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MORPHO-YIELD RESPONSE AND QUALITY CHARACTERIZATION OF BOTTLE GOURD (*LAGENARIA SICERARIA*) VARIETIES TO NITROGEN FERTILIZATION

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ABSTRACT

The morpho-yield and quality traits of bottle gourd varieties were tested in response to nitrogen (N) nutrition during the year 2020 at the horticulture research area of Sindh Agriculture University Tandojam. The study was performed by applying Randomized complete block design (RCBD) with three replications. The two varieties Anmol and Long green were tested by applying six N rates that included (0 Kg N, (control), 50, 75 ,100, 125 and 150 Kg N ha^{-1}). Both the varieties exhibited positive response to nitrogen fertilization. The maximum vine length, branches vine^{-1} were noted in plants, fertilized with increasing N rates (150 and 125 kg ha^{-1}). In contrast shorter plants with less branches were noted when they were not fertilized with N nutrition.). The N nutrition also had a positive effect on fruit traits. The maximum fruit number with greater length and weight was recorded in plants supplied with increasing N fertilization. The N fertilization had beneficial influence on plant quality characteristics. The maximum pH, TSS, moisture and ash content in plants were observed, nourished with increasing N supply. The varietal comparison indicates that fruits of "Long green" had lower pH (5.88 vs. 6.0), higher in TSS (5.39 vs. 4.28%), moisture (67.74 vs. 55.52%), ash contents (19.96 vs. 19.01%), fruit yield (18178 vs. 17123 kg ha^{-1}) than variety “Anmol”. In general, vines fertilized at 150 kg ha^{-1} N performed better than those fertilized at lower N levels for entire studied attributes, and "Long green" did better than "Anmol" among the evaluated varieties. The data clearly indicated severe soil N deficiency; and with each increment in applied N, the crop response was positive and significant ($p<0.05$). Hence, the farmers are suggested that “Long Green” bottle gourd variety may preferably be adapted with N at 150 kg ha^{-1} due to intense performance under agro-ecological conditions of Tandojam Sindh, Pakistan

Keywords: Bottle gourd, varieties, N-levels, morpho-yield, quality

INTRODUCTION

The bottle gourd, *Lagenaria siceraria* (Molina) Standl., is a crop of tropical to subtropical environments in the Cucurbitaceae family. It is a widely cultivated vegetable with a long history of domestication and used by human societies (Kore *et al*., 2003). The origin and early domestication of bottle gourd have been a subject of interest among researchers (Meena *et al*., 2017). The origin of the bottle gourd can be traced back to Africa and its surrounding regions such as Egypt, supports the presence and use of bottle gourds dating back thousands of years (Sharma and Lal, 2016). Additionally, genetic studies that analyzed the diversity and distribution of bottle gourd varieties have provided further evidence for an African origin (Sanjur, 2005). Meyer (2010) have also supported the African origin of the crop and proposed that bottle gourds were likely dispersed to other regions through human migration and trade routes. Bottle gourd needs a well-distributed rainfall and adapted to semi-arid environments (Singh, 2012). The optimal temperature range for bottle gourd germination is between 20°C and 25°C. Below 15°C or above 35°C, the germination rate diminishes (Basal, 2009). While bottle gourd exhibits some tolerance to low temperatures, temperatures dropping below 10°C can lead to reduced flowering (Sharma and Lal, 2016).

However, it is not frost-tolerant. Both low temperatures and drought conditions can result in flower and fruit abortion. Bottle gourd is adaptable to various soil types, but it thrives best in well-aerated and fertile soils with a pH range of 6 to 7 (Chungheddon *et al*., 1999; Kore *et al*., 2003; Ram *et al*., 2006).

NPK fertilizers have crucial role in *L. siceraria* production, as they provide essential nutrients that are vital for the plant growth, development, and overall yield. Each of the NPK fertilizers serve specific functions in promoting healthy plant growth and fruit production (Cakmak, 2011). N is a fundamental nutrient required for the formation of proteins, enzymes, and chlorophyll, which are essential components of plant tissues and play a key role in photosynthesis. Adequate nitrogen supply enhances leaf growth, green foliage, and overall vegetative development in bottle gourd plants. Nitrogen deficiency can lead to stunted growth, yellowing of leaves (chlorosis), and reduced fruit setting (Marschner, 2011). Phosphorous (P) is crucial for energy transfer and is involved in various physiological processes such as cell division, root development, and fruiting. It aids in the early establishment of root systems, which is essential for nutrient uptake and water absorption. Bottle gourd plants with sufficient P levels exhibit improved root growth, increased flower production, and enhanced fruit development (Hanumanthappa, 2012). Similarly, K is responsible for regulating water uptake and retention in plant cells. It plays a vital role in maintaining turgidity, thereby enhancing the plant ability to withstand environmental stresses such as drought and disease. K also supports fruit development and quality, contributing to larger and more flavorful bottle gourds (Singh, 2004; Basal, 2009; Sharma and Lal, 2016; Meena *et al*., 2017).

By providing the appropriate balance of nitrogen, phosphorus, and potassium through NPK fertilizers, farmers can optimize bottle gourd production, leading to healthier plants, improved fruit yield, and better economic returns. However, it is essential to apply fertilizers in accordance with recommended guidelines to prevent over-fertilization and minimize environmental impacts. Regular soil testing can help determine the precise nutrient requirements of the bottle gourd crop, enabling farmers to tailor their fertilization practices accordingly (Jan *et al*., 2000; Singh, 2012; Sharma and Lal, 2016). However, the rate of NPK application is linked with the sowing pattern and soil quality. Patil *et al*. (1996) in their studies applied NPK (10-10-20) fertilizer with at 500 kg ha^{-1}, and found significant treatment influence on fruit size, branches and the N use efficiency. In another study, Patil *et al*. (1998) applied NPK fertilizer at a rate of 150-50-50 kg ha^{-1} and reported optimized crop performance and fruit quality. Moreover, the application of 150 kg ha^{-1} N in bottle gourd showed positive and substantial ($p<0.05$) effect on crop produce (Umamaheshwarappa *et al*., 2003). Similarly, Umamaheshwarappa *et al*. (2009) recommended NPK at 120-100-30 kg ha^{-1} for achieving desired fruit yields in bottle gourd. However, Rashmi (2003) suggested a 50N, 50P and 37.5K coupled with FYM at 25 t ha^{-1} for achieving desired fruit yields in bottle gourd. In a recent study, Khadka et al. (2022) recommended 60 kg N and 80 kg P for Pusa manjri variety of bottle gourd under Kanpur (India) conditions. Considering wide variation in nutrient requirement of bottle gourd in different soils, this study was performed to test the morpho-yield and quality characterization of bottle gourd varieties in response to N nutrition under agro-ecological conditions of Tandojam, Sindh Pakistan).

MATERIALS AND METHODS

Experimental design: In order to investigate the impact that varying rates of nitrogen (N) on the growth and production of bottle gourd, the trial was laid out in RCBD (Factorial) with 3-replicates having 5m×5m ($25m^2$) sub-plot size.

Methodology: The land was prepared by tractor driven disc plow and a disc harrow that were operated in the process of tilling the soil and breaking up the hard pan. The field was broken up with a plough, crushing the clods, followed by leveling to even the soil surface for the distribution of irrigation water, as well as to get rid of weeds that may have been there. After a sufficient amount of irrigation (soaking dose), when soil came to a workable state, a tractor driven cultivator was used to develop a desired seed bed. that the study was initiated on April 21, 2020 and crop was sown on raised beds of 2m, keeping planting space of 100 cm, with three to four seeds planted in each point.

Seed Source: The seeds of most commonly grown varieties of the area (Anmol and long green) were purchased from local agricultural shop.

Fertilizer Application: After the seedlings had established, thinning was carried out. The urea, which contains 46% N, was utilized as a N fertilizing source at different rates according to the treatment plan. Moreover, uniform dose of P (100 kg as DAP 18-45% N-P) and K (75 kg as SOP) was also applied to all the sub-plots. At the time of planting, all P and K as well as one-third of the N were added to the soil and well mixed in before the plots were watered for soaking dose. The remainder of the N was applied in two separate applications; the first one took place three weeks after the planting, and the second one came exactly one month after that. Following the administration of each dose of fertilizer (N), irrigation was carried out.

Cultural practices: The experimental field was kept clean, and weeds were eradicated on a regular basis in order to exclude the possibility of any interference with the experimental method that may have been caused by uneven irrigation. As a consequence of this, each and every one of the cultural practices including hoeing, weeding and earthing up were carried out uniformly throughout all of the sub-plots, taking into consideration the requirements of the experimental crop.

Statistical analysis: The data were collected from a total of five plants that had been chosen at random, and the averages were computed based on those values. The data was examined using the LSD test to discern superiority of treatments using statistical techniques developed by Steel and Torrie (1997). All statistical analyses were performed on the computer using the Statistix (Ver. 8.1) Computer Software Package.

RESULTS

Length of vines: Figure-1 exhibits the findings of vine length of two bottle gourd varieties ("Anmol" and "Long Green") to observe how N application at different rates influences vines length. The study found a statistically significant ($p<0.05$) impact of different N levels and varieties on vine length. This trait remained unaffected by the interactive effect of N rates and varieties ($p>0.05$). Specifically, the average vine length was highest at 150 kg ha^{-1} N application (261.50 cm), followed by 125 kg ha^{-1} N application (248 cm), and 100 kg ha^{-1} N application (239.33 cm). The vines in the control group, on the other hand, only measured 182.17 cm in length. The "Anmol" variety had shorter vines (220.44 cm) than the "Long green" cultivar, which grows longer vines (240 cm). The interaction between control N and the "Anmol" variety resulted in the shortest vines, measuring 174.33 cm in length, whereas the interaction between 150 kg N and variety "Long green" caused the longest vines, measuring 272.67 cm. It indicates that the length of the vines grows in direct proportion to the quantity of N fertilizer

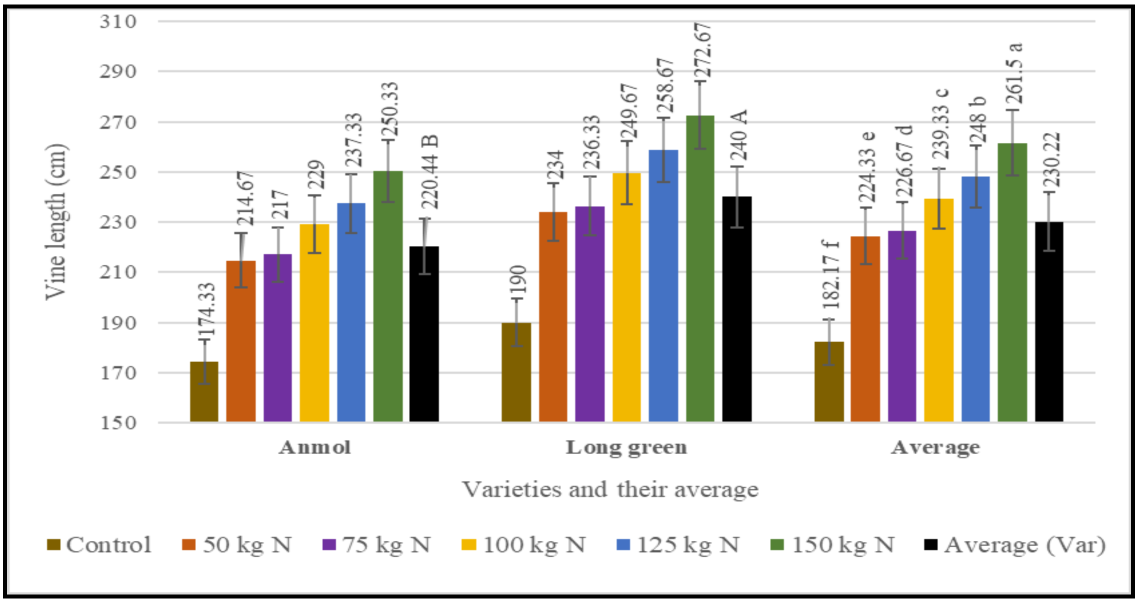


Figure 1: Vine length (cm) of *L. siceraria* varieties under the influence of different N levels

	N levels (N)	Varieties (V)		N levels (N)	Varieties (V)
S.E.±	2.26	1.30	LSD 0.05	4.64	2.69

Branches vine^{-1}: Figure 2 illustrates branches vine^{-1} in two varieties of bottle gourd when they were subjected to varying quantities of N application. There was a statistically significant impact ($p<0.05$) of both N level and variety on branches number, but there was no significant interaction between N level and variety for branches vine^{-1} ($p>0.05$). Plots treated with 150 kg ha^{-1} of N showed the highest branches number vine^{-1} (4.49), followed by those treated with 125 kg ha^{-1} N (4.21), and 100 kg ha^{-1} N (4.06). In contrast, the control plots (zero N) had a lower branches number (3.10). Variety "Long green" exhibited a higher branch count (4.08) than variety "Anmol" (3.76). The interaction between 150 kg N and "Long green" variety maximized branches number (4.64 vine^{-1}), while control N × variety "Anmol" resulted in least branches number (2.96 vine^{-1}). Additionally, there was a linear and statistically significant ($p<0.05$) increase in the number of branches with the rise in the applied N amount.

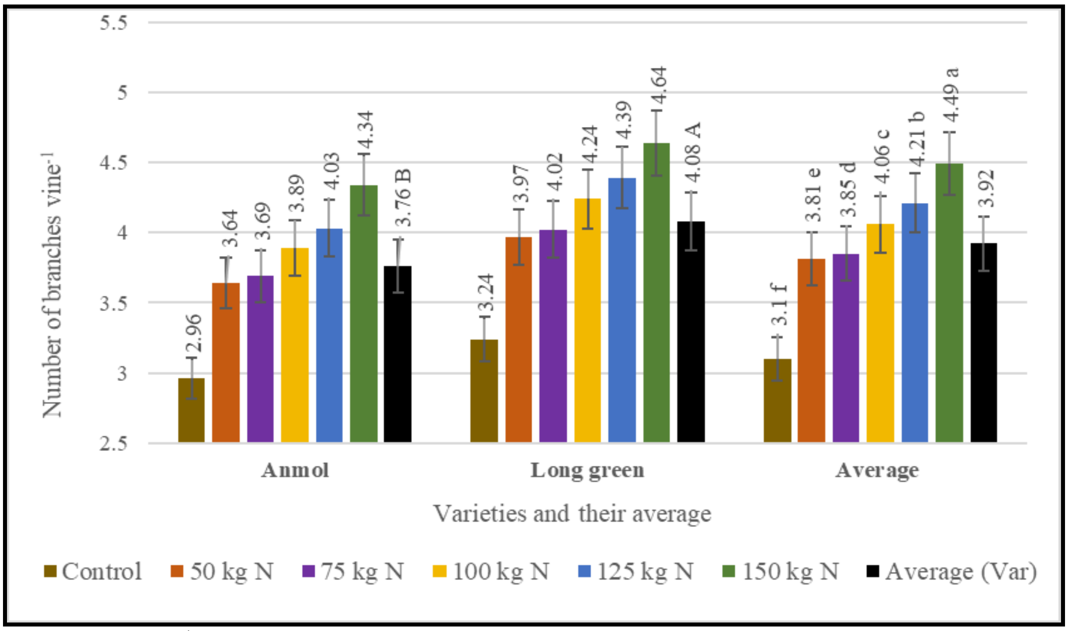


Figure 2: Branches vine^{-1} of *L. siceraria* varieties under the influence of different N levels

	N levels (N)	Varieties (V)		N levels (N)	Varieties (V)
S.E.±	0.067	0.041	LSD 0.05	0.131	0.072

Fruits vine^{-1}: The effects of various N levels on fruits bearing by a single bottle gourd vine were compared (Figure 3). According to the findings, N at varying rates and crop varieties showed significant impact (*p<0.05*) on fruits number vine^{-1}, although the interaction of N level × variety did not appear to have a significant impact on this trait (*p>0.05*). The fruits number was highest when soil received N at 150 kg (7.75 vine^{-1}), but values for this trait deteriorated when crop received N at 125 kg (7.41 fruits vine^{-1}) and 100 kg ha^{-1} (7.03 fruits vine^{-1}). The control group (untreated), on the other hand produced the fewest fruits number (4.47 vine^{-1}). However, variety "Anmol" only produced 5.91 fruits vine^{-1}, but the "Long green" produced 7.35 fruits vine^{-1}. The interaction 150 kg N × "Long green" variety maximized the number of fruits (8.35 vine^{-1}); whereas the interactive effect of zero N (control) × "Anmol" variety caused the fewest fruits (3.11 vine^{-1}). The fruits count was enhanced at higher N rates, following a similar pattern of effectiveness noted for vine elongation and the number of branches. The fruits number vine^{-1} increased linearly and significantly up to 125 kg ha^{-1} of N; while fruits vine^{-1} did not increase noticeably as the difference between 125 kg ha^{-1} and 150 kg ha^{-1} for this trait was not statistically significant (*p>0.05*).

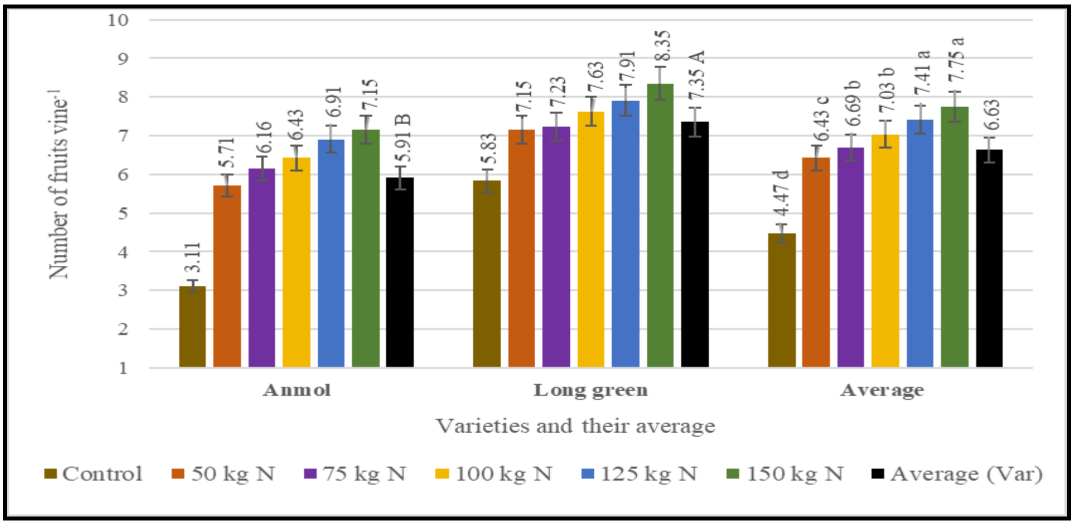


Figure 3: Fruits vine^{-1} of *L. siceraria* varieties under the influence of different N levels

	N levels (N)	Varieties (V)		N levels (N)	Varieties (V)
S.E.±	0.34	0.19	LSD 0.05	0.68	0.41

Average weight of fruits (g): The experimental results, as shown in Figure 4, demonstrated that average fruit weight was affected significantly (*$p<0.05$*) by fertilizer treatments and varieties, whereas, N × variety interaction was not significant ($p>0.05$). The difference in average fruit weight was markedly influenced across treatments, yielded 588, 477.33 and 729.17g average weight of fruits under 125, 100 and 150 kg N ha^{-1}, respectively. However, the single fruit weight was found to be least (158.33 g) in the group served as control (zero N). The "Long green" variety produced heavier fruits on average (484.39 g) than those produced by the "Anmol" variety (428.39 g). When 150 kg ha^{-1} N was applied, the "Long green" variety produced the heaviest single fruit (783.33 g); whereas the "Anmol" variety produced the fruits with least weight (150.33 g) in control N plot. Such heavier fruits in plots fertilized with higher N levels followed a similar pattern of results as seen for vines length, branches and fruits number bearing by each vine reflecting the impact of higher N application rates.

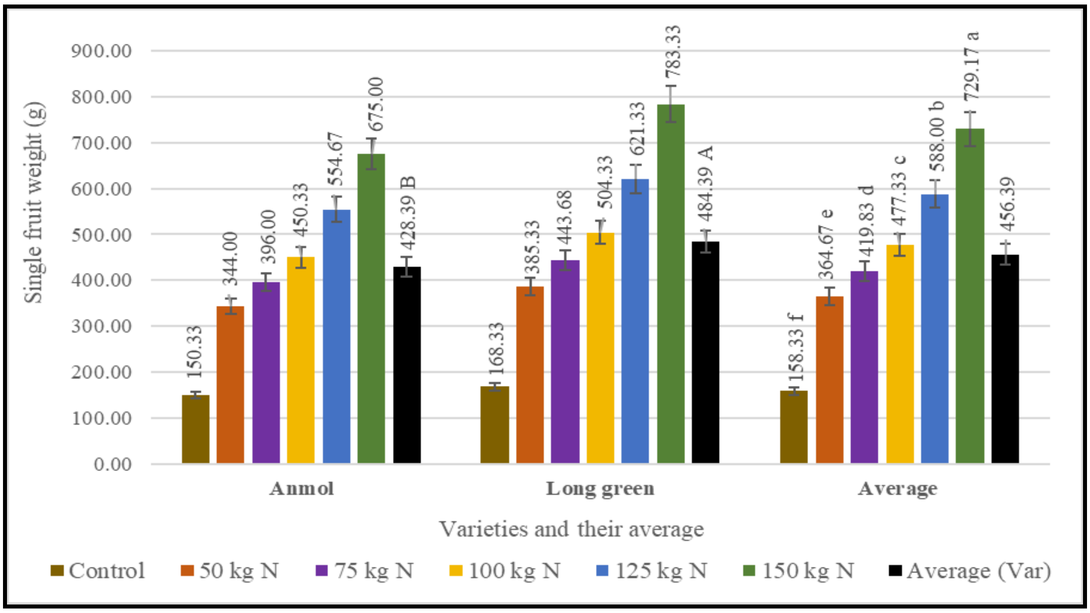
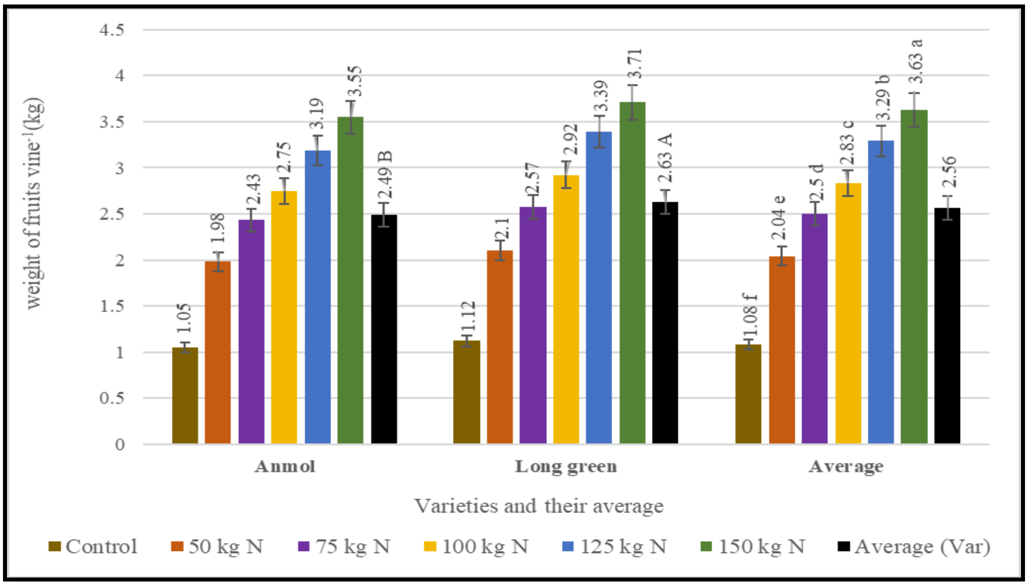


Figure 4: Average fruit weight (g) of *L. siceraria* varieties under the influence of different N levels

	N levels (N)	Varieties (V)		N levels (N)	Varieties (V)	
S.E.±	13.35	8.25	LSD 0.05	29.35	16.99	

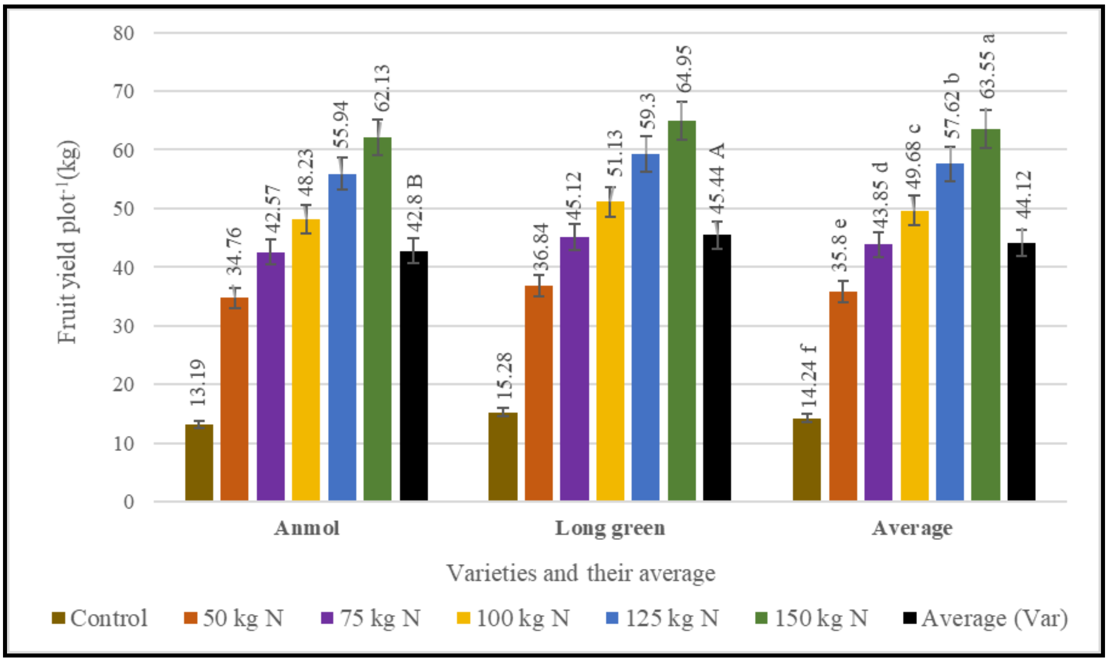
Fruits weight vine^{-1}: The findings from Figure 5 regarding the weight of fruits per vine in response to varying N rates in bottle gourd varieties indicated that both increasing N levels and the selection of different varieties had a statistically significant effect ($p<0.05$) on this trait. However, the interaction between N levels and varieties did not yield a statistically significant impact ($p>0.05$). Notably, the highest fruit weight per vine was observed in vines fertilized with 150 kg N (3.63 kg), followed by 125 kg N (3.29 kg) and 100 kg N ha^{-1} (2.83 kg). Conversely, the control (zero N) showed the lowest fruit weight with only 1.08 kg per vine. Regarding varieties, "Long green" exhibited an average fruit weight of 2.63 kg per vine, while "Anmol" produced fruits with an average weight of 1.49 kg per vine. In particular, the combination of "Long green" variety with 150 kg N resulted in the highest fruit weight per vine (3.71 g). On the other hand, the interaction between "Anmol" variety and the control (zero N) yielded the lowest fruit weight per vine (1.05 g). The observed higher overall fruit weight per vine at higher N levels could be attributed to several factors, including an increase in the number of branches, greater number of fruits per vine, and higher average fruit weight. The weight of fruits per vine consistently increased with each incremental rise in N levels.



	N levels (N)	Varieties (V)		N levels (N)	Varieties (V)
S.E.±	0.112	0.049	LSD 0.05	0.202	0.123

Figure 5: Fruits weight vine^{-1} (kg) of *L. siceraria* varieties under the influence of different N levels

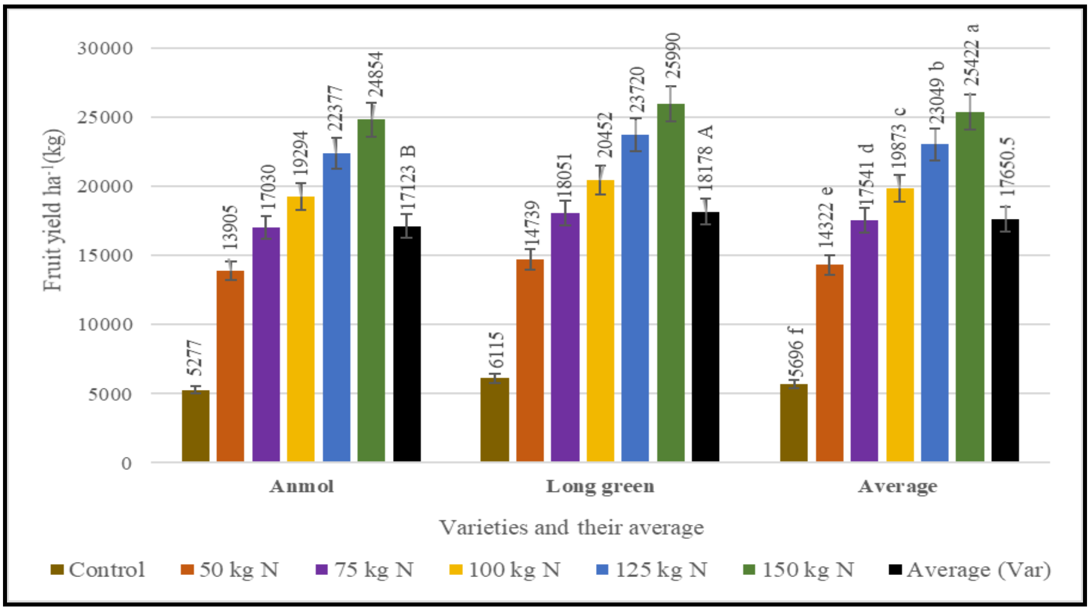
Yield plot^{-1}: Figure 6 presents the fruit yield of bottle gourd varieties in response to different levels of nitrogen (N) fertilizer. The study revealed a statistically significant ($p<0.05$) influence of fertilizer N and varieties on this trait, whereas their interaction was not found to be significant ($p>0.05$). The crop exhibited the highest yield (63.55 kg) when 150 kg of N was applied to the soil, followed by 125 kg (57.62 kg), and 100 kg ha^{-1} (49.68 kg plot^{-1}). In contrast, the control without N fertilizers resulted in only 14.24 kg of fruit yield. Regarding varieties, the "Long green" produced 45.44 kg of fruit yield per plot, while the "Anmol" variety produced an average of 42.80 kg of fruit yield. Notably, when supplied with 150 kg N, the "Long green" variety achieved the highest fruit yield (64.95 kg); whereas the interaction between variety "Anmol" and control resulted in the least fruit yield of 13.19 kg per plot



	N levels (N)	Varieties (V)		N levels (N)	Varieties (V)
S.E.±	1.71	1.09	LSD 0.05	3.33	1.98

Figure 6: Fruit yield plot^{-1} of *L. siceraria* varieties under the influence of different N levels

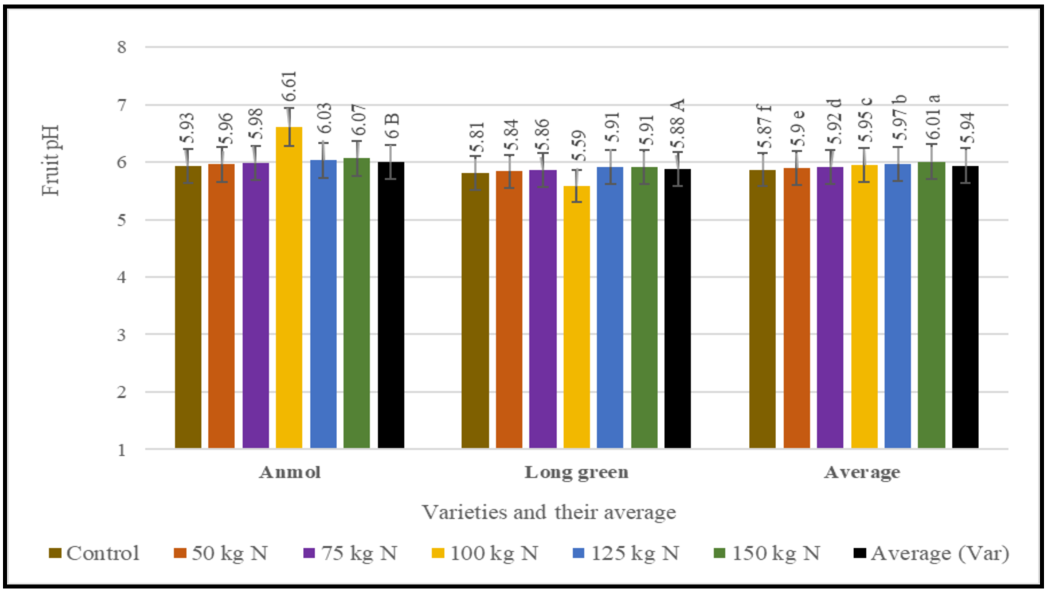
Yield ha^{-1}: The findings (Figure 7) proved that the effect of varying rates of N and varieties on test crop yield ha^{-1} was significant ($p<0.05$). However, the interaction between N levels and varieties did not show a significant effect ($p>0.05$) on yield. The highest yield (25422 kg ha^{-1}) was observed with higher N application (150 kg), which later decreased under 125 kg N (23049 kg) and 100 kg N (19733 kg ha^{-1}). Fruit yield exhibited a decline with decreasing N application rates, with the lowest yield (5696 kg ha^{-1}) observed in plots without N application. Regarding varietal comparison, the "Long green" variety exhibited a higher yield ha^{-1} (18178 kg) compared to the "Anmol" (17123 kg ha^{-1}). Further analysis indicated that N at 150 kg × variety "Long green" maximized crop produce (25990 kg ha^{-1}); whereas control N × "Anmol" variety resulted in the lowest yield (5277 kg ha^{-1}). The increased yield ha^{-1} under higher N levels was attributed to various factors, including increased branching, more fruits number, average weight of fruits, per vine fruit weight and yield plot^{-1}. These factors collectively contributed to the enhanced yield ha^{-1}.



	N levels (N)	Varieties (V)		N levels (N)	Varieties (V)
S.E.±	671.11	379.26	LSD 0.05	1401.33	798.66

Figure 7: Fruit yield ha^{-1} (kg) of *L. siceraria* varieties under the influence of different N levels

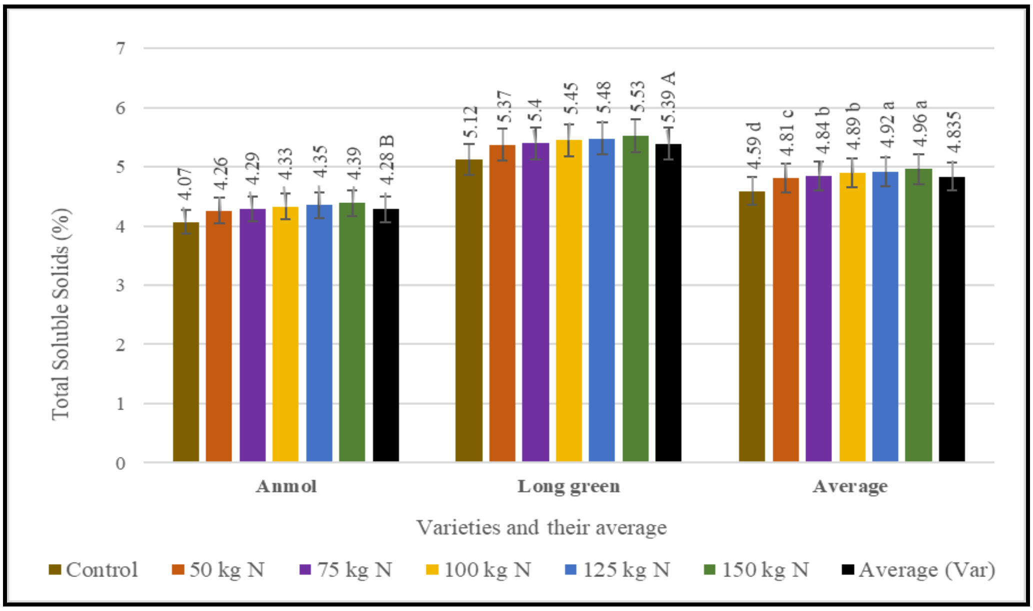
Fruit pH: The results on pH levels of the fruits (Figure 8) of bottle gourds varieties "Anmol" and "Long Green" revealed that N levels and variety both had a statistically significant influence ($p<0.05$) on fruit pH; while there was no statistically significant interaction effect of N levels × variety on this quality trait ($p>0.05$). The fruit pH on average was 6.01 in case the N was provided at higher level (150 kg) and slight decrease in pH was seen when N was applied at 125 kg (5.97), and then 100 kg N ha^{-1} (5.95). On the other hand, the results of control plot showed that the fruit pH was 5.87 in control plots. Varietal comparison suggested that fruits of "Anmol" variety determined with higher pH value (6.00) than did the "Long green" variety (5.88). The interaction between 100 kg ha^{-1} N and the "Anmol" variety produced fruits with a highest pH of 6.61; whereas the interaction between 100 kg N ha^{-1} and the "Long green" variety created fruits with a pH of 5.59. It was shown that variation in the fruit pH was mainly associated with the variation in the rate of N application regardless of varieties.



	N levels (N)	Varieties (V)		N levels (N)	Varieties (V)
S.E.±	0.613	0.499	LSD 0.05	0.020	0.011

Figure 8: Fruit pH of *L. siceraria* varieties under the influence of different N levels

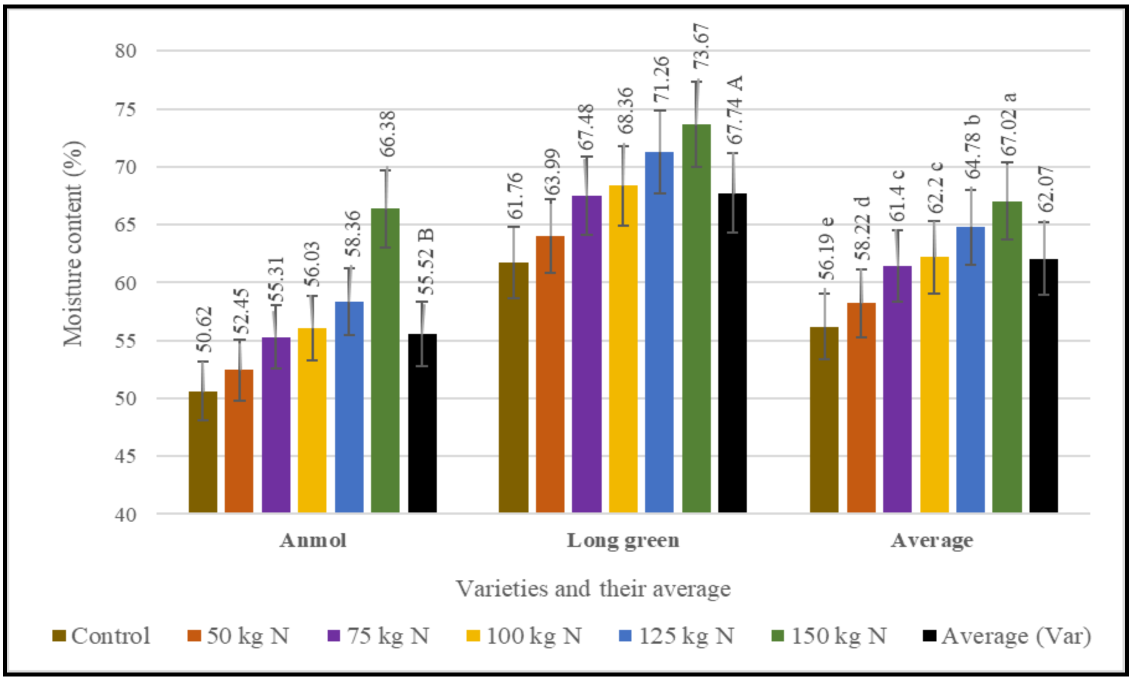
TSS content in fruit (%): Figure 9 presents the findings of a comparative analysis of the total soluble solids (TSS) content in the fruits of bottle gourd varieties under the influence of various doses of nitrogen (N) fertilizer. The study revealed that both different N levels and varieties significantly influenced the TSS content (*p<0.05*). However, the interaction effect between N levels and varieties on this trait was not statistically significant (*p>0.05*). The TSS level in fruit was highest (4.96%) when N was applied at 150 kg ha^{-1}, followed by 125 kg (4.92%) and 100 kg ha^{-1} (4.89%). Nevertheless, the fruit of control plots resulted in TSS content of 4.59%. When comparing cultivars, the fruit of "Long green" had a higher TSS content (5.39%) than the fruit of "Anmol" (4.28%). The "Long green" × 150 kg N interaction resulted in highest fruit TSS (5.53%), whereas the "Anmol" × control N interaction produced fruits with the lowest TSS content (4.07%) in fruits. The levels of TSS in fruit were shown to grow in parallel with the amounts of applied N across the treatments and regardless of variety.



	N levels (N)	Varieties (V)		N levels (N)	Varieties (V)
S.E.±	0.031	0.014	LSD 0.05	0.049	0.029

Figure 9: TSS (%) in fruit of *L. siceraria* varieties under the influence of different N levels

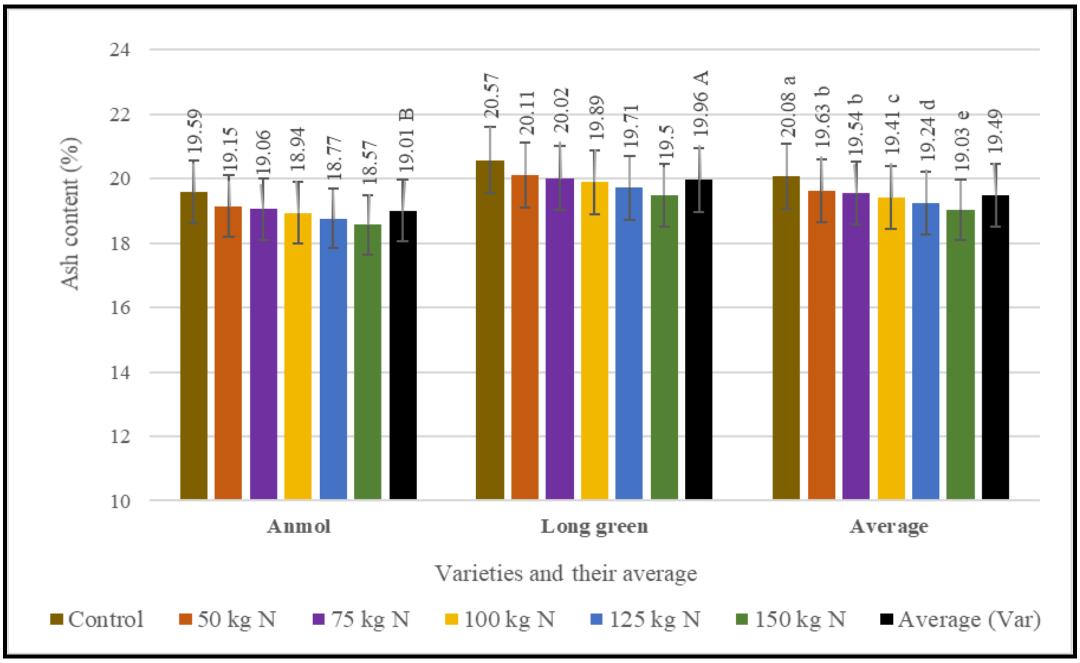
Moisture content in fruit (%): Figure 10 exhibits statistically significant impact of varying N application rates and varieties (*p<0.05*) on fruit moisture content. While, the interaction between the two factors had no significant impact on fruit moisture content (*p>0.05*). When N was applied at a rate of 150 kg ha^{-1}, the averagwhileure content of bottle gourd fruit was at its highest level (67.02%), and significant decrease in fruit moisture i.e. 64.78 and 62.2% was determined in crop fertilized with 125 kg and 100 kg N ha^{-1}, respectively; and it reached its lowest level (56.19%) when N application was discontinued (control). When looking at the two different cultivars side by side, the fruits of the "Long green" variety had a higher percentage (67.74) of moisture in fruit; while it was lower (55.52%) in fruits of variety "Anmol". The interaction of 150 kg ha^{-1} N with the "Long green" variety caused fruits with a highest moisture content (73.67%) that was higher than the average, whereas the interaction of control N with the "Anmol" variety produced fruits with a moisture content (50.62%) which was lower than the average. It was shown that when the levels of N increased, the fruit moisture content of both varieties increased as well.



	N levels (N)	Varieties (V)		N levels (N)	Varieties (V)
S.E.±	0.559	0.329	LSD 0.05	1.199	0.666

Figure 10: Fruit moisture (%) of *L. siceraria* varieties under the influence of different N levels

Fruit ash content (%): The results depicted in Figure 11 clearly demonstrate a statistically significant (*p<0.05*) influence of different nitrogen (N) levels and varieties on the ash content in bottle gourd fruits. However, there was no statistically significant (*p>0.05*) interaction effect between N levels and varieties on this trait. Notably, the bottle gourd fruits treated with the highest N rate of 150 kg exhibited the lowest average ash content (19.03%), followed by 125 kg N (19.24%) and 100 kg N ha^{-1} (19.41%). The maximum ash content, however, was seen in fruits obtained from control plots, where it stood at 20.08%. The fruits of variety "Long green" had ash level of 19.96%, which was higher than the ash percentage determined in fruits of "Anmol" variety (19.01%). The fruits with lowest ash content were obtained in the interactions between the 150 kg N × variety "Anmol" (18.57%) and highest in interaction of control N × variety "Long Green" (20.57%). The increasing the amount of N in the soil led to a reduction in the amount of ash found in fruit of both bottle gourd varieties.



	N levels (N)	Varieties (V)		N levels (N)	Varieties (V)
S.E.±	0.069	0.049	LSD 0.05	0.158	0.087

Figure 11: Fruit Ash content (%) of *L. siceraria* varieties under the influence of different N levels

DISCUSSION

Nitrogen (N) inadequacy in agricultural soils result in decreased crop productivity (Ghafoor *et al*., 2000) and this element is vital for the growth of plants and the development of their roots. The relatively common practice of applying low rates of N in a single application has not been successful to achieve desired crop yields due to the multiple environmental and social variables that have exacerbated the decline in soil productivity within the context of the agricultural community. In order to optimize the N requirement for bottle gourds, this study was carried out. According to the findings of this research, fruit produced at the highest N level of 150 kg ha^{-1} had a pH of 6.01, TSS 4.96%, a moisture 67.02%, ash 19.03%, 7.75 fruits vine^{-1}, greatest fruit yield ha^{-1} (25422 kg), fruit weight vine^{-1} (3.63 kg) and single fruit (729.17 g). With the exception of a few growth traits, a decrease in nitrogen (N) levels, such as 125, 100, 75, and 50 kg ha^{-1}, led to a reduction in values for nearly all analyzed characters. The results indicated that bottle gourd vines treated with N at a rate of 150 kg ha^{-1} outperformed other N levels for all examined traits. Additionally, the "Long green" bottle gourd variety demonstrated better performance compared to the "Anmol" variety.

These findings are consistent with numerous prior studies conducted across different regions. For instance, Umamaheshwarappa *et al*. (2003) observed a significant increase in fruit yield, reaching 32.47 t ha^{-1} with the application of 120 kg N ha^{-1}. Rashmi (2003) suggested a combination of 50-50-37.5 kg NPK ha^{-1} alongside 25 tons of FYM. In a study by Tan *et al*. (2009), higher N rates were found to enhance bottle gourd yield, while the impact of P and K was relatively minor. Baloch (2012) similarly concluded that elevated N levels contributed to improved growth and yield of bottle gourd, recommending 150 kg N for achieving a higher fruit yield of 47.5 t ha^{-1}. Singh and Chhonkar (1996) also recommended the application of 150 kg N ha^{-1} to promote longer bottle gourd vines (747.6 cm) and an increased number of branches (6.5 vine^{-1}). For higher bottle gourd production, Umamaheswarappa *et al*. (2009) suggested the use of 120-100-30 kg NPK. Additionally, studies by Umamaheswarappa *et al*. (2008), Bairwa and Khandelwal (2010), and Farah Deeba *et al*. (2010) reported that augmenting N and P concentrations in bottle gourd cultivation led to a substantial rise in overall crop yield.

The higher N levels improved vine growth and yield because of vital role of N for plant development, which is crucial component of various biological molecules, such as proteins, nucleic acids, and chlorophyll, which are vital for the proper functioning and growth of plants. Mishra *et al*. (2016) reported that N is the major building block for plant proteins having critical role in enzyme activity, photosynthesis, and nutrient transport; and increased N availability enables plants to produce more proteins, leading to better cellular functions and improved growth. Souri *et al*. (2020) reported that N is a key chlorophyll constituent and pigment responsible for capturing light energy during photosynthesis. Photosynthesis is the process through which plants convert light energy into chemical energy, ultimately producing sugars and supporting plant growth. Higher N levels can increase chlorophyll production, leading to more efficient photosynthesis and increased biomass and crop productivity. Tari *et al*. (2018), Khah *et al*. (2010) and Maia *et al*. (2018) concluded that N promotes cell elongation, stimulating root and shoot growth. Moreover, N facilitates the uptake and transport of other nutrients, such as P and K. Adequate N levels can improve nutrient uptake and utilization efficiency of all nutrients, supporting overall plant health and development (Khadka *et al*., 2022).

CONCLUSIONS

Based on the findings of the current study, it is evident that bottle gourd vines treated with a N application rate of 150 kg ha^{-1} exhibited significantly better performance across all evaluated traits compared to other nitrogen levels. Additionally, the variety "Long Green" outperformed the companion variety "Anmol" in terms of the examined characteristics. Consequently, we recommend 150 kg N preferably for cultivation of the "Long Green" variety to bottle gourd growers for optimal results.

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CONFLICTS OF INTEREST

The authors have declared no conflict of interest.

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