International Journal of Horticulture and Food Science 2025; 7(6): 28-32

E-ISSN: 2663-1067
P-ISSN: 2663-1075
NAAS Rating: 4.74
www.hortijournal.com
IJHFS 2025; 7(6): 28-32
Received: 11-04-2025
Accepted: 13-05-2025

Jayesh Garg
Department of Vegetable Science, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, India

Kuldeep Singh Thakur
Department of Vegetable Science, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, India

Priyank Sharma
Assistant Professor (Agribusiness Management), Department AIHSR, Amity University Noida, Uttar Pradesh, India

Shiv Kumar Shivandu
Department of Fruit Science, Dr Yashwant Singh Parmar University of Horticulture and Forestry Nauni, Himachal Pradesh, India

Corresponding Author:
Jayesh Garg
Department of Vegetable Science, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, India

Improving garlic quality and bulb yield through integrated use of conventional and nanofertilizers

Jayesh Garg, Kuldeep Singh Thakur, Priyank Sharma and Shiv Kumar Shivandu

DOI: https://www.doi.org/10.33545/26631067.2025.v7.i6a.316

Abstract
To maximize yield per unit area, modern global agricultural systems rely heavily on the intensive application of fertilizers, pesticides, and herbicides. For resolving these problems in crop production nanofertilizers, are an effective tool. Therefore, the experiment was carried out to evaluate the effectiveness of combined applications of conventional fertilizers and nanofertilizers on qualitative characters as well as garlic bulb yield. The results exhibited that application of 80 percent RDF + 3 sprays of nano NPK + 3 sprays of nano Zn and nano Fe resulted in enhancing the overall nutritional quality as well as yield of garlic. Thus, applying nanofertilizers via foliar applications and in conjunction with conventional fertilizers as soil applications resulted in reducing of 20 percent of synthetic fertilizers while simultaneously maintaining the quality as well as yield. Further research and field trials on nanofertilizers—both alone and in combination with conventional fertilizers—are necessary to fully assess their benefits and long-term effects. These studies could pave the way for more efficient and environmentally sustainable crop nutrition.

Keywords: Agricultural, conventional, garlic, nanofertilizers, quality and yield

1. Introduction
Global food security and agricultural sustainability are being seriously affected by factors including industrialization, climate change, severe weather, and population growth. The adoption of chitosan-based nano-fertilizers—an innovative and economically viable approach—could be pivotal in transforming modern agriculture and mitigating worldwide food insecurity.

Garlic (*Allium sativum* L.), a diploid species (2n=16) from the Amaryllidaceae family, is the second most widely cultivated *Allium* crop after onion. Originating primarily in Central Asia, it later spread to the Mediterranean region, which became its secondary center of diversity. Globally, garlic holds significant agricultural and economic importance among *Allium* vegetables. Nutritionally superior to many other bulbous crops, garlic is rich in carbohydrates (29%), proteins (6.3%), and minerals (0.3%), along with essential oils (0.1-0.4%). It also contains notable amounts of fat, vitamin C, and sulfur compounds, enhancing its dietary and medicinal value. (Hu and Xianyu, 2021) [12]. The herb contains various bioactive compounds, including sulphur-containing compounds, phenols, enzymes, vitamins, and minerals. Garlic (*Allium sativum* L.) is the second most widely cultivated bulb crop after onion, valued globally as a popular spice. According to recent statistics (2023), it is grown on approximately 1.63 million hectares worldwide, with an annual production exceeding 30.7 million metric tonnes. China dominates global garlic cultivation, both in area and output, followed by India, South Korea, Egypt, and the Russian Federation. Modern agricultural systems rely heavily on intensive use of synthetic fertilizers, pesticides, and herbicides to maximize crop yields per unit area (Kihara *et al*., 2020) [14]. However, excessive application of these agrochemicals beyond optimal levels has led to significant environmental degradation—including soil, water, and air pollution (Krasilnikov *et al*., 2022) [15] along with reduced input efficiency and compromised food quality. There is a growing imperative to shift toward sustainable production of nutrient-rich, high-quality food (Verma *et al*., 2022) [28].

Nanofertilizers have emerged as a promising solution for addressing these challenges in modern agriculture. These nano-scale materials (<100 nm) enhance nutrient management through superior penetration capacity, higher surface-area-to-volume ratios, and increased use efficiency, thereby minimizing environmental residues (Upadhyay *et al*., 2023) [26]. By encapsulating or delivering essential nutrients in controlled-release formulations, nanofertilizers optimize plant uptake while reducing ecological harm.

Advances in nanotechnology have opened new frontiers in nanoparticle synthesis and application, with notable potential in vegetable production. Compared to conventional fertilizers, nanofertilizers demonstrate superior performance in enhancing crop growth, yield, and nutrient absorption while mitigating nutrient losses and environmental hazards. Given these advantages, this study evaluates the synergistic effects of combined conventional and nanofertilizer applications in garlic cultivation to improve productivity and sustainability.

2. Materials and Methods

2.1 Site description

The field trial was conducted at the Experimental Farm of Department of Vegetable Science Dr YS Parmar University of Horticulture and Forestry. The site is located at Nauni, about 13 km away from Solan city at an elevation of 1,270 meters above mean sea level lying between latitude 30°51'N and longitude 77'11'E. It falls under the mid-hill zone of Himachal Pradesh.

2.2. Experimental details

The study utilized 'Agrifound Parvati,' a long-day garlic variety, during the Rabi season (2021-22). The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications, evaluating seventeen treatment combinations of conventional fertilizers (NPK) and nanofertilizers applied through both soil and foliar methods. Urea (46%), served as the primary nitrogen source for the NPK treatments, SSP (16%) and MOP (60%), respectively. Nitrogen (half or 1/3rd), full dose of phosphorus and potash were given to all the treatment plots as basal dressing. Remaining dose of N was given in split as prescribed in the standard cultivation practices recommended for garlic crop. Different nanofertilizer treatment combinations were applied as foliar applications. Table 1 shows the details of the treatments.

Fig 1: Cultivar “Agrifound Parvati” used during experiment

Table 1: Treatment details

Treatment code	Treatment Details
T_1	Recommended Dose of Fertilizers (RDF)
T_2	90% RDF + 3 Sprays of Nano NPK
T_3	90% RDF + 3 Sprays of Nano NPK+ 3 Sprays of Nano- Zn
T_4	90% RDF + 3 Sprays of Nano NPK+ 3 Sprays of Nano- Fe
T_5	90% RDF+ 3 Sprays of Nano NPK+ 3 Sprays each of Nano- Zn and Fe
T_6	80% RDF + 3 Sprays of Nano NPK
T_7	80% RDF + 3 Sprays of Nano NPK+ 3 Sprays of Nano- Zn
T_8	80% RDF + 3 Sprays of Nano NPK+ 3 Sprays of Nano- Fe
T_9	80% RDF + 3 Sprays of Nano NPK+ 3 Sprays each of Nano- Zn and Fe
T_{10}	70% RDF + 3 Sprays of Nano NPK
T_{11}	70% RDF + 3 Sprays of Nano NPK+ 3 Sprays of Nano- Zn
T_{12}	70% RDF + 3 Sprays of Nano NPK+ 3 Sprays of Nano-Fe
T_{13}	70% RDF + 3 Sprays of Nano NPK+ 3 Sprays each of Nano- Zn and Fe
T_{14}	60% RDF + 3 Sprays of Nano NPK
T_{15}	60% RDF + 3 Sprays of Nano NPK+ 3 Sprays of Nano- Zn
T_{16}	60% RDF + 3 Sprays of Nano NPK+ 3 Sprays of Nano- Fe
T_{17}	60% RDF + 3 Sprays of Nano NPK+ 3 Sprays each of Nano- Zn and Fe

In all plots, FYM was applied at a rate of 250 q per hectare.

Application of conventional fertilizers

Before sowing seeds, calculated amounts of nutrients in the form of urea, SSP and MOP were applied as per treatment details. As a baseline dose, one- third dose of N was applied together with full doses of P and K. The remaining one-third dose of N was applied after a month of planting, and the remaining one-third dose was applied after 50 days.

Application of nanofertilizers

Foliar applications of nanofertilizers comprising three nanofertilzers namely Nano NPK, Nano Zinc and Nano Fe was given to the garlic plants. Table 2 shows the standardized dosage and spray schedule of the above nanofertilizers.

Table 2: Dose and Spray schedule of nanofertilizers

Dose	250g/ha/500l of water
First spray	After one month of full germination.
Second spray	After two months of 1st spray

Third spray	After two months of 2nd spray

Observations Recorded

The observation was recorded on phenotypically superior ten selected plants from each plot with the following characteristics: dry weight of plant (g), dry matter content (%) TSS (°Brix), nitrogen content (%), phosphorus content (%), potassium content (%), zinc content (ppm), iron content (ppm), bulb yield plot^{-1} and hectare^{-1}.

Statistical Analysis

Analysis of variance for the study was done as per the design model suggested by Panse and Sukhatme (2000) [19].

3. Results and discussion

3.1 Quality Characters

Dry weight of the plant (g): The dry weight of a plant refers to its mass when all moisture has been removed, providing a measure of its actual biomass. This measurement is vital in assessing plant growth, productivity, and nutrient content. The dry weight of the plant in different treatment combinations (Table 3) ranged from 23.27-33.89 g. The highest dry weight of plant (33.89 g) was recorded in the treatment comprising of 80% RDF + 3 sprays each of nano NPK, nano Zn and nano Fe (T_9) which was observed statistically at par with treatment T_5 (33.19 g) which comprised of 90% RDF + 3 sprays each of nano NPK, nano Zn and nano Fe. The treatment combination T_{13} (70% RDF + 3 sprays of nano NPK+ 3 sprays each of nano Zn and nano Fe) recorded lowest (23.27 g) dry weight of plant. Similar findings were also reported by Anwar *et al*. (2021) [3] who reported the highest values for the dry weight of plant with the application of nano potassium and nano phosphorus. Razaq *et al*. 2019 [21] conducted their findings on gulabi variety of garlic and reported maximum values for the dry weight of the plant with the application of zinc sulphate and boric acid.

Dry matter content (%): The dry matter content of a plant refers to the percentage of its total weight that remains after removing all the moisture. A perusal of data (Table 3) revealed significant differences for the trait dry matter content (%). The dry matter content of the plant in different treatment combinations ranged from 32.23-43.32%. Nano-fertilizers, containing essential plant nutrients, enable enhanced dissolution, rapid absorption, and improved utilization by plants relative to traditional fertilizer formulations. (Ditta and Arshad, 2016) [7]. These are some of the possible reasons which might have attributed to the higher dry matter content in garlic and resulting in good quality of garlic production. Similar findings were also reported by Selen, 2019 [22] who reported the dry matter content range of (36.60-39.59%) in four garlic varieties in his experiment

TSS (° Brix): Total soluble solids (TSS) are the total amount of dissolved solids in a liquid. Total soluble solids (TSS) are an important quality parameter for garlic. A perusal of data in table 3 reported the total soluble solids content in garlic in different treatment combinations ranged from 29.24 to 35.48 °Brix. Vigorous plant growth coupled with dense foliage coloration appears to have stimulated photosynthetic activity. The resulting surplus of assimilates, primarily carbohydrates, accumulated in the bulb and contributed to increased TSS formation**.** Similar findings were also reported by Selen, 2019 [22] who reported the TSS range of (33.13-36.80° Brix) in four garlic varieties in his experiment.

Nitrogen content (%) of garlic plant: Nitrogen is an essential nutrient for plants. It is used to build proteins, enzymes, and other important molecules. A perusal of data with respect to nitrogen content (%) of garlic plant, given in table 3 showed that different treatments in both the years had significant effects. The nitrogen content (%) of garlic plant in different treatment combinations ranged from 1.12 to 1.99%. Treatment comprising of 80% RDF + 3 sprays of nano NPK + 3 sprays each of nano Zn and nano Fe (T_9) had significantly higher nitrogen content (%) of garlic plant (1.99%) which was followed by treatment T_5 (1.78%). Foliar application represents the most effective approach for remedying nutrient deficiencies while simultaneously enhancing both crop yield and quality**.** The rise in nitrogen content of the plant can be attributed to an increased and consistent supply of nutrients from various sources during the crucial growth phase, which likely increased growth factors, leading to higher nitrogen content. Similar findings were also reported by Shiferaw *et al*. (2013) [23] and Tang *et al*. (2018) [24].

Phosphorus content (%) of garlic plant: Phosphorus is an essential nutrient for plants. It is involved in many important cellular processes, including energy transfer, photosynthesis, and protein synthesis. Among different treatment combinations treatment with 80% RDF + 3 sprays of nano NPK + 3 sprays nano Zn (T_7) had significantly higher phosphorus content (%) of garlic plant (0.66%) followed by treatment T_9 (0.59%) comprising of 80% RDF + 3 sprays of nano NPK + 3 sprays each of nano Zn and nano Fe. While treatment T_1 (100% RDF) and treatment T_{14} (60% RDF+ 3 sprays of nano NPK) recorded the minimum value for the phosphorus content (%) of garlic plant i.e., 0.29% for both the treatments respectively. Synergistic nutrient management was achieved through RDF application in initial growth phases complemented by foliar sprays of Nano-NPK, Nano-Zn, and Nano-Fe during later stages, collectively boosting both nutrient assimilation and water uptake efficiency. Similar results were also obtained by Hasan (2015) [11], Dawood *et al*, (2011) [6] Abou El-Magd *et al*, (2014) [1] and Zaki *et al*, (2014) [29].

Potassium content (%) of garlic plant: Potassium is an essential nutrient for plants. It is involved in many important cellular processes, including water regulation, photosynthesis, and enzyme activation. Data pertaining with respect to potassium content (%) of garlic plant, is mentioned in table 3 showed that different treatments had significant effects. The potassium content (%) of garlic plant in different treatment combinations ranged from 2.14 to 3.84%. Plants effectively utilized RDF-supplied nutrients during early development, while subsequent foliar application of nano-formulated NPK, zinc, and iron further optimized nutrient absorption and enhanced water uptake mechanism**s.** Similar results were also obtained by (Hasan 2015) [11], Dawood *et al*, (2011) [6], Abou El-Magd *et al*, (2014) [1] and Zaki *et al*, (2014) [29].

Zinc content (ppm) of garlic plant: Zinc is an essential micronutrient for plants. It is involved in many important cellular processes, including enzyme activation, protein synthesis, and gene expression. Data pertaining with respect to Zinc content (ppm) of garlic plant, is mentioned in table 3 showed that different treatments had significant effects. The zinc content (ppm) of garlic plant in different treatment combinations ranged from 105.61 to 130.58 ppm. Among all the treatments, treatment comprising of 80% RDF + 3 sprays of nano NPK + 3 sprays each of nano Zn and nano Fe (T_9) had significantly higher zinc content (ppm) of garlic plant (130.58 ppm) which was found statistical at par with treatment T_8 (128.77 ppm) with 80% RDF + 3 sprays of nano NPK + 3 sprays of nano Fe. Foliar fertilization of zinc has been proved to be an effective practice to overcome the problems of zinc binding, and fixation in soil though the timing of application is of prime concern. Therefore, keeping the above facts in concern and selecting the appropriate nanofertilizer concentration is important for overall plant growth and development. The results of present findings are in consonant with the findings of Uzma *et al*. (2016) [27] who reported the interactive effect of phosphorus and zinc on the growth, yield and nutrient uptake of garlic (*Allium sativum* L.).

Iron content (ppm) of garlic plant: Iron serves as a vital micronutrient in plant physiology, playing fundamental roles in chlorophyll biosynthesis, electron transport chains, and catalytic activation of essential enzymes. Scrutiny of data with regards to iron content (ppm) of garlic plant, is recorded in Table 3 reported that different treatments in both the years had significant effects. The iron content (ppm) of garlic plant in different treatment combinations ranged from 85.48 to 103.65 ppm. Among all the treatments treatment T_9 (80% RDF + 3 sprays of nano NPK + 3 sprays each of nano Zn and nano Fe) had significantly higher iron content (ppm) of garlic plant (103.65 ppm) which was found statistical at par with treatment T_8 (80% RDF + 3 sprays of nano NPK + 3 sprays of nano Fe) (100.36 ppm), treatment T_{10} (70% RDF + 3 sprays of nano NPK) (100.74 ppm) and treatment T_{11} (70% RDF + 3 sprays of nano NPK) (99.84 ppm). While treatment T_1 (100% RDF) recorded the minimum value for the iron content of garlic plant (85.48 ppm). Nano-Fe fertilizers are more efficient than conventional forms, enhancing plant growth and metabolic efficiency, such as photosynthesis, leading to increased accumulation and translocation of photosynthates to the economically valuable plant parts Similar results were also reported by Nasar *et al*. (2020) [18] who studied the effect of nitrogen fertilization when coupled with foliar application of iron resulted in improved photosynthetic activities and increased nitrogen use efficiency as well as iron concentration in maize plants

3.2 Yield Characters

Bulb yield per plot and per hectare (q): Among different treatment combinations T_9 which comprised of (80% RDF + 3 sprays each of nano NPK + nano Zn and nano Fe) recorded maximum yield of 5.59 kg/plot and 193.72 q/ha (Table 3) significantly excelled the recommended dose of fertilization (T_1) i.e., 100% RDF (N 125: P_2O_5 75: K_2O 60 kg/ha and FYM @ 25 t/ha) with a yield of 1.85 kg/plot and 89.32 q/ha. The observed yield enhancement in garlic likely stems from the superior performance of nanofertilizers across all measured parameters, attributable to their nanoparticles' exceptionally high surface area-to-volume ratio that amplifies enzymatic activity and biochemical processes.

Conclusion

The use of nano NPK, nano Zn and nano Fe in combination with conventional fertilizers has immense scope to improve crop quality as well as yields. Among all the treatment combinations, T_9 which comprised of 80% RDF + 3 sprays of Nano NPK+ 3 sprays each of Nano Zn and Nano Fe was rated as the best treatment for nutritional quality and garlic bulb yield as compared to RDF or the treatments in which other fertilizer treatment combinations were used. Ongoing investigation requires thorough commitment to further research and extensive field experiments involving nanofertilizers, both independently and in conjunction with conventional ones. Conducting these efforts across various crops and diverse locations is crucial, representing a vital initiative aimed at uncovering the full extent and possibilities of this innovative approach.

Table 3: Effects of conventional and nanofertilizers on quality and yield of garlic

Treatment code	Dry weight of plant (g)	Dry matter content (%)	TSS (°Brix)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Zinc (ppm)	Iron (ppm)	Bulb yield per plot (kg)	Bulb yield per hectare (q)
T_1	24.65	32.23	29.24	1.18	0.28	2.16	105.61	85.48	1.85	89.32
T_2	24.95	35.41	30.28	1.25	0.44	2.84	110.25	90.24	2.86	105.63
T_3	25.12	33.25	31.88	1.12	0.49	2.58	111.27	90.58	2.15	92.03
T_4	30.18	40.22	34.58	1.32	0.38	2.39	109.47	91.28	3.84	173.83
T_5	33.19	43.32	33.27	1.74	0.29	2.44	120.47	94.68	4.52	190.49
T_6	24.58	35.56	32.74	1.17	0.37	2.69	119.54	93.47	3.65	146.95
T_7	26.33	36.42	33.15	1.55	0.66	3.84	126.32	95.85	4.68	168.12
T_8	28.65	41.28	31.24	1.68	0.54	3.78	129.96	100.36	3.66	169.86
T_9	33.89	42.58	35.48	1.99	0.59	3.64	130.58	103.65	5.59	193.72
T_{10}	30.74	37.51	33.05	1.52	0.44	3.15	125.84	100.74	4.52	181.68
T_{11}	26.58	36.54	32.71	1.35	0.41	3.28	122.39	99.84	3.78	164.61
T_{12}	25.12	38.25	30.98	1.38	0.36	2.87	127.45	94.65	3.65	154.36
T_{13}	23.27	40.85	31.45	1.29	0.38	2.98	118.54	95.64	3.32	143.24
T_{14}	24.98	33.54	30.26	1.21	0.29	2.15	119.65	98.48	3.69	147.81
T_{15}	24.85	37.42	29.62	1.39	0.39	2.65	112.87	90.36	2.65	115.61
T_{16}	27.94	35.47	30.94	1.57	0.34	2.74	111.28	90.52	2.52	105.81
T_{17}	26.62	37.28	31.26	1.48	0.33	2.14	119.85	89.59	2.39	110.29
(CD 0.05)	1.20	1.48	NS	0.59	NS	0.15	5.99	3.97	0.18	21.20

References

1. Abou El-Magd MMT, El-Shourbagy MMT, Shehata SM. A comparative study on the productivity of four Egyptian garlic cultivars grown under various organic material in comparison to conventional chemical fertilizer. Aust J Basic Appl Sci. 2012;6:415-421.
2. Anonymous. Food and agriculture organization of United Nations. FAOSTAT [Internet]. 2020. Available from: http://www.fao.org/faostat/en/#data/QC
3. Anwar N, El-Salehein A, El Hamady M, Mandour M. Response of garlic to nitrogen and phosphorus in the common form and nano. J Prod Dev. 2021;26:1033-1052.
4. Badal DS, Dwivedi AK, Kumar V, Singh S, Prakash A, Verma S, *et al*. Effect of organic manures and inorganic fertilizers on growth, yield and its attributing traits in garlic (*Allium sativum* L.). J Pharmacogn Phytochem. 2019;8:587-590.
5. Brar B, Singh J, Singh G, Kaur G. Effects of long-term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize-wheat rotation. Agronomy. 2015;5:220-238.
6. Dawood AR, Abd-Elaal SA, Badawey AS, Attallah SY. Testing of some garlic (*Allium sativum* L.) cultivars under Assiut conditions. Assiut J Agric Sci. 2011;42:378-390.
7. Ditta A, Arshad M. Applications and perspectives of using nanomaterials for sustainable plant nutrition. Nanotechnol Rev. 2016;2:209-229.
8. Fekry W. Effect of NPK and some biofertilizers on growth, yield and quality of garlic plants. J Prod Dev. 2009;14(3):655-671.
9. Gashaw B. Evaluation of different rates of NPS on growth and yield performances of garlic (*Allium sativum* L.) in Cheha District, Gurage Zone, Ethiopia. Int J Agron. 2021;2021:1-5.
10. Gupta N, Bhargav KS, Kumari S, Dixit AK. Impact assessment of integrated nutrient management on growth, yield and economics of garlic (*Allium sativum* L.) Cv. G-282 through front line demonstration. Ecol Environ Conserv. 2021;27:116-120.
11. Hassan A. Improving growth and productivity of two garlic cultivars (*Allium sativum* L.) grown under sandy soil conditions. Middle East J Agric Res. 2015;4:332-346.
12. Hu J, Xianyu Y. When nano meets plants: a review on the interplay between nanoparticles and plants. Nano Today. 2021;38:101143.
13. Jay P, Kumar S, Kumar VP, Verma S, Verma VK. Effect of organic manure and inorganic fertilizer on growth and yield of garlic (*Allium sativum* L.). Ann Hortic. 2017;10:95-98.
14. Kihara J, Bolo P, Kinyua M, Rurinda J, Piikki K. Micronutrient deficiencies in African soils and the human nutritional nexus: opportunities with staple crops. Environ Geochem Health. 2020;42:3015-3033.
15. Krasilnikov P, Taboada MA, Amanullah. Fertilizer use, soil health and agricultural sustainability. Agriculture. 2022;12:462.
16. Kumari S. Study on genetic parameters in garlic (*Allium sativum* L.) for yield and quality traits. Electron J Plant Breed. 2021;12:477-484.
17. Millan AF, Morales F, Abadía A, Abadía J. Effects of iron deficiency on the composition of the leaf apoplastic fluid and xylem sap in sugar beet. Implications for iron and carbon transport. Plant Physiol. 2000;124:873-884.
18. Nasar J, Wang GY, Ahmad S, Muhammad I, Zeeshan M, Gitari H, *et al*. Nitrogen fertilization coupled with iron foliar application improves the photosynthetic characteristics, photosynthetic nitrogen use efficiency, and the related enzymes of maize crops under different planting patterns. Front Plant Sci. 2022;13:98805.
19. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. 4th ed. New Delhi: ICAR; 2000. p. 157-165.
20. Pathak S, Shukla YR. Differential responses of integration of organic and inorganic manures on growth and yield of garlic (*Allium sativum* L.). Pharma Innov J. 2023;12(2):640-645.
21. Razaq T, Madiha U, Najeebullah M, Riaz M. Effect of zinc and boron on the growth and yield of gulabi variety of garlic (*Allium sativum* L.) under agro-climatic condition of Peshawar. Int J Agron Agric Res. 2019;14:11-15.
22. Selen A. Evaluation and comparison of some parameters in four garlic varieties. J Inst Sci Technol. 2019;9:1866-1875.
23. Shiferaw D, Nigussie DR, Kebede W, Getachew T, Sharma JJ. Growth and nutrients content and uptake of garlic (*Allium sativum* L.) as influenced by different types of fertilizers and soils. Sci Technol Arts Res J. 2013;2:35-50.
24. Tang QX, Tewolde H, Liu HB, Ren TZ, Jiang PA, Zhai LM, *et al*. Nitrogen uptake and transfer in broad bean and garlic strip intercropping systems. J Integr Agric. 2018;17:220-230.
25. Tang QX, Tewolde H, Liu HB, Ren TZ. Nitrogen uptake and transfer in broad bean and garlic strip intercropping systems. J Integr Agric. 2018;17:220-230.
26. Upadhyay PK, Sen A, Singh Y, Singh RK, Prasad SK, Sankar A. Soil health, energy budget, and rice productivity as influenced by cow products application with fertilizers under South Asian Eastern Indo-Gangetic Plains zone. Front Agron. 2022;3:758572.
27. Uzma A, Hussain S, Shah SZA, Hamid A, Yaqoob A, Arif AA, *et al*. Interactive effect of phosphorus and zinc on the growth, yield and nutrient uptake of garlic (*Allium sativum* L.) variety Gulabi. Asian J Agric Food Sci. 2016;4:81-86.
28. Verma KK, Song XP, Joshi A, Tian DD, Rajput VD, Singh M. Recent trends in nano-fertilizers for sustainable agriculture under climate change for global food security. Nano. 2022;12:173.
29. Zaki H, Toney H, Elraouf RM. Response of two garlic cultivars (*Allium sativum* L.) to inorganic and organic fertilization. Nat Sci J. 2014;12:52-60.