Research Article

Evaluating the Impact of Farmyard Manure and Urea on Growth and Harvest Yield of High-Altitude Onion (*Allium cepa L.*)

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Abstract | In many agricultural lands, soil nitrogen levels are limited to support optimal crop yields therefore to address the agriculture sustainability integrated use of organic and inorganic fertilizers has emerged as a promising solution. Herein this study aimed to investigate the efficacy of different levels of nitrogen from Farmyard manure (FYM) and urea on onion (*Allium cepa* L.) yield and yield parameters. The Swat-1variety was initially planted in October and subsequently relocated to designated plots in December. Employing a randomized complete block design (RCBD), the experiment evaluated various treatments, including a control, differing levels of FYM application (5, 10, and 15tons ha^{-1}), and varying rates of N application (0, 60, 120 kg ha^{-1}). Upon meticulous examination, it was discerned that the integration of 10 tons of FYM with 120 kg ha^{-1} of N from an inorganic fertilizer source yielded the most positive outcomes across multiple critical parameters. This combination elicited maximum plant height (66 cm), number of leaves913.2), bulb weight (130.8), total number of bulbs (23.07), and marketable bulbs yield 21.59 tons ha^{-1}). Notably, the application of a higher FYM dose (10 tons ha^{-1}) alongside the recommended N level from urea demonstrated higher efficacy in augmenting the growth and associated parameters of onion crops. These findings highlight the potential advantages of integrating organic and inorganic fertilizers as a sustainable strategy for enhancing crop production.

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Introduction

Onion is the most widely consumed vegetable on the planet (Sharma *et al.*, 2016). Its popularity can be attributed to its medicinal, functional, and nutritional qualities (Pareek *et al.*, 2017). It consists of dual properties of edible as well as medicinal purposes as it acts heart stimulant, useful for eyes, and is helpful against anti-rheumatic cures (Memariani *et al.*, 2020). It is an important ingredient in numerous dishes, desired for its flavor and aroma (Javaid and Rauf, 2015). Statistical analysis highlights substantial disparities in average onion productivity of 54.5 tons ha^{-1} in the USA and 13.1 tons ha^{-1} in developing countries like Pakistan (FAOSTAT, 2013). Worldwide annual production of onion is 400,000 tons (Barla and Upasani, 2019) where Pakistan is placed in 8^{th} position in the world with 1939.6 thousand tons of production (Munir *et al*., 2018). Numerous factors influence onion yield, with nutrient management emerging as a pivotal component for optimizing both the quality and quantity of harvested crop products (Lakshmi and Sekhar, 2018). In modern farming practices, synthetic fertilizers are widely promoted to boost crop productivity. However, a significant challenge arises as 50–70% of the applied fertilizer is lost to the surrounding environment, leading to severe environmental consequences. On the other hand nutrients in animal, wastes were recycled in the form of FYM and tested for their ability to increase crop yield and soil fertility (Bhunia *et al*., 2021). FYM contributes to the improvement of soil physical, chemical, and biological properties while supplying essential macro and micronutrients (Thakur *et al*., 2021). Nutrient management is essential in intensive cropping systems to effectively address processes like mineralization, denitrification, and immobilization. This is crucial for ensuring the social and economic sustainability of agriculture. Goulding *et al*., (2007) emphasize the significance of nutrient management in providing affordable and efficient plant nutrients through fertilizer use. Mountain communities face significant challenges in achieving food security due to a combination of factors, including low land productivity, rising production, rocky terrain, and exposure to natural disasters (Caiserman *et al*., 2022). Indigenous vegetation plays an important role in ecosystem function and has the potential to bolster food security (Behnassi *et al*., 2022).

Nutrient levels, particularly nitrogen play significant roles in influencing both the yield and quality of onion bulbs (Syed *et al*., 2000). Nitrogen is the primary nutrient, a crucial constituent of proteins, enzymes, and vitamins, and is a central part of an essential photosynthetic molecule, chlorophyll (Raj *et al*., 2021). Nitrogen deficiency and excess both can have significant impacts on onion bulb development, maturity, and storage quality. Nitrogen deficiency reduces the size of bulbs and yield (Mohammed *et al*., 2019) while excess nitrogen can lead to a shift in the normal maturity index, which delays maturity and lowers storage quality in onion (Syed *et al*., 2000). The beneficial effect of nitrogen addition on crop yield was observed in many studies (Peng *et al*., 2021), applying sufficient doses of nitrogen fertilizers to onions can increase yields and bulb size (da Silva *et al*., 2022) but more than 90 percent of Pakistani soil is nitrogen deficient (Rafique *et al*., 2023). Addressing this crucial nutrient requirement involves supplementing the soil with nitrogen-containing fertilizers to support optimal growth (Tyagi *et al*., 2022). Overapplication of fertilizers led to nutrient surpluses and threatened environmentally sustainable farming as per capita use of nitrogen increased many folds (Mosier *et al*., 2013). Neither organic nor inorganic fertilizer alone can sustain productivity (Cook, 2006), therefore the combination of organic and inorganic fertilizers is the most common suggestion where animal manure and legumes with chemical fertilizers can be used to meet the nutritional needs of crops. The positive effect of the integrated use of organic and mineral fertilizers on the productivity of crops has been reported (Hati *et al*., 2006, Bhattacharyya *et al*., 2008). In combination with chemical fertilizers, FYM improves soil health, nutrient use efficiency (Midya *et al*., 2021), and the yield of bulb crops (Verma *et al*., 2014). Bulb crops like onions are more vulnerable to nutrient insufficiencies compared to other crops because of their shallow and unbranched root system (Brewster, 1997). On the other hand, high levels of nitrogenous fertilizer were found to cause reduced storage life (Bekele *et al*., 2018), delay in bulb maturity, and bolting in onion, which is an undesirable characteristic (Tekeste *et al*., 2018). Onion falls second out of 15 vegetables in terms of total annual world production (Gulati *et al*., 2022). With the expected increase in the population in the upcoming year, the increase in onion productivity per unit area is a critical need to meet the anticipated surge in food demand. A precise selection of fertilizers and varieties is required to achieve the task of food security. To assess the roles of nitrogen in onion cultivation, and its management in N-deficient soil, the current study was undertaken to assess the effects of varying rates of organic (FYM) and inorganic N sources on onion growth and associated parameters.

Materials and Methods

A field trial was laid out at the National Tea and High-Value Crops Research Institute (NTHRI) Shinkiari, Mansehra, Khyber Pakhtunkhwa, Pakistan to find the impact of different levels of organic and mineral N sources on the growth and yield parameters of onion (*Allium cepa* L.). Before the initiation of the experiment, soil samples were randomly collected from the entire experimental site to study the physico-chemical characteristics of the field. The results depicted that the experimental soil was silt-loam in texture, having a pH value of 7.10 with a soil conductivity of 0.15 dSm^{-1}, lower in soil organic matter content (0.45 %), deficient soil total N (0.015 %), soil extractable P (3.13 mg kg^{-1}) and K (87 mg kg^{-1}).

The nursery of onion assortment (swat-1) was planted in October 2021 and was moved in December 2021 to each plot, arranged in RCBD design. The experiment was replicated three times in the plot size 2×3m². The row-to-row distance was 20 cm while the plant-to-plant distance was 10 cm. FYM (5, 10, and 15 t ha^{-1}), and nitrogen from urea at the rate of 0, 60, 90, and 120 kg ha^{-1} were applied. Various cultural practices such as harrowing, hoeing, and weeding were applied throughout the experiment .

A composite sample of the experimental soil was analyzed for different parameters including pH, which was determined in 1:5 soil suspension by using a pH meter (Mclean, 1983) while an EC meter was used to determine the electric conductivity of the soil (Richard, 1954). Nelson and Sommers's, (1982) method was used to calculate soil organic matter and the texture was determined by Gee and Bauder's (1986) techniques using a soil textural triangle. Soil nitrogen was examined by using the method of Bremner and Mulvaney (1996) while the soil P and K were determined by the AB-DTPA extractable method (Soltanpour and Schwab, 1977). Phosphorus was estimated using a spectrophotometer and potassium by flame photometer. In agronomic parameters, five random plants were selected from each plot to determine the plant height in cm using a measuring tape while the number of leaves per plant was counted and the average was determined. Similarly, the width of the bulb of the onion was determined with the help of a vernier caliper. Similarly, five bulbs from each plot were selected to determine the weight in g. To measure the above-ground biomass, ten plants were collected. The above-ground parts were then cut and dried in a cabinet at 65 °C until they reached a constant dry weight. This weight was recorded as dry biomass. Subsequently, the average dry biomass of the ten plants was calculated and used as the measure of above-ground biomass. Days to maturity were recorded by counting the number of days from a seedling of plants to a date when 70 % or more plants in a plot showed yellowish leaves or reached substantial maturity. A weight that ranges between 20-160g of the bulb weight in each plot at harvest time is considered a good, healthy, and marketable bulb. The low weight ranges of less than 20 g of onions and small sizes that looked unhealthy were counted as nonmarketable, expressed in tons per hectare . The total yield was determined using the following formula.

$$\text{Total yield (ton ha} - 1) = \frac{\text{Bulb yield plot} - 1}{\textit{Area of }\text{plot (m2)}} \times 10000m2$$

The obtained data on various soil and plant parameters underwent rigorous statistical analysis employing a two-factor analysis of variance (ANOVA) methodology. This analysis was performed utilizing specialized statistical tools such as Statistic 8.1 software and Microsoft Excel (Steel *et al.*, 1997). Furthermore, the evaluation of the impact of distinct groups was conducted through a particular mean assessment utilizing the Least Significant Difference (LSD) technique and orthogonal difference analysis.

Table 1: *Physico-chemical characteristics of the soil of the experimental site at the nthri shinkiari, district mansehra, khyber pakhtunkhwa, pakistan*

Physico-chemical properties	Units	Soil
Sand	-	24
Silt	-	63
Clay	-	13
Textural class	-	Silt loam
pH $_{(1:5)}$	-	7.01
Ece $_{(1:5)}$	dSm^{-1}	0.15
Organic matter	%	0.45
Total nitrogen	%	0.015
AB-DTPA Extractable P	mg kg^{-1}	3.13
AB-DTPA Extractable K	mg kg^{-1}	87

Results and Discussion

Plant height (cm).

The findings of plant height demonstrate the impact of combining FYM with nitrogen from urea, as detailed in the Table 1 showed that different N levels efficiently increased the height of the onion as evaluated by Parewa and Yadav. (2014). Among different N levels, the maximum plant height of 64.24 cm was noticed in the plots of 120 kg N ha^{-1} followed by the treatment of 90 kg N ha^{-1} (60.15 cm) while the control plot showed the shortest plant height (49.99 cm). The interaction of FYM and N levels on plant height was found to be significant. Among the interaction data, the maximum plant height (66.07 cm) was recorded in the plots that were amended with 10 tons FYM and 120 kg N ha^{-1}. The plot that was treated with 15 tons FYM and 120 kg N ha^{-1} resulted in a plant height of 64.65 cm, while the plant height of 45.34 cm was noted in the control treatment. These results are similar to the findings of Wahab *et al*. (2021), where plant height was significantly increased with the integrated use of N sources. Elouattassi *et al*. (2023) also concluded that the addition of organic amendments at the right level alongside the synthetic nitrogen fertilizer increased the height of onion plants.

Table 2: *Effect of FYM along with different levels of n on bulb diameter of onion. the data is presented as mean+ standard deviation.*

Sources (tons ha^{-1})	N Levels (kg ha^{-1})				
	0	60	90	120	Mean
FYM 5	59±2	60±1	62.5±1	66±1	61.87 c
FYM 10	62.7±0.1	63.6±0.1	65.4±0.1	70.8±0.1	65.62 a
FYM 15	61.5±0.1	62.8±0.1	64±1	69±1	64.32 b
Mean	61.06 d	62.13 c	63.96 b	68.6 a	
LSD for N = 0.78					
LSD for FYM = 0.68					
LSD for N*FYM = 1.36					
Control= 56.3					

Bulb diameter (mm)

The utilization of FYM in conjunction with varying N levels resulted in a notable increase in onion bulb diameter, as depicted in the empirical findings outlined in Table 2. The bulb diameter of 65.62 mm was obtained in the plot treated with 10 tons FYM ha^{-1} followed by 15 tons FYM ha^{-1} application (64.32 mm) whereas 56.3 mm was noted in the control treatment. Gebremichael *et al*., (2017) observed a similar trend as different levels of N positively increased the bulb diameter. The bulb diameter of 68.6 mm was noticed in the plots with N doses of 120 kg ha^{-1}, while a breadth of 61.06 mm was noted in the control treatment in the current study. The interaction of FYM and different N levels on bulb diameter was found to be non-significant.

The interaction impacts of organic and mineral fertilizers has been shown by Aneseyee and Wolde, (2021) to increase the onion bulb diameter. The fact can be explained that rising main nutrient elements, especially N, through organic sources may have sped up the production of chlorophyll and amino acids, causing more photosynthesis to be transferred from leaves to bulbs and increasing bulb mass and diameter (Shedeed *et al*., 2015). It was also clear from Al-Fraihat (2016) investigation that the applying manures combined with nitrogenous fertilizer boosted onion bulb diameter.

Table 3: *Effect of FYM along with different levels of N on bulb weight of onion (g). The data is presented as mean+ standard deviation.*

Sources (tons ha^{-1})	N Levels (kg ha^{-1})				
	0	60	90	120	Mean
FYM 5	80.2±1	95.6 ±2	111.5 ±2	121.1 ±2	102.1 c
FYM 10	92.5±2	107.4 ±0.1	117.8 ±0.1	130.8 ±2	112.1 a
FYM 15	86.1± 2	104.7 ±0.1	114.8 ±2	125.5 ±2	107.8 b
Mean	86.3 d	102.6 c	114.7 b	126 a	
LSD for N = 1.69					
LSD for FYM = 1.46					
LSD for N*FYM = 2.92					
Control= 77.65					

Bulbs weight (g)

The synergistic effects of integrating FYM with varying levels of N exerted a significant influence on bulb weight. The application showed the highest mean bulb weight (112.1 g) in a plot that was treated with 10 tons FYM ha^{-1} with different N levels, whereas the smallest bulb weight (77.65 g) was noted in the untreated plot, as indicated in Table 3. Among different levels of N application, the maximum mean bulb weight (126 g) was recorded in the plot where basal N doses were applied, followed by the plot with a 90 kg N ha^{-1} (114.7 g). A significant interaction was found between FYM and different N levels, with a bulb weight of 130.8

g in the plot that was amended with 10 tons FYM and 120 kg N ha^{-1} followed by the treatment with 15 tons FYM and 120 kg N ha^{-1}(125.5 g) whereas 80.2 g was obtained in untreated plots. Increased onion weight was observed with the combined use of organic and mineral N fertilizers in previous studies (Gebremichael *et al*., 2017, Sahoo *et al*., 2022). The higher rate of N in the plants results in growing taller, producing more and longer leaves, results higher bulb weight (Shedeed *et al*., 2015).

Table 4: *Effect of FYM along with different levels of N on the number of leaves of onion. The data is presented as mean+ standard deviation.*

Sources (tons ha^{-1})	**N Levels (kg ha^{-1})**				
	0	60	90	120	Mean
FYM 5	9.4 ±0.2	9.6 ±0.2	10.6 ±0.3	12.2 ±0.1	10.45 c
FYM 10	9.7 ±0.2	10.4 ±0.1	12.5 ±0.1	13.2 ±0.2	11.45 a
FYM 15	9.9 ±0.2	10.2 ±0.3	11.1 ±0.2	12.6 ±0.2	10.95 b
Mean	9.66 d	10.06 c	11.40 b	12.66 a	
LSD for N = 0.20					
LSD for FYM = 0.17					
LSD for N*FYM = 0.34					
Control= 9.1					

Number of leaves

The integration of farmyard manure (FYM) with different nitrogen (N) levels notably enhanced the number of leaves, reflecting a substantial improvement in foliar. The application of FYM with different levels of N efficiently improved the number of leaves in the onion with the higher number of leaves (11.45) in a plot that was treated with 10 tons FYM ha^{-1} followed by 10.95 leaves in the plot that received 15 tons FYM ha^{-1} indicated in (Table 4). Among different levels of N application, the maximum number of leaves (12.66) was noted in the plot with a 120 kg N ha^{-1} application, followed by the plot treated with 90 kg N ha^{-1} (11.40) whereas the least number of leaves (9.66) was recorded in a control treatment . A significant interaction of FYM and N levels on the number of onion leaves was found. Maximum leaves of 13.2 were obtained in the plot that was applied with 10 tons FYM and 120 kg N ha^{-1} followed by the plot that was treated with 15 tons FYM and 120 kg N ha^{-1} with a leaf count of 12.6, while 9.4 leaves were obtained in the untreated plot.

Several studies corroborated comparable results, exemplified by Maurya *et al*., (2023) and Aakash *et al*., (2023), wherein plants subjected to FYM in conjunction with N fertilizers exhibited augmented biomass production (Chander *et al*., 2023). Additionally, Pj and Pd, (2022) and Tekeste *et al*., (2017) demonstrated an increase in leaf count with the combined application of inorganic fertilizers and FYM. This observed phenomenon is attributed to the elevated levels of nitrogen and FYM, which facilitate nutrient availability, thereby promoting a stimulatory effect on cellular processes such as division and elongation, consequently enhancing vegetative growth.

Table 5: *Effect of FYM along with different levels of N on onion total yield (tons ha^{-1}). The data is presented as mean+ standard deviation.*

Sources (tons ha^{-1})	**N Levels (kg ha^{-1})**				
	0	60	90	120	Mean
FYM 5	14.13 ±0.04	16.86 ±0.04	19.66 ±0.06	21.36 ±0.04	18 c
FYM 10	16.31 ±0.01	18.94 ±0.02	20.78 ±0.03	23.07 ±0.04	19.77 a
FYM 15	15.18 ±0.03	18.46 ±0.04	20.25 ±0.05	22.13 ±0.03	19 b
Mean	15.21 d	18.08 c	20.23 b	22.18 a	
LSD for N = 1.63					
LSD for FYM = 1.41					
LSD for N*FYM = 2.83					
Control= 12.21					

Total yield (ton ha^{-1})

Several studies demonstrated that the integrated application of FYM and urea has a significant influence on the yield of onion (Adekiya *et al*., 2020, Ejigu *et al*., 2021). The application of farmyard manure (FYM) with varying N ratios resulted in significant improvements in yield, with the highest yield of 19.77 ha^{-1} in plots treated with 10 tons of FYM ha^{-1}, followed by those treated with 15 tons FYM ha^{-1}, yielding 19 tons ha^{-1} explicated in Table 5. Notably, among different levels of N application, the plot receiving 120 kg of N ha^{-1} demonstrated the highest onion yield of 22.18 tons ha^{-1}, while 20.23 tons ha^{-1} was determined in the plot with 90 kg N ha^{-1}. Regarding interaction effects, the highest onion yield of 23.07 tons ha^{-1} was achieved in plots treated with

10 tons of FYM alongside 120 kg N ha$^{-1,}$ followed by those treated with 15 tons of FYM and 120 kg N ha^{-1}, with a yield of 22.13 tons ha^{-1}. These findings underscore the synergistic benefits of FYM-N combinations in optimizing onion yields aligned with Singh (2022) that the integrated application of N fertilizers significantly enhances bulb yield in onions.

The combined application of N and FYM indicates the beneficial impact of the integration of fertilizers across various crops. The sufficient provision of nitrogen from integrated fertilizer applications is essential for synthesizing crucial components such as amino acids, nucleic acids, and chlorophyll, thereby substantially increasing yield (Sher *et al.*, 2019). Additionally, organic manures play a pivotal role in enhancing crop yields by providing supplementary nutrients and improving the physical and biological properties of the soil (Marinari *et al.*, 2000). These collective findings underscore the importance of combining strategies of organic and inorganic fertilizers and the beneficial effects in optimizing agricultural productivity .

Table 6: *Effect of FYM and different N levels on marketable bulb yield (tons ha^{-1}). The data is presented as mean+ standard deviation.*

Sources (tons ha^{-1})	N Levels (kg ha^{-1})				
	0	60	90	120	Mean
FYM 5	10.61±0.06	13.89 ±0.03	17.24 ±0.08	19.33 ±0.02	15.26 c
FYM 10	13 ±0.02	16.24 ±0.03	18.86 ±0.05	21.59 ±0.05	17.42 a
FYM 15	12.12 ±0.01	15.64±0.06	18.08 ±0.07	20.27 ±0.04	16.52 b
Mean	11.91 d	15.25 c	18.06 b	20.39 a	
LSD for N = 0.04					
LSD for FYM = 0.04					
LSD for N*FYM = 0.08					
Control= 9.33					

Marketable and unmarketable bulb yield (tons ha^{-1})

The results elucidate the notable effects of the synergistic application of fertilizers on marketable bulb yield. Maximum marketable bulb harvest (17.42 tons ha^{-1}) resulted in the plot treated with 10 tons ha^{-1} among various rates of FYM and N sources, followed by 15 tons FYM ha^{-1} of 16.52 tons ha^{-1} yield. Observing the influence of different N levels, the maximum marketable bulb yield (20.39 tons ha^{-1}) was obtained at the plots with 120 kg N ha$^{-1,}$ with the following yield of 18.06 tons ha^{-1} at the plot treated with 90 kg N ha^{-1}. Conversely, the highest unmarketable bulb yield (3.31 tons ha^{-1}) was obtained from the control plot, due to limited nutrient availability and soil conditions. The plot that received 5 tons FYM ha^{-1}produced 2.73 tons ha$^{-1,}$ while the yield of 2.35 tons ha^{-1} lowest unmarketable bulb yield noted in the plot of 10 tons FYM ha^{-1}.

The dynamic interplay between FYM and N levels had a notable impact on marketable bulb yield, demonstrating a significant influence. Among these interactions, the highest yield of 21.59 tons ha^{-1} was found in the plots that were amended with 10 tons FYM and 120 kg N ha^{-1} followed by the plot that was treated with 15 tons FYM and 120 kg N ha^{-1} yielded 20.27 tons ha^{-1} marketable yield (Figure 1). Conversely, the control plot produced the minimum marketable bulb yield (10.61 tons ha^{-1}). The findings of Díaz-Pérez *et al.*, (2021) showed a similar trend with the current findings that combined application of inorganic and organic fertilizers increased the amount of marketable bulb yield. The application of nitrogen boosted vegetative growth and assimilated production leading to the enhancement of bulb diameter and average bulb weight (Yoldas *et al.*, 2020) Additionally, Askari-Khorasgani and Pessarakli, (2020) observed the combined application of FYM and N fertilizer considerably improved the production of marketable onion bulb yield. Dhakad *et al.*, (2019) and Mekonnen *et al.*, (2017) evaluated a similar finding during the field study. The maximum onion unmarketable bulb yield (3.30 tons ha^{-1}) was explored in the control plot. The plot treated with 60 kg N ha^{-1} yielded 2.83 tons ha^{-1} unmarketable bulb whereas the minimum unmarketable bulb yield (1.79 tons ha^{-1}) was recorded in the plot treated with 120 kg N ha^{-1}. Furthermore, a significant interaction of FYM and N levels was found in onion unmarketable bulb yield. Among these interactions, the highest unmarketable onion bulb yield (3.52 tons ha^{-1}) was obtained in a control plot followed by the plot that was treated with 10 tons FYM and 0 kg N ha^{-1} (3.31 tons ha^{-1}). Conversely, the lower unmarketable bulb yield (1.48 tons ha^{-1}) was noticed in the plot that was amended with 10 tons FYM and 120 kg N ha^{-1} underscoring the intricate relationship between N application levels, FYM, and onion bulb yield.

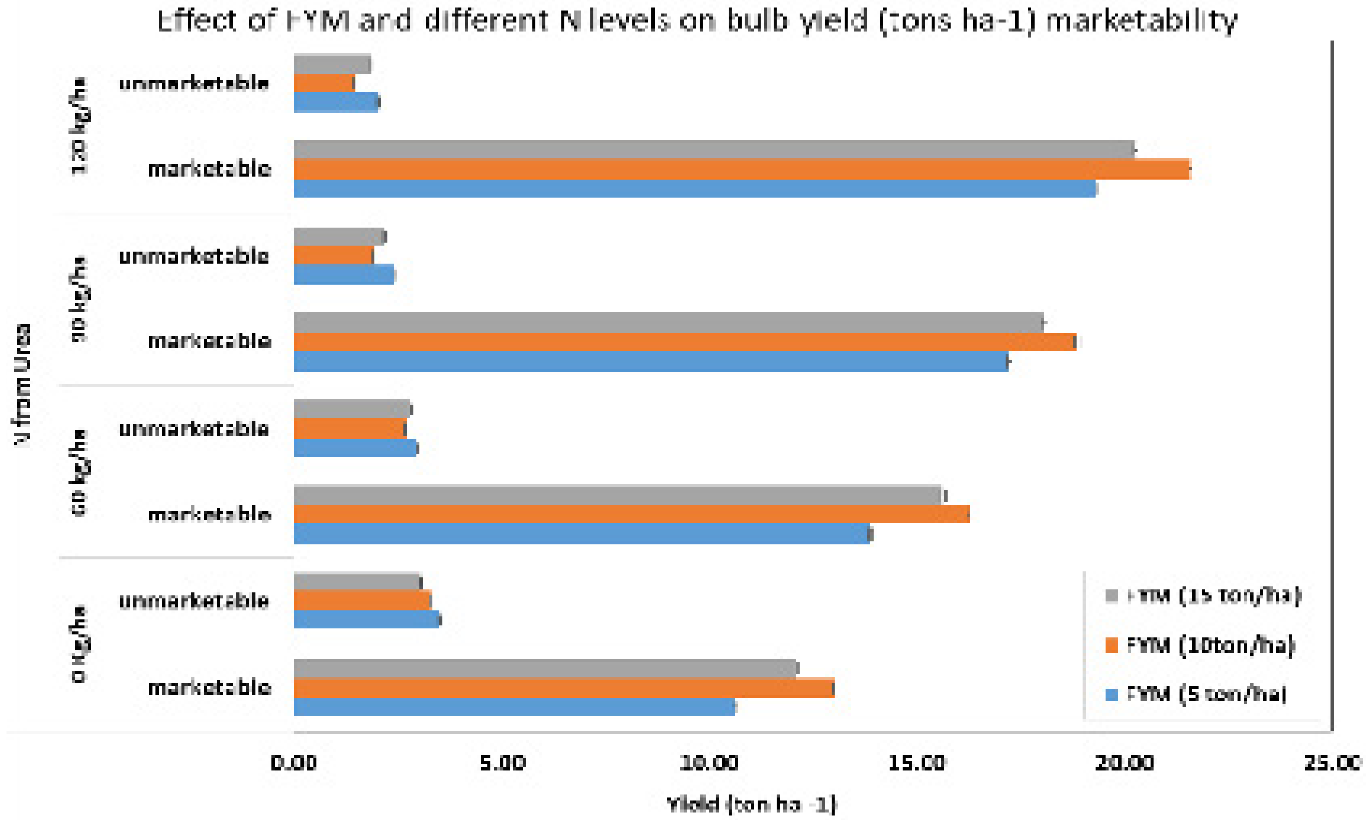

Figure 1: *Marketability of onion as affected by organic and inorganic nitrogen levels*

Table 7: *Effect of FYM along with different levels of N on above ground dry biomass of onion (g). The data is presented as mean+ standard deviation.*

Sources (tons ha^{-1})	N Levels (kg ha^{-1})				
	0	60	90	120	Mean
FYM 5	3.87±0.00	4.11 ±0.01	4.43 ±0.01	4.72 ±0.02	4.28 c
FYM 10	4.91 ±0.01	5.13 ±0.03	5.22 ±0.02	5.48 ±0.03	5.18 b
FYM 15	5.62 ±0.20	5.81 ±0.10	6.02 ±0.01	6.21 ±0.20	5.92 a
Mean	4.80 d	5.02 c	5.22 b	5.47 a	
LSD for N = 0.0740					
LSD for FYM = 0.0641					
LSD for N*FYM = 0.1282					
Control= 3.51					

Above-ground dry biomass (g)

Measuring above-ground dry biomass can provide valuable information about plant productivity and measurements to assess the effectiveness of different agricultural practices as significantly affected by the integrated application fertilizers presented in Table 7 The plot treated with 15 tons FYM ha^{-1} showed the maximum above-ground dry biomass of 5.92 g followed by 5.18 g in a plot of 10 tons FYM ha^{-1}. The highest above-ground dry biomass (5.47 g) was noticed in the plots of 120 kg N ha^{-1} followed by the treatment of 90 kg N ha^{-1} (5.22 g), while the minimum above-ground dry biomass (4.80 g) was noted in untreated plots. Bhardwaj *et al*., (2022) observed a notable enhancement in onion yield associated with increased nutrient dosages. The significant interaction between FYM and N levels concerning above-ground dry biomass was identified. The highest above-ground dry biomass of 6.21 g, recorded in plots treated with 15 tons of FYM and 120 kg N ha^{-1}, followed by 6.02 g in plots treated with 15 tons of FYM and 90 kg N ha^{-1}. The combined application of FYM and varying N rates substantially augmented the essential soil nutrient content, thereby positively affecting above-ground dry biomass in onion crops (Dinega *et al*., 2023). Additionally, integrated fertilizer application significantly improved the growth and yield of onions (Kumar *et al*., 2019).

Days to maturity

The crops in a plot that was treated with 15 tons FYM ha^{-1} matured at the highest number of days 127.92, followed by the plot that received 10 tons FY ha^{-1} (123.35) (Table 8)Among different levels of N application, the maximum days to maturity (125.20) was noted in the plot where the basal dose of N was applied, followed by the plot that was treated with 90 kg N ha^{-1} (123.90) whereas the minimum days to maturity (122.10) was recorded in the control plot. The interaction of FYM and N levels on onion days to maturity was found to be non-significant. The results presented by Gererufael *et al*., (2020) also revealed that the application of FYM in combination with N fertilizer significantly influenced the days to maturity in onions. The application of farmyard manure (FYM) in conjunction with nitrogen (N) fertilizer significantly impacts the maturation period of onions due to the provision of ample chlorophyll. This chlorophyll content extends the greenness of the crop for a prolonged duration. Conversely, in control plots where nitrogen supply is limited, chlorophyll levels decrease, leading to a reduction in the time required for onion maturation. It was also evident from the research work of Tadić *et al*., (2021) that the inorganic and organic fertilizers altered the days to maturity of the onion.

Table 8: *Effect of FYM along with different levels of N on the days to maturity of onion. The data is presented as mean+ standard deviation.*

Sources (tons ha^{-1})	**N Levels (kg ha^{-1})**				
	0	60	90	120	Mean
FYM 5	118.2±2	118.9±3	119.7±2	120.8±2	119.40 c
FYM 10	121.6±1	122.8±2	123.7±2	125.3±1	123.35 b
FYM 15	126.5±1	127.4±1	128.3±1	129.5±2	127.92 a
Mean	122.10 c	123.03 bc	123.90 ab	125.20 a	
LSD for N = 1.7439					
LSD for FYM = 1.5102					
LSD for N*FYM = 3.0205					
Control= 117.4					

Conclusions and Recommendations

The study showed the notable positive influence of FYM supplemented with varying N levels on the growth and development of onion crops. Particularly, the combination of FYM at 10 tons ha^{-1} along with N level 120 kg ha^{-1} exhibited better performance in enhancing marketable yield of 23.07 tons ha^{-1}. These results underscore the potential of such strategies in fostering sustainable crop production. These findings not only promise cost-effectiveness but also offer substantial environmental benefits, contributing to the overall sustainability of agricultural systems by reducing reliance on chemical fertilizers. However, it is imperative to conduct long-term research trials with diverse onion varieties under field conditions to validate and further refine the efficacy of these treatments.

This research accentuates the significance of integrating organic and chemical fertilizers synergistically as a sustainable agricultural practice. By optimizing nutrient utilization and minimizing environmental impact, this integrated approach holds great potential for advancing sustainable crop production. Further exploration and implementation of these findings across various ecological contexts and onion varieties are crucial for determining the optimal balance between organic and inorganic fertilizers, ensuring both agricultural productivity and environmental stewardship.

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Novelty Statement

This study is the first to evaluate the integrated application of farmyard manure and urea under high-altitude conditions of northern Pakistan for onion cultivation. The research uniquely demonstrates that combining 10 tons ha^{-1} of FYM with 120 kg N ha^{-1} from urea substantially en-hances onion growth, bulb weight, and marketable yield compared to single fertilizer applications. These findings introduce a sustainable nutrient management strategy tailored for high-altitude agroecosystems, improving productivity while reducing dependence on chemical fertilizers.

Author's Contributions

Hamida Bibi: Project design and conceptualization, supervision, investigation, data curation and analysis, original draft preparation.
Mubashar Ayaz: Investigation, data curation and analysis.
Mudassar Iqbal: Project design and conceptualiza-

tion, original draft preparation.
Hajra Haroon: Read and agreed to the published version of the manuscript.
Hassan Wahab: Review and editing.

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Data Availability Statement
The datasets generated during and/or analyzed during the current study are available from the corresponding author on request.

Conflict of interest
The authors have no conflict of interest to declare.

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