Original Research Article

EFFECT OF TIMING AND LEVELS OF NITROGEN APPLICATION ON GROWTHAND YIELD OF CHILLI (*Capsicum annuum* L.)

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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) @ 25 t/ha and thirteen subplots consisting of four different N levels: 0, 75, 113 and 150 kg/ha 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 in 4 split doses integrated with FYM and recorded 45.8% higher fruit yield than the recommended dose of fertilizer, *i.e.* 75 kg N/ha 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 in 4 equal split doses integrated with FYM can be recommended to farmers for achieving maximum yield in chilli under Punjab conditions.

Keywords: Chilli;Fruityield;Growth; Nitrogen; Yield attributes.

1. INTRODUCTION

Chilli (*Capsicum annuum* L.) is one of the most important spice and vegetable crop grown for green as well as 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 foodstuffs 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 food, which are items of exports for income to 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 [3]. The CH-3 hybrid is suitable for forming paste for export purposes, while the CH-27 hybrid is most common for processing and pharmaceuticals industries.

Chilli is a long duration vegetable crop since it requires optimal N fertilizer for plant physiology, yield attributes and synthesizing chlorophyll in plants [4]. The indiscriminate use of chemical N-fertilizer can lead to a reduction in growth and yield-attributes, which results in increase in total expenditure of farmersincreases farmers' 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 suggest farmers to shift their mindsets towards integrated nutrient management (INM) strategy 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]. The integrated application of FYM with N-fertilizer helps to improve the fruit productivity, which otherwise deteriorates the soil fertility with sole use of N-fertilizer [9].

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]. Limited information is available related to 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. MATERIAL AND METHODS

2.1 Site and weather: The current study was conducted at 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 and contributes, contributing to around 76% of total rainfall. The meteorological data (Figure 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 at inthe 29th week (17-23 July) and maximum evaporation occured at 23rd week (5-11 June), respectively. The overall 452.5 mm of rainfall was recorded throughout the crop.

2.2 Experimental details: The current study was undertaken to study the effect of N-fertilizer integrated with FYM @ 25 t/ha on growth, quality and yield-related attributes of chilli.

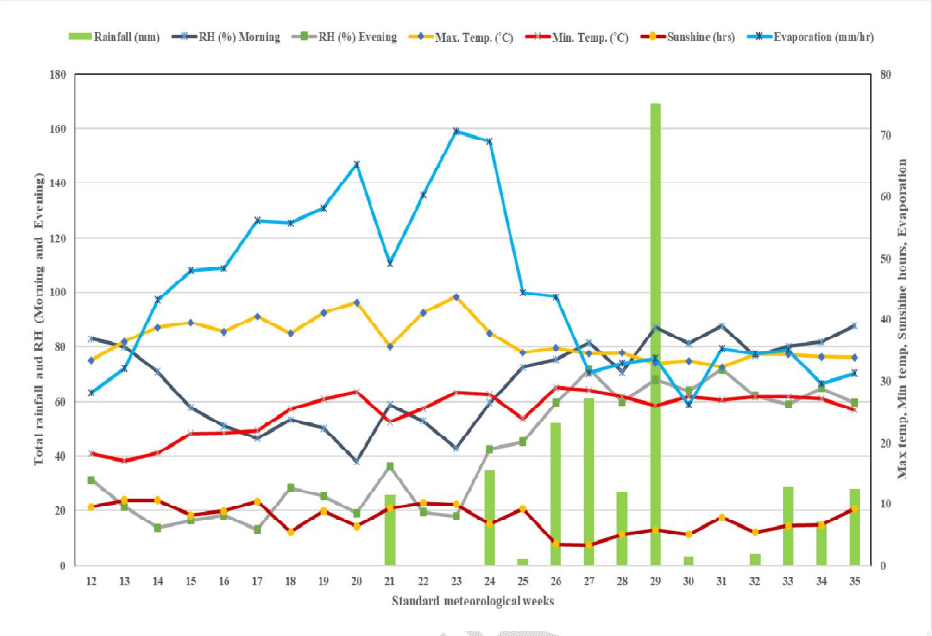

Fig. 1. Weekly average mean meteorological data recorded during the crop season (March-August 2022) at PAU, Ludhiana

The experimental study was laid out in a split-plot design. The experiment was replicated thrice with hybrid CH 27. The experiment comprised of two main plots (F_0 and F_{25}) i.e., without and with FYM @ 25 t/ha and thirteen N sub plots treatments. Four different levels of N: 0, 75, 113 and 150 kg/ha 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 was the control, in T_2, T_3, T_4 and T_5, 75 kg N/ha was applied in 2 equal splits at transplanting andafter 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, 113 kg N/ha and T_{10}, T_{11}, T_{12} and T_{13}, 150 kg
N/ha 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 and K @ 30 kg K_2O/ha was 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 pH 7.4, determined by the glass electrode method using pH meter and EC value of 0.23 dS/m, measured by potentiometric method using a conductivity meter [13]. The soil was medium in SOC (0.41%), computed by wet digestion method [14]; available P (18.4 kg/ha), determined using

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UV-VIS spectrophotometer [15]; available K (127.6 kg/ha) using a flame ionization technique [16]; low in available N (137.6 kg/ha), analyzed by alkaline permanganate method [17] and adequate in DTPA-extractable micronutrients i.e., Zn (2.48 mg/kg), Cu (0.29 mg/kg), Fe (11.3 mg/kg) and Mn (3.71 mg/kg) as determined by atomic absorption spectrophotometer [18].

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 and leaf area index at flowering stage measured by canopy analyzer; The quality attribute such as capsaicin content and dry matter content in fruit were estimated by methods [19]. 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.

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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 [20]. The least significant difference (LSD) test was used to compare the means at ($P < 0.05$).

3. RESULTS AND DISCUSSION

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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 FYM and N-fertilizer 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 (@25 t/ha) plots attained higher plant height than without FYM plots. Among the levels of N treatment at 150 DAT, T_{12} treatment resulted in highest plant height (83.7 cm), which was at par with T_3 (81.3 cm), T_4 (81.4 cm), T_5 (80.4 cm), T_6 (82.1cm), T_7 (82.5 cm), T_8 (82.6 cm), T_9 (81.8 cm), T_{10} (83.3 cm), T_{11} (83.5 cm) and T_{13} (83.1 cm). All treatments were statistically significantly better than T_1 treatment. The highest plant height was observed due to higher availability of N through the combineduse of FYM with chemical fertilizer as compared to sole application of chemical fertilizer [21]. The higher dose of N resulted in rapid cell enlargement and elongation and ultimately higher plant height, as reported by Kumar et al. [22].

Comment [MRI4]: This result is perplexing, as Table 1 indicates no significant variation (NS) at any level of interaction.

3.1.2 Number of primary branches per plant: Nitrogen helps in promoting cell division and growth of lateral branches by auxin, which eventually led to the formation of more branches per plant. The INM results in formation of more branches per plant rather than sole use of N-fertilizer [23]. The data pertaining to the different levels of N-fertilizer and FYM on number of branches per plant were presented in Table 2. The results revealed that there was significant effect of FYM application. The FYM plots attained significantly higher number of branches per plant (6.46) than without FYM plots (5.45). 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. The application of FYM resulted in better nutrition to plant along with improving the soil health as reported by Gare et al. [25] and Puli et al. [26].

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 surface area for theprocess of photosynthesis, which is the basis of growth of

plant.Thus,greater leaf number per plant will increase vegetative growthand increase the overall yield. The data showing leafnumber per plant as influenced by various doses of N arepresented in Table 2. Thehigher number of leaves per plant (321.7) ~~were~~ wasobservedin FYM plots andthe lowest

Table 1. Effect of different levels of nitrogen on plant height (cm) at different growth stages of chilli

S. No.	Treatments	30 DAT			60 DAT			90 DAT			120 DAT			150 DAT		
		FYM (@25 t/ha)			FYM (@25 t/ha)			FYM (@25 t/ha)			FYM (@25 t/ha)			FYM (@25 t/ha)		
		Without	With	Mean	Without	With	Mean	Without	With	Mean	Without	With	Mean	Without	With	Mean
T_1	0kg N/ha(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	75kg N/ha(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	75kg N/ha(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	75kg N/ha(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	75kgN/ha(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	113kg N/ha(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	113kg N/ha(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	113kg N/ha(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	113kg N/ha(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}	150kg N/ha(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}	150kg N/ha(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}	150kg N/ha(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}	150kg N/ha(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	

(245.0) in without FYM plots. Among the different levels of N treatments, T_{12} treatment attained higher number of leaves per plant (381.2), which was at par with T_{11} treatment (364.2) and lowest number of leaves per plant (160.2) was attained in T_1 treatment. 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 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 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] and [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 [29]. 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 recorded maximum LAI (3.37), which was at par with T_6 (3.25), T_7 (3.27), T_8 (3.29), T_9 (3.23), T_{10} (3.34) and T_{13} (3.32). The T_1 treatment had the minimum LAI (2.65) which was significantly lower than other treatments. The LAI is influenced through various physiological processes and biomass accumulation [30]. 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 thus, resulting in better plant growth [31].

3.2 Quality Parameters

3.2.1 Capsaicin content in red ripe chilli (%): 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%). Among the N management strategies, T_8 treatment 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. [32] 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.

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%). Non-significant difference was observed among different N levels. Nitrogen is the chief constituent of chlorophyll and aids in transportation of water needed for photosynthesis [33].

3.3 Yield Parameters

3.3.1 Fruit length (cm): Fruit length is ~~important growth attribute, which is~~an important growth attribute positively correlated with fruit weight. The data presented in Table 3 showed that FYM application ~~resulted in significant effect on~~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 was at par with T_{10} (5.75 cm) and T_{11} (5.78 cm). The fruit length (5.50 cm) were minimum in T_1, which was significantly lower than other treatments. The increase in levels of N can increase the fruit length due to synthesis of more amino acid, sugars and accumulation of biomass [34].

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The increase in N application results in a significantincrease in fruit length due to improvement in physico-chemical and biological properties of soil [35].

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

S. No.	Treatments	Number of primary branches per plant			Number of leaves per plant			Leaf area index			Capsaicin Content			Dry matter content in fruit (%)		
		FYM (@25 t/ha)			FYM (@25 t/ha)			FYM (@25 t/ha)			FYM (@25 t/ha)			FYM (@25 t/ha)		
		With-out	With	Mean	With-out	With	Mean	With-out	With	Mean	With-out	With	Mean	With-out	With	Mean
T_1	0kg N/ha(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	75kg N/ha(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	75kg N/ha(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	75kg N/ha(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	75kgN/ha(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	113kg N/ha(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	113kg N/ha(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	113kg N/ha(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	113kg N/ha(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}	150kg N/ha(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}	150kg N/ha(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}	150kg N/ha(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}	150kg N/ha(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	

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} treatment, which was at par with T_7 (1.25 cm), T_8 (1.24 cm), T_{10} (1.26 cm) and T_{13} (1.25 cm). Dhaliwal et al. [36] and Simon and Tesfaye [37] showed that increasing the level of N could increase the fruit width up to 150 kg N/ha 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 and the lowest number of fruits per plant (211.2) were attained in T_5 treatment. The interaction effect of FYM and N-fertilizer was observed to be significant on number of fruits per plant. 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. [38] 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): 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[39]. The data with respect to the effect of timing and levels of N-fertilizer and FYM on fruit yield are presented in Table 3. The results clearly showed that higher mean fruit yield (229.1 q/ha) was obtained in FYM plots than without FYM treated plots (169.8 q/ha). Fruit yield was 34.9% higher with FYM plots than without FYM treated plots. Among the N treatments, T_8 treatment i.e. 113 kg N/ha application in four equal splits produced significantly higher fruit yield (254.4 q/ha) 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/haapplication in four equal splits integrated with FYM. Further it was found that within each N level i.e. 75, 113 and 150 kg/ha, 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 organic manure can supplement the N to crop for better plant growth that was reflected on the resultant productivity of chilli[40]. 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. [41].

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 and FYM 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 which was at par with T_3 (40.5 g), T_4 (41.3 g), T_6 (40.7 g), T_7 (41.2 g), T_8 (41.2 g), T_{10} (41.6 g) and T_{11} (41.8 g). 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 [42] and[43].

4. CONCLUSION

It is concluded from the current study that combined use of FYM @ 25 t/ha along with the N-

fertilizer improved the growth, quality and fruit productivity as compared to sole application of

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

S. No.	Treatments	Fruit length (cm)			Fruit width (cm)			Number of fruits per plant			Total fruit yield (q/ha)			Average 10 fruit weight (g)		
		FYM (@25 t/ha)			FYM (@25 t/ha)			FYM (@25 t/ha)			FYM (@25 t/ha)			FYM (@25 t/ha)		
		With-out	With	Mean	With-out	With	Mean	With-out	With	Mean	With-out	With	Mean	With-out	With	Mean
T_1	0kg N/ha(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	75kg N/ha(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	75kg N/ha(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	75kg N/ha(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	75kgN/ha(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	113kg N/ha(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	113kg N/ha(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	113kg N/ha(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	113kg N/ha(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}	150kg N/ha(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}	150kg N/ha(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}	150kg N/ha(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}	150kg N/ha(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	

N-fertilizer. The highest fruit yield was recorded in 113 kg N/ha applied in four split doses integrated with FYM @ 25 t/ha which resulted in 45.8% higher yield than RDF treatment i.e., 75 kg N/ha applied in two split doses 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), 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 in 4 equal split doses integrated with FYM can be recommended to farmers for achieving maximum yield in chilli under Punjab conditions.

REFERENCES

Comment [MRI6]: Revise carefully

Saleh BK, Omer A and Teweldemedhin B. Medicinal uses and health benefits of chilli pepper (Capsicum spp.) J Food Process Technol 2018;6:325-28.

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.

Anonymous 2021. Indiastat https://www.indiastat.com/table/agriculture/area-production-and-yield-of-dry-chillies-in-indi/29195

Comment [MRI7]: Use proper reference

Dhaliwal MS. Handbook of Vegetable Crops. Kalyani Publications, India, 274p; 2015.

Powlson DS, Gregory PJ, Whalley WR, Quinton JN, Hopkins DW, Whitmore AP, Hirsch PR and Goulding KW. Soil management in relation to sustainable agriculture and ecosystem services. Food Policy 2011;36: 72-87.

Bijay-Singh. Nitrogen use efficiency in crop production in India: trends, issues and challenges. Agric Res 2023;12: 32-44.

Bijay-Singh and Craswell E. Fertilizers and nitrate pollution of surface and ground water: an increasingly pervasive global problem. Springer Sci Nature Rev 2021;3: 518-34.

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.

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 integratednutrientmanagement.IndianJAgron 2017;62: 25-30.

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.

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.

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

responsivebasmati rice varieties using newly developed PAU-leaf colour chart. Commun Soil Sci Plant Anal 2022;19: 451-67.

Walkley A and Black CA. An examination of the digtjareff method for determiningsoil organic matter and a proposed modification of chromic acid titration method.*SoilSci*1934;37:27-38.

OlsenSR,ColeCV,WatanabeFSandDeanLA.Estimationofavailablephosphorus by extraction with sodium bicarbonate. U SDepttAgriCirc, 939;1954.

Merwin HD and 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.

Subbiah BV and Asija GL. A rapid procedure for estimation of available nitrogen in soils. Curr Sci 1956;25: 259-60.

Lindsay WL and Norvell WA. Development of a DTPA soil test method for zinc, iron, manganese and copper. Soil Sci Soc Am J 1978;42: 421-28.

Bajaj KL and Kaur G. Colorimetric determination of capsaicin in capsicum fruits with the folin-ciocalteu reagent. Mikrochimacta 1979;71: 81-86.

Cheema H S and Singh B. Software statistical package CPCS-1. Department of Statistics, Punjab Agricultural University, Ludhiana, India;1991.

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 doi:2020; 10.1080/03650340.2020.1808627.

Kumar P, Choudhary SK and Singh A. Effect of nitrogen scheduling on growth, yield and economics of rice under different establishment methods. Int J CurrMicrobiolApplSci 2018;7: 5153-60.

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.

Gare BN, More SM, Jadhav MG and Burli AV. Effect of spacing and fertilizer on yield of rainfedchilli in sub-montane zone of Maharashtra. J Maharashtra Agric Univ 2001;25: 270-71.

Puli MR, Prasad PRK, Babu PR, Rao KLN and Subbaiah G. Effect of organic and inorganic sources of nutrients on nitrogen content in tomato at various growth stages. Orzya 2019;56: 312-17.

Khurana DS, Singh R, Sidhu AS and Singh R. Effect of different levels of nitrogen in split doses on growth and yield of chilli. Indian J Hortic 2006;63: 467-71.

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.

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.

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.

Babanjeet,TalwarD, Singh K and Jindal SK. Influence of nitrogen and potassium on growth and yield of chilli (*Capsicum annuum*L.). J Veg Sci 2022a;49: 41-46.

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.

Pervez MA, Ayub CM, Bashart A, Nave AV and 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.

Ananthi S, Veeraragavathatham D and Srinivasan K. Comparative efficiency of muriate of potash and sulphate of potash on yield attributes, yield and economics of chilli (capsicum annuum l.). Indian J Hortic 2004;52: 158-63.

Pariari A and Khan S. Integrated nutrient management of chilli (*Capsicum annuum* L.) In gangetic alluvial plains. J Crop Weed 2013;9: 128-30.

Dhaliwal KK, Ghai N and Jindal SK. Variation in fruit quality parameters of chilli genotypes during early and timely sown conditions. Int J CurrMicrobiolApplSci 2020;9: 2178-86.

Simon T and 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.

Kumar MHD, Prasad SM, Astaputre SA, Chittapur BM, Tatagar MH and Mesta RK. Yield and quality of chilli as influenced by primary and secondary nutrients. J Agric Sci 2010;22: 1090-92.

Khan A, Shah SNM, Rab A, Sajid M, Ali K, Ahmed A and Faisal S. Influence of nitrogen and potassium levels on growth and yield of chillies (*Capsicum annuum* L.). Int J Farm Sci 3: 2014;260-64.

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.

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.

Dubey AK, Rajput DS, Singh P, Verma YK, Kumar A and Chandraker SK. Effect of NPK on plant growth, yield and quality of capsicum cv swarna under shade net conditions. Int J CurrMicrobiolApplSci 6: 2017;1085-91.

Shabir A, Khan SH and 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.