



Effect of Nitrogen Management Practices in Conjunction with Farmyard Manure on Soil Properties and Fruit Yield of Chilli (*Capsicum annum* L.)

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Abstract: Nitrogen (N) management practices has a significant impact on soil sustainability and chilli fruit yield. Therefore, an experiment study was conducted at PAU, Ludhiana during 2022-23 in split-plot design with three replicates. There are two main plots *i.e.* without and with farmyard manure (FYM) and thirteen N treatments in sub plots *i.e.* 4 different N-fertilizer levels: 0, 75, 113 and 150 kg N/ ha applied in two, three, four and five equal split doses. The results revealed that INM plots *i.e.* integration of N-fertilizer practices in conjunction with FYM @ 25 t/ha result significantly higher fruit yield along with improving the soil properties than N-fertilizer practices without FYM. The treatment 113 kg N/ha applied in 4 split doses has significantly higher fruit yield (45.8%) along with higher macro and micro-nutrients with respect to recommended dose of fertilizer treatment 75 kg N/ha applied in two split doses. Only two split N-fertilizer doses were not ensured the sustainable crop performance. Therefore, 113 kg N/ha applied in four equal split doses integrated with FYM @ 25 t/ha in chilli would be beneficial for sustainable fruit production and soil fertility.

Keywords: Chilli, Farmyard manure, Fruit yield, Nitrogen management, Soil fertility

Chilli (*Capsicum annum* L.) is one of the most significant spice crop grown for their aromatic fruit which is used for pungency, spice, taste and culinary purposes (Naz et al., 2006). It is a rich source of vitamins, capsaicin alkaloid, protein, and minerals such as iron, copper, phosphorus and calcium (Prathibha et al., 2013). It is prominent for its medicinal effects, therapeutic uses and nutritional value in addition to its use as flavouring agent in food-based industry (Deepa et al., 2007). India is largest producer, consumer and exporter of chillies in world followed by Bangladesh, China and Thailand. Andhra Pradesh is largest producer of chilli in India contributing 30% of total area (Kumar et al., 2016). In Punjab, evolution of chilli hybrids has boosted the production and area under vegetables growers and occupies an area of 8.78 thousand ha with a production of 17.63 thousand tonnes and productivity of 2.01 t/ha (Dhaliwal et al., 2015).

Nitrogen (N) plays the most significant role in increasing the metabolic and physiological exertion of plants. It is a structural component of proteins, plant physiology, fruit yield and photosynthesis assimilation. Most of the Indian soils are deficient in N element (Rekha et al., 2018). The excessive application of chemical N-fertilizer cannot sustain soil fertility and optimal fruit yield in highly intensive agricultural systems (Powlson et al., 2011). The widespread use of chemical N-fertilizers and the limited use of farmyard manure (FYM) in modern agriculture are resulting in loss of soil organic carbon (SOC) and multi-nutrient deficiencies. India consumed 16% out of total N-fertilizer globally due to knowledge gap between

farmers and scientists and availability of higher subsidized N-fertilizers. The trends of N consumption have increased substantially in India which can leads to nitrate contamination of surface and groundwater (Bijay-Singh and Craswell 2021). Currently, agriculture specialists suggest farmers to shift their mindsets towards utilizing Integrated Nutrient Management (INM) approach to replace a portion of inorganic N-fertilizers with more sustainable and eco-friendly sources of nutrients. The FYM is an eco-friendly practice of INM approach which helps in improving the slow decomposition of nutrients. It can help in sustaining the productivity by conservation of organic N to available form and hence improve the soil fertility along with fruit yield. The conjoint integration of FYM with chemical N-fertilizer helps to improve the fruit productivity and agricultural sustainability, whereas sole application of N-fertilizer degrades the soil fertility. The INM can improve the microbial decomposition of organic matter which helped in conversion of organic N to plant available form (Sinha et al., 2017).

Nitrogen management techniques such as optimizing the distant timing and levels of N-fertilizer application have proven to be effective in increasing nitrogen use efficiency, yield and reducing nutrient losses such as leaching, denitrification, etc (Shafeek et al., 2012). The fruit yield of chilli reduced in present RDF treatment *i.e.* 75 kg N/ha applied in two split doses due to drastic reduction in fruit yield at later pickings (Babanjeet et al., 2022). Limited information is available related to the effect of timing and levels of N

application with and without FYM on soil properties along with fruit yield in chilli. Therefore, the present investigation has been planned to investigate for enhancing the chilli productivity while maintaining the organic carbon stocks under different N management practices.

MATERIAL AND METHODS

The present study was conducted on chilli crop at Research Area, Department of Soil Science, Punjab Agricultural University, Ludhiana, Punjab, India during the summer season of 2022-23. The research area has a semi-arid and subtropical climate which represents the Indo-Gangetic alluvial plains in north-western India. The area is situated at 247 m AMSL with 30°55' N latitude and 75°49'E longitude. It contributes around 76% of total rainfall obtained (660 mm) during the period of July-September. The agrometeorological data (Fig. 1) recorded during the crop period (March-August) showed that the average maximum weekly temperature fluctuates between 32.8°C and 43.7°C and average minimum weekly temperature fluctuates between 17.1°C and 29.0°C. Further, maximum evaporation occurs at 23rd week (5-11 June) and maximum rainfall occurs at 29th week (17-23 July), respectively. The overall 452.5 mm of rainfall was recorded throughout the crop period.

Experimental methodology: The soils of the experimental field was sandy-loam in texture, optimal pH and EC, low in available nitrogen, medium in available phosphorus and potassium. The chilli (*Capsicum annum* L.) crop was sown in nursery on 13th November, 2021 and transplanting was done on 13th March, 2022, respectively. Farmyard manure was applied at the rate of 25 t/ha as per recommended practices for vegetable crop in Punjab, PAU, Ludhiana. The N-fertilizer

was applied through drilling at transplanting and top dressing at every picking. The P-fertilizer at the rate of 30 kg P₂O₅/ha was drilled through SSP (16% P₂O₅) and K-fertilizer at the rate of 30 kg K₂O/ha was drilled through MOP (60% K₂O) before chilli transplanting. The study was undertaken to integrate N-fertilizer management practices with and without FYM on soil properties along with fruit yield. The treatments details are given in Table 1. The crop was planted on ridges at 75 cm apart with plant to plant spacing of 45 cm. About 0.5 grams of composite soil samples was taken before and after harvesting of crop and analyzed in soil testing laboratory by following the standard methods (Table 2 and 3). The fruit yield (q/ha) was recorded from each plot at every picking when chilli turns colour from green to red. The experimental results were statistical analyzed using CPCS-1 software given by Cheema and Singh (1991). Mean comparisons were carried out to compare the means at ($p = 0.05$).

RESULTS AND DISCUSSION

Soil Chemical Parameters

Soil pH, electrical conductivity and soil organic carbon:

There were significant variation between the without and with FYM for soil pH. The initial values of the experimental field were depicted in Table 3. The results depicted in Table 4 showed that FYM treated plots have a lower pH value (7.24) than without FYM plots (7.32). The T₁ treatment (0 kg N/ha) recorded the highest pH value (7.33). The decrease in surface soil pH with the integrated application of N-fertilizer with FYM may be attributed to the release of CO₂ and the production of organic acid during the mineralization and persistent decomposition of FYM (Singh et al., 2015). Rajneesh et al., (2017) revealed that an increase in N-

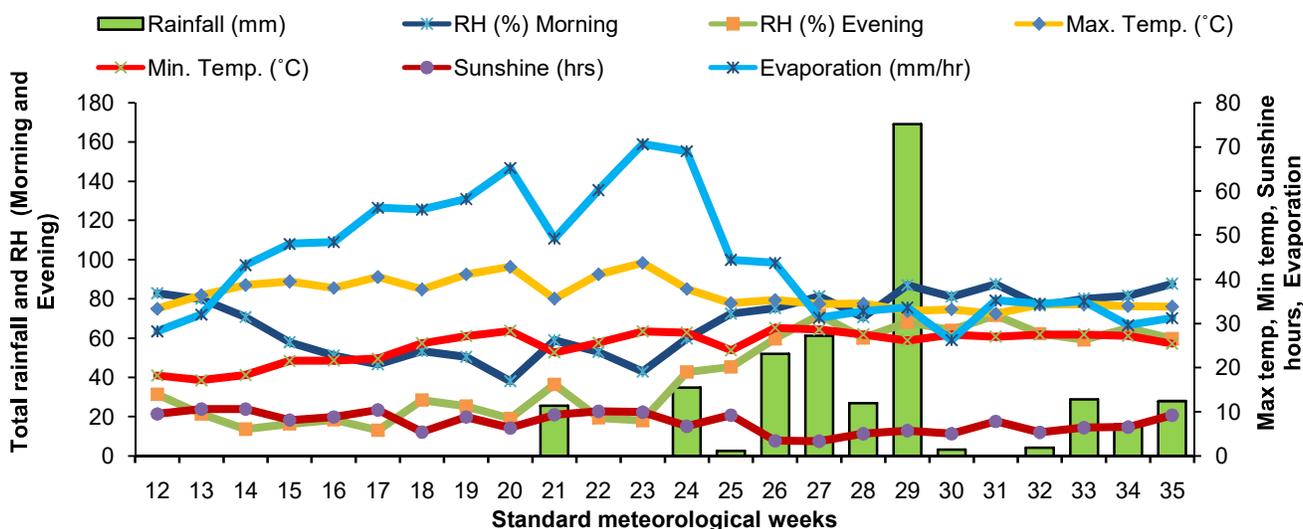


Fig. 1. Weekly mean meteorological data recorded during 2022-23 at PAU, Ludhiana

fertilizer levels can decrease the soil pH due to the release of H⁺ ions and hydrolysis of inorganic urea. The decrease in surface soil pH has a positive influence on the availability of different nutrients, notable Zn, Mn, Fe and P (Benbi et al., 2012). The N-fertilized plots without FYM plots have higher EC value (0.18 dS/m) than FYM plots (0.15 dS/m). There was a significant decrease in EC range with an increase in the level of N-fertilizer application (Table 4). The higher EC value (0.20 dS/m) was observed in the T₁ treatment and the lowest EC (0.15 dS/m) was attained in T₁₁, T₁₂ and T₁₃ treatments by substitution of 150 kg N/ha in three, four and five equal splits, respectively. The lower EC values under organic amendment (FYM) could be attributed to increased soil water holding capacity because of improved soil aggregation (Duhan and Singh 2002). Soil organic carbon is the most imperative indicator of agricultural sustainability and soil health. The treatments T₄, T₈, T₁₁ and T₁₂ have maximum SOC (0.43%) due to higher build-up of SOC due to slower and less persistent decomposition rate of FYM because of polyphenol

Table 3. Basic initial soil properties (0-15 cm soil profile)

Soil parameters	Initial values
Sand (%)	74.5
Silt (%)	16.3
Clay (%)	9.2
Textural class	Sandy-loam
Bulk density (g/cm ³)	1.62
Particle density (g/cm ³)	2.61
Soil pH	7.40
Electrical conductivity dS/m at 25°C	0.23
Soil organic carbon (%)	0.41
Available nitrogen (kg/ha)	137.6
Available phosphorus (kg/ha)	18.4
Available potassium (kg/ha)	127.6
DTPA extractable zinc (mg/kg)	2.59
DTPA extractable copper (mg/kg)	0.35
DTPA extractable iron (mg/kg)	11.7
DTPA extractable manganese (mg/kg)	3.71

Table 1. Treatments details

S. No.	Main plots (2)
F ₀	Without FYM
F ₂₅	With FYM @ 25 t/ha (RDF)
	Sub plots (13)
T ₁	0 kg N/ha (Control)
T ₂	75 kg N/ha application in 2 equal splits at transplanting and after 1 st picking (RDF)
T ₃	75 kg N/ha application in 3 equal splits at transplanting, after 1 st and 2 nd picking
T ₄	75 kg N/ha application in 4 equal splits at transplanting, after 1 st , 2 nd and 3 rd picking
T ₅	75 kg N/ha application in 5 equal splits at transplanting, after 1 st , 2 nd , 3 rd and 4 th picking
T ₆	113 kg N/ha application in 2 equal splits at transplanting and after 1 st picking
T ₇	113 kg N/ha application in 3 equal splits at transplanting, after 1 st and 2 nd picking
T ₈	113 kg N/ha application in 4 equal splits at transplanting, after 1 st , 2 nd and 3 rd picking
T ₉	113 kg N/ha application in 5 equal splits at transplanting, after 1 st , 2 nd , 3 rd and 4 th picking
T ₁₀	150 kg N/ha application in 2 equal splits at transplanting and after 1 st picking
T ₁₁	150 kg N/ha application in 3 equal splits at transplanting, after 1 st and 2 nd picking
T ₁₂	150 kg N/ha application in 4 equal splits at transplanting, after 1 st , 2 nd and 3 rd picking
T ₁₃	150 kg N/ha application in 5 equal splits at transplanting, after 1 st , 2 nd , 3 rd and 4 th picking

Table 2. Standard analytical methods followed in soil analysis (0-15 cm soil profile)

Soil properties	Standard estimation method	References
pH (1:2 soil: water suspension)	Glass membrane electrode using pH meter	Jackson (1973)
Electrical conductivity (1:2soil: water suspension)	Potentiometric method using EC Solubridge meter	Jackson (1973)
Soil organic carbon	Rapid titration method	Walkley and Black (1934)
Available nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
Available phosphorus	0.5 M Sodium bicarbonate using US-VIS spectrophotometer	Olsen et al. (1954)
Available potassium	1 N Ammonium acetate using flame photometer technique	Merwin and Peech (1950)
DTPA zinc, copper, iron and managanese	Atomic absorption spectrophotometer	Lindsay and Norwell (1978)

as well as lignin content. The SOC content can be improved application through manure and chemical fertilizers due to root anatomy and plant residue through conjoint (Dhaliwal et al., 2019).

Table 4. Effect of farmyard manure and nitrogen levels on pH, EC and SOC of surface (0-15 cm) soil after harvesting of chilli

Treatments	pH			EC (dS/m)			SOC (%)		
	FYM		Mean	FYM		Mean	FYM		Mean
	Without	With		Without	With		Without	With	
T ₁	7.39	7.28	7.33	0.22	0.18	0.20	0.40	0.42	0.41
T ₂	7.35	7.26	7.31	0.20	0.16	0.18	0.41	0.43	0.42
T ₃	7.34	7.26	7.30	0.20	0.15	0.18	0.42	0.43	0.42
T ₄	7.34	7.25	7.29	0.19	0.15	0.17	0.42	0.44	0.43
T ₅	7.33	7.25	7.29	0.19	0.14	0.17	0.41	0.43	0.42
T ₆	7.33	7.24	7.29	0.19	0.15	0.17	0.41	0.43	0.42
T ₇	7.32	7.23	7.28	0.18	0.15	0.17	0.41	0.43	0.42
T ₈	7.31	7.23	7.27	0.18	0.14	0.16	0.42	0.44	0.43
T ₉	7.31	7.23	7.27	0.17	0.14	0.15	0.41	0.43	0.42
T ₁₀	7.29	7.22	7.26	0.18	0.16	0.17	0.41	0.44	0.42
T ₁₁	7.28	7.21	7.24	0.17	0.14	0.15	0.42	0.44	0.43
T ₁₂	7.28	7.21	7.25	0.16	0.14	0.15	0.42	0.44	0.43
T ₁₃	7.28	7.20	7.24	0.16	0.13	0.15	0.41	0.43	0.42
Mean	7.32	7.24		0.18	0.15		0.41	0.43	
CD (p=0.05)	FYM	0.01		NS			NS		
	Nitrogen	NS		0.01			NS		
	Interaction	NS		NS			NS		

Table 5. Effect of farmyard manure and nitrogen levels on available N, P and K of surface (0-15 cm) soil after harvesting of chilli

Treatments	Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)		
	FYM		Mean	FYM		Mean	FYM		Mean
	Without	With		Without	With		Without	With	
T ₁	119.8	152.5	136.2	19.6	29.3	24.5	129.8	147.5	138.6
T ₂	135.4	161.4	148.4	19.8	29.8	24.8	131.1	149.7	140.4
T ₃	137.5	163.4	150.5	20.6	28.5	24.6	131.4	151.5	141.5
T ₄	139.8	167.4	153.6	19.3	29.4	24.4	133.6	151.7	142.6
T ₅	141.6	172.2	156.9	19.5	28.5	24.0	134.5	154.4	144.4
T ₆	144.3	185.5	164.9	20.3	28.7	24.5	132.5	153.3	142.9
T ₇	144.4	187.1	165.8	19.4	29.3	24.4	134.5	153.7	144.1
T ₈	144.6	191.4	168.0	20.7	29.7	25.2	135.4	156.4	145.9
T ₉	145.3	193.5	169.4	19.5	27.7	23.6	132.5	156.9	144.7
T ₁₀	147.3	201.6	174.5	19.9	28.4	24.2	133.5	155.3	144.4
T ₁₁	148.3	202.2	175.3	19.5	27.9	23.7	133.6	155.5	144.5
T ₁₂	149.3	205.1	177.2	19.3	29.5	24.4	133.7	153.3	143.5
T ₁₃	152.1	210.2	181.2	20.5	28.2	24.3	133.7	155.5	144.6
Mean	142.3	184.1		19.8	28.8		133.1	153.4	
CD (p=0.05)	FYM	1.06		0.23			0.66		
	Nitrogen	4.89		0.19			NS		
	Interaction	6.70		0.32			NS		

Available primary macronutrients (nitrogen, phosphorus and potassium): The integrated application showed a considerable increase in the available N content of surface soil with respect to initial available N content (137.6 kg/ha). There was a significant difference exhibited without and with FYM on available N content (Table 5). A significantly higher N content (184.1 kg/ha) in FYM plots with respect to without FYM plots (142.3 kg/ha). There was a significant increase in N content of surface (0-15 cm) soil concerning increase in different levels and splits of N-fertilizer and revealed that higher N content (181.2 kg/ha) in T₁₃ treatment which was at par with T₁₂ treatment. There was significant interaction observed between FYM and N-fertilizer on the available N content of surface soil. The F₂₅T₁₃ treatment *i.e.*, 150 kg N/ha was applied in five splits integrated with FYM practices had 210.2 kg N/ha which resulted (42.7%) significantly higher than F₀T₁₀ treatment *i.e.*, 150 kg N/ha in two splits without FYM practices. The INM treatments have higher available N content than sole inorganic N-fertilizer treatments due to the improvement of SOC and slow mineralization of available N in surface soil (Guo et al., 2016; Yan et al., 2021). There was a significant difference among without and with treated FYM plots on available P content (Table 5). The FYM treated plots have higher available P

(28.8 kg/ha) with respect to without FYM plots (19.8 kg/ha). The T₈ treatment has the highest available P (25.2 kg/ha), which was significantly higher than the rest of all the treatments and the lowest P content (23.6 kg/ha) was observed in T₉ treatment. Significant interaction was observed between FYM and N-fertilizer on the available P content. The F₂₅T₂ treatment has significantly higher available P (29.8 kg/ha) than the F₀T₁₂ (19.3 kg/ha). The FYM strategies with inorganic N-fertilizer have higher available P content than inorganic N-fertilizer due to soil organic matter (SOM) coating the sesquioxides (Al-P and Fe-P), rendering them inactive and reducing the P fixing capacity of surface soil resulting in improvement of P in soil (Subehia et al., 2013). There was a significant difference among the available K content (Table 5) between the without and with FYM plots and revealed that FYM treated plots resulted higher K content (153.4 kg/ha) than without treated FYM plots (133.1 kg/ha). The increase in available K of surface soil with combined application of of N-fertilizer with FYM may be attributed to improves the water holding capacity (WHC) and slow mineralization of nutrients (Meena et al., 2024). The farmyard manure can significantly increase the available K content as compared to inorganic N fertilizer plots (Urkurkar et al., 2010).

Table 6. Effect of farmyard manure and nitrogen levels on DTPA-extractable Zn, Cu, Fe and Mn of surface (0-15 cm) soil after harvesting of chilli

Treatments	DTPA-extractable Zn			DTPA-extractable Cu			DTPA-extractable Fe			DTPA-extractable Mn		
	FYM		Mean									
	Without	With		Without	With		Without	With		Without	With	
T ₁	2.56	3.17	2.87	0.35	0.52	0.44	11.5	16.4	13.9	3.70	4.78	4.24
T ₂	2.58	3.21	2.90	0.37	0.53	0.45	11.8	16.5	14.2	3.81	4.94	4.38
T ₃	2.59	3.22	2.90	0.36	0.53	0.45	11.9	16.6	14.3	3.56	4.97	4.26
T ₄	2.58	3.24	2.91	0.36	0.54	0.45	11.5	18.2	14.8	4.01	5.10	4.56
T ₅	2.60	3.27	2.94	0.38	0.56	0.47	12.1	17.0	14.6	4.13	5.24	4.68
T ₆	2.57	3.23	2.90	0.40	0.55	0.48	11.9	17.2	14.6	4.03	5.00	4.52
T ₇	2.57	3.24	2.91	0.39	0.54	0.47	12.2	17.5	14.9	4.19	5.12	4.66
T ₈	2.59	3.26	2.93	0.37	0.56	0.47	12.4	17.9	15.2	4.08	5.20	4.64
T ₉	2.60	3.29	2.95	0.40	0.53	0.46	12.1	18.2	15.1	4.15	5.06	4.61
T ₁₀	2.59	3.27	2.93	0.39	0.55	0.47	12.3	18.5	15.4	4.06	5.10	4.58
T ₁₁	2.60	3.28	2.94	0.40	0.54	0.47	11.7	17.9	14.8	4.21	5.04	4.62
T ₁₂	2.61	3.30	2.95	0.38	0.58	0.48	12.8	18.1	15.4	4.15	5.21	4.68
T ₁₃	2.58	3.25	2.91	0.37	0.53	0.45	12.1	17.7	14.9	3.93	5.12	4.53
Mean	2.59	3.25		0.38	0.54		12.0	17.5		4.00	5.06	
CD	FYM			0.02			0.01			0.08		
(p=0.05)	Nitrogen			NS			NS			NS		
	Interaction			NS			NS			NS		

DTPA-extractable micronutrients (Zn, Cu, Fe and Mn):

The integrated application of chemical N-fertilizer with FYM showed a considerable increase in micronutrients *i.e.*, Zn, Cu, Fe and Mn of surface soil in comparison with initial soil samples. There was significantly higher available micronutrients in FYM treated plots than without FYM plots (Table 6). There was non-significant increase in an available micronutrients of soil with respect to increase in different levels and splits of N-fertilizer. The lowest micronutrients were observed in the T₁ (no application of N fertilizer). The INM treatments have higher available micronutrients than sole inorganic N fertilizer due to increasing soil microbial activity during mineralization and decomposition of organic matter which improved the DTPA-extractable Zn, Cu, Fe and Mn content in surface soil by preventing leaching, fixation and precipitation (Walia et al., 2010). Integrated management plots have higher micronutrients as compared to inorganic N-fertilizer due to increasing microbial activity during mineralization and decomposition of SOM (Dhaliwal et al., 2020).

Fruit yield (q/ha): The higher fruit yield (229.1 q/ha) was obtained in FYM treated plots than without FYM treated plots (169.8 q/ha) (Table 7). The T₈ treatment *i.e.* 113 kg N/ha application in four equal splits produced significantly higher fruit yield (254.4 q/ha). There was significant interaction

Table 7. Effect of farmyard manure and nitrogen levels on total fruit yield (q/ha) of chilli

Treatments	Red ripe fruit yield		
	FYM		Mean
	Without	With	
T ₁	104.7	188.0	146.3
T ₂	140.2	207.6	173.9
T ₃	158.0	220.8	189.4
T ₄	180.4	234.5	207.5
T ₅	124.9	196.8	160.9
T ₆	171.6	248.2	209.9
T ₇	184.4	269.9	227.1
T ₈	206.2	302.6	254.4
T ₉	143.8	217.2	180.5
T ₁₀	196.6	219.3	208.0
T ₁₁	208.7	237.6	223.2
T ₁₂	225.2	245.9	235.5
T ₁₃	162.8	189.7	176.3
Mean	169.8	229.1	
CD	FYM	4.30	
(p=0.05)	Nitrogen	7.40	
	Interaction	10.7	

observed between FYM and N-fertilizer on fruit yield and showed that F₂₅T₈ treatment resulted 25.6 % significantly higher fruit yield than F₀T₁₂ treatment. With in each N-fertilizer level *i.e.*, 75, 113 and 150 kg/ha, four split doses performed best followed by three, two and five split doses. The fruit yield is the total quantity of mature red ripe fruits produced per unit of land. It is influenced by many parameters, besides its most important parameter for attaining monetary returns for farmers. Nitrogen is an important deficient plant nutrient that affect the fruit productivity of chilli (Khan et al., 2014).

CONCLUSIONS

The integrated application of farmyard manure and nitrogen fertilizer practices resulted optimal fruit yield along with builds-up of macro and micronutrients for sustainable growth and development of chilli. The higher fruit yield and nutrients availability was attained with 113 kg N/ha applied in four equal splits. There was significantly higher fruit yield by substitution of 113 kg N/ha applied in four equal splits than RDF treatment *i.e.*, 75 kg N/ha applied in two split doses. Within each N level: 75, 113 and 150 kg N/ha, four equal splits of N-fertilizer performed better than three, two and five splits, respectively both in without and with FYM plots. Only two splits of N-fertilizer were not ensured the optimal fruit yield and nutrients availability as per plant demands. Therefore, 113 kg N/ha applied in four equal splits can be recommended to farmers for achieving higher fruit yield and agricultural sustainability.

ACKNOWLEDGEMENT

The authors express their gratitude to Department of Soil Science, Punjab Agricultural University, Ludhiana for providing research facilities.

AUTHOR'S CONTRIBUTION

Conceptualization and designing of research work (DK,AG); Execution of field/lab experiments and data collection (DK); Analysis of data and interpretation (DK, AG, VS); Preparation of manuscript (DK).

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