

***Original Research Article***  
**EFFECT OF TIMING AND LEVELS OF NITROGEN APPLICATION WITH  
FARMYARD MANURE APPLICATION ON GROWTH AND YIELD OF  
CHILLI (*Capsicum annuum* L.)**

**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 farmyard manure (FYM) @ 25 t.ha<sup>-1</sup> and thirteen subplots consisting of four different N levels: 0, 75, 113 and 150 kg N.ha<sup>-1</sup> 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<sup>-1</sup> 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<sup>-1</sup> 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<sup>-1</sup> in 4 equal split doses integrated with FYM can be recommended to farmers for achieving maximum yield in chilli under Punjab conditions.

**Comment [s1]:** Was the experiment conducted for one season or two? The entire research focuses on one season only.

**Keywords:** Chilli; Fruityield; 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 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 ~~which are items of that are exported for income to~~ generate revenue 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<sup>-1</sup> [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.

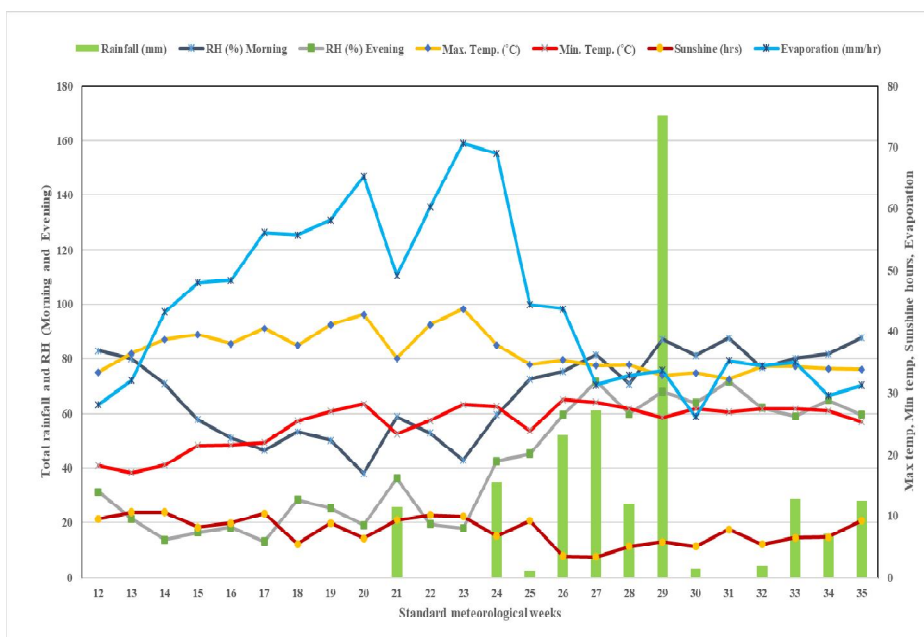
Chilli is a long duration vegetable crop since it requires optimal N fertilizer for plant physiology, yield attributes and ~~synthesizing~~ chlorophyll synthesis in plants [4]. The indiscriminate use of chemical N-fertilizer can ~~lead to reduction in~~ reduce growth and yield-attributes ~~which results resulting in a rise/increase in farmers' total spending total expenditure of farmers~~ 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~~ suggest farmers to change their perspective and adopt ~~an~~ ~~shift their mindsets towards~~ integrated nutrient management (INM) strategy in order to replace sole N-fertilizer with more sustainable sources of nutrients. The farmyard 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. Hence, it is necessary to use organic and inorganic fertilizers in chili pepper cultivation. 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]. ~~There is limited information is~~ available ~~about related to~~ the effect of timing and level of N application with and without FYM on chilli yield. As a result, the current study was designed ~~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 *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 to around 76% of total rainfall. The meteorological data (Figure 1) recorded during the growth period of 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 29<sup>th</sup> week (17-23 July) and maximum evaporation occurred at 23<sup>rd</sup> 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 ~~@~~ ~~at~~ 25 t.ha<sup>-1</sup> 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 farmyard manure application (FYM) that applied at 25 t.ha<sup>-1</sup> (F<sub>25</sub>) or not (F<sub>0</sub>) two main plots (F<sub>0</sub> and F<sub>25</sub>) i.e., without and with FYM @ 25 t.ha<sup>-1</sup> 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<sup>-1</sup> were applied in 2 equal splits at transplanting and after 1<sup>st</sup> picking, 3 equal splits at transplanting, after 1<sup>st</sup> and 2<sup>nd</sup> picking, 4 equal splits at transplanting, after 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> picking and 5 equal splits at transplanting, after 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> picking. Treatment T<sub>1</sub> (0 Kg N. ha<sup>-1</sup>) was the control, in treatments T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub> and T<sub>5</sub>, 75 kg N.ha<sup>-1</sup> (recommended N dose) was applied in 2 equal splits at transplanting and after 1<sup>st</sup> picking, 3 equal splits at transplanting, after 1<sup>st</sup> and 2<sup>nd</sup> picking, 4 equal splits at transplanting, after 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> picking and 5 equal splits at transplanting, after 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> picking. Similarly, in T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub> and T<sub>9</sub> treatments 113 kg N.ha<sup>-1</sup> was applied. Also, in treatments T<sub>10</sub>, T<sub>11</sub>, T<sub>12</sub> and T<sub>13</sub>, 150 kg N.ha<sup>-1</sup> 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<sub>2</sub>O<sub>5</sub>. ha<sup>-1</sup>) and K @ (30 kg K<sub>2</sub>O. ha<sup>-1</sup>) were drilled through SSP and MOP before transplanting of crop. The transplanting was done on 19<sup>th</sup> 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 proper mixed to make one composite sample before the start of the experiment. The soil of experimental site was sandy-loam in texture, having pH 7.4, determined by glass electrode method using pH meter and EC value of 0.23 dS/m, measured by potentiometric

method using conductivity meter [13]. The soil was medium in SOC (0.41%), computed by wet digestion method [14]; available P (18.4 kg.ha<sup>-1</sup>), determined using UV-VIS spectrophotometer [15]; available K (127.6 kg.ha<sup>-1</sup>) using a flame ionization technique [16]; low in available N (137.6 kg.ha<sup>-1</sup>), analyzed by alkaline permanganate method [17] and adequate in DTPA-extractable micronutrients i.e., Zn (2.48 mg.kg<sup>-1</sup>), Cu (0.29 mg.kg<sup>-1</sup>), Fe (11.3 mg.kg<sup>-1</sup>) and Mn (3.71 mg.kg<sup>-1</sup>) 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 in the experimental section 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.

**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

#### 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 FYM and 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<sup>-1</sup>) plots attained higher plant height than without FYM plots. Among the levels Application of N treatments at 150 DAT were positively affected on plant height. Treatment T<sub>12</sub> (150 kg N.ha<sup>-1</sup> was applied in 4 equal splits) treatment resulted in highest plant height (83.7 cm), which was at par with T<sub>3</sub> (81.3 cm), T<sub>4</sub> (81.4 cm), T<sub>5</sub> (80.4 cm), T<sub>6</sub> (82.1cm), T<sub>7</sub> (82.5 cm), T<sub>8</sub> (82.6 cm), T<sub>9</sub> (81.8 cm), T<sub>10</sub> (83.3 cm), T<sub>11</sub> (83.5 cm) and T<sub>13</sub> (83.1 cm). All treatments were statistically significantly better than T<sub>1</sub> treatment (0 Kg N. ha<sup>-1</sup>). The highest plant height was observed due to higher availability of N through combined use of FYM with chemical N fertilizer as compared to sole application of chemical N fertilizer [21]. The higher dose of N resulted in rapid cell division, differentiation, expansion and enlargement cell enlargement and elongation and ultimately higher plant height as reported by Kumar et al. [22].

**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<sub>12</sub> treatment (150 kg N.ha<sup>-1</sup> was applied in 4 equal splits) resulted in higher number of branches per plant (6.29), which was at par with T<sub>8</sub> (6.18), T<sub>10</sub> (6.25), T<sub>11</sub> (6.27) and T<sub>13</sub> (6.23). The lowest number of branches per plant (5.17) was observed in T<sub>1</sub>(0 Kg N. ha<sup>-1</sup>) treatment. The application of

**Comment [s2]:** Define each stage by plant age in days after transplanting for more clarification

**Comment [s3]:** Calculate the number of days that this stage is equivalent to after transplanting.

**Comment [s4]:** Calculate the number of days that this stage is equivalent to after transplanting

**Comment [s5]:** Define each growth stage

**Comment [s6]:** Define growth stage

**Comment [s7]:** Define an abbreviation

FYM at 25 t.ha<sup>-1</sup> 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 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 ~~doses~~ timing and levels of N with FYM application are represented in Table 2. The higher number of leaves per plant (321.7) were observed in FYM plots and the lowest

**Comment [s8]:** Rewrite the paragraph such that the impact of the FYM and the reason behind it comes first, followed by an explanation of the effects of time and nitrogen rates, and then the interaction. As occur in previous paragraph ( plant height )

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Table 1. Effect of different timing and levels of nitrogen with farmyard manure application 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)		
		With-out	With	Mean	With-out	With	Mean	With-out	With	Mean	With-out	With	Mean	With-out	With	Mean
T <sub>1</sub>	0kg 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 <sub>2</sub>	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 <sub>3</sub>	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 <sub>4</sub>	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 <sub>5</sub>	75kg N/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 <sub>6</sub>	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 <sub>7</sub>	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 <sub>8</sub>	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 <sub>9</sub>	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 <sub>10</sub>	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 <sub>11</sub>	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 <sub>12</sub>	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 <sub>13</sub>	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	
	FYM		0.79			1.11			0.39			0.45			0.86	
LSD (P<0.05)	Nitrogen		2.27			2.58			2.66			3.13			3.58	
	Interaction		NS			NS			NS			NS			NS	

Comment [s9]: Define growth stage for more clarification

Comment [s10]: Modify all tables

Comment [s11]: Kg N.ha<sup>-1</sup>

Comment [s12]: Please review the statistics, since the numbers are significant. How come all interaction treatments are non-significant?

(245.0) in without FYM plots. Among the different levels of N treatments, T<sub>12</sub> treatment (150 kg N.ha<sup>-1</sup> was applied in 4 equal splits) attained higher number of leaves per plant (381.2), which was at par with T<sub>11</sub> treatment (364.2) and the lowest number of leaves per plant (160.2) was attained in T<sub>1</sub> treatment (0 kg N.ha<sup>-1</sup>). The interaction was found to be significant on number of leaves per plant. The higher number of leaves per plant were obtained in F<sub>25</sub>T<sub>12</sub> treatment which was 45.3% higher than F<sub>0</sub>T<sub>12</sub> treatment (best under without FYM plots) and 3.84 folds higher than F<sub>0</sub>T<sub>1</sub> treatment. The increase in levels of N-fertilizer up to 150 kg N.ha<sup>-1</sup> 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. 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 (LAI):** 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<sub>11</sub> and T<sub>12</sub> treatments (150 kg N.ha<sup>-1</sup> was applied in 3 and 4 equal splits, respectively) recorded maximum LAI (3.37), which was at par with T<sub>6</sub> (3.25), T<sub>7</sub> (3.27), T<sub>8</sub> (3.29), T<sub>9</sub> (3.23), T<sub>10</sub> (3.34) and T<sub>13</sub> (3.32). The T<sub>1</sub> treatment (0 kg N.ha<sup>-1</sup>), 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 which led to production of more photosynthetic surfaces thus, resulting in better plant growth [31].

Comment [s13]: Add the unite

## 3.2 Quality Parameters

**3.2.1 Capsaicin content in red ripe chilli (%):** Improving pungency in red ripe chili 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%). Among the Regarding to N fertilizer applications management strategies, T<sub>8</sub> treatment (113 kg N.ha<sup>-1</sup> was applied in 4 equal splits) resulted in higher capsaicin content (0.733%) which was at par with T<sub>6</sub>, T<sub>7</sub>, T<sub>9</sub>, T<sub>10</sub>, T<sub>11</sub> and T<sub>12</sub> 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 which gives plants 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 and aids in transportation of water needed for photosynthesis [33].

Comment [s14]: It contradicts the statement that follows, which describes the importance of nitrogen in the process of photosynthesis and the generation of carbohydrates. Please offer a scientific explanation for that or re-analyze the data

## 3.3 Yield Parameters

**3.3.1 Fruit length (cm):** Fruit length is important growth attribute which is positively correlated with fruit weight. The data presented in Table 3 showed that FYM application resulted in significant effect on 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<sub>12</sub> treatment (150 kg N.ha<sup>-1</sup> was applied in 4 equal splits ) was at par with T<sub>10</sub> (5.75 cm) and T<sub>11</sub> (5.78 cm). The fruit length (5.50 cm) were minimum in T<sub>1</sub> (0 kg N.ha<sup>-1</sup>) 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]. The increase in N application results in a significant increase in fruit length due to improvement in physico-chemical and biological properties of soil [35].

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Table 2. Effect of different timing and levels of nitrogen with farmyard manure application 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 (cm <sup>2</sup> )			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 <sub>1</sub>	0kg N.ha <sup>-1</sup> (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 <sub>2</sub>	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 <sub>3</sub>	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 <sub>4</sub>	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 <sub>5</sub>	75kg N/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 <sub>6</sub>	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 <sub>7</sub>	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 <sub>8</sub>	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 <sub>9</sub>	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 <sub>10</sub>	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 <sub>11</sub>	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 <sub>12</sub>	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 <sub>13</sub>	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	
	FYM		0.03			7.27			0.02			0.01			0.71	
LSD (P<0.05)	Nitrogen		0.12			22.5			0.16			0.01			NS	
	Interaction		NS			31.2			NS			NS			NS	

Comment [s15]: Add unit

Comment [s16]: Add unit (%)

Comment [s17]: KgN.ha<sup>-1</sup>

**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<sub>11</sub> and T<sub>12</sub> treatments ((150 kg N.ha<sup>-1</sup> was applied in 3 and 4 equal splits, respectively), which was at par with T<sub>7</sub> (1.25 cm), T<sub>8</sub> (1.24 cm), T<sub>10</sub> (1.26 cm) and T<sub>13</sub> (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<sup>-1</sup> 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<sub>8</sub> treatment(113 kg N.ha<sup>-1</sup> was applied in 4 equal splits) and the lowest number of fruits per plant (211.2) were attained in T<sub>5</sub> ( 75 kg N.ha<sup>-1</sup> was applied in 5 equal splits)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<sub>25</sub>T<sub>8</sub> treatment (113 kg N.ha<sup>-1</sup> in 4 equal split doses integrated with FYM) was 9.23% higher than F<sub>0</sub>T<sub>12</sub> treatment (best without FYM treated plots) and 1.54 folds higher than F<sub>0</sub>T<sub>1</sub> (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<sup>-1</sup>):**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 with and FYM application on fruit yield are presented in Table 3. The results clearly showed that higher mean fruit yield (229.1 q.ha<sup>-1</sup>) was obtained in FYM plots than without FYM treated plots (169.8 q.ha<sup>-1</sup>). Fruit yield was 34.9% higher with FYM plots than without FYM treated plots. Among the For N treatments, T<sub>8</sub> treatment i.e. 113 kg N/ha application in four equal splits produced significantly higher fruit yield (254.4 q.ha<sup>-1</sup>) than other treatments. Significant interaction was observed between FYM and N application on fruit yield. The highest fruit yield was found in F<sub>25</sub>T<sub>8</sub> treatment i.e. 113 kg N.ha<sup>-1</sup> 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<sup>-1</sup>, 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 farmyard 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 timing and levels of N-fertilizer and 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<sub>12</sub>, 150 kg N.ha<sup>-1</sup> was applied in 4 equal splits ) treatment which was at par with T<sub>3</sub> (40.5 g), T<sub>4</sub> (41.3 g), T<sub>6</sub> (40.7 g), T<sub>7</sub> (41.2 g), T<sub>8</sub> (41.2 g), T<sub>10</sub> (41.6 g) and T<sub>11</sub> (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].

**Comment [s18]:** Add the effect of different timing and levels nitrogen fertilizer as well as effect of interaction

**Comment [s19]:** If possible, include the economic feasibility of the research to establish the most productive and cost-effective treatment.

#### 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

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Table 3. Effect of 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

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 <sub>1</sub>	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 <sub>2</sub>	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 <sub>3</sub>	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 <sub>4</sub>	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 <sub>5</sub>	75kg N/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 <sub>6</sub>	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 <sub>7</sub>	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 <sub>8</sub>	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 <sub>9</sub>	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 <sub>10</sub>	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 <sub>11</sub>	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 <sub>12</sub>	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 <sub>13</sub>	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	

Comment [s20]: kgN.ha<sup>-1</sup>

Interaction

NS

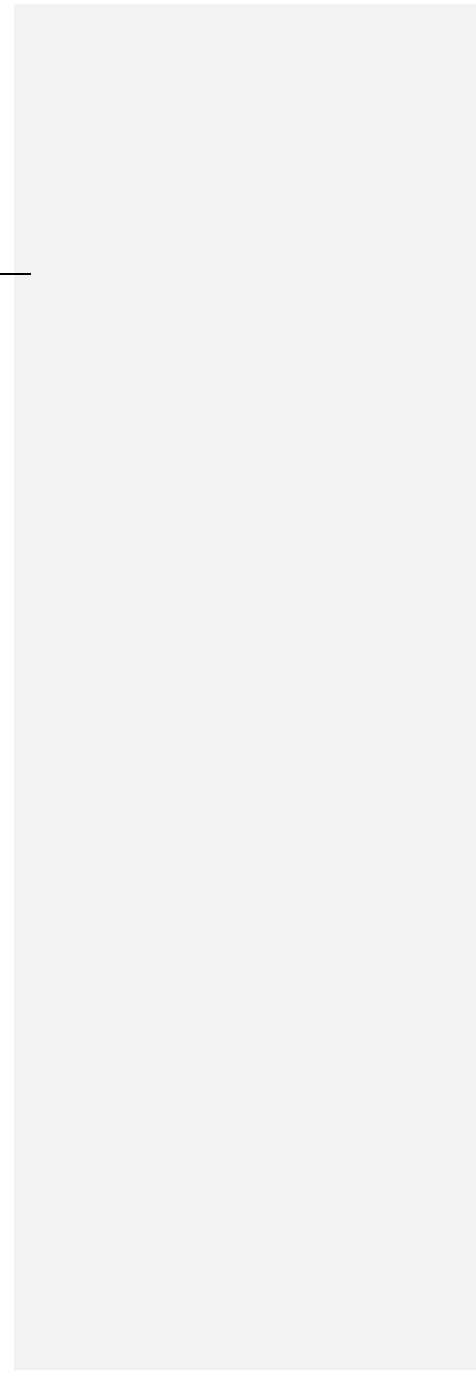
NS

29.5

10.7

NS

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N-fertilizer. The highest fruit yield was recorded in treatment  $F_{25}T_8$  (113 kg N.ha<sup>-1</sup> that was applied in four split doses integrated with FYM application at 25 t.ha<sup>-1</sup>). Treatment  $F_{25}T_8$  resulted in 45.8% higher yield than RDF treatment i.e., 75 kg N.ha<sup>-1</sup> 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<sup>-1</sup> in 4 equal split doses integrated with FYM can be recommended to farmers for achieving maximum yield in chilli under Punjab conditions.

Comment [s21]: define abbreviation

Comment [s22]: with or without FYM

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Comment [s23]: Two references are missing since the total number of references is 43, but only 41 are included in the references section. Please review and document what is missing.

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