Journal of Advances in Biology & Biotechnology

Volume 27, Issue 9, Page 11-22, 2024; Article no.JABB.121474
ISSN: 2394-1081

Effect of Timing and Levels of Nitrogen Application with Farmyard Manure Application on Growth and Yield of Chilli (*Capsicum annuum* L.)

Dimple Kamboj [a*], AAS Gill [a] and Salesh Kumar Jindal [b]

[a] Department of Soil Science, Punjab Agricultural University, Ludhiana - 141004, Punjab, India.
[b] Department of Vegetable Science, Punjab Agricultural University, Ludhiana - 141004, Punjab, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jabb/2024/v27i91269

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/121474

Original Research Article

Received: 10/06/2024
Accepted: 12/08/2024
Published: 17/08/2024

ABSTRACT

Nitrogen (N) plays a significant role in plant metabolic and physiological exertions. As a key factor in ensuring sustainable soil fertility and fruit productivity, N management is crucial. Therefore, a field experiment was conducted during *kharif* season of 2022-23 at PAU, Ludhiana. The soil of the experimental field was sandy-loam in texture, low in available nitrogen, medium in available phosphorus and potassium. The chilli hybrid CH 27 was grown in split-plot design that comprised two main plots, *i.e.* without and with farm yard manure (FYM) at 25 t ha^{-1} and thirteen subplots consisting of four different N levels: 0, 75, 113 and 150 kg N ha^{-1} applied in 2, 3, 4 and 5 split doses. The results revealed that higher fruit yield was attained by the application of 113 kg N ha^{-1} in 4 split doses integrated with FYM and recorded 45.8% higher fruit yield than the recommended dose of

**Corresponding author: Email: dimple-2316009@pau.edu;*

Cite as: *Kamboj, Dimple, AAS Gill, and Salesh Kumar Jindal. 2024. "Effect of Timing and Levels of Nitrogen Application With Farmyard Manure Application on Growth and Yield of Chilli (Capsicum Annuum L.)". Journal of Advances in Biology & Biotechnology 27 (9):11-22. https://doi.org/10.9734/jabb/2024/v27i91269.*

fertilizer, *i.e.* 75 kg N ha^{-1} applied in 2 split doses integrated with FYM due to greater number of fruits per plant. Within each N level, 4 split doses of N-fertilizer performed better than 3, 2 and 5 split doses in both without and with FYM treated plots. Only two split doses were not ensured the optimum supply of N at later growth stages. Therefore, 113 kg N ha^{-1} in 4 equal split doses integrated with FYM can be recommended to farmers for achieving maximum yield in chilli under Punjab conditions.

Keywords: Chilli; fruit yield; growth; nitrogen; farmyard manure; yield attributes.

1. INTRODUCTION

Chilli (*Capsicum annuum* L.) is one of the most important spice and vegetable crops grown for both its green and red aromatic fruits. It is a rich source of minerals, vitamins, proteins and capsanthin pigment, which are famous for pungency, culinary and nutritional value [1]. It is used as a condiment in various food stuffs such as curries, sauces, chutney and soups to add flavour and pungency. It is widely used in the preparation of curry paste, curry powder and all kinds of pickles [2]. The extracts of chilli such as oleoresin, concentrate and sausage are used in processed foods that are export to generate income for the growers. It is grown over an area around 729 thousand hectares with production of 2.09 MT and the average productivity of 2.9 t ha^{-1} [3]. The CH-3 hybrid is suitable for forming paste for export purposes, while the CH-27 hybrid is most common for processing and pharmaceutical industries.

Chilli is a long duration vegetable crop since it requires optimal N fertilizer for plant physiology, yield attributes and chlorophyll synthesis in plants [4]. The indiscriminate use of chemical N-fertilizer can reduce growth and yield-attributes increase farmer's total expenditure year after year [5]. India consumed 16% out of total N-fertilizer globally [6]. High fertilizer consumption in developing countries is due to high population pressure, availability of highly subsidized N-fertilizers and knowledge gap between farmers and scientists [7]. As a result, soil scientists and agronomists advise farmers to change their perspective and adopt an integrated nutrient management (INM) strategy in order to replace sole N-fertilizer with more sustainable sources of nutrients. The farm yard manure (FYM) is an important practice of INM, which help in less and persistent mineralization of nutrients [8]. Aside from delivering essential nutrients and minerals, farmyard manure increases a variety of soil qualities and soil health, all of which help with crop productivity [9]. Hence, it is necessary to use organic and inorganic fertilizers in chilli pepper cultivation.

The N management strategies, such as optimizing the timing and levels of N-fertilizer with FYM increase the fruit yield [10]. The growth, quality and yield-related attributes of chilli were improved when N-fertilizer was applied in more than 2 split doses [11]. The N-fertilizer demand was synchronized with real time N management such as application of N in right rate, right time, right place and right source. It is now possible to optimizing the fertilizer N management to account for the variation in the N supplying capacity of the soil through variable rates and timings of N-fertilizer application [12]. There is limited information available about the effect of timing and levels of N application with and without FYM on chilli yield. Therefore, the present investigation was planned to investigate the impact of different timing and levels of N application with and without FYM on growth and yield of chilli.

2. MATERIALS AND METHODS

2.1 Site and Weather

The current study was conducted during the *kharif* season of 2022-23 at Research Farm, Department of Soil Science, PAU, Ludhiana, Punjab which is located at 247 m ASL with 30°54' N latitude and 75°48' E longitude. The area has a subtropical and semi-arid climate. The south-west monsoon occurs from July to September contributing to around 76% of total rainfall. The meteorological data (Fig. 1) recorded during the growth period of the crop showed that the average maximum weekly temperature was between 32.8°C and 43.7°C while the average minimum weekly temperature was between 17.1°C and 29.0°C during the crop period (March-August). Further, maximum rainfall occurred in the 29th week (17-23 July) and maximum evaporation occurred at 23rd week (5-11 June), respectively. The overall 452.5 mm of rainfall was recorded throughout the crop.

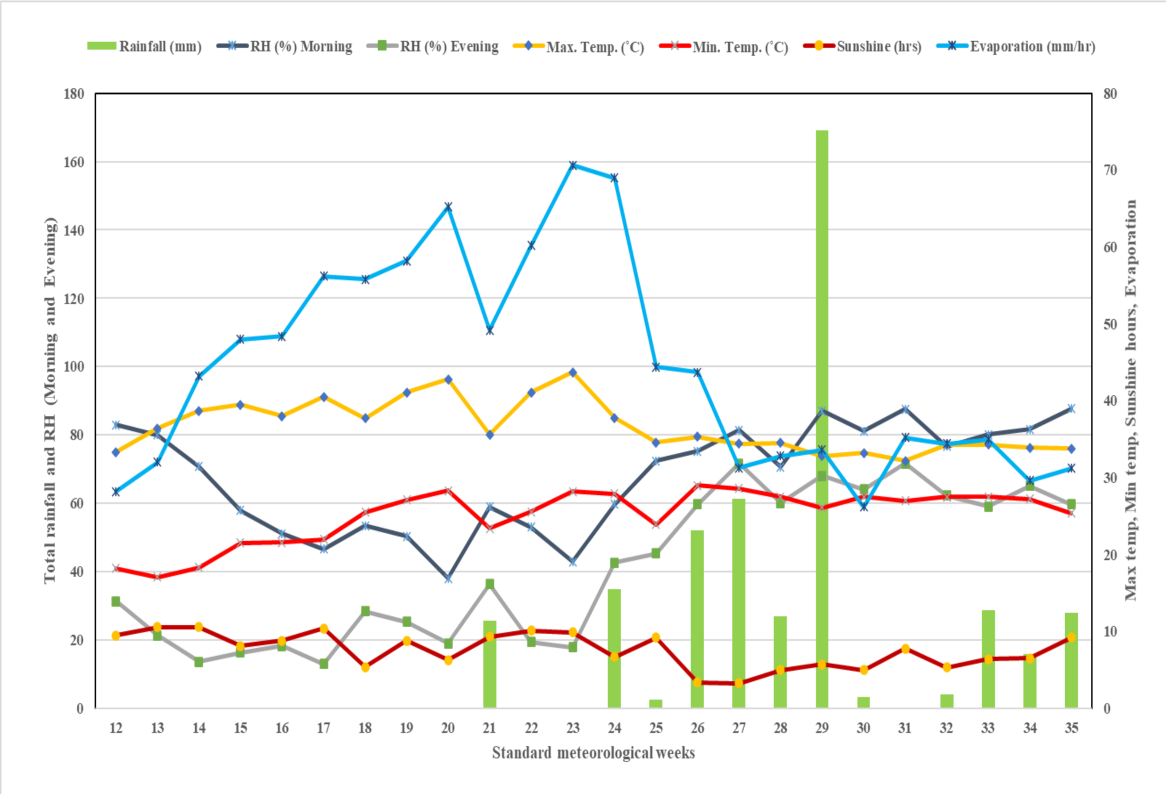

Fig. 1. Weekly average mean meteorological data recorded during the crop season (March-August 2022) at PAU, Ludhiana

2.2 Experimental Details

The current study was undertaken to study the effect of N-fertilizer integrated with FYM at 25 t ha^{-1} on growth, quality and yield-related attributes of chilli. The experimental study was laid out in a split-plot design. The experiment was replicated thrice with hybrid CH 27. The experiment comprised of farmyard manure (FYM) that is applied at 25 t ha^{-1} (F_{25}) or not (F_0) as main plots and thirteen N fertilizer applications as sub plots treatments. Four different levels of N fertilizer: 0, 75, 113 and 150 kg ha^{-1} were applied in 2 equal splits at transplanting and after 1st picking, 3 equal splits at transplanting, after 1st and 2nd picking, 4 equal splits at transplanting, after 1st, 2nd and 3rd picking and 5 equal splits at transplanting, after 1st, 2nd, 3rd and 4th picking. Treatment T_1 (0 kg N ha^{-1}) was the control, in treatments T_2, T_3, T_4 and T_5, 75 kg N ha^{-1} (recommended N dose) was applied in 2 equal splits at transplanting and after 1st picking, 3 equal splits at transplanting, after 1st and 2nd picking, 4 equal splits at transplanting, after 1st, 2nd and 3rd picking and 5 equal splits at transplanting, after 1st, 2nd, 3rd and 4th picking. Similarly, in T_6, T_7, T_8 and T_9 treatments, 113 kg N ha^{-1} was applied. Also, in treatments T_{10}, T_{11}, T_{12} and T_{13}, 150 kg N ha^{-1} was applied in 2, 3, 4 and 5 equal splits, respectively. The layout design contained 78 plots with size 7.5 m × 4.5 m each. The N-fertilizer was applied through drilling at transplanting and top dressing at every picking. The recommended rate of P (30 kg P_2O_5 ha^{-1}) and K (30 kg K_2O ha^{-1}) were drilled through SSP and MOP before transplanting of crop. The transplanting was done on 19th March, 2022. The crop was planted on ridges at 75 cm apart with plant to plant spacing of 45 cm. The picking of crop was done when fruits of chilli turn from green to red colour.

2.3 Soil Characteristics

Initial soil samples were randomly collected from different sites and properly mixed to make one composite sample before the start of the experiment. The soil of the experimental site was sandy-loam in texture, having *p*H 7.4, determined by the glass electrode method using *p*H meter and EC value of 0.23 dS m^{-1}, measured by potentiometric method using a conductivity meter. The soil was medium in SOC (0.41%), computed by wet digestion method [13];

available P (18.4 kg ha^{-1}), determined using UV-VIS spectrophotometer [14]; available K (127.6 kg ha^{-1}) using a flame ionization technique [15]; low in available N (137.6 kg ha^{-1}), analyzed by alkaline permanganate method [16] and adequate in DTPA-extractable micronutrients i.e., Zn (2.48 mg kg^{-1}), Cu (0.29 mg kg^{-1}), Fe (11.3 mg kg^{-1}) and Mn (3.71 mg kg^{-1}) as determined by atomic absorption spectrophotometer [17].

2.4 Observations Recorded

The growth-related parameters such as plant height (cm) was measured at 30 days growth intervals viz. 30, 60, 90, 120 and 150 days after transplanting (DAT), number of branches and leaves per plant at full growth stage (146 DAT) and leaf area index at flowering stage (48 DAT) measured by canopy analyzer; The quality attribute such as capsaicin content and dry matter content in fruit were estimated as reported by Bajaj and Kaur et al. [18]. The yield-related parameters such as fruit length (cm), fruit width (cm), number of fruits per plant was taken after averaging of 5 plants, fruit yield was measured by digital weighing balance and fruit weight was taken after averaging of 10 fruits.

2.5 Statistical Analysis

To test the significance of treatments, the data collected on different growth, quality and yield-related attributes were analyzed using analysis of variance (ANOVA) in split-plot design using CPCS-1 software given by Cheema and Singh [19]. The least significant difference (LSD) test was used to compare the means at ($P < 0.05$).

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height

Height is an important growth-attribute depicting the fitness of the plant. It provides an estimate of growth and development of the crop which is related to biomass production. The results with respect to different timing and levels of N-fertilizer with or without FYM application on plant height at 30 days interval *viz.* 30, 60, 90, 120 and 150 DAT were presented in Table 1. The data showed that FYM application (25 t ha^{-1}) attained higher plant height than without FYM plots. Application of N treatments at 150 DAT were positively affected on plant height, Treatment T_{12} (150 kg N ha^{-1} applied in 4 equal splits) resulted in highest plant height (83.7 cm), which was at par with T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11} and T_{13}. The highest plant height was observed due to higher availability of N through combined use of FYM with N fertilizer as compared to sole application of N fertilizer [20]. The higher dose of N resulted in rapid cell division, differentiation and enlargement [21] and ultimately higher plant height as reported by Kumar et al. [22].

3.1.2 Number of primary branches per plant

The data pertaining to the different levels of N-fertilizer and FYM on number of branches were presented in Table 2. The results revealed that FYM plots attained significantly higher number of branches per plant (6.46) than without FYM plots (5.45). The integrated nutrient management (INM) results in formation of higher branches per plant rather than sole use of N-fertilizer. The application of FYM resulted in better nutrition to plant along with improving the soil health as reported by Gare et al. [24] and Puli et al. [25]. Furthermore, T_{12} treatment resulted in higher number of branches per plant (6.29), which was at par with T_8 (6.18), T_{10} (6.25), T_{11} (6.27) and T_{13} (6.23). The lowest number of branches per plant (5.17) was observed in T_1 treatment. Nitrogen helps in promoting cell division and growth of lateral branches by auxin, which eventually led to the formation of more branches per plant [23].

3.1.3 Number of leaves per plant

The leaf number per plant is crucial growth-attribute depicting the health, vigor and yield of plant. The leaf number directly increases the leaf area for the process of photosynthesis, which is the basis of growth of plant. Thus, greater leaf number per plant will increase vegetative growth and increase the overall yield. The data showing leaf number per plant as influenced by various timing and levels of N with FYM application are presented in Table 2. The higher number of leaves per plants was observed in FYM plots and the lowest in without FYM plots. Among the different levels of N treatments, T_{12} treatment (150 kg N ha^{-1} applied in 4 equal splits) attained higher number of leaves per plant, which was at par with T_{11} treatment and the lowest number of leaves per plant was attained in T_1 treatment (control). The interaction was found to be significant on number of leaves per plant. The higher number of leaves per plant were obtained in $F_{25}T_{12}$ treatment which was 45.3% higher than

Table 1. Effect of different timing and levels of nitrogen with farmyard manure application on plant height (cm) at different growth stages of chilli

Treatments	30 DAT			60 DAT			90 DAT			120 DAT			150 DAT		
	FYM			FYM			FYM			FYM			FYM		
	With-out	**With**	**Mean**	**With-out**	**With**	**Mean**	**With-out**	**With**	**Mean**	**With-out**	**With**	**Mean**	**With-out**	**With**	**Mean**
T_1: 0 kg N ha^{-1} (Control)	12.5	15.1	13.8	21.4	28.2	24.8	48.1	65.0	56.6	57.2	80.3	68.7	61.9	88.0	74.9
T_2: 75 kg N ha^{-1} (2 equal splits)	16.9	19.9	18.4	29.0	34.9	32.0	53.4	70.3	61.8	61.9	84.4	73.2	66.4	92.4	79.4
T_3: 75 kg N ha^{-1} (3 equal splits)	16.8	19.8	18.3	28.8	34.7	31.7	53.5	70.3	61.9	62.3	86.0	74.2	67.0	95.6	81.3
T_4: 75 kg N ha^{-1} (4 equal splits)	16.1	19.0	17.5	26.7	32.2	29.4	53.0	69.8	61.4	62.4	83.6	73.0	67.1	95.8	81.4
T_5: 75 kg N ha^{-1} (5 equal splits)	15.4	18.1	16.7	26.4	31.8	29.1	52.1	68.6	60.4	60.9	83.6	72.3	66.2	94.6	80.4
T_6: 113 kg N ha^{-1} (2 equal splits)	18.5	21.7	20.1	30.3	37.0	33.7	55.5	73.1	64.3	62.8	85.9	74.3	67.0	97.1	82.1
T_7: 113 kg N ha^{-1} (3 equal splits)	18.4	21.6	20.0	30.3	36.9	33.6	55.6	73.2	64.4	63.0	86.2	74.6	67.3	97.6	82.5
T_8: 113 kg N ha^{-1} (4 equal splits)	18.1	21.3	19.7	30.2	36.8	33.5	55.4	72.6	64.0	63.1	87.1	75.1	67.4	97.7	82.6
T_9: 113 kg N ha^{-1} (5 equal splits)	17.9	21.1	19.5	29.9	36.5	33.2	55.3	72.8	64.0	62.7	86.4	74.5	66.7	97.0	81.8
T_{10}: 150 kg N ha^{-1} (2 equal splits)	18.9	22.5	20.7	30.5	37.6	34.0	55.8	74.4	65.1	62.9	87.7	75.3	67.5	99.2	83.3
T_{11}: 150 kg N ha^{-1} (3 equal splits)	18.8	22.4	20.6	30.4	37.6	34.0	55.9	74.5	65.2	63.1	88.7	75.9	67.6	99.5	83.5
T_{12}: 150 kg N ha^{-1} (4 equal splits)	18.7	22.3	20.5	30.4	37.5	33.9	55.6	74.2	64.9	63.2	84.4	73.8	67.8	99.7	83.7
T_{13}: 150 kg N ha^{-1} (5 equal splits)	18.6	22.2	20.4	30.3	37.4	33.8	55.5	74.0	64.8	62.9	86.4	74.6	67.3	98.9	83.1
Mean	17.4	20.5		28.8	35.3		54.2	71.7		62.2	85.4		66.7	96.4	
LSD (P<0.05) FYM		0.79			1.11			0.39			0.45			0.86	
Nitrogen		2.27			2.58			2.66			3.13			3.58	
Interaction		NS			NS			NS			NS			NS	

Table 2. Effect different timing and levels of nitrogen with farmyard manure on number of branches, leaves, leaf area index, capsaicin content and dry matter content of chilli

Treatments	Number of primary branches per plant			Number of leaves per plant			Leaf area index			Capsaicin Content			Dry matter content in fruit (%)		
	FYM			FYM			FYM			FYM			FYM		
	With-out	With	Mean	With-out	With	Mean	With-out	With	Mean	With-out	With	Mean	With-out	With	Mean
T_1: 0 kg N ha^{-1} (Control)	4.80	5.55	5.17	117.5	202.9	160.2	2.24	3.06	2.65	0.606	0.717	0.661	18.9	21.5	20.2
T_2: 75 kg N ha^{-1} (2 equal splits)	5.18	6.16	5.67	199.7	248.6	224.2	2.98	3.28	3.13	0.630	0.759	0.694	21.7	24.6	23.2
T_3: 75 kg N ha^{-1} (3 equal splits)	5.20	6.19	5.69	232.7	261.0	246.7	2.99	3.29	3.14	0.635	0.763	0.699	21.7	24.6	23.2
T_4: 75 kg N ha^{-1} (4 equal splits)	5.23	6.24	5.73	240.5	281.0	260.8	3.01	3.29	3.15	0.637	0.766	0.701	21.8	24.7	23.3
T_5: 75 kg N ha^{-1} (5 equal splits)	5.17	6.13	5.65	194.9	240.7	217.8	2.97	3.26	3.12	0.628	0.749	0.688	21.7	24.5	23.1
T_6: 113 kg N ha^{-1} (2 equal splits)	5.58	6.59	6.08	251.0	309.7	280.3	3.07	3.43	3.25	0.679	0.776	0.727	22.4	26.2	24.3
T_7: 113 kg N ha^{-1} (3 equal splits)	5.61	6.68	6.14	259.2	325.0	292.1	3.08	3.46	3.27	0.679	0.781	0.730	22.5	26.5	24.5
T_8: 113 kg N ha^{-1} (4 equal splits)	5.65	6.70	6.18	264.0	352.2	308.1	3.11	3.48	3.29	0.683	0.784	0.733	22.6	26.6	24.6
T_9: 113 kg N ha^{-1} (5 equal splits)	5.57	6.57	6.07	244.3	299.4	271.9	3.06	3.41	3.23	0.673	0.774	0.723	22.4	26.1	24.2
T_{10}: 150 kg N ha^{-1} (2 equal splits)	5.71	6.80	6.25	287.9	399.0	343.4	3.14	3.54	3.34	0.685	0.762	0.724	22.9	26.7	24.8
T_{11}: 150 kg N ha^{-1} (3 equal splits)	5.74	6.81	6.27	303.7	424.6	364.2	3.15	3.59	3.37	0.687	0.763	0.725	22.9	27.1	25.0
T_{12}: 150 kg N ha^{-1} (4 equal splits)	5.76	6.83	6.29	310.8	451.6	381.2	3.15	3.60	3.37	0.690	0.770	0.730	22.9	28.1	25.5
T_{13}: 150 kg N ha^{-1} (5 equal splits)	5.69	6.78	6.23	278.6	385.9	322.2	3.13	3.52	3.32	0.684	0.755	0.719	22.8	26.5	24.7
Mean	5.45	6.46		245.0	321.7		3.00	3.40		0.661	0.763		22.1	25.7	
LSD (P<0.05) **FYM**		0.03			7.27			0.02			0.01			0.71	
Nitrogen		0.12			22.5			0.16			0.01			NS	
Interaction		NS			31.2			NS			NS			NS	

Table 3. Effect different timing and levels of nitrogen with farmyard manure application on fruit length, fruit width, number of fruits per plant, total fruit yield and average fruit weight of chilli

Treatments	Fruit length (cm)			Fruit width (cm)			Number of fruits per plant			Total fruit yield (q/ha)			Average 10 fruit weight (g)		
	FYM			FYM			FYM			FYM			FYM		
	With-out	**With**	**Mean**	**With-out**	**With**	**Mean**	**With-out**	**With**	**Mean**	**With-out**	**With**	**Mean**	**With-out**	**With**	**Mean**
T_1: 0 kg N ha^{-1} (Control)	4.59	6.40	5.50	1.09	1.24	1.17	213.9	226.0	220.0	104.7	188.0	146.3	24.7	41.8	33.3
T_2: 75 kg N ha^{-1} (2 equal splits)	4.70	6.57	5.64	1.17	1.26	1.22	204.4	232.1	218.3	140.2	207.6	173.9	34.4	44.9	39.7
T_3: 75 kg N ha^{-1} (3 equal splits)	4.72	6.59	5.65	1.17	1.27	1.22	228.4	239.8	234.1	158.0	220.8	189.4	34.9	46.2	40.5
T_4: 75 kg N ha^{-1} (4 equal splits)	4.73	6.60	5.67	1.18	1.27	1.23	253.8	251.4	252.6	180.4	234.5	207.5	35.7	46.9	41.3
T_5: 75 kg N ha^{-1} (5 equal splits)	4.69	6.56	5.62	1.16	1.25	1.20	191.9	230.5	211.2	124.9	196.8	160.9	32.8	43.0	37.9
T_6: 113 kg N ha^{-1} (2 equal splits)	4.74	6.62	5.68	1.19	1.27	1.23	241.8	271.9	256.8	171.6	248.2	209.9	35.6	45.8	40.7
T_7: 113 kg N ha^{-1} (3 equal splits)	4.75	6.63	5.69	1.21	1.28	1.25	255.1	294.3	274.7	184.4	269.9	227.1	36.3	46.0	41.2
T_8: 113 kg N ha^{-1} (4 equal splits)	4.76	6.65	5.71	1.20	1.28	1.24	285.0	329.9	307.4	206.2	302.6	254.4	36.4	46.1	41.2
T_9: 113 kg N ha^{-1} (5 equal splits)	4.73	6.60	5.67	1.18	1.26	1.22	204.9	251.4	228.2	143.8	217.2	180.5	35.2	43.3	39.3
T_{10}: 150 kg N ha^{-1} (2 equal splits)	4.81	6.70	5.75	1.22	1.30	1.26	268.1	237.6	252.8	196.6	219.3	208.0	36.8	46.3	41.6
T_{11}: 150 kg N ha^{-1} (3 equal splits)	4.83	6.73	5.78	1.23	1.31	1.27	282.3	256.8	269.6	208.7	237.6	223.2	37.1	46.4	41.8
T_{12}: 150 kg N ha^{-1} (4 equal splits)	4.85	6.74	5.80	1.23	1.31	1.27	302.0	253.6	277.8	225.2	245.9	235.5	37.4	48.7	43.0
T_{13}: 150 kg N ha^{-1} (5 equal splits)	4.80	6.68	5.74	1.21	1.29	1.25	252.4	209.2	230.8	162.8	189.7	176.3	32.5	45.5	39.0
Mean	4.75	6.62		1.18	1.28		244.9	252.6		169.8	229.1		34.6	45.5	
LSD (P<0.05) FYM		0.08			0.02			6.63			4.30			0.45	
Nitrogen		0.05			0.03			21.3			7.40			2.78	
Interaction		NS			NS			29.5			10.7			NS	

F_0T_{12} treatment (best under without FYM plots) and 3.84 folds higher than F_0T_1 treatment. The increase in levels of N-fertilizer up to 150 kg N ha^{-1} could increase the number of leaves per plant [26]. The combined use of FYM with inorganic N fertilizers gave more branches and leaves as compared to sole N fertilizer which resulted in better growth of plants [27]. The improvement in vegetative growth was due to increased N availability in the soil nutrient pool and its uptake [11].

3.1.4 Leaf area index

The leaf area index (LAI) is crucial growth-attribute which is used to evaluate the assimilating capacity and photosynthetic efficiency of plants. It plays a key role to determine the photosynthetically and transpiration rates of plants. Thus, optimum LAI is pre-requisite for strengthening the source-sink relationship [28]. The data showed that maximum LAI (3.40) was recorded in FYM plots, which was significantly higher than without FYM treated plots (3.00). The LAI increased significantly with increase in levels of N-fertilizer and showed that T_{11} and T_{12} treatments (150 kg N ha^{-1} applied in 3 and 4 equal splits, respectively) recorded maximum LAI, which was at par with T_6, T_7, T_8, T_9, T_{10} and T_{13} treatments. The T_1 treatment had the minimum LAI which was significantly lower than other treatments. The LAI is influenced through various physiological processes and biomass accumulation [29]. The higher LAI was recorded with increase in N levels due to the increased availability of N, which is essential for leaf cell multiplication and elongation which led to production of more photosynthetic surfaces thus, resulting in better plant growth [30].

3.2 Quality Parameters

3.2.1 Capsaicin content in red ripe chilli (%)

Improving pungency in red ripe chilli is critical to increase its overall quality because this trait is valued by consumers. Capsaicin is mainly confined to placenta and pericarp of chilli fruit which has various functions such as anti-diabetic, anti-carcinogenic, and anti-inflammatory properties, etc. The data depicted in Table 2 showed that FYM plots resulted in significantly higher capsaicin content (0.763%) than without FYM treated plots (0.661%). Regarding to N management applications, T_8 treatment (113 kg N ha^{-1} was applied in 4 equal splits) resulted in higher capsaicin content (0.733%) which was at par with T_6, T_7, T_9, T_{10}, T_{11} and T_{12} treatments. Sarma et al. [31] revealed that boost in capsaicin content was witnessed up to certain level of N application. The amino acids such as leucine and valine play an important role in synthesis of capsaicin [32].

3.2.2 Dry matter content in fruit (%)

Dry matter is the sum total of all constituents of plants except water. The data presented in Table 2 showed that FYM plots attained significantly higher dry matter content (25.7%) than without FYM treated plots (22.1%). Nitrogen is the chief constituent of chlorophyll which gives their green colour and enables them to convert sun energy into the carbohydrates they need to develop. As a result of increased tissue cell division, which produced more photosynthetic surfaces and the accumulation of photosynthates [33].

3.3 Yield Parameters

3.3.1 Fruit length (cm)

Fruit length is an important growth attribute positively correlated with fruit weight. The data presented in Table 3 showed that FYM application significantly affected fruit length. The fruit length (6.62 cm) was maximum in FYM plots, which was significantly better than without FYM treated plots (4.75 cm). Furthermore, fruit length recorded in T_{12} treatment (150 kg N ha^{-1} was applied in 4 equal splits) was at par with T_{10} (5.75 cm) and T_{11} (5.78 cm). The increase in levels of N can increase the fruit length due to synthesis of more amino acid, sugars and accumulation of biomass [34]. The increase in N application results in a significant increase in fruit length due to improvement in physico-chemical and biological properties of soil [41].

3.3.2 Fruit width (cm)

Fruit width is important growth-parameter which is positively correlated with fruit yield. The data pertaining to FYM and N fertilizer on fruit width are presented in Table 3. The mean fruit width (1.28 cm) was more in FYM plots than without FYM treated plots (1.18 cm). The highest fruit width (1.27 cm) was attained under T_{11} and T_{12} treatments (150 kg N ha^{-1} was applied in 3 and 4 equal splits, respectively). Dhaliwal et al. [35] and Simon and Tesfaye [36] showed that increasing the level of N could increase the fruit width up to 150 kg N ha^{-1} due to consumption of secondary metabolites such as alkaloids, antibiotics and ricin toxins.

3.3.3 Number of fruits per plant

The number of fruits per plant delineate the ability of plants to reproduce the flower and fruit production. There was positive correlation between number of fruits per plant and fruit yield. Higher number of fruits per plant were observed in FYM plots (252.6) than without FYM treated plots (244.9). The highest number of fruits per plant (307.4) were attained in T_8 treatment ((113 kg N ha^{-1} applied in 4 equal splits). The interaction effect was observed to be significant. The number of fruits per plant of $F_{25}T_8$ treatment (113 kg N/ha in 4 equal split doses integrated with FYM) was 9.23% higher than F_0T_{12} treatment (best without FYM treated plots) and 1.54 folds higher than F_0T_1 (control). Kumar et al. [37] described that incorporation of N-fertilizer resulted in the higher number of fruits per plant than unfertilized N plots because N is a constituent of chlorophyll which is required for more fruit production.

3.3.4 Total red fruit yield (q ha^{-1})

The fruit yield is the measure of total quantity of mature red fruits produced per unit of land. It is determined by individual fruit weight, fruit length and number of fruits per plant. N is one of the indispensable plant nutrients that affect fruit productivity of chilli [38]. The data with respect to the effect of N-fertilizer with FYM application on fruit yield are presented in Table 3. The results showed that higher mean fruit yield (229.1 q ha^{-1}) was obtained in FYM plots than without FYM treated plots (169.8 q ha^{-1}). Fruit yield was 34.9% higher with FYM plots than without FYM treated plots. For N treatments, T_8 treatment i.e. 113 kg N ha^{-1} application in four equal splits produced significantly higher fruit yield (254.4 q ha^{-1}) than other treatments. Significant interaction was observed between FYM and N application on fruit yield. The highest fruit yield was found in $F_{25}T_8$ treatment i.e. 113 kg N ha^{-1} application in four equal splits integrated with FYM. Further it was found that within each N level i.e. 75, 113 and 150 kg ha^{-1}, application of N fertilizer in 4 split doses performed best followed by 3, 2 and 5 split doses, respectively. The yield of chilli increased in FYM treated plots because application of farmyard manure can supplement the N to crop for better plant growth that was reflected on the resultant productivity of chilli [39]. A higher source generates a more efficient sink, which increases fruit and dry matter production. The results confirmed by the findings of Wahocho et al. [40].

3.3.5 Average fruit weight (g)

Average fruit weight has a key role in promoting the yield of chilli. The data pertaining to average fruit weight as influenced by different levels of N-fertilizer with FYM application are presented in the Table 3. The FYM plots attained higher average fruit weight (45.5 g) than without FYM treated plots (34.6 g). The higher average fruit weight (43.0 g) was obtained in T_{12} treatment (113 kg N ha^{-1} applied in four equal splits). N is an integral part of chlorophyll which plays important role in photosynthesis and all the photosynthates synthesized during photosynthesis are translocated with the help of potassium to sink which are generally fruits [40] and [42].

4. CONCLUSION

It is concluded from the current study that combined use of FYM at 25 t ha^{-1} along with the N-fertilizer improved the growth, quality and fruit productivity as compared to sole application of N-fertilizer. The highest fruit yield was recorded in treatment $F_{25}T_8$ (113 kg N ha^{-1} applied in four split doses integrated with FYM at 25 t ha^{-1}). Treatment $F_{25}T_8$ which resulted in 45.8% higher yield than recommended doses of fertilizer treatment i.e., 75 kg N ha^{-1} applied in two split doses with FYM due to a greater number of fruits per plant. The growth parameters such as leaf area index, branches and plant height increased significantly with an increase in N level due to more biomass accumulation. Within each N level (75, 113 and 150 kg N ha^{-1}), four split doses of N-fertilizer performed better than three, two and five split doses in both without and with FYM treated plots. Only 2 splits were ensured the fruit yield at later growth stages. Therefore, application of 113 kg N ha^{-1} in 4 equal split doses integrated with FYM can be recommended to farmers for achieving maximum yield in chilli.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENTS

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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Singh K, Tirunima P, Yadav SL, Yadav SS and Singh N. Effect of NPK levels with biofertilizers on growth and yield of chilli (*Capsicum annum* L.) in alluvial soil of Gwalior, Madhya Pradesh. Int J Plant Soil Sci. 2022;34:1337-42.
   Available:https://doi.org/10.9734/ijpss/2022/v34i2231504.
2. Deepa N, Kaur C, George B, Singh B and Kapoor HC. Antioxidant constituents in some sweet pepper genotype during maturity. LWT-Food Sci Technol. 2007;40:121-29.
3. Anonymous. Indiastat; 2021.
   Available:https://www.indiastat.com/table/agriculture/area-production-and-yield-of-dry-chillies-in-indi/29195
4. Dhaliwal MS. Handbook of vegetable crops. Kalyani Publications, India. 2015;274p.
5. Powlson DS, Gregory PJ, Whalley WR, Quinton JN, Hopkins DW, Whitmore AP, Hirsh PR and Goulding KW. Soil management in relation to sustainable agriculture and ecosystem services. Food Policy. 2011;36:72-87.
6. Bijay-Singh. Nitrogen use efficiency in crop production in India: trends, issues and challenges. Agric Res. 2023;12:32-44.
7. Bijay-Singh, Craswell E. Fertilizers and nitrate pollution of surface and ground water: An increasingly pervasive global problem. Springer Sci Nature Rev. 2021;3:518-34.
8. Meena RK, Meena RS, Gaurav L and Jatav HS. Green manure: An approach to improve soil fertility and crop production. Agri Res Tech Open Access J. 2019;20:115-18.
9. Sinha SK, Jha CK, Kumar V and Pandey SS. Yield and soil organic carbon pool in relation to soil fertility of sugarcane (*Saccharum* species hybrid complex) plant-ratoon system under integrated nutrient management. Indian J Agron. 2017;62:25-30.
10. Babanjeet, Singh K, Talwar D and Jindal SK. Effect of potassium nitrate on yield and quality of chilli. Agric Res J. 2022b;59:1034-41.
11. Shafeek MR, Nagwa MK, Hassan MK, Awatef, Beheiry G and Rizk FA. Productivity of sweet pepper plant (*Capsicum annuum* L.). as affected by different sources of nitrogen and sulphur fertilizers under newly reclaimed soil. J Appl Sci Res. 2012;8:5365-71.
12. Varinderpal-Singh, Kunal, Kaur J, Bhatt R, Kaur S, Dhillon BS, Singh KB, Singh S, Sharma S and Bijay-Singh. Site-specific fertilizer nitrogen management in less and high N responsive basmati rice varieties using newly developed PAU-leaf colour chart. Commun Soil Sci Plant Anal. 2022;19:451-67.
13. Walkley A, Black CA. An examination of the digtjareff method for determining soil organic matter and a proposed modification of chromic acid titration method. Soil Sci. 1934;37:27-38.
14. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus by extraction with sodium bicarbonate. U S Deptt Agri Circ. 1954;939.
15. Merwin HD, Peech M. Exchangeability of soil potassium in sand, silt and clay fractions as influenced by the nature of the complimentary exchangeable cations. Soil Sci Soc Am Proc. 1950;15:125-28.
16. Subbiah BV, Asija GL. A rapid procedure for estimation of available nitrogen in soils. Curr Sci. 1956;25:259-60.
17. Lindsay WL, Norvell WA. Development of a DTPA soil test method for zinc, iron, manganese and copper. Soil Sci Soc Am J. 1978;42:421-28.
18. Bajaj KL, Kaur G. Colorimetric determination of capsaicin in capsicum fruits with the folin-ciocalteu reagent. Mikrochim Acta. 1979;71:81-86.
19. Cheema HS, Singh B. Software statistical package CPCS-1. Department of Statistics, Punjab Agricultural University, Ludhiana, India; 1991.
20. Verma RK, Shivay YS, Prasanna R, Choudhary M and Ghasal PC. Nutrient management options modulating soil

physical-chemical and biological properties under direct-seeded rice-based cropping systems. Arc Agron Soil Sci; 2020.
DOI: 10.1080/03650340.2020.1808627

21. Ujjal HM, Naher N, Habib ZBF, Rahaman H, Halim A. Growth and yield performance of chili (*Capsicum annuum* L.) on rooftop of different height of buildings. J Exp Agri Int 2023; 45:104-21.
Available:https://doi.org/10.9734/jeai/2023/v45i112240.
22. Kumar P, Choudhary SK and Singh A. Effects of nitrogen scheduling on growth, yield and economics of rice under different establishment methods. Int J Curr Microbiol Appl Sci. 2018;7:5153-60.
23. Nagarjuna P, Venkateswarlu B, Sreerekha M, Prasad PRK and Jayalalitha K. Effect of crop establishment methods and nitrogen management on growth and yield of rice. Int J Agric Environ Biotechnol. 2021; 14:185-89.
24. Gare BN, More SM, Jadhav MG, Burli AV. Effect of spacing and fertilizer on yield of rainfed chilli in sub-montane zone of Maharashtra. J Maharashtra Agric Univ. 2001;25:270-71.
25. Puli MR, Prasad PRK, Babu PR, Rao KLN, Subbaiah G. Effect of organic and inorganic sources of nutrients on nitrogen content in tomato at various growth stages. Orzya. 2019;56: 312-17.
26. Mali S S, Naik SK, Jha BK, Singh AK and Bhatt BP. Planting geometry and growth stage linked fertigation patterns: Impact on yield, nutrient uptake and water productivity of chilli pepper in hot and sub-humid climate. Scient Hort. 2019;249:289-98.
27. Mahmud K, Hossain T, Mou TH, Ali A and Islam M. Effect of nitrogen on growth and yield of chilli (*Capsicum annuum* L.) In roof top garden. Turk J Agric Food Sci Technol. 2020;8:246-51.
28. Sone C, Saito K and Futakuchi K. Comparison of three methods for estimating leaf area index of upland rice cultivars. J Crop Sci. 2009;49:1438-43.
29. Patel TU, Vihol KJ, Thanki JD, Gudagbe NN and Desai LJ. Weed and nitrogen management in direct-seeded rice. Indian J Weed Sci. 2018;50:320-23.
30. Babanjeet, Talwar D, Singh K, Jindal SK. Influence of nitrogen and potassium on growth and yield of chilli (*Capsicum annuum* L.). J Veg Sci. 2022a;49:41-46.
31. Sarma UJ, Baruah JP, Suhrawardy J, Narzry BD and Chakravarty M. effect of various NPK levels on yield and capsaicin content in chilli (*Capsicum annuum* L.) Indian J Hill Agric. 2004;17:15-18.
32. Pervez MA, Ayub CM, Bashart A, Nave AV, Nasir M. Effect of nitrogen levels and spacing on growth and yield of chilli (*Capsicum annuum* L.). Int J Agric Biol. 2004;6:504-06.
33. Sekhon NK, Singh CB, Sidhu AS, Thind SS, Hira GS, Khurana DS. Effect of straw mulching, irrigation and fertilizer nitrogen levels on soil hydrothermal regime, water use and yield of hybrid chilli. Arch Agron Soil Sci. 2008;54:163-74.
34. Pariari A, Khan S. Integrated nutrient management of chilli (*Capsicum annuum* L.) in gangetic alluvial plains. J Crop Weed. 2013;9:128-30.
35. Dhaliwal KK, Ghai N and Jindal SK. Variation in fruit quality parameters of chilli genotypes during early and timely sown conditions. Int J Curr Microbiol Appl Sci. 2020;9:2178-86.
36. Simon T, Tesfaye B. Growth and productivity of hot pepper (*Capsicum annuum* L.) as affected by variety, nitrogen and phosphorous at Jinka, Southern Ethiopia. J Biol Agric Healthcare. 2014;4:2224-30.
37. Kumar MHD, Prasad SM, Astaputre SA, Chittapur BM, Tatagar MH, Mesta RK. Yield and quality of chilli as influenced by primary and secondary nutrients. J Agric Sci. 2010;22:1090-92.
38. Khan A, Shah SNM, Rab A, Sajid M, Ali K, Ahmed A, Faisal S. Influence of nitrogen and potassium levels on growth and yield of chillies (*Capsicum annuum* L.). Int J Farm Sci. 2014;3:260-64.
39. Tambe AJ, Dhawan AS and Gourkhede PH. Effect of integrated nutrient management on yield, quality improvement and nutrient uptake of chilli. Int Trop Agric. 2015;33:3777- 81.
40. Wahocho NA, Zehan Ahmed, Sheikh, Jogi Q, Talpur KH and Leghari SJ. Growth and productivity of chilli (*Capsicum annuum* L.) Under various nitrogen levels. Sci Int. 2016;28:517-23.
41. Dubey AK, Rajput DS, Singh P, Verma YK, Kumar A, Chandraker SK. Effect of NPK on plant growth, yield and quality of capsicum cv swarna under shade net conditions. Int J Curr Microbiol Appl Sci. 2017;6:1085-91.

42. Shabir A, Khan SH, Wani SH. Evaluation of integrated nutrient management practices on yield and economics of chilli var. Kashmir Long. Chem Sci Rev Lett. 2017;6:2195-2201.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/121474