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Integrated fertilization: An approach for higher apple (*Malus domestica*) productivity and ecological health of soil

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ABSTRACT

A field experiment was conducted to study the effect of organic and inorganic fertilizers supplemented with bio-fertilizers (*Azotobacter* and *Microphos*) on growth parameters of apple (*Malus domestica* Borkh. cv. Oregon Spur) for three years (2012 to 2014) in Srinagar, Jammu and Kashmir, India. The pooled data of three years revealed that, maximum fruit number (127/plant), fruit weight (113 g), yield/plant (14.5 kg), yield/ha (23.2 tonnes) and production efficiency (117g/cm^2 TCSA) were recorded in treatment received 75% of recommended dose of fertilizer (RDF) + 25% N through FYM + *Microphos* while minimum was recorded in control. The percentage increase in trunk cross section area during the three years of experiment was maximum 17.5% and 16.8% with application of 75% of RDF + 25% N through FYM + *Microphos* and *Azotobacter*, respectively, while minimum (8.0%) in control. Among the INM, treatment comprising 75% of RDF + FYM and biofertilizers (either *Azotobacter* or *Microphos*) was found significantly superior over rest of the treatments in-terms of improving soil health parameter, viz. dehydrogenase activity, organic carbon, available NPK and DTPA-Zn. Overall, study reveals that, through application of 75% of RDF + FYM and biofertilizers double the productivity of apple, which can gain the momentum of apple production in Kashmir valley of India with quality produce and maximize economic benefits to farmers.

Key words: Apple productivity, Bio-fertilizers, Integrated nutrient management, North-Western Himalayan region, Soil health

Apple (*Malus domestica* Borkh.) is one of the most important temperate fruits in North Western Himalayan Region (NWHR) of India, which accounts for 50% of total area and 64% of total production in India. Nutrient management through inorganic fertilizers has played a major role in accomplishing the enormous increase in apple production in past few years, but application of imbalanced and/or excessive inorganic fertilizers led to declining nutrient-use efficiency making fertilizer consumption uneconomical and producing adverse effects on atmosphere. Besides uneconomical use of chemical fertilization, it also leads to the deterioration of soil health. Even the use of heavy doses of inorganic fertilizers, the apple productivity (6.14) of country is far behind than the major apple producing countries like China (16.4 tonnes/ha), USA (31.1 tonnes/ha), Italy (40.1 tonnes/ha) and Chile (45.5 t/ha) (NHB 2016). Another major apprehension for improving apple productivity of the region is that, the majority of the orchards are under traditional density comprising old cultivars. Therefore, adoption of high density apple orcharding along with an integrated nutrient management module based on balanced supply of need based nutrient from inorganic, organic and biofertilizers at appropriate proportions and at specified time depending upon the age of the tree will effectively improve the productivity.

In general, most of the farmers apply fertilizers in single soil application during dormant season and no fertilizers are applied during vegetative, flowering and fruit growth stages of apple. Application of integrated manure and fertilizers may be a viable option for enhancing overall performance of apple trees in terms of yield and fruit quality (Verma and Chauhan 2013) and organic mulches also facilitates better availability of nutrients like N, P, K, Ca, Mg and B for enhancing fruit yield and quality without any negative effect (Merwe 2012). Recently, Das *et al.* (2016) advocated that integrated nutrient management by incorporation of organic manures in sufficient quantities and mulching increase the productivity of apple and improve the quality of produce under high density plantation. The soil organic matter (SOM) is generally associated with soil quality traits and is beneficial for apple yield and quality. Thus,

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maintaining SOM level in soil which is extremely essential for high and stable apple yield. Application of farmyard manure (FYM) is effective in enhancing the resistance and resilience of soil microorganisms, dehydrogenase activity and substrate induced respiration of soil (Kumar *et al.* 2013 and 2014) against heat stress, which indicates there is more functional as well as structural microbial diversity in soil. However, the systematic information on unified application of biofertilizers, FYM and inorganic fertilizers and their implications for long term soil productivity and sustainability are not well understood or characterized under North Western Himalayan Region. Considering all these, the present study was carried out with the objectives to examine the effect of integrated application of biofertilizer, FYM and inorganic fertilizer on apple productivity and soil health under high density plantation system of apple (Oregon Spur).

MATERIALS AND METHODS

Field experiment was conducted on eight-year-old uniform apple orchard of Oregon Spur variety grafted on seedling root stock at the research farm of the ICAR-Central Institute of Temperate Horticulture (CITH), Srinagar, Jammu and Kashmir, India, during 2012 to 2014 under plantation 4 × 4 m intra row spacing or 625 plants/ha with four replications under randomized block design. The research farm of Srinagar is situated in a latitude of 34° 05′ N and longitude of 74° 50′ E and at an altitude of 1640 m above mean sea level (MSL). The soils of this experimental field fall under Inceptisol and sandy loam in texture with sand 65%, silt 22% and clay 13%. The initial chemical characteristics of soil, viz. pH 6.7 (1:2.5 soil-water suspension), electrical conductivity 0.23 d/m (1:2.5 soil-water suspension), soil organic carbon (8.7 mg/kg), available-N (263 kg/ha), available-P (16.8 kg/ha), available-K (339 kg/ha) and DTPA extractable Zn, Cu, Fe and Mn are 0.54, 1.03, 10.4, and 7.2 mg/kg, respectively were recorded.

The experiment comprised nine treatments, viz T_1-Control (without fertilizer); T_2-Recommended dose of NPK (RDF); T_3-RDF + Zn +B; T_4-75% of RDF; T_5-75% of RDF+*Azotobacter*; T_6-75% of RDF+ *Microphos*; T_7-75% of RDF+25% N through FYM; T_8-75% of RDF+25% N through FYM+*Azotobacter*; T_9-75% of RDF+25% N through FYM+ *Microphos*. Recommended dose of fertilizers means 70:35:70 g of NPK/plant for one-year-old plant +10 kg FYM. The required quantity of organic fertilizer as per treatment combination was applied just after snow cover was over from field. The required quantities of chemical fertilizers were applied before bloom and after fruit set. Nitrogen was applied in 3 split doses, first dose (half the quantity) applied along with full dose of P and K, a fortnight before the bloom, second dose of nitrogen (1/4 of the total quantity) applied three weeks after fruit set and third dose (1/4 of total quantity) applied during fruit development stage, i.e. during last fortnight of May. The biofertilizers were applied with the first dose of chemical fertilizers as per recommended procedure. The experimental field was irrigated by drip irrigation and other cultural practices followed on uniform basis.

The observation on tree trunk girth was recorded before the execution and at the end of each year of experiment during study period. The trunk cross-sectional area (TCSA) of plant was calculated by using formula TCSA = Girth^2/4π. Plant yield attribute like fruit number, fruit weight was recorded at proper stage and yield/tree and yield/ha was calculated in kilogram (kg) and tonne (t) respectively. The productivity efficiency was calculated by the formula:

$$\text{Prouctivity efficienyt (g cm}^{-2}\text{ TCSA)} = \frac{\text{Fruit yield (g)}}{\text{TCSA (cm}^{-2}\text{)}}$$

Composite soil samples (i.e. 4 samples from each plant and thoroughly mixed to make one) were collected at 0-20 cm depth within plant area (just below plant canopy) after 30 days of third dose of fertilizer application for soil enzymes assay and after harvest of crop for physico-chemical properties of soil. The moisture content was immediately determined by gravimetric method. In a 1:2.5 (soil/water) soil suspension, soil pH and electrical conductivity were measured. Soil organic carbon was determined using potassium dichromate oxidation method. Available N determined by alkaline permanganate method (Subbaiah and Asija 1956), available P (Watanabe and Olsen 1965), available potassium determined by ammonium acetate method (Hanway and Heidal 1952), DTPA extractable micronutrients (Lindsay and Norvell 1978). Dehydrogenase activity (DHA) was determined, using the reduction of 2,3,5-triphenyltetrazolium chloride (3%) method (Klein *et al.* 1971).

Measured variables were submitted for analysis of variance (ANOVA) and comparisons among means were made using the Tukey's honest significant difference test using SAS 9.3 version packages (Chicago, IL, USA). Unless otherwise stated, the level of significance referred to in the results is $P < 0.05$.

RESULTS AND DISCUSSION

Trunk cross sectional area **(***TCSA***)**

Data on trunk cross section area (TCSA) of apple tree as influenced by integrated use of inorganic fertilizer and FYM with biofertilizers over the year presented in Table 1. In 2014, maximum TCSA (133/cm^2) was recorded in 75% RDF + 25% N through FYM + *Microphos* (T_9) treatment, which was statistically at par with T_7, and T_8 treatments and minimum TCSA (108/cm^2) was recorded in T_1 (control). On the basis of average of three years data, maximum (123/cm^2) TCSA was also observed with the 75% RDF + 25% N through FYM + *Microphos* (T_9) treatment which was significantly higher as compared to most of the treatments except T_7 and T_8. The maximum enhancement in TCSA in FYM + biofertilizers treatments over the year as compared to control (T_1) might be due to use of biofertilizers along with organic fertilizer had a beneficial effect on favorable soil microorganism which help in timely transformation of

Table 1 Effect of integrated application of biofertilizer and farm-yard manure on trunk cross section area (TCSA) of apple var. Oregon Spur

Treatment	Trunk cross section area (cm^2)				
	2012	2013	2014	Average	% change
T_1	100^{c}	104^{d}	108^{d}	104^{d}	8.0^{d}
T_2	102^{bc}	107^{cd}	113^{cd}	107^{cd}	11.2^{bc}
T_3	106^{abc}	112^{bc}	120^{bc}	113^{bc}	12.9^{b}
T_4	103^{bc}	108^{bcd}	114^{cd}	108^{bcd}	10.1^{c}
T_5	107^{ab}	111^{bcd}	117^{bc}	112^{bc}	9.9^{cd}
T_6	107^{ab}	112^{bc}	119^{bc}	113^{bc}	11.4^{bc}
T_7	107^{ab}	115^{ab}	124^{ab}	115^{ab}	16.2^{a}
T_8	113^{a}	121^{a}	132^{a}	122^{a}	16.8^{a}
T_9	113^{a}	122^{a}	133^{a}	123^{a}	17.5^{a}
Mean	106	112	120	113	12.7
SE(d)	3.02	3.38	3.78	3.35	0.87
LSD (P = 0.05)	6.97	7.80	8.73	7.72	2.01

Means followed by same letter are not significantly (P < 0.05) different according to Duncan's multiple range test.

Table 2 Effect of integrated application of biofertilizer and farm yard manure on fruit number and fruit weight (g) of apple var. Oregon Spur

Treatment	Fruit number				Fruit weight (g)			
	2012	2013	2014	Average	2012	2013	2014	Average
T_1	77^{c}	80^{e}	81^{e}	79^{d}	91	100^{b}	99^{b}	97
T_2	96^{ab}	96^{d}	105^{cd}	99^{c}	109	111^{ab}	111^{ab}	110
T_3	99^{ab}	111^{c}	123^{bc}	111^{b}	106	120^{a}	118^{a}	114
T_4	87^{bc}	92^{d}	100^{de}	93^{c}	110	114^{ab}	108^{ab}	110
T_5	103^{a}	114^{c}	108^{bcd}	108^{b}	101	104^{b}	110^{ab}	105
T_6	98^{ab}	111^{c}	119^{bcd}	109^{b}	104	109^{b}	115^{ab}	109
T_7	98^{ab}	121^{bc}	128^{ab}	116^{b}	102	110^{b}	111^{ab}	108
T_8	103^{a}	126^{ab}	147^{a}	125^{a}	103	113^{ab}	117^{ab}	111
T_9	101^{a}	134^{a}	146^{a}	127^{a}	102	117^{a}	121^{a}	113
Mean	95	109	117	107	103	111	112	108
SE(d)	5.35	4.94	8.75	3.42	7.52	4.59	7.20	7.31
LSD (P=0.05)	12.3	11.3	20.1	07.8	NS	10.3	16.5	NS

Means followed by same letter are not significantly (P < 0.05) different according to Duncan's multiple range test.

nutrient from unavailable pool to available pool. The highest (17.5%) change in TCSA was recorded in T_9 treatment and statistically higher with rest of treatments except T_7 and T_8 treatments. Minimum (8.0%) change in TCSA was recorded in T_1 treatment which was at par with T_5 treatment. Kumar *et al.* (2015) reported that FYM significantly influenced the growth parameters of almond tree which confer our results. Lepsis and Blanke (2004) advocated that the TCSA being a more reliable indicator of vegetative growth intensity and a yield forecasting model in apple.

Fruit number and fruit weight

Fruit number and fruit weight were affected by different INM treatments of apple (Table 2). The number of fruit and fruit weight increased with increasing the age of apple tree or over the years in all the treatments. Overall average of three years' data revealed a significantly higher (127) number of apple fruits was recorded in T_9 treatment which was at par with T_8 treatment as compared to rest of other treatments. This effect might be due to the production of phytohormones produced by biofertilizers near root morphology and in turn influencing assimilation of nutrients for sufficient nutrients supply to the plants. Treatments T_5 and T_6 were inferior in respect of number of fruits when fertilizer was applied as 75% RDF along with biofertilizer alone, but these treatments were at par with T_7 and T_3 treatment in respect of number of fruits. Minimum number of fruits (79) was recorded in T_1 treatment. In case of fruit weight of apple, maximum fruit weight (113.0 g) and minimum (97 g) was observed in T_9 and T_1 treatments. Increase in fruit weight and fruit number with combined application of biofertilizer and FYM might be due to constant shoot growth during spring which provides enough photosynthetic area for fruit growth and development.

Yield

Fruit yield of apple as influenced by different treatment is given in Table 3. Maximum fruit yield (17.7 kg/plant) in 2014 and minimum (7.0 kg/plant) in 2012 was recorded with 75% RDF + 25% N through FYM + *Microphos* (T_9) and control (T_1), respectively. Both treatments T_9 and T_8 were at par, but significantly higher as compared to other rest of the treatments in respect of fruit yield of apple. The use of organic and biofertilizers resulted in higher yield as compared to rest of the treatments due to higher fruit number as well as fruit weight which might be due to more spur density apart from better fruit set and retention due to proper supply of nutrients by solubilization and mineralization effect of biofertilizers. On the basis of average of three years data, significant highest yield of apple (23.2 tonnes/ha) was recorded in T_9 treatment and at par with T_8 treatment. The minimum yield of fruits yield (12.3 tonnes/ha) was observed in control (T_1). In case of percent changes in fruit yield, the treatment T_9 recorded maximum (73.2%) changes in fruit yield of apple which was statistically at par with T_7 (42.9%) and T_8 (62.7%) treatments. The minimum (10.9%) changes in fruit yield was observed with 100% RDF followed T_4 (12.9%)<T_1(14.1%)< T_5(14.8%)< T_6(35.2%)< T_3 (40.3%). The maximum fruit weight, fruit number and yield under T_9 treatment were higher obviously due to the vigorous plant growth. In treatments T_9 and T_8 vigorous plant growth might be due to effective colonization of introduced microorganism which changed the soil microbial community composition (Zhao *et al.* 2014) and improved the fertility of soil. These results were in accordance with the results of Verma and Chauhan (2013). Das *et al.* (2016) also reported integrated application of organic manure and inorganic fertilizers may

Table 3 Effect of integrated application of biofertilizer and farmyard manure on yield and production efficiency of apple var. Oregon Spur

Treatment	Yield (kg/plant)				Yield (t/ha)					Production efficiency (g/cm^2 TCSA)			
	2012	2013	2014	Mean	2012	2013	2014	Mean	% Change	2012	2013	2014	Mean
T_1	7.0	8.1^{e}	8.0^{e}	7.7^{f}	11.2	12.9^{e}	12.8^{e}	12.3^{f}	14.1^{cd}	70	78^{c}	74^{d}	74^{c}
T_2	10.5	10.6^{d}	11.6^{cd}	10.9^{de}	16.8	17.0^{d}	18.7^{cd}	17.5^{de}	10.9^{d}	103	99^{bc}	102^{bc}	101^{ab}
T_3	10.4	13.2^{bc}	14.6^{b}	12.7^{bc}	16.6	21.2^{bc}	23.3^{b}	20.4^{bc}	40.3^{bcd}	97	117^{ab}	122^{ab}	112^{ab}
T_4	9.5	10.5^{d}	10.7^{d}	10.2^{e}	15.2	16.8^{d}	17.2^{d}	16.4^{e}	12.9^{cd}	92	97^{bc}	94^{cd}	94^{b}
T_5	10.3	11.8^{cd}	11.8^{cd}	11.3^{cde}	16.5	18.9^{cd}	19.0^{cd}	18.1^{cde}	14.8^{cd}	96	106^{ab}	100^{c}	101^{ab}
T_6	10.1	12.0^{bcd}	13.6^{bc}	11.9^{cd}	16.1	19.2^{bcd}	21.9^{bc}	19.1^{cd}	35.2^{bcd}	94	106^{ab}	114^{abc}	105^{ab}
T_7	10.0	13.3^{abc}	14.1^{b}	12.4^{bcd}	16.0	21.3^{abc}	22.5^{b}	19.9^{bcd}	42.9^{abc}	93	115^{ab}	113^{abc}	107^{ab}
T_8	10.6	14.2^{ab}	17.1^{a}	14.0^{ab}	17.0	22.7^{ab}	27.4^{a}	22.4^{ab}	62.7^{ab}	94	117^{ab}	129.4^{a}	113^{a}
T_9	10.2	15.6^{a}	17.7^{a}	14.5^{a}	16.4	25.0^{a}	28.4^{a}	23.2^{a}	73.2^{a}	90	127^{a}	133^{a}	117^{a}
Mean	9.8	12.1	13.2	11.7	15.8	19.4	21.2	18.8	34.1	92.5	107	109	109
SE(d)	0.86	1.03	0.92	0.67	1.39	1.64	1.46	1.08	13.52	9.72	10.49	9.10	9.10
LSD (P=0.05)	NS	2.39	2.13	1.56	NS	3.79	3.38	2.50	31.2	NS	24.2	20.9	20.9

Means followed by same letter are not significantly ($P < 0.05$) different according to Duncan's multiple range test.

be a better option for enhancing yield and fruit quality of apples. Mean production efficiency (PE) of apple ranged from 74 to 117 g/cm^2 TCSA with different treatments. Highest PE of apple (117 g/cm^2 TCSA) was recorded with 75% RDF + FYM +*Microphos* (T_9) followed by T_8 (113 g/cm^2 TCSA) and T_3 (112 g/cm^2 TCSA) treatment and minimum PE 74 g/cm^2 TCSA in control.

Soil properties

Soil physico-chemical and microbiological properties like soil reaction, soil organic carbon (SOC) content, available N, P and K contents, dehydrogenase activity (DHA) in apple orchard after three years were significantly affected by different treatments (Table 4). The treatment comprising 75% RDF + 25% N through FYM + *Microphos* (T_9) in apple improved the pH, EC, SOC, DHA, available major nutrients as well as DTPA extractable zinc than where biofertilizer and FYM used alone under the different treatments. No significant difference among different treatments in DTPA extractable Cu, Fe and Mn were observed after three years of experiment (Table 4).

Soil pH was recorded in the range of 6.40 (T_3) to 6.97 (T_8) under different treatments in the 0-20 cm soil depth after three years of the study. Data also revealed that there was a positive skeweness in soil pH towards neutral by use of FYM and biofertilizers. Soil electrical conductivity recorded higher values in the organic treatments, especially in the treatment comprising FYM alone, possibly because of the elevated soluble salts content of the manure, which might be converted to other form. Significant highest SOC 10.9 g/kg was recorded with 75% RDF + 25% N through FYM+*Microphos* (T_9) treatment and at par with T_7 and T_8 treatments and lowest organic carbon (8.53 g/kg) noticed in control. The increase in SOC in the FYM treated soil may be due to the high C/N ratio, cellulose and lignin content in the added FYM. FYM application have accelerated the plant growth, photosynthetic carbon assimilation and root exudation, thereby, accelerated microbial activity or microbial biomass content of soils, eventually resulted in organic C accumulation in soil. In the period of our study, enhancement of SOM and fertility was observed, which is consistent with other long-term organic fertilizer experiments (Ge *et al.* 2013, Sharma *et al.* 2015).

The integrated use of 75% recommended dose of fertilizer with biofertilizer and FYM significantly enhanced the available N, P and K. Significant highest N (334 kg/ha) and P (24.2 kg/ha) were recorded under 75% RDF+25% N through FYM+*Microphos* (T_9) treatment, which were superior over other treatments except T_7 and T_8, while significant highest available K (387 kg/ha) was recorded with T_8 treatment, which was statistically at par with T_2, T_3, T_5, T_7 and T_9 treatments. The treatments T_7, T_8 and T_9 were statistically at par with each other in respect of available N and P. The fact that the highest values of available N and P were found in the organic fertilization systems which suggests that N and P, mainly present in organic forms, was were released gradually through mineralization and/ or solubilization, enriching the soil and supplying N and P to the crop.

The DTPA- Zn content in soil improved significantly (0.30 to 0.80 mg/kg) with 75% RDF+ 25% N through FYM+*Microphos* (T_9) (0.80 mg/kg) treatment and at par with T_6, T_7 and T_8 treatments. Rest of the treatments were similar in respect of DTPA-Zn, other DTPA extractable micronutrients Cu, Fe and Mn in post-harvest of soil ranged from 0.80-1.15 mg/kg, 8.40-11.85 mg/ kg and 6.25-9.90 mg/kg respectively, they were not significantly influenced due to application of RDF along

Table 4 Fertility status of post-harvest soil as influenced by integrated application of biofertilizer and farm yard manure in apple (var. Oregon Spur) orchard

Treatment	pH	EC (dS/m)	SOC (g/kg)	DHA (µg TPF/hr/g soil)	Available major nutrients (kg/ha)			Available micro nutrients (µg/kg)			
					N	P	K	Zn	Cu	Fe	Mn
T_1	6.64	0.25^{a}	8.53^{c}	10.3^{e}	247^{d}	15.5^{d}	321^{c}	0.30^{d}	0.80	8.40	6.25
T_2	6.72	0.18^{c}	9.37^{bc}	12.1^{de}	299^{bc}	21.1^{b}	359^{ab}	0.40^{d}	1.04	8.90	6.65
T_3	6.40	0.20^{b}	9.53^{ab}	14.9^{bc}	310^{ab}	20.9^{b}	361^{ab}	0.65^{bc}	1.15	11.45	9.60
T_4	6.74	0.20^{b}	8.45^{c}	10.8^{e}	281^{c}	17.6^{cd}	345^{bc}	0.55^{c}	1.11	11.95	8.10
T_5	6.70	0.21^{b}	0.93^{bc}	15.2^{bc}	282^{c}	17.3^{cd}	375^{ab}	0.60^{bc}	1.10	10.30	8.75
T_6	6.73	0.22^{b}	9.42^{bc}	13.3^{cd}	292^{bc}	19.4^{bc}	343^{bc}	0.70^{ab}	1.13	10.05	7.50
T_7	6.84	0.26^{a}	10.1^{ab}	15.7^{bc}	316^{ab}	21.1^{b}	373^{ab}	0.70^{ab}	0.98	10.75	9.05
T_8	6.97	0.20^{b}	10.7^{a}	16.3^{ab}	315^{ab}	23.5^{a}	387^{a}	0.70^{ab}	0.99	11.80	8.45
T_9	6.90	0.20^{b}	10.9^{a}	18.4^{a}	334^{a}	24.2^{a}	376^{ab}	0.80^{a}	1.06	11.35	9.90
Mean	6.74	0.21	0.96	14.1	297	20.1	360	0.60	1.04	10.55	8.25
SE(d)	0.26	0.01	0.07	1.08	10.6	0.95	17.9	0.05	0.08	2.03	1.06
LSD (P=0.05)	NS	0.02	0.15	2.51	24.4	2.19	38.2	0.13	NS	NS	NS

Means followed by same letter are not significantly ($P < 0.05$) different according to Duncan's multiple range test. * EC- Electrical Conductivity; SOC- Soil organic carbon; DHA- Dehydrogenase activity of soil.

with biofertilizer and FYM, but recorded increasing trend in DTPA-Cu, Fe and Mn. The increase in micronutrients content in soil, especially DTPA-Zn in FYM treatment might be due to FYM involved in formation of chelates with organic ligands which have lowered susceptibility to adsorption, fixation and precipitation in the soil and also it was attributed to mineralization of organic manures and consequent release of micronutrients which might have resulted in better uptake by the crops and responses well in terms of yield.

Significant highest DHA (18.4 µg TPF/hr/g soil) was recorded in 75% RDF+ 25% N through FYM+*Microphos* (T_9) treatment, which was superior over rest of other treatments except treatment T_8. Dehydrogenase enzymes present in viable cells, and it reflect the total range of oxidative capacity of soil microflora and considered an indicator of microbial activity in soil. Higher DHA with NPK + FYM fertilizer applications has also been reported earlier by Kumar *et al.* (2014) under long-term fertilizer experiment. The increase in DHA was 78.6 and 58.3% in T_9 and T_8 treatments respectively over control. The results are in conformity with the finding of Sharma *et al.* (2016) and observed significantly higher DHA due to integrated use of fertilizer with FYM @ 10 t/ha in pearl millet based cropping system as compared to FYM alone.

The present study suggests that apple trees (var. Oregon Spur) under high density plantation are very responsive to the application of 75% RDF + 25% N through FYM + biofertilizers (*Microphos*/*Azotobacter*) and this particular treatment improved apple productivity soil health components. Application of this particular treatment not only improve productivity to almost double but also lead to sustainable apple production by improving soil health. In nut shell, it is a cost effective and economically viable technology for apple grower under high density plantation.

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