fodder equivalent yield.

Among different nutrient management practices, the application of recommended NPK through inorganic sources resulted in significantly higher oat green fodder equivalent yield of sorghum + pearl millet– oat + *sarson* cropping system (83.75 t/ha), which remained statistically at par with the integrated nutrient management treatments comprised of 50% recommended N + 10 t/ha FYM + *Jeevamrit*. Significantly higher oat green fodder equivalent yield of sorghum + pearl millet - wheat cropping system was obtained with integrated nutrient management treatments, *i.e.*, 50% recommended N + 10 t/ha FYM + 10% *Jeevamrit* (65.57 t/ha) and 50% recommended N + 10 t/ha FYM + 5% *Jeevamrit* (65.10 t/ha) which remained at par with recommended NPK through inorganic sources. Following integrated and inorganic nutrient management, organic nutrient management treatments, *i.e.*, 10 t/ha FYM + 5% *Jeevamrit* and 10 t/ha FYM + 10% *Jeevamrit*, remaining at par with each other, resulted in significantly higher oat green fodder equivalent yield of sorghum + pearl millet - oat + *sarson*/wheat cropping systems than natural farming nutrient management treatments of *Beejamrit* + 10% *Jeevamrit* and *Beejamrit* + 5% *Jeevamrit.* The lowest oat green fodder equivalent yield of both the cropping systems was recorded in absolute control, which was at par with 5% *Jeevamrit* treatment. In the sorghum + pearl millet - oat + *sarson* cropping system, application of recommended NPK produced 64.54, 60.33, 56.73, 40.26 and 2.73% more oat green fodder equivalent yield over absolute control, *Jeevamrit*, natural farming, organic and integrated nutrient management treatments, respectively. The increase in yield in sorghum + pearl millet - wheat cropping system with integrated nutrient management was 54.99, 49.14, 45.33, 31.52 and 2.44% over absolute control, *Jeevamrit*, natural farming, organic and inorganic nutrient management, respectively.

Higher productivity of both the cropping systems under inorganic and integrated nutrient management could be due to adequate availability of nutrients to the crops. Combined application of FYM along with inorganic fertilizers was reported to increase the status of major and micronutrients along with enhancement of organic carbon and other physical properties of soils (Vyas *et al.,* 2003). The contribution of *Jeevamrit* in integrated management practices could be attributed to higher microbial load and growth hormones, which might have enhanced the soil biomass, thereby sustaining the availability and uptake of applied as well as inherent soil nutrients, which ultimately resulted in better growth and yield of crops (Palekar, 2006; Devakumar *et al*., 2014). Organic nutrient management failed to supply the required quantities of nutrients to vigorously grow fodder crops. However registered higher yields than natural farming systems of nutrition. The nutrient content of *Beejamrit* and *Jeevamrit*, irrespective of the source, was very low to meet the nutritional requirement of fodder crops and their only addition to the soil led to the starvation of plants for nutrients (Aulakh *et al.,* 2013).

System productivity: Data pertaining to system productivity of sorghum + pearl millet - oat + *sarson* and sorghum + pearl millet - wheat cropping systems differed significantly under different nutrient management practices (Table 1). System productivity varied from 132 to 372 kg/ha/day in the sorghum + pearl millet - oat + *sarson* cropping system, whereas in sorghum + pearl millet – wheat cropping systems, the system productivity varied from 108 to 241 kg/ha/day. Since the sorghum + pearl millet – wheat cropping system took a longer duration, the system productivity was lower compared to other system due to low yield in this system.

An examination of the data revealed that the system productivity of both the cropping systems under different nutrient management treatments was in accordance with oat green fodder equivalent yield obtained in respective

Table 1. Effect of nutrient management treatments on green fodder equivalent yield and system productivity of two cropping systems (mean of two years)

Treatments	Oat green fodder equivalent yield (t/ha)		System productivity (kg/ha/day)	
	Sorghum + pearl millet - oat + *sarson*	**Sorghum + pearl millet – wheat**	**Sorghum + pearl millet - oat + *sarson***	**Sorghum + pearl millet – wheat**
Absolute control	29.70	29.41	132	108
5% *Jeevamrit*	32.66	32.81	145	120
10% *Jeevamrit*	33.79	33.65	150	124
Beejamrit + 5% *Jeevamrit*	36.15	35.48	161	130
Beejamrit + 10% *Jeevamrit*	36.32	35.96	161	132
10 t/ha FYM + 5% *Jeevamrit*	50.45	44.71	225	164
10 t/ha FYM + 10% *Jeevamrit*	49.62	44.77	221	165
50% recommended N + 10 t/ha FYM + 5% *Jeevamrit*	81.40	65.10	362	239
50% recommended N + 10 t/ha FYM + 10% *Jeevamrit*	81.52	65.57	362	241
Recommended NPK	83.75	63.74	372	234
SEM	0.99	1.29	4.39	4.90
CD ($p < 0.05$)	2.97	3.87	13.18	14.70

treatments. Recommended NPK through inorganic sources and integrated nutrient management practices, *i.e.,* 50% recommended N + 10 t/ha FYM + 10% *Jeevamrit* and 50% recommended N + 10 t/ha FYM + 5% *Jeevamrit* remaining at par with each other recorded significantly higher system productivity of sorghum + pearl millet - oat + *sarson*/wheat cropping systems than organic (10 t/ha FYM + 10% *Jeevamrit* and 10 t/ha FYM + 5% *Jeevamrit*) and natural farming (*Beejamrit* + 10% *Jeevamrit* and *Beejamrit* + 5% *Jeevamrit)* nutrient management practices.

Composition of herbage

Nutrient uptake: The N, P and K uptake by sorghum + pearl millet - oat + *sarson* and sorghum + pearl millet - wheat cropping systems varied significantly under different nutrient management practices (Table 2). The higher uptake of N, P and K by sorghum + pearl millet – oat + *sarson* cropping system as compared to sorghum + pearl millet - wheat cropping system might be due to the inclusion of exhaustive fodder crops in this system. Significantly higher uptake of N, P and K by both the cropping systems was recorded under integrated nutrient management practices of 50% recommended N + 10 t/ha FYM + 10% *Jeevamrit* and 50% recommended N + 10 t/ha FYM + 5% *Jeevamrit*, which remained statistically at par with recommended NPK through inorganic sources. Organic nutrient management practices *i.e.* 10 t/ha FYM + 10% *Jeevamrit* and 10 t/ha FYM + 5% *Jeevamrit*, were next in place, followed by natural farming nutrient management practices of *Beejamrit* + 10% *Jeevamrit* and *Beejamrit* + 5% *Jeevamrit* which remained statistically at par with 10 and 5% *Jeevamrit* treatments. Lowest uptakes of N, P and K were observed under absolute control which was found at par with 5 and 10% *Jeevamrit* treatments.

Higher uptake of N, P and K under integrated nutrient management practices might be ascribed to a continuous supply of nutrients throughout the crop growth period as nutrients from inorganic sources were readily available to the crop in early stages besides the slow and continuous release of nutrients from organic source made available at later stages of the crop growth. Ghodpage and Datke (2005) in sorghum and Thumar *et al.* (2016) in pearl millet reported higher nutrient uptake with integrated nutrient management, while Gupta *et al.* (2007) in sorghum and Singh *et al.* (2018) in pearl millet recorded higher NPK uptake with the application of a recommended dose of inorganic fertilizers.

Table 2. Effect of nutrient management treatments on NPK uptake of two cropping systems (mean of two years)

Treatments	Nutrient uptake (kg/ha)					
	Sorghum + pearl millet – oat + *sarson*			Sorghum + pearl millet – wheat		
	N	P	K	N	P	K
Absolute control	55.4	11.2	52.9	54.7	9.2	58.7
5% *Jeevamrit*	62.5	12.8	59.2	62.8	11.0	68.0
10% *Jeevamrit*	66.1	13.4	62.2	65.7	11.4	71.0
Beejamrit + 5% *Jeevamrit*	72.5	15.0	68.4	72.1	13.1	77.1
Beejamrit + 10% *Jeevamrit*	71.5	15.0	68.9	72.0	13.3	78.7
10 t/ha FYM + 5% *Jeevamrit*	114.2	25.1	107.9	102.9	20.1	110.7
10 t/ha FYM + 10% *Jeevamrit*	112.6	24.3	106.0	103.3	20.5	111.7
50% recommended N + 10 t/ha FYM + 5% *Jeevamrit*	205.6	46.6	197.4	178.2	38.2	196.3
50% recommended N + 10 t/ha FYM + 10% *Jeevamrit*	208.5	45.9	200.6	182.9	38.3	199.8
Recommended NPK	203.0	44.2	193.8	169.3	35.3	187.0
SEM	19.02	1.74	4.59	13.41	1.45	4.37
CD (P<0.05)	57.06	5.23	13.78	40.22	4.34	13.12

Profitability

Net returns: Significantly highest net returns of Rs 1, 93,217 from sorghum + pearl millet - oat + *sarson* cropping system and Rs 1, 91,574 per ha from sorghum + pearl millet - wheat cropping system were obtained with the application of recommended NPK through inorganic sources, which was followed by application of 50% recommended N + 10 t/ha FYM + 5% *Jeevamrit* and 50% recommended N + 10 t/ha FYM + 10% *Jeevamrit* (Table 3). The difference between the green fodder equivalent yield obtained with recommended NPK and integrated nutrient management was not very high but the cost of cultivation increased due to the cost of FYM in integrated nutrient management reduced the net returns. Organic nutrient management practices (10 t/ha FYM + 5% *Jeevamrit* and 10 t/ha FYM + 10% *Jeevamrit*) in sorghum + pearl millet - oat + *sarson* cropping system and natural farming nutrient management practices (*Beejamrit* + 5% *Jeevamrit* and *Beejamrit* + 10% *Jeevamrit*) in sorghum + pearl millet - wheat cropping system being at par with each other, were next in place to inorganic and integrated nutrient management practices.

Benefit-cost ratio: Application of recommended NPK through inorganic sources in sorghum + pearl millet - oat + *sarson* and sorghum + pearl millet - wheat cropping systems resulted in a significantly highest benefit-cost ratio of 3.55 and 3.53, respectively. This was followed by integrated nutrient management practices of 50% recommended N + 10 t/ha FYM + 5% *Jeevamrit* and 50% recommended N + 10 t/ha FYM + 10% *Jeevamrit*. The lowest benefit-cost ratio was obtained with organic nutrient management practices of 10 t/ha FYM + 5% *Jeevamrit* and 10 t/ha FYM + 10% *Jeevamrit* in both cropping systems. Although natural farming nutrient management comprised of *Beejamrit* + *Jeevamrit* produced lower yield but, their low cost of cultivation makes these treatments more economical than organic nutrient management comprised of farmyard manure. Anusha (2018) also obtained maximum net returns and benefit-cost ratio with the sole application of *Jeevamrit* four times than the application of vermicompost @ 7.5 t/ha + *Jeevamrit* as a soil drench four times.

Soil fertility

pH: Soil pH after completion of sorghum + pearl millet-oat + *sarson* or wheat cropping systems varied from 5.38 to 5.64 (Table 4). It was maximum under organic nutrient management practices (10 t/ha FYM + 5% *Jeevamrit* and 10 t/ha FYM + 10% *Jeevamrit*), which remained at par with integrated nutrient management practices (50% recommended N + 10 t/ha FYM + 5% *Jeevamrit* and 50% recommended N + 10 t/ha FYM + 10% *Jeevamrit*), while minimum under inorganic nutrient management which

Table 3. Effect of nutrient management treatments on cost of cultivation, net returns and B:C ratio of two cropping systems (mean of two years)

Treatments	Sorghum + pearl millet – oat + *sarson*			Sorghum + pearl millet – wheat		
	Cost of cultivation (Rs./ha/year)	Net returns (Rs./ha/year)	B:C ratio	Cost of cultivation (Rs./ha/year)	Net returns (Rs./ha/year)	B:C ratio
Absolute control	62572	31675	1.51	62710	33232	1.53
5% *Jeevamrit*	66597	35164	1.53	66735	40674	1.61
10% *Jeevamrit*	67947	36710	1.54	68085	43654	1.64
Beejamrit + 5% *Jeevamrit*	67015	46806	1.70	67154	50233	1.75
Beejamrit + 10% *Jeevamrit*	68365	43909	1.64	68504	51842	1.76
10 t/ha FYM + 5% *Jeevamrit*	112028	56039	1.50	114386	40701	1.36
10 t/ha FYM + 10% *Jeevamrit*	113378	48578	1.43	115736	40148	1.35
50% recommended N + 10 t/ha FYM + 5% *Jeevamrit*	122630	132080	2.08	124989	141650	2.13
50% recommended N + 10 t/ha FYM + 10% *Jeevamrit*	123980	127003	2.02	126339	144773	2.15
Recommended NPK	75706	193217	3.55	75844	191574	3.53
SEM	-	5786	0.06	-	4684	0.07
CD (P<0.05)	-	15358	0.20	-	14053	0.21

was found at par with absolute control, *Jeevamrit* (5 and 10%) and natural farming nutrient management practices (*Beejamrit* + 5% *Jeevamrit* and *Beejamrit* + 10% *Jeevamrit*). Marked decline in soil pH due to the application of chemical fertilizers alone could be attributed to the acid-producing nature of nitrogenous fertilizers (Magdoff *et al.*, 1997) that, upon nitrification, released H^+ ions which were a potential source of soil acidity. However, the marginal increase in soil pH observed in treatments involving conjoint use of organic manures and chemical fertilizers might be due to the moderating effect of organic manure (FYM) as it decreased the activity of exchangeable Al^{3+} ions in soil solution due to the chelation effect of organic molecules (Hue, 1992). Similar results were also reported by Hati *et al*. (2008) and Prasad *et al*. (2010).

Organic carbon content: The data on soil organic carbon content, irrespective of treatments, indicated slightly higher values of organic carbon content after completion of the sorghum + pearl millet-oat + *sarson* cropping system than the sorghum + pearl millet – wheat cropping system (Table 4). Production of more leaf litter, root biomass and short duration of sorghum + pearl millet - oat + *sarson* cropping system might have influenced the status of soil organic carbon content. After completion of both the cropping systems, integrated nutrient management practices of 50% recommended N + 10 t/ha FYM + 10% *Jeevamrit* and 50% recommended N + 10 t/ha FYM + 5% *Jeevamrit* resulted in significantly highest soil organic carbon content and remained at par with organic nutrient management practices of 10 t/ha FYM + 10% *Jeevamrit* and 10 t/ha FYM + 5% *Jeevamrit*, which further behaved statistically similar with inorganic practice of recommended NPK. Following after, natural farming nutrient management (*Beejamrit* + 5% *Jeevamrit* and *Beejamrit* + 10% *Jeevamrit*) and *Jeevamrit* (5 or 10%) treatments remaining at par with each other and absolute control could not significantly influence the soil organic carbon content as compared to integrated, organic as well as inorganic nutrient management practices. Improvement in soil organic carbon status with the treatments involving FYM and *Jeevamrit* might be due to the direct addition of organic matter through FYM and the stimulating effect of *Jeevamrit* with FYM on the growth and activity of microorganisms. This effect was further enhanced by the addition of NPK fertilizers that improved the root and shoot growth. Similar results were reported by Dhonde and Bhakare (2008), Katkar *et al.* (2012), Sepehya *et al.* (2012), Dixit *et al.* (2017) and Khan *et al.* (2017). Aulakh *et al.* (2013) in their study observed non-significant differences in soil organic carbon content with the application of *Jeevamrit* and stated that microbes present in *Jeevamrit* were purely saprophytic and devoid of specific characteristics.

Table 4. Effect of nutrient management treatments on soil properties of two cropping systems

Treatments	Sorghum + pearl millet – oat + *sarson*					Sorghum + pearl millet – wheat				
	pH	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	pH	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Absolute control	5.47	0.69	167	6.50	120	5.47	0.66	169	7.70	122
5% Jeevamrit	5.45	0.72	164	6.45	119	5.46	0.69	166	7.65	121
10% Jeevamrit	5.46	0.73	163	6.41	118	5.46	0.70	165	7.45	120
Beejamrit + 5% Jeevamrit	5.49	0.74	162	6.35	117	5.49	0.71	165	7.40	119
Beejamrit + 10% Jeevamrit	5.49	0.74	161	6.37	115	5.49	0.70	163	7.36	116
10 t/ha FYM + 5% Jeevamrit	5.64	0.86	204	15.01	174	5.64	0.82	212	15.84	178
10 t/ha FYM + 10% Jeevamrit	5.61	0.88	208	15.31	177	5.63	0.84	214	16.27	181
50% recommended N + 10 t/ha FYM + 5% Jeevamrit	5.55	0.94	254	24.68	186	5.56	0.87	263	25.46	190
50% recommended N + 10 t/ha FYM + 10% Jeevamrit	5.54	0.95	251	24.65	184	5.56	0.89	261	25.43	188
Recommended NPK	5.38	0.83	249	23.44	170	5.38	0.77	265	24.34	173
SEM	0.03	0.03	7.15	0.50	5.60	0.03	0.03	7.27	0.52	5.67
CD (P<0.05)	0.09	0.10	21.44	1.49	16.81	0.09	0.09	21.82	1.56	17.01
Initial	5.47	0.70	230	17.64	168	5.47	0.70	230	17.64	168

Available nitrogen, phosphorus and potassium: The data on soil available N, P and K, irrespective of treatments, indicated lower values after completion of the sorghum + pearl millet - oat + *sarson* cropping system than sorghum + pearl millet – wheat cropping system (Table 4). This might be due to the fact that sorghum + pearl millet - oat + *sarson* appeared to be an exhaustive cropping system and caused a considerable reduction in soil available nutrients than the sorghum + pearl millet– wheat cropping system. After the completion of both cropping systems, integrated nutrient management practices, *i.e.,* 50% recommended N + 10 t/ha FYM + 10% *Jeevamrit* and 50% recommended N + 10 t/ha FYM + 5% *Jeevamrit* and recommended NPK remaining at par with each other resulted in significantly highest values of soil available N, P and K contents. Following organic nutrient management practices of 10 t/ha FYM + 10% *Jeevamrit* and 10 t/ha FYM + 5% *Jeevamrit* resulted in significantly higher values of soil available N, P and K contents. Significantly lowest soil available N, P and K contents were recorded with natural farming nutrient management practices of *Beejamrit* + 5% *Jeevamrit* and *Beejamrit* + 10% *Jeevamrit*, which were found statistically at par with *Jeevamrit* (5 and 10%) treatments and absolute control. The continuous application of recommended doses of nitrogen through urea to fodder and cereal crops might be the cause for an appreciable build-up of nitrogen in the soil. Integrated nutrient management enhanced the available N content of soil due to the additional quantity of nitrogen supplied by FYM and also due to favorable soil conditions under organic manure (FYM), which might have helped in the mineralization of nutrients, leading to higher build-up of available N. The lower content under natural farming nutrient management practices was a result of mining of available N with continuous cropping without fertilization over a long period of time. Similar results were reported earlier (Kanwar *et al*., 2005; Chandrakala, 2008; Pathan and Kamble, 2012; Kashyap *et al*., 2017; Chaubey *et al*., 2018; Tomar *et al*., 2018). The build-up of available P with the application of NPK fertilizers in conjunction with FYM might be due to the release of organic acids during decomposition which in turn helped in releasing phosphorus through the solubilizing action of native phosphorus in soil. The results were in agreement with those of Verma *et al.* (2005), Urkurkar *et al*. (2010) and Thakur *et al.* (2011). An increase in available K due to the addition of FYM might be due to a reduction of potassium fixation and release of potassium due to the interaction of organic matter with clay, besides the direct potassium addition to the pool of soil (Urkurkar *et al.,* 2010).

Conclusion

The study conclusively indicated that in sorghum + pearl millet - oat + *sarson* and sorghum + pearl millet- wheat cropping systems, integrated nutrient management (50% recommended N + 10 t/ha FYM + *Jeevamrit*) and recommended NPK through inorganic sources resulted in higher green fodder equivalent yield, system productivity, nutrient uptake, monetary returns and soil available NPK content than organic and natural farming nutrient management practices. Hence, to have round the year fodder supply, sorghum + pearl millet - oat + *sarson* appeared to be a suitable cropping system.

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