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LONG TERM EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON PEARL MILLET-WHEAT CROPPING SYSTEM - A REVIEW

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SUMMARY

Food security for a huge country like India, with high density of population in general and below poverty line is of vital importance. India has to produce around 300 mt of food grains by 2025 A.D. to nourish over 1.4 billion population from 0.15 ha land per capita or less. To feed this burgeoning population, many intensively cropped cereal based cropping systems are under cultivation in the country. Pearl millet [*Pennisetum glaucum* (L.) R. Br. Emend. Stuntz.] - wheat (*Triticum aestivum* L.) is one of the important cropping systems of the country and spreads over arid eco-region; semi-arid eco-region with alluvium derived soils. Higher food production needs higher amount of plant nutrients. To avoid wastage of resources and to reduce the environmental damage, there is a need to develop and demonstrate balanced use of organic/inorganic fertilizers. This will not only ensure the crop production in a sustainable way but also sustain the crop production system. As no single source of nutrient is capable of supplying the balanced amount of nutrients, integrated use of all sources is a solution to supply balanced nutrients. Long term studies being carried out at several locations on different cropping systems indicated that application of all the needed plant nutrients through chemical fertilizers has deleterious effect on soil health. Since, the nutrient turnover in soil-plant system is considerably high under intensive cropping system. So, neither the chemical fertilizers nor the organic/biological sources alone can achieve production sustainability. Even with the so called balance use of NPK fertilizers in long term studies, higher yield levels could not be maintained for years because of emergence of secondary and micro-nutrient deficiency and deterioration in the soil physical properties. Organic manure alone or in combination with inorganic fertilizers are known to have favourable effect on soil and can correct marginal deficiency of secondary & micro-nutrients and interns will ensure efficient supply of applied nutrients. Therefore, there is need to strengthen nutrient supply system especially through INM for sustainable production of this cropping system. Use of chemical fertilizers in conjunction with FYM, vermicompost, green manure, wheat straw etc. have proven good for sustainability of pearl millet- wheat cropping system which have been thoroughly discussed in this review.

Key word : Pearl millet-wheat cropping system, productivity, OC, INM, FYM, fertilizer

Last five decades have witnessed a phenomenal growth in production and productivity of Indian agriculture. Now, India has gained self sufficiency in food production. The food grain production quadrupled from a low of 51.0 mt in 1950-51 to 275.11 mt in 2016-17 (Anonymous, 2017). The population in India has crossed 1.2 billion. The country has to produce around 300 mt of food grains by 2025 A.D. to feed over 1.4 billion population from 0.15 ha land per capita or less. To feed this huge population many intensively cropped cereal based cropping systems are under cultivation in India.

Agricultural research had been oriented towards developing agro-technologies for commodity and components rather than a production system. Only in recent years, it has been widely recognized that system oriented production research is needed to be strengthened as it is essential for maximizing land productivity.

In India, pearl millet [*Pennisetum glaucum* (L.) R. Br. Emend. Stuntz.]-wheat (*Triticum aestivum* L.) is one of the important cropping system and spreads over arid eco-region comprising western plains, Kachh and parts of Kathiawar Peninsula in Gujarat, Rajasthan and southern parts of Haryana; semi-arid eco-region comprising northern plains of Haryana, western UP and central high lands of Rajasthan with alluvium soils. During the last five decades, consumption of chemical fertilizers (NPK) has increased phenomenally from 0.07 mt in 1950-51 to 25.95 mt in 2016-17

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(Anonymous, 2017). There is a considerable gap between production and consumption of chemical fertilizers. Therefore, currently Indian agriculture is operating on a negative balance of plant nutrients at the rate of 8-10 mt per annum. With the application of recommended dose of fertilizers, yield potential of this cropping system (cereal-cereal) has reached to a plateau because of deteriorated soil health and especially low organic matter content. Higher food production needs higher amount of plant nutrients Without careful management, manures can cause yield loss and lower crop quality as a result of both under and over fertilization. To avoid wastage of resources and to minimize the environmental damage there is a need to develop and demonstrate balanced use of organic/inorganic fertilizers. This will not only improve the crop production in sustainable way but also ensure better economic returns from the crop production. No single source is capable of supplying the balanced amount of nutrients; integrated use of all sources is a must to supply balanced nutrients to plants (Hedge and Babu, 2004).

Long term experiments being carried out at many locations on different cropping systems indicated that application of all the essential nutrients through chemical fertilizers has deleterious effect on soil health, leading to stagnated yields (Swarup, 2002; Behra *et al.*, 2007). This further has led to aggravated micro-nutrient deficiency in soil system. Since, the nutrient turnover in soil-plant system is considerably high under intensive cropping system. So, neither the chemical fertilizers nor the organic/biological sources alone can achieve production sustainability. Even with the so called balance use of NPK fertilizers in long term studies, higher yield levels could not be maintained for years because of emergence of secondary and micro-nutrient deficiency and deterioration in the soil physical environment. Whereas, organic manure alone or in combination with inorganic fertilizers is known to have favourable effect on soil environment and correct marginal deficiency of secondary and micro-nutrients and enhance efficiency of applied nutrients. Therefore, there is need to improve nutrient supply system for sustainable production of this very important cropping system of India.

Organic matter contributes significantly to the soil reserves of N, P, K and S and other essential plant nutrients. However, less than 50% N contained in organic matter is available to the immediate crop to which it is applied, depending on the state of its decomposition, C N ratio, aeration and other factors. Organic sources when applied to preceding crop, leaves the residual effect and this benefit is harvested by succeeding crop to a greater extent (Kumpawat, 2004; Meena *et al.*, 2008) and system becomes sustainable through integrated use of organic and inorganic sources of nutrients. Cropping systems is dynamic in time and space, making it difficult to precisely determine their spread using conventional methods, over a large acreage. Throughout the country, more than 250 double cropping systems are followed and pearl millet-wheat is among the important cropping systems spread over north-west plain zone and central India. The yield potential of this cropping system (cereal-cereal) has reached to a plateau with the application of recommended dose of fertilizers (RDF) because soil health has deteriorated and especially organic matter has depleted. Therefore, there is need to improve nutrient supply system especially through integrated nutrient management (INM) for sustainable production for this cropping system.

An attempt has been made to review the pertinent research work done by various workers in different agro climatic conditions on pearl millet-wheat cropping system in respect of INM. The available information is reviewed under following heads:

Effect of Nutrient sources on crop and soil

Inorganic sources

Effect on crops

Many research workers have reported that imbalance use of chemical fertilizers affects the crop productivity. Patidar and Mali (2001) reported that with successive increase in fertilizer levels from 75% to 100% RDF significantly enhanced N (157.0 kg/ha), P (47 kg/ha) and K (247 kg/ha) uptake by sorghum in sorghum-wheat sequence.

Hegde and Katyal (1999) based on a long term study reported that at Hanumangarh both pearl millet and wheat responded significantly to N upto 120 kg/ ha. However, the magnitude of response in both crops was lower during initial years (1977-82), reached the peak during 1982-87 and declined in the following years (1987-90). At Junagarh, during initial 10 years (1977-87) pearl millet responded significantly only upto 80 kg N/ha, but in later years (1988-91) there was significant response even upto 120 kg N/ha. In case of wheat response was upto 80 kg/ha except

during 1981-86 when it responded upto 120 kg N/ha. At Bichpuri, both crops responded significantly up to 120 kg N/ha. They further reported that at Hanumangarh, pearl millet responded significantly to P application only upto 175 kg/ha, but wheat responded even up to the highest level of 345 kg/ha. At Junagarh, they recorded significant response even upto 349 kg P/ha in pearl millet and wheat crop also responded significantly upto 349 kg/ha. At Bichpuri, both pearl millet and wheat responded only upto 175 kg P/ha. In response to K they reported that at Hanumangarh pearl millet started showing significant response to K only after 5 cycles of pearl millet-wheat cropping, but in wheat no response to K was observed.

Patidar and Mali (2001) observed that application of FYM increased net gain from sorghum-wheat sequence by Rs. 3428/ha, though maximum net returns of Rs. 49335/ha were obtained under 100 per cent recommended dose of fertilizers followed by Rs. 47229 under 75 per cent recommended dose of fertilizers compared with Rs 38231 under control.

Beneficial effects of fertilizer N + P on plant height in wheat have been reported by Patidar and Mali (2001) reported that application of chemical fertilizers at different levels i. e. 50%, 75% and 100% RDF significantly increased plant height and LAI in sorghum in sorghum-wheat sequence.

Katyal *et al.* (2002) reported that with application of 100% NPK through chemical fertilizers to both pearl millet and wheat resulted in significantly higher yield of pearl millet (2.38 t/ha) and wheat (4.08 t/ha). Maximum productivity of the system to the tune of 6.44 t/ha was obtained with 100% NPK applied to both crops through inorganic fertilizers. Jain and Poonia (2003) reported that application of recommended dose of inorganic nutrients (90, 13.2

TABLE 1

Effect of integrated nutrient supply on average grain yield (kg/ha) of pearl millet and wheat

Treatment	Hisar Average of 9 years			Hanumangarh Average of 7 years			Sardar Krushinagar Average of 7 years			Junagrah Average of 5 years			Bichpuri Average of 3 years		
	Pearl millet	Wheat	Total	Pearl millet	Wheat	Total	Pearl millet	Wheat	Total	Pearl millet	Wheat	Total	Pearl millet	Wheat	Total
T_1	1110	1497	3056	1056	0861	2175	0249	0379	0842	0857	1497	2803	1225	1288	2899
T_2	1609	2957	5453	2273	2751	5849	0995	1166	2511	1253	2427	4408	1785	3094	5807
T_3	1741	3722	5680	2340	3560	6968	1084	1823	3454	1375	2928	5181	1885	4278	7466
T_4	1905	3485	6434	2382	3261	6621	1119	1431	2979	1398	2586	4760	2068	4015	7287
T_5	2448	3937	7566	2508	3663	7270	1302	1552	3320	1483	2851	5189	2262	4545	8170
T_6	2038	3944	7165	2364	3845	7362	1225	1736	3482	1568	3106	5606	2059	4600	8032
T_7	2235	3602	6918	2331	3236	6538	1394	1685	3584	1532	2835	5217	2116	4126	7480
T_8	1610	3600	6290	2295	3572	6935	1145	1790	3472	1448	2954	5288	1901	4415	7640
T_9	1719	3535	6386	2342	3377	6732	1202	1438	3071	1411	2824	5082	2029	4001	7230
T_{10}	2012	3903	7086	2639	4044	7894	1666	1633	3789	1621	2952	5459	1754	4416	7445
T_{11}	2145	3598	6822	2519	3682	7306	1835	1478	3756	1539	2699	5048	1957	3944	7084
T_{12}	1668	2772	5272	2283	3310	6586	1076	1393	2887	1331	2803	4975	1623	2837	5311

(Source : Hegde, 1998)

Treatment details:

Treatment	*Kharif*	*Rabi*
T_1	Control (no fertilizer)	Control (no fertilizer)
T_2	50% recommended NPK dose through fertilizers	50% rec NPK dose through fertilizers
T_3	50% recommended NPK dose through fertilizers	100% NPK dose through fertilizers
T_4	75% recommended NPK dose through fertilizers	75% rec NPK dose through fertilizers
T_5	100% recommended NPK dose through fertilizers	100% rec NPK dose through fertilizers
T_6	50% recommended NPK dose through fertilizers+50% N through FYM	100% rec NPK dose through fertilizers
T_7	75% recommended NPK dose through fertilizers+25% N through FYM	75% rec NPK dose through fertilizers
T_8	50% recommended NPK dose through fertilizers+50% N through wheat straw	100% rec NPK dose through fertilizers
T_9	75% recommended NPK dose through fertilizers+25% N through wheat straw	75% rec NPK dose through fertilizers
T_{10}	50% recommended NPK dose through fertilizers+50% N through GM	100% rec NPK dose through fertilizers
T_{11}	75% recommended NPK dose through fertilizers+25% N through GM	75% rec NPK dose through fertilizers
T_{12}	Farmer's Practice	Farmer's Practice

kg NP/ha) resulted in significant improvement in plant height, number of effective tillers per metre row length, ear length and test weight of pearl millet compared with application of FYM or vermicompost alone or integrating their use at half the rates with inorganic nutrients @ 40, 8.8 kg N and P/ha. Khan *et al.* (2005) observed that the yields of crops were 36-78% lower in organic treatment compared to treatment receiving 100% recommended NPK through inorganic fertilizers

Yadav *et al.* (2005) reported that plant height and effective tillers/m row increased significantly with each successive increment of N from 120 to 180 kg/ ha. While grains/earhead increased significantly with 180 kg N/ha over 120 kg N/ha. Effective tillers/m row length increased by 29.3% with 180 kg N/ha over 120 kg N/ha. This might be due to the fact that nitrogen plays a vital role both in cell division and cell enlargement as well as increased sink size. Application of N up to 150 kg/ha significantly increased the grain yield. The increased in grain yield was 12.3 and 17.3% with 150 and180 kg/ha, respectively, over 120 kg N/ ha. Jain and Dahama (2006) reported that increasing Zn rate upto 12 kg/ha, supplied to the preceding wheat crop, reduced P content and increased Zn content in grains and stover in pearl millet.

Shukla *et al.* (2005) reported that depending upon the crops, the treatment where 100% NPK were supplied through organic manures gave 40-85% lower yield compared to treatment receiving 100% recommended NPK through inorganic fertilizers. Parihar *et al.* (2006) stated that increasing levels of N application increased N, P and K contents both in grain and stover and their uptake significantly Such increase in N content in stover, P and K content in grain and stover and N, P and K uptake were variables. Sammauria and Yadav (2008) reported that residual effect of 40 kg P_2O_5/ha significantly enhanced the effective tillers/plant of succeeding pearlmillet**,** whereas ear length and test weight increased up to residual effect of 60 kg P_2O_5/ha. Residual effect of 50 kg Zn/ha significantly increased effective tillers, stover and biological yields, whereas seed yield and harvest index improved significantly up to 7.5 kg Zn/ha and ear length and test weight improved only up to 2.5 kg Zn/ha.

Bahar *et al.*, (2008) observed that greater fertilizers application and seed priming helped the plants to maintain canopy temperature (higher canopy temperature depression) due to higher rates of transpiration. These treatments also had higher rates of photosynthesis in flag leaves measured at anthesis. Barnaba *et al.,* (2008) studied grain yield of eight semi dwarf spring wheat cultivars to recognize the physiological basis of selection for grain yield. These traits were closely and positively correlated with increase in the mean yield. Some leaf traits like stomatal conductance, photosynthetic rate and canopy temperature were determined.

Some leaf traits like stomatal conductance, photosynthetic rate and canopy temperature were determined Kumar *et al.*, (2012) reported on the mean basis that number of grain increased by 12.6 and 23.42 %, number of effective tillers m^{-2} increased by 5.3 and 9.1 %, respectively, of wheat measured under lowest level of fertilizers.

Sheoran *et al.* (2016) reported that under semi arid conditions the increasing levels of nitrogen from 0 to 90 kg/ha significantly increased the green fodder and dry matter yield over their lower levels. Application of 90 kg/ha brought out an increase of 44.3, 29.7 and 7.0 per cent in green fodder and 54.0, 18.2 and 3.7 per cent in dry matter over 0, 30 and 60 kg/ha, respectively.

Satpal *et al.* (2017) under semi arid conditions of Hisar recorded that the sorghum crop fertilized with 100 RDF (Nitrogen: 75 kg/ha & Phosphorus: 15 kg/ a) significantly higher total green and dry fodder yield over the application of 50 and 75 per cent RDF. The magnitude of the increase with RDF was 33.95 and 12.84 per cent in total green fodder; and 55.31 and 21.14 per cent in total dry fodder yield over 50 and 75 per cent RDF, respectively

Jat and Kaushik (2018) reported that 110 kg N/ha produced significantly higher nitrogen 314.49 and 309.94 kg/ha, crude protein 1965.59 and 1937.13 kg/ha, crude fibre 5271.72 and 5061.22 kg/ha, ether extract 308.28 and 303.25 kg/ha, mineral matter 1290.18 and 1277.18 kg/ha, nitrogen free extract 8759.00 and 8877.58 kg/ha and total digestible nutrient 12688.15 and 12595.72 kg/ha.

Effect on soil

The soil health is deteriorated due to continuous use of chemical fertilizers across the country many research workers have reported effect of chemical fertilizers on soil health concluded that pearl millet-wheat sequence exhausted large amount of NPK from the soil and resulted in increasing the fertility status of soil.

Shelke *et al.* (1997) reported that application of recommended dose of nutrients through inorganic

TABLE 2(A)
Effect of sources of nutrients on organic carbon (%) after pearl millet in pearl millet-wheat cropping system

Treatmentr	Years								
	2008	2009	2010	2011	2012	2103	2014	2015	2016
T_1	0.41	0.39	0.35	0.32	0.34	0.33	0.34	0.35	0.36
T_2	0.48	0.43	0.39	0.36	0.37	0.36	0.39	0.40	0.42
T_3	0.50	0.47	0.42	0.38	0.40	0.38	0.40	0.41	0.43.
T_4	0.51	0.48	0.43	0.37	0.39	0.41	0.40	0.42	0.44
T_5	0.52	0.51	0.46	0.44	0.47	0.44	0.47	0.49	0.50
T_6	0.56	0.52	0.48	0.46	0.42	0.47	0.48	0.51	0.52
T_7	0.55	0.51	0.46	0.43	0.38	0.42	0.43	0.42	0.46
T_8	0.52	0.48	0.42	0.39	0.40	0.39	0.39	0.44	0.46
T_9	0.49	0.48	0.42	0.38	0.40	0.39	0.39	0.43	0.44
T_{10}	0.54	0.50	0.44	0.39	0.40	0.43	0.42	0.47	0.48
T_{11}	0.52	0.49	0.43	0.39	0.40	0.40	0.43	0.45	0.45
T_{12}	0.48	0.47	0.42	0.38	0.41	0.37	0.41	0.43	0.43

(Source : Annual report 2008-09 to 2016-17, AICRP-IFS, CCS HAU, Hisar).

sources recorded the loss of nutrients in sorghum-wheat sequence. Application of P also enhanced the available K content in soil after the harvest of wheat crop. They further reported non significant variation in available N and K of the soils by the application of zinc in wheat pearl millet cropping system.

Hegde and Katyal (1999) observed that response of N was closely related to available nitrogen status in pearl millet-wheat cropping system.

Jain and Dahama (2006) concluded that available P status of soil increased and Zn status decreased significantly with the increase in phosphorus level up to 90 kg P_2O_5/ha. However, P status decreased and Zn status increased significantly with the increase in zinc level up to 12 kg Zn/ha. Application of 60 kg P_2O_5/ha and 6-9 kg Zn/ha to wheat significantly improved the growth and yield attributes, yield, protein content and P uptake in succeeding pearlmillet over control, while application of P @ 90 kg P_2O_5/ha decreased Zn and zinc @ 12 kg/ha improved Zn uptake by pearlmillet significantly over lower levels. Kundu *et al.*. (2006) reported that application of inorganic N during the incorporation of crop residue must have some positive effects on the rate of decomposition of organic matter. The application of N during ploughing was most beneficial to soil nutrient status Behra *et al.*. (2007) and Shivakumar and Ahlawat (2008) reported that due to prolonged cultivation of crops with

TABLE 2(B)
Effect of sources of nutrients on organic carbon (%) after wheat in pearl millet-wheat cropping system

Treatment	Years								
	2008-9	2009-10	2010-11	2011-12	2012-13	2103-14	2014-15	2015-16	2016-17
T_1	0.40	0.39	0.34	0.33	0.34	0.34	0.35	0.36	0.37
T_2	0.45	0.43	0.39	0.39	0.40	0.39	0.40	0.42	0.41
T_3	0.49	0.47	0.44	0.45	0.46	0.40	0.43	0.44	0.44
T_4	0.50	0.48	0.45	0.44	0.45	0.39	0.42	0.45	0.45
T_5	0.52	0.49	0.47	0.46	0.47	0..48	0..49	0.51	0.51
T_6	0.55	0.51	0.50	0.49	0.50	0.48	0.50	0.52	0.53
T_7	0.51	0.47	0.47	0.47	0.49	0.49	0.46	0.45	0.47
T_8	0.50	0.48	0.44	0.44	0.45	0.47	0.43	0.45	0.47
T_9	0.51	0.47	0.43	0.42	0.43	0.44	0.42	0.44	0.46
T_{10}	0.51	0.49	0.45	0.46	0.45	0.46	0.46	0.47	0.49
T_{11}	0.52	0.48	0.42	0.42	0.43	0.44	0.45	0.46	0.48
T_{12}	0.50	0.46	0.41	0.40	0.40	0.38	0.42	0.41	0.45

(Source : Annual report 2008-09 to 2016-17, AICRP-IFS, CCS HAU, Hisar).

recommended dose of inorganic fertilizers alone, the productivity of soils has down.

Kumar *et al.* (2010) observed that application of higher dose of fertilizers enhanced nitrogen, phosphorus and potassium uptakes by pearl millet and wheat. The nitrogen, phosphorus and potassium uptake (means of two years) were 180.0, 39.2 and 418.3 kg/ha, respectively with the application of recommended inorganic fertilizers during both the seasons, while these values were 188.8, 42.7 and 436.3 kg/ha with the application of 50 % RD-N through FYM + 50 % RD-N through chemical fertilizers during *kharif* and 100 % recommended fertilizers during the *rabi* season. Saha *et al.* (2013) observed that on an average, 45 to 55 % increase of N, P and K uptake were found upon fertilization of water soluble phosphate fertilizers over mineral acid soluble sources *viz*, RP (rock phosphate). With increasing levels of P from 60 to 120 kg P_2O_5/ha, N, P, K and Mn uptake improved significantly, whereas, Fe, Zn and Cu uptake decreased significantly. The increase of 25.6 and 32.4 kg/ha N uptake, 4.9 and 6.5 kg/ha P uptake and 28.1 and 36.9 kg/ha phosphatic fertilizers, respectively, over control was also noticed Cumulative mode of P application was found the best for NPK and Mn uptake by wheat as compared to direct and residual mode.

Singh *et al.* (2013) found that pH of the soil decreased from 8.2 to 7.6 and available P status of the soil increased from 13.2 to 38.8 kg/ha with the application of P for 40 years where highest dose of P (120 kg P_2O_5/ha) was supplied. However, the $CaCO_3$, CEC, available N increased, organic carbon and EC decreased slightly without changing its texture. Available P content of the soil decreased from its original level of 13.2 to 38.8 kg/ha where no phosphorus was added over last 40 years.

Organic sources

Effect on crop

Organic sources of nutrients play an important role in maintaining the sustainability of crop production and review have been reported by many workers. Singh and Gangwar (2000) reported that application of recommended doses of fertilizer and 50 per cent N through FYM and remaining 50 per cent NPK through fertilizers out yielded maize by 39.27 and 33.57 per cent over farmers practice (2088 kg/ha) in Udaipur district, whereas, in case of wheat maximum yield (3912 kg/ha) was obtained with the use of 50 per cent N through FYM and 50 per cent through NPK fertilizers followed by recommended dose of NPK (3760 kg/ha).

Shukla *et al.* (2005) confirmed that depending upon the crops, the treatment where 100% NPK were supplied through organic manures gave 40-85% lower yield compared to treatment receiving 100% recommended NPK through inorganic fertilizers. Meena *et al.* (2008) reported that both farm yard manure and sewage sludge were found beneficial in increasing grain yield and oil content of pearlmillet and it had a similar (residual) effect on succeeding mustard. Kumar *et al.* (2009) observed that the application of organic amendments, such as the direct application of residues with a wide C : N and residues with farm yard manure failed to increase crop yield. The yield contributing characters (dry matter accumulation and number of panicles/m^2) and yields increased when the crop was treated with inorganic N fertilizer along with crop residues. The finding corroborated the results of Kundu *et al.* (2006).

Alagawadi *et al.* (2011) showed that B : C of organic nutrient management practices was significantly high, which is might due to higher gross return and lower cost of cultivation of organic nutrient management practices in comparison to the inorganic nutrient management practices. Gupta *et al.*, (2012) reported that the grain yield and dry matter production of wheat was significantly better in treatments where FYM @ 5 t/ha was applied in previous maize crop in main plots In sub-plots the yield trend increased with increase in RDF level *i.e.* from 50 to 150 %, respectively.

Abdullahi *et al.* (2014) revealed that organic manure and bio-fertilizer alone or in combination enhanced plant growth, per cent root colonization by AM fungi, shoot and root dry biomass compared to control highest plant performance *viz* ; plant height (72.6 cm), number of tillers per plant (4.1), shoot and root dry biomass (8.8 and 3.9 g) recorded in Bio-fertilizer + poultry manure treatment followed by bio-fertilizer alone and poultry manure. Applying 10 t/ha of cow dung produced plants with the lowest growth attributes although not statistically at par with control N and P concentration varied significantly between all treatments.

Effect on soil

For maintaining the good health of the soil, the review have been reported by many workers across the country. Hegde (1996) reported that organic sources increased the organic carbon of the soil, but

available P and K was not affected. Shelke *et al.* (1997) reported that application of recommended dose of NPK through organic manures increased soil fertility status irrespective of the source. They further reported that the maximum net gain of 23.6 kg N, 4.10 kg P_2O_5 and 14 kg K_2O when 50 per cent recommended NPK was applied through FYM. However, inclusion of organic matter during kharif season recorded net gain in the range of 10.35 to 23.6 kg N, 0.30 to 4 kg P_2O_5 and 8 to 14 kg K_2O.

Vaidya and Gabhane (1998) found that FYM increased the organic carbon and available NPK status of soil on vertisol in sorghum-wheat cropping sequence. Organic manures are potent source of essential plant nutrients. However, their uses is generally ignored due to advent of chemical fertilizers. Farmyard manure (FYM) is an important source containing macro as well as micronutrient in an appropriate proportion. Toor *et al.* (2001) reported that there was an increase in available nitrogen content of soil, with increasing rates of manure application. An increase in available nitrogen content of soil, with increasing rates of manure application has been reported by Toor *et al.* (2001). Kumar *et al.* (2005) observed that 50 % RD-NPK + 50 % RD-N through wheat straw to pearl millet and 100 % RD-NPK to wheat was found significantly superior in contributing organic carbon after one and two years of crop cycle.

Rajput (2006) reported that available phosphorus increase over initial value when organic manures were incorporated. Organic carbon status declined in the control, while there was build up in organic source incorporated plots. Tripathi *et al.* (2007) found that application of FYM, WCS and *Sesbania* (green manure) showed higher values of organic carbon and available P while available K was higher only in WCS than 100% RDF through fertilizers to both the crops in rice-wheat cropping system. Verma *et al.* (2009) reported that water stable aggregate organic carbon was found maximum in treatment receiving FYM alone followed by treatments where FYM was used in combination with inorganic fertilizers. In 100% N alone treatment, decreased content of water stable aggregate organic carbon was recorded in all size fractions. Ramesh *et al.* (2009) observed that application of organic manures resulted

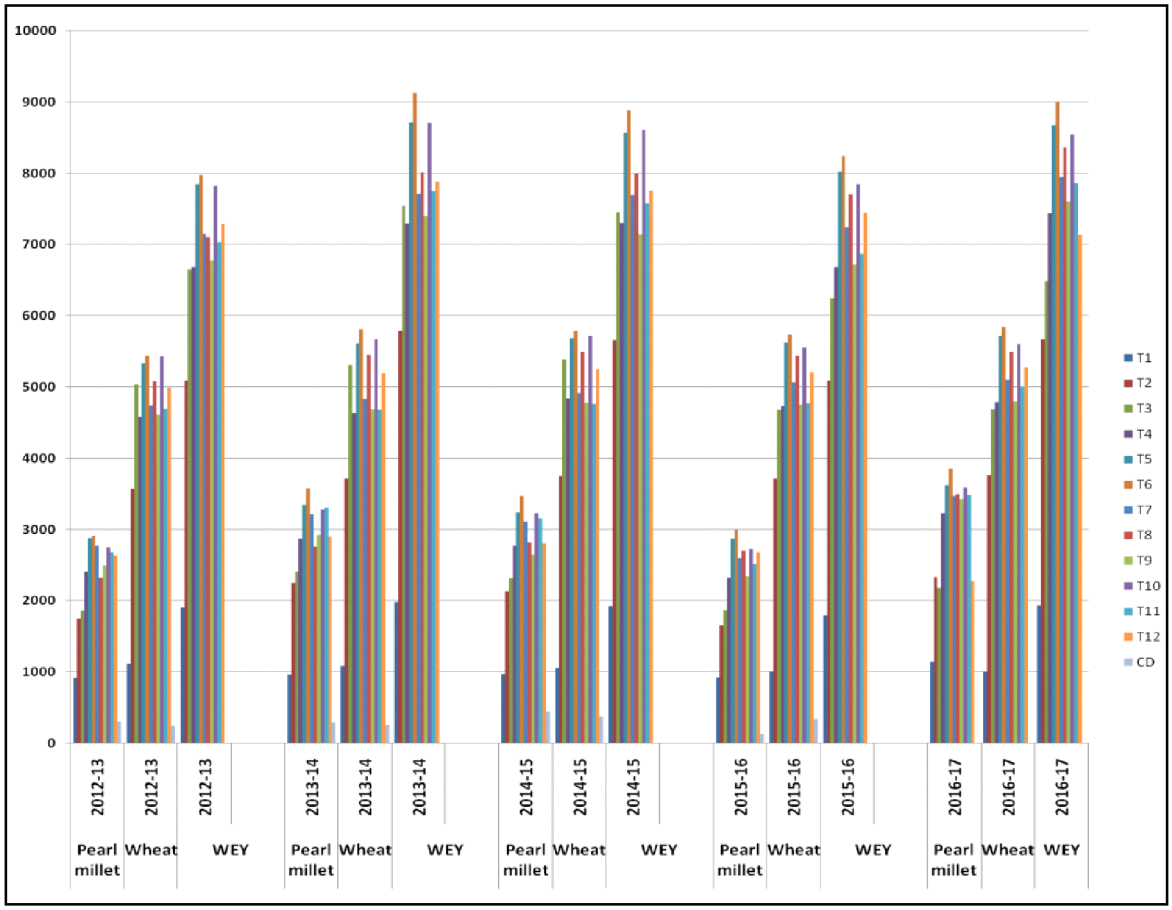

Fig. 1. Yield level (kg/ha) of pearl millet, wheat and wheat equivalent yield over the years.

in significantly higher soil organic carbon, available N, P and K than chemical fertilizers but was at par with the integrated nutrient management.

Among different organic nutrient sources the effect was more with the use of FYM which might have been due to its rich constituents and sustained availability Verma and Mathur (2009) had also found such type of results.

Integrated nutrient management

Effect on crop

Integrated nutrient management is the most important plant nutrient supply system for sustaining the production potential of cropping system like pearl millet- wheat. Shelke *et al.* (1997) reported that in sorghum-wheat cropping system the maximum grain as well as fodder yield was recorded when 50 per cent NPK dose was given through fertilizers and 50 per cent through FYM, but remained at par with 100 per cent NPK and 75 per cent NPK + 25 per cent FYM, indicating that application of FYM could save 25-50 per cent NPK fertilizers. The highest grain yield of wheat (33.96 q ha^{-1}) was recorded when 100 per cent NPK given during rabi season. They also reported that 25% N could be saved in rabi when subabul, glyricidia or wheat straw were used as organic manures. During three years of experiments in a alluvial soil of Ludhiana, application of FYM alongwith 100 per cent NPK increased the yield by 54.0 per cent over 100 per cent NPK alone in a long term fertilizer experiment (Tandon, 1997).

Hegde (1998) reported that in total production of the system only farmyard manure could replace 50 per cent N needs of pearl millet without much adverse effect on production. He further reported the possibility of substituting 25-50 per cent N need of pearl millet through all the organic sources, except 25 per cent N by wheat straw (Table 1) . Singh *et al.* (1998) reported that in pearl millet (fodder)-wheat crop rotation application of organic manures in combination with 120 kg N/ha was better than other nutrient combination. Vaidya and Gabhane (1998) reported greater yield stability through conjunctive use of FYM and fertilizer.

Vasanthi and Kumaraswamy (2000) reported that green and dry fodder yields of sorghum, maize and pearl millet the content and uptake of N, P and K were significantly higher in the treatments that received poultry manure or sheep-goat manure at 10 t/ha with 50 per cent of the recommended NPK schedule than the yields in the treatment that had received recommended dose of NPK alone. Integrated use of 75 per cent recommended dose of fertilizers and 10 t FYM along with bio fertilizers resulted in maximum sorghum productivity with some residual effect on wheat crop (Patidar and Mali, 2001). Santhy *et al.* (2001) reported that application of 100 per cent NPK + FYM @ 10 t/ha significantly increased crop yield, content and N, P and K uptake by all the three experimental crops, finger millet, maize and cow pea. Katyal *et al.* (2002) reported that 50 per cent N substitution in pearl millet through FYM and 100 per cent NPK through inorganic fertilizers to wheat recorded almost similar (616 t/ha) system productivity to that of 100 per cent NPK. Shelke *et al.* (1997) reported that in sorghum-wheat sequence maximum uptake of nutrients (91.9, 11.4, 124.9, N: P_2O_5 : K_2O kg/ha) was observed where 50 per cent recommended NPK was given through fertilizers and 50 per cent through FYM to sorghum, followed by 100 per cent NPK to wheat in rabi The nutrient uptake at 100 per cent recommended dose for both the crops was 87.9, 10.7 and 120.2 kg NPK/ha. However, the lowest uptake was noticed in control where fertilizers were not applied.

Kumar *et al.* (2005) reported that highest system grain yield (8.07 tones/ha) of both pearl millet and wheat was obtained with the application of 100% recommended dose of NPK in both crops. This may however be supplied either entirely through inorganic fertilizers or 50% recommended dose of NPK + 50% N through FYM to pearlmillet. Satyajeet *et al.* (2006) reported that application of inorganic nutrients integrated with organic fertilizers to pearl millet crop left behind sufficient residual effect, which tended significant increase in growth and seed yield of mustard. During the two years of study Dahiya *et al.* (2008) concluded that replacement of 25% N through vermicompost or farm yard manure brought appreciable improvement in yield attributes and yield over chemical source of nutrients at different doses except at recommended dose.

Yengade and Mairan (2009) reported that substitution of 50% recommended N through organic sources (FYM/ press mud (PMC)/ wheat straw (WS)/ green manure (GM)) and 100% recommended NPK dose and micronutrient dose through inorganic fertilizer to sorghum resulted in higher grain productivity in sorghum-sunflower sequence cropping. Khambalkar *et al.*, (2012) noticed significantly maximum straw yield of pearl millet (860 t/ha) in treatment 100 % RD-NPK + FYM @10 t/ha/year +

Azotobacter + PSB. The application of optimal dose of NPK in combination with FYM, *Azotobacter* and PSB registered significantly higher seed yield of pearlmillet (407 t/ha) over other fertility treatments and control. Rekha (2013) while working on pearl millet observed that the treatments receiving application of bio-fertilizers have important and significant influence on growth than the uninoculated treatments in combination with inorganic sources; bio-fertilizers corroborative results were reported by Choudhary and Gautam (2007) in pearlmillet.

Kumar *et al.*, (2014) reported that the yield of pearl millet improved significantly with incorporation of 10 t FYM ha^{-1} and 2.5 t/ha vermicompost over control, which may be ascribed to increased availability of nutrients in soil. The yield of pearl millet crop increased significantly when 100 % RD-NPK was applied with 2.5 t/ha vermicompost over 100 % RD-NPK alone. Kumar *et al.*, (2014) revealed that effect of different nitrogen levels and biomix biofertilizers resulted in significantly higher leaf area, higher dry matter accumulation and attraction index with 125 % RDN which was statistically at par with 100 % RDN + Biomix. Meena and Gautam (2005) observed significantly more grain and stover yields of pearlmillet with 20 kg N + 15 kg P_2O_5 ha^{-1} + PSB + *Azospirillum* over control and rest of the other bio-fertilizers, chemical fertilizers and their combinations treatments.

Singh and Kumar (2015) found that the protein content in grain and straw varied from 11.96 to 15.60 % and 4.47 to 5.96 %, respectively. The significantly highest protein content in grain (15.60 %) and straw (5.96 %) was found with 150 % STR NPK + 108 t FYM/ha. The significantly lower protein content in wheat grain and straw was recorded in control. Thumar *et al.* (2016) observed that the economics of different treatment T_9 (T_1 + FYM 25 t ha^{-1} + *Azotobacter* + PSB) secured maximum net return of 43435 ? ha^{-1} with benefit cost ratio of 1.94, followed by the treatments T_8 (T_1 + Biocompost 2.5 t ha^{-1} + *Azotobacter* + PSB), T_4 (T_1 + FYM 2.5 t/ha) and T_1 (RDF 120-60-00 NPK kg ha^{-1}) with corresponding net realization values of 40301, 38531 and 37047 ? ha^{-1} respectively, with BCR (Benefit cost ratio) of 1.87 (T_1), 1.73 (T_4) and 171 (T_8) ? ha^{-1}.

Choudhary *et al.* (2017) found that application of 100 % RDF + *Azotobacter* + PSB significantly improved growth attributes, leaf area index, leaf area duration, crop growth rate, relative growth rate and net assimilation rate on pooled analysis over farmer's practice while was found statistically at par with 100 % RDF. Kumar and Kumar (2017) observed that highest uptake of nitrogen, phosphorous and potassium in grain as well as straw was recorded in treatment T_6 (50 % RD-NPK + 50 % RD-N (FYM) to pearl millet and 100 % recommended NPK to wheat), which is significantly more than T_1, T_2, T_3, T_4, T_7, T_8, T_9, T_{11} and T_{12} but statistically at par with T_5 and T_{10} in wheat. In wheat, treatment T_6 was recorded 435 and 12 % higher grain yield over T_1 (control) and T_{12} (farmers' practice) respectively, indicating that 50 % RD-N can be supplied through FYM in pearlmillet-wheat cropping sequence.

Jat (2017) concluded that adaptation of conservation agriculture based practices with site specific nutrient management resulted in more carbon sustainability index, reflecting the ability of the crop to sequester more carbon than conventional tillage and resulting in more sustainable cropping system.

Anonymous (2017 b) from Hisar reported that the substitution of nitrogen to the tune of 50% from FYM in pearl millet, followed by 100% recommended dose of fertilizers in wheat increased pearl millet, wheat and wheat equivalent yield. The magnitude of increase among organic sources of nutrients was higher with FYM, green gram and wheat straw, respectively (Fig 1).

Shetye *et al.* (2018) on the basis of two years of experimentation concluded that combined application of 75% RDN (150 kg/ha) through chemical fertilizer + 25% RDN (50 kg/ha) through vermicompost registered higher values of growth attribute (plant height, no of leaves per plant, leaf area index and dry matter accumulation per plant) in green cob yield with sheath, green fodder yield and total biological yield.

Effect on soil

The degraded soil health can be improved by adopting the integrated nutrient management practices as reported by various researchers. Hegde (1996) was also of the view that integrated nutrient supply increased soil organic carbon, available N, S, Mn and Fe, thus improved soil fertility.

Bulk density of subsurface layers was higher as compared to surface soil, irrespective of the treatments. Bulk density remained unaffected due to interaction effect of organic manure and inorganic fertilizers. These findings are in close conformity with those of Mishra and Sharma (1997).

Hundekar *et al.* (1997) reported that application of organic manure in conjunction with

fertilizers increased organic carbon, N, P and K contents of soil. Shelke *et al.* (1997) reported that fertility status of soil was maximum at 50 per cent recommended NPK through fertilizers + 50 per cent NPK through FYM to sorghum followed by 100 per cent NPK through fertilizers to wheat crop. Organic carbon status increased due to integrated nutrient sources (Hegde, 1998). He further reported that available P status in unfertilized plots decreased with continuous cropping at Sardar Kurshinagar, Junagarh and Hanumangarh but not at Hisar Substitution of a part of N in the rainy season by organic sources had no conspicuous effect on available P status K uptake was much higher than its application, there was reduction in available K after continuous cropping. Hegde (1996) reported that integrated nutrient supply increased soil organic carbon and available N compared to application of all nutrients through fertilizers. It had a variable effect on available P status and reduced the decline in available K. Available soil S, Mn, and Fe increased, while available Cu and Zn remained unaffected.

The application of FYM in combination with recommended dose of NPK increased the contents of available N, P and K by 17.66, 3.33 and 8.0 per cent, respectively over NPK applied through fertilizer alone (Vaidya and Gabhane, 1998). Swarup and Yaduvanshi (2000) reported that application of 100 per cent NPK plus GM or FYM was significantly better than 150% NPK. The soil organic carbon, available Zn and Mn significantly increased by application of NPK with FYM over rest of the treatments. Similar trends were also observed in case of available P and K status of soil.

Sharma and Bali (2000) reported that reduction in bulk density and improvement in water holding capacity were higher in surface soils than in subsurface soils.

Swarup and Wanjari (2000) from long term studies reported that incorporation of FYM along with recommended level of fertilizers improves soil physical properties like bulk density, aggregate stability, water retention and hydraulic conductivity considerably. Tiwari *et al.* (2002) while working on vertisols reported that an increase in hydraulic conductivity of surface soil from 0.192 cm/hr with N alone to 0.416 cm/hr under 100% NPK + FYM treatment. Balanced fertilization recorded higher hydraulic conductivity values as compared to those receiving N alone or no fertilizer.

Katyal *et al.* (2002) reported that OC status and available soil P increased due to integrated use of organic manures and in organic fertilizers, but failed to improve available soil N and K over their initial status. Subba Rao *et al.* (2002) reported that integrated plant nutrient system maintain soil fertility and plant nutrient supply by optimizing the benefits from all possible sources of plant nutrients.

Prakash *et al.* (2002) reported that soil bulk density undergoes more reduction with the application of nutrients through FYM than through chemical fertilizers. The effect of FYM however is more pronounced after second year, due to accumulation of FYM. Subba Rao *et al.* (2002) reported that integrated plant nutrient system (IPNS) improves the water infiltration and water holding capacity of soil. Bonde *et al.* (2004) reported that incorporation of organic residues significantly lowered the bulk density over control. Among the organic residues, wheat straw recorded lowest value of bulk density but hydraulic conductivity recorded reverse values as that of bulk density and help in soil aggregation in cotton-soybean inter cropping. Gawai and Pawar (2005) concluded that the nodule count of chickpea showed higher values where FYM was combined with reduced levels of RDF in preceding sorghum crop. Satyajeet and Nanwal (2007) reported that NP concentration in grain and stover, uptake and total uptake was higher in integrated nutrient management treatments as compared to inorganic fertilizers in pearlmillet-wheat cropping system. Satyajeet *et al.* (2007) reported that the treatments where inorganic fertilizers were applied in conjunction with organic sources recorded significantly higher available nitrogen and phosphorus and organic carbon in soil.

Dahiya *et al.* (2008) observed that integration of vermicompost or farm yard manure with chemical fertilizers exhibited beneficial effect on water holding capacity of soil for better growth of plants.

Kaur *et al.* (2008) reported that dehydrogenase activity, improved significantly with an application of NPK and NPK+FYM. A general increase in carbon mineralization with time period was observed throughout the experiment and was maximum in 100% NPK+FYM treated plots. The estimated annual C input value in NPK+FYM treatment was 1.05 Mg C/ha/year. The overall net change in organic carbon was maximum in treatment receiving FYM along with inorganic fertilizers. Therefore, these results suggest that the integrated use of NPK and FYM is an important nutrient management option for sustaining maize-wheat cropping system. Vandana *et al.* (2008) found that application of fertilizers especially nitrogen [both by organic

(vermicompost and FYM) and inorganic fertilizers] known to increase the cation exchange capacity of roots and enhance NPK absorption by crop plants. Kaur *et al.* (2008) their finding says that overall net change in organic carbon was maximum in treatment receiving FYM along with inorganic fertilizers. Therefore, these results suggest that the integrated use of NPK and FYM is an important nutrient management option for sustaining maize-wheat cropping system.

Dahiya *et al.* (2008) stated that integration of vermicompost or farm yard manure with chemical fertilizers exhibited beneficial effect on yield attributes and yield by improving the nutrient availability to plants and increasing water holding capacity of soil for better growth of plants. Verma *et al.* (2009) reported that water stable aggregate organic carbon was found maximum in treatment receiving FYM alone followed by treatments where FYM was used in combination with inorganics. In 100% N alone treatment, decreased content of water stable aggregate organic carbon was recorded in all size fractions. Kumar *et al.* (2010) observed that the increase in available P content was improved with the integrated use of FYM and chemical fertilizers over the use of chemical fertilizers alone FYM increased relatively more availability of P in comparison to GM and WS treated treatments. It was due to increase in microbial population and decomposition of humic substances. Yadav *et al.* (2010) concluded that among different integrated nutrient management treatments, the per cent organic carbon varied between 0.44 and 0.49 during first year and between 0.46 and 0.52 per cent during experimentation.

Babalad *et al.* (2011) showed that the available nutrients were significantly better under INM practices as compared to inorganic nutrient management practices, however, was statistically at par with organic nutrient management practices during both *kharif* and *rabi* crop at the harvest. Whereas, under inorganic nutrient management practices, there was declining trend of available nutrients was observed.

Kumar *et al.*, (2014) recorded that at 100 % RD-NPK in wheat and where FYM was applied in pearlmillet (T_6) recorded highest counts and establishment of *Azotobacter* and *Azospirillum*. Sharma (2015) noticed that highest organic carbon (0.87 %) found in treatment with 50 % RD-NPK + 50 % FYM (T_6), followed by 0.72 % in 50 % RD-NPK + 50 % through wheat crop straw (T_8) and 0.70 % in 50 % RD-NPK + 50 % GM (T_{10}). Higher nitrogen (746.4 kg ha^{-1} and 691.2 kg ha^{-1} respectively) was observed with the application of 50 % RD-NPK + 50 % FYM (T_6) as well as 50 % RD-NPK + 50 % GM (T_{10}), while the lower nitrogen was observed in control treatment (T_1) The percent increase in nitrogen content over control was noticed to be 0.35 and 0.25%, respectively.

The organic carbon was recorded higher where nitrogen was replaced with FYM as compared to chemical sources of nutrients under semi arid conditions (Anonymous, 2017 b) table 2(a) and 2 (b).

REFERENCES

Abdullahi, R., H. H. Sherrif, and A. Buba. 2014 : Effect of bio-fertilizers and organic manure on growth and nutrients content of pearlmillet. *J. Agric. Biol. Sci.*, **9**(10): 351.

Alagawadi, A. R., Vidyavathi, G. S. Dosog, Babalad, H. B. Hebsur, S. K. Gali, and S. G. Patil. 2011 : Influence of nutrient management practices on crop response and economics in different cropping systems in a vertisol. *Karnataka J. Sci.*, **24**(4) : 455-460.

Anonymous. 2017b : Annual reports of AICRP-IFS, Department of Agronomy, CCS HAU Hisar.

Anonymous. 2017 : *Agricultural statistics at a glance.*

Anonymous. 2017 : http://agricoopnicin/Inm/cfinm9210pdf.

Babalad, B., A. R. Alagawadi, Vidyavathi, G. S. Dosog, Hebsur, N. S. Gali, S. K. and S. G. Patil. 2011 : Influence of nutrient management practices on crop response and economics in different cropping systems in a vertisol *Karnataka J. Sci.*, **24**(4) : 455-460.

Bahar, B., M. Yildinim, C. Barutcular, and I. Genc. 2008 : Effect of canopy temperature depression on grain yield and yield components in bread and durum wheat *Not. Bot. Horti. Agrobot. Cluj Napoca*, **36**(1) : 34-37.

Barnaba, S. B., K. Jarger, and A. Feher. 2008 : The effect of drought and heat stress on reproductive processes in cereals. *Plant Cell Environ.,* **31** : 11-38.

Behra, U. K., A. R. Sharma, and H. N. Pandey. 2007 : Sustaining productivity of wheat-soybean cropping system through integrated nutrient management practices on the vertisols of central India. *Plant Soil*, **297** (1-2) : 185-199.

Bonde, A. N., B. G. Korle, M. S. Deshmukh, K. U. Tekale, and N. P. Patil. 2004 : Effect of different organic residues on physico-chemical properties of soil in cotton-soybean intercropping. *J. Soils Crops,* **14** : 112-115.

Choudhary, R. R., H. L. Yadav, S. L. Choudhary, A. L. Prajapat, and R. Choudhary. 2017 : Effect of integrated nutrient management on growth of wheat (*Triticum aestivum*) cultivars. *Int. J. Curr. Microbiol. App. Sci.*, **6**(8) : 2369-2374.

Choudhary, R. S., and R. C. Gautam. 2007 : Effect of nutrient management practices on growth and yield of

Pearlmillet (*Pennisetum glaucum*) *Indian J. Agron.*, **52** (1) : 64-66.

Dahiya, D. S., S. S. Dahiya, O. P. Lathwal, R. Sharma, and R. S. Sheoran. 2008 : Integrated nutrient management in wheat under rice-wheat cropping system. *Haryana J. Agron.* **24** (1&2) : 51-54.

Gawai, P. P., and V. S. Pawar. 2005 : Yield and yield components of sorghum (*Sorghum bicolor*) as influenced by integrated nutrient management system and its residual effect on chickpea (*Cicer arietinum*). *Ann Agric. Res.*, **26**(1) : 97-100.

Gupta, V., A. Kumar, B. C. Sharma, M. Singh, and J. Kumar. 2012 : Legume intercropping and *in-situ* green manuring as well as FYM application in maize along with inorganic fertilizers in wheat for sustainability of maize-wheat system under rainfed conditions. *Haryana J. Agron.*, **28** (1 & 2) : 19-24.

Hegde, D. M. and Babu, S. N. S. 2004 : Role of balanced fertilization in improving crop yield and quality. Fertilizer News, 49 : 103-110, 113-114.

Hegde, D. M. 1996 : Long term sustainability of productivity in an irrigated sorghum-wheat system through integrated nutrient supply. *Field Crops Res.,* **48** (2-3) : 67-75.

Hegde, D. M. 1998 : Effect of integrated nutrient management on productivity and soil fertility in pearl millet (*Pennisetum glaucum*)-wheat (*Triticum aestivum*) cropping system *Indian J. Agron.,* **43** : 580-587.

Hegde, D. M. and V. Katyal. 1999 : Long term effect of fertilizer use on crop productivity and soil fertility in pearlmillet-wheat cropping system in different agro-eco regions. *J. Maharashtra Agric. Uni.,* **24** : 16-20.

Hundekar, S. T., V. P. Badanur, and T. Satyanarayana, 1997 : Influence of crop residue in conjunction with fertilizers on soil fertility nutrient uptake, and yield of sorghum *Karnataka J. Agric. Sci.* **10** : 25-31.

Jain, N. K. and A. K. Dahama, 2006 : Direct and residual effects of phosphorus and zinc fertilization on productivity of wheat (*Triticum aestivum*)-pearlmillet (*Pennisetum glaucum*) cropping system. *Indian J. Agron.* **51** : 165-169.

Jain, N. K. and B. L. Poonia. 2003 : Integrated nutrient management in pearlmillet (*Pennisetum glaucum*) and optimising fertilizer requirement in succeeded wheat (*Triticum aestivum*). *Crop Res.*, **26** : 62-66.

Jat, H., and M. Kaushik. 2018 : Quality and economic of fodder oat (*Avena sativa* L) as influnced by irrigation and nitrogen under southern Rajasthan. *Forage Res.*, **44**(1) : 28-31.

Jat, R. D., R. K. Nanwal, H. S. Jat, D. K. Bishnoi, R. S. Dadarwal, S. K. Kakraliya, A. Yadav, K. M. Choudhary, and M. L. Jat. 2017 : Effect of conservation agriculture and precision nutrient management on soil properties and carbon sustainability index under maize-wheat cropping sequence. *Int. J. Chem. Studies*, **5** : 1746-1756.

Katyal, V., B. Gangwar and K. S. Gangwar, 2002 : Yield trends and soil fertility changes in pearlmillet-wheat cropping system under long term integrated nutrient management. *Ann. Agri. Res.*, **23** : 201-205.

Kaur, T., B. S. Brar, and N. S. Dhillon, 2008: Soil organic matter dynamics affected by long term use of organic and inorganic fertilizers under maize-wheat cropping system. *Nutr. Cycl. Agroecosys.* **81**(1): 59-69.

Khambalkar, A. P., P. S. Tomar, and S. K. Verma. 2012 : Long term effects of integrated nutrient management on productivity and soil fertility in pearlmillet (*Pennisetum glaucum*)- mustard (*Brassica juncea*) cropping sequence *Indian J. Agron.* **57** (3) : 222-228.

Khan, M. A., A. K. Shukla, N. C. Upadhayay and O. P. Singh. 2005 : Nutrient management strategies for maize-potato-wheat cropping system in Typic Ustochrept Soils. *Potato J.* **32** : 167-168.

Kumar, A., and M. Kumar, 2017: Performance of integrated nutrient management on nutrient uptake and productivity of pearl millet (*Pennisetum glaucum* L.) - wheat (*Triticum aestivum* L.) cropping system. *Int. J. Agric. Innov. Res.*, **6** : 2319-1473.

Kumar, A., V. Gupta, B. C. Sharma, M. Singh, and J. Kumar, 2012 : Legume intercropping and *in-situ* green manuring as well as FYM application in maize along with inorganic fertilizers in wheat for sustainability of maize-wheat system under rainfed conditions. *Haryana J. Agron.*, **28** : 19-24.

Kumar, P., R. K. Nanwal, and S. K. Yadav, 2005 : Integrated nutrient management in pearlmillet (*Pennisetum glaucum*)-wheat (*Triticum aestivum*) cropping system *Indian J. Agric. Sci.* **75**: 640-43.

Kumar, P., R. Singh, A. Singh, D. Paliwal, and S. Kumar, 2014 : Integrated nutrient management in pearlmillet (*Pennisetum glaucum*) - wheat (*Triticum aestivum*) cropping sequence in semi arid condition of India. *Int. J. Agric. Sci.,* **10**: 96-101.

Kumar, P., S. K. Yadav, and M. Kumar. 2010 : Influence of integrated fertilizer management on nutrients utilization and soil chemical properties by pearlmillet-wheat cropping system. *Haryana J. Agronomy*, **26** (1 & 2): 1-8.

Kumar, S., P. Kumar, S. K. Yadav, and M. Kumar. 2009 : Sustaining yield of pearl millet-wheat cropping system in semi arid condition *Haryana J. Agron.,* **25** : 1-3.

Kumpawat, B. S. 2004 : Integrated nutriernt management for maize (*Zea mays*)-Indian mustard (*Brassica juncea*) cropping system. *Indian J. Agron.,* **49**(1) : 18-21.

Kundu, S, A. L. Kundu, S. Pal, and N. N. Mandal. 2006 : Studies on crop yield and changes on soil

properties as influenced by sustainable nutrient management in rice-wheat cropping system. *J. Interacademicia*, **10** : 36-39.

Meena, M. C., K. P. Patel, D. Singh, and B. S. Dwivedi. 2008 : Long term effect of sewage sludge and farm yard manure on grain yields and availability of zinc and iron under pearl millet (*Pennisetum glaucum*)-Indian mustard (*Brassica juncea*) cropping sequence. *Indian J. Agric. Sci.,* **75** : 281-84.

Meena, R. and R. C. Gautam. 2005 : Effect of Integrated Nutrient Management on productivity, nutrient uptake and moisture use functions of Pearl millet. *Indian J. Agron.*, **50** : 305-307.

Mishra, V. K. and R. B. Sharma. 1997 : Effect of fertilizer alone and in combination with manures on physical properties and productivity of entisol under rice based cropping systems. *J. Indian Soc. Soil Sci.,* **41** : 84-88.

Parihar, M. D., H. Singh, R. S. Hooda, J. Dayal, and K. P. Singh. 2006 : Performance and uptake of nutrients by pearl millet hybrids as influenced by N application. *Haryana J. Agron.,* **22**: 79-80.

Patidar, M. and A. L. Mali. 2001 : Integrated nutrient management in sorghum (*Sorghum bicolor*) and its residual effect on wheat (*Triticum aestivum*). *Indian J. Agric. Sci.,* **71** : 587-590.

Prakash, Y. S., P. B. S. Bhadoria, and A. Rakshit. 2002 : Comparative efficacy of organic manures on the changes in soil properties and nutrient availability in an Alfisol. *J. Indian Soc. Soil Sci.,* **50** : 219-221.

Rajput, R. L. 2006 : Effect of nutrient management for sustainable productivity in pearlmillet (*Pennisetum glaucum*)-wheat (*Triticum aestivum*) system. *Advances Plant Sci.,* **19** : 491-495.

Ramesh, P., N. R. Pawan, A. B. Singh, and S. Ramana. 2009 : Production potential, nutrient uptake, soil fertility and economics of soybean (*Glycine max*)-based cropping systems under organic, chemical and integrated nutrient management practices. *Indian J. Agron.,* **54** : 278-83.

Rekha. 2013 : Maximization in Pearlmillet (*Pennisetum glaucum* L.) productivity through potash, zinc and bio-fertilizer application. MSc Thesis, CCS Haryana Agricultural University, Hisar.

Saha, K. P., K. G. Mandal, P. K. Ghosh, K. M. Hati, and K. K. Bandyopadhyay. 2013 : Bioenergy and economic analysis of soybean-based crop production systems in central India. *Biomass and Bioenerg*, **23** : 337-345.

Sammauria, R. and R. S. Yadav. 2008 : Effect of phosphorus and zinc application on growth and yield of fenugreek (*Trigonella foenum graecum*) and their residual effect on succeeding pearlmillet (*Pennisetum glaucum*) under irrigated conditions of north west Rajsthan. *Indian J. Agric. Sci.,* **78** : 61-64.

Santhy, P., P. Muthuvel, and D. Selvi. 2001 : Status and impact of organic matter fractions on yield, uptake available nutrients in a long-term fertilizer experiment. *J. Indian Soc. Soil Sci.*, **49** : 281-285.

Saptal, J. Tokas, B. S. Duhan, S. K. Pahuja and S. Ravi Kumar. 2017 : Potential productivity, forage quality and relative economics of multi-cut sorghum genotypes under different fertilizers rates *Forage Re*s., **43** : 39-45.

Satyajeet and R. K. Nanwal. 2007 : Integrated nutrient management in pearlmillet-mustard cropping system. *Indian J. Fert.,* **3** : 59-62, 76.

Satyajeet, R. K. Nanwal, and V. K. Yadav. 2006 : Effect of vermicompost, biofertilizer and inorganic fertilizers on growth, yield and water use efficiency on pearlmillet-mustard cropping sequence. *Haryana J. Agron.*, **22** : 113-118.

Satyajeet, R. K. Nanwal, and V. K. Yadav. 2007 : Residual effect of integrated nutrient management on Indian mustard under pearlmillet (*Pennisetum glaucum*)-mustard (*Brassica juncea*) cropping sequence. *Brassica*, **9** : 79-82.

Sharma, M. P. and B. V. Bali. 2000 : Long term effect of different cropping system on physico-chemical properties and soil fertility *J. Indian Soc. Soil Sci.,* **48** : 181-183.

Sharma, P. K. and S. S. Manohar. 2002 : Response of wheat (*Triticum aestivum*) to nitrogen and sulphur and their residual effect on succeeding pearl millet (*Pennisetum glaucum*). *Indian J. Agron.,* **47** : 473-76.

Sharma, T. 2015 : Response of integrated nutrient supply on yield of wheat and physical-chemical properties of soil. *Bioscan,* **10** : 77-80.

Shelke, V. B., V. M. Bhale, and P. S. Josh. 1997 : Integrated nutrient management in sorghum-wheat cropping system *J. Maharashtra Agric. Uni.,* **22** : 93-95.

Sheoran, R. S., Satpal, U. N. Joshi, B. S. Duhan and S. Arya. 2016 : Response of forage pearlmillet (*Pennisetum glaucum* L) genotypes to different nitrogen levels. *Forage Res*., **42** : 115-118.

Shetye, V., R. Tiwari, S. Kadam, and U. Mahadkar. 2018 : Effect of tillage practices and nutrient sources on performance of sweet corn. *Forage Res.,* **43** (4) : 295-298.

Shivakumar, B. G. and I. P. S. Ahlawat. 2008 : Integrated nutrient management in soybean (*Glycine max*)-wheat (*Triticum aestivum*) cropping system. *Indian J. Agron.*, **53** : 273-278.

Shukla, A. K., M. A. Khan, N. C. Upadhayay, and O. P. Singh. 2005 : Evaluation of nutrient management option for rice-potato-wheat cropping system for upper Gangetic Plain Region. *Potato J.*, **32** : 159-160.

Singh, A. K., Murmu, Sindhu, B. Saha, S. Saha, and P. Poddor. 2013 : Uptake of nutrients by wheat as influenced by long-term phosphorus fertilization.

J. Life Sci., **8**(4) : 1331-1335.

Singh, D. and A. Kumar. 2015 : Effect of inorganic and organic sources of nutrients on yield and nutrient uptake by wheat and soil fertility. *Ann. Plant Soil Res.*, **17**(2) : 146-149.

Singh, O. P. 1995 : Integrated nutrient management in sorghum based cropping system *In :* Integrated nutrient management in intensive cropping systems (lecture notes) Summer Institute (June 22 to July 11, 1995), pp 376-386, Pantnagar.

Singh, P. and B. Gangwar. 2000 : Nitrogen substitution through FYM in maize-wheat cropping sequence under irrigated condition Proc. Int Conf Managing Natural Resources for Sustainable Agricultural Production in the 21st century, New Delhi **3** : 881-882.

Singh, R. P., M. C. Mundra, S. C. Gupta, and S. K. Agarwal. 1999 : Effect of integrated nutrient management on productivity of pearl millet (*Pennisetum glaucum*) – wheat (*Triticum aestivum*) cropping system. *Indian J. Agron.,* **44** : 250-255.

Sinha, S. K., V. N. Singh, and K. P. Singh. 1997 : Effect of continuous use of fertilizers on physico-chemical properties of alluvial soil. *J. Res. Birsa Agric. Univ.,* **9** : 31-34.

Subba, R. A., S. Chand and S. Srivastava. 2002 : Opportunities for integrated plant nutrient supply system for crop/cropping systems in different agro-eco regions. *Fert. News*, **47** : 75-78.

Swarup, A. and N. P. S. Yaduvanshi. 2000 : Effects of integrated nutrient management on soil properties and yield of rice in Alkali soil. *J. Indian Soc. Soil Sci.* **48** : 279-282.

Swarup, A. and R. H. Wanjari. 2000 : *Three decades of All India Coordinated Research Project on long term fertilizer experiments to study changes in soil quality, crop productivity and sustainability* Indian Institute of Soil Science, Bhopal, India, pp 59.

Swarup, A. 2002 : Lessons from long term fertilizer experiments in improving fertilizer use efficiency and crop yield. *Fert. News*, **47** : 59-66.

Tandon, H. L. S. 1997 : Bulky organic manures and crop residues Fertilizer, organic manures, recyclable wastes and biofertilizers components of integrated plant nutrition Binny Printers, New Delhi, pp 47.

Thumar, C. M., M. S. Dudhat, N. N. Chaudhari, N. J. Hadiya, and N. B. Ahir. 2016 : Growth, yield attributes, yield and economics of summer pearlmillet (*Pennisetum glaucum* L) as influenced by integrated nutrient management. *Int. J. Agric. Sci.*, **59** : 3344-3346.

Tiwari, A., H. R. Nema, B. R. Tembhare, and S. K. Sharma. 2002 : Soil physical environment in long term fertilizer experiment on Typic Haplusterts. *JNKVV Res. J.,* **34** : 29-33.

Toor, A. S., S. R. Bishnoi, and R. Kumar. 2001 : Available N release pattern from farmyard manure, Cage system and deep litter system of poultry manure with time. *J. Indian Soc. Soil Sci.*, **49**: 358-360.

Tripathi, H. P., A. K. Mauriya, and A. Kumar. 2007 : Effect of integrated nutrient management on rice-wheat cropping system in eastern plain zone of Uttar Pradesh. *J. Farming Sys. Devel.,* **13** : 198-203.

Vaidya, P. H. and V. V. Gabhane. 1998 : Availability of nutrient in vertisol as influence by sorghum-wheat cropping sequence. *J. Soil Crops,* **8** : 70-72.

Vandana, S. S. Pahuja, S. K. Thakral, and A. Kumar. 2008 : Nutrient content and their uptake in hybrid pearl millet as affected by organic and inorganic fertilizers. *Haryana J. Agron.,* **24** : 88-89.

Vasanthi, D. and K. Kumaraswamy. 2000 : Effects of manure-fertilizer schedules on the yield and uptake of nutrients by cereal fodder crops and soil fertility. *J. Indian Soc. Soil Sci.*, **48** : 510-515.

Verma, G. and A. K. Mathur. 2009 : Effect of integrated nutrient management on active pools of soil organic matter under maize-wheat system of a Typic Haplustept. *J. Indian Soc. Soil Sci.*, **57** : 317-22.

Verma, G., A. K. Mathur, P. C. Kanthaliya, and A. Verma. 2009 : Assessment of slow pool of soil organic matter under integrated nutrient management in maize-wheat cropping system in Typic Haplustepts. *J. Soils Crops*, **19** : 54-57.

Yadav, D. S., R. P. Shukla, Sushant and B. Kumar. 2005 : Effect of zero tillage and nitrogen levels on wheat (*Triticum aestivum*) after rice (*Oryza sativa*). *Indian J. Agron.*, **50** : 52-53.

Yadav, S. K., P. Kumar, and M. Kumar. 2010 : Influence of integrated fertilizer management on nutrients utilization and soil chemical properties by pearl millet-wheat cropping system. *Haryana J. Agron.,* **26** : 1-8.

Yengade, P. W. and N. R. Mairan. 2009 : Soil productivity as influenced by integrated nutrient management and cropping system. *Asian J. Soil Sci.*, **4** : 46-48.