Journal of Pure and Applied Agriculture (2024) 9(1): 91-97
ISSN (Print) 2617-8672, ISSN (Online) 2617-8680
http://jpaa.aiou.edu.pk/

Interactive impact of zeolite with nitrogen sources on garlic yield under temperate agro-ecosystem of Azad Jammu and Kashmir

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Abstract

Absorbable N (NO_3^-) leaching losses have been a challenge for a long time to agricultural scientists, in all types of vegetable and field crop production. Zeolites are alumino-silicate minerals that have the capacity to hold moisture, N and other nutrients due to large reactive surface area making sustainable N supply to plants throughout the cropping season. We studied the impact of various nitrogen sources like zeolite, poultry manure, and urea N individually and in combinations on garlic production. Zeolite, poultry manure, and urea along with combinations (3 only, 6 combinations and Control) comprising 10 treatments, were used to assess nitrogen supply during garlic crop and its yield under temperate agroecosystem. Combinations of zeolite, poultry manure, and urea positively enhanced biological yield, but differences among combinations were non-significant and significantly differed from the control and single source. Urea-nitrogen and poultry-manure combination at 60 + 60 kg ha^{-1} gave a maximum yield of garlic 8.7 tones ha^{-1}; zeolite, Urea-Nitrogen and poultry-manure at 250 + 60 + 30 kg ha^{-1} yielded 7.68 tones ha^{-1}. Poultry-manure plus zeolite, and poultry-manure plus urea combinations increased ascorbic acid 0.2 mg.100g^{-1} and antioxidant 0.2597 mg 100 g^{-1} in the garlic crop. Zeolite, urea, and poultry-manure at the doze of (500 kg + 30 kg + 30 kg ha^{-1}) were proved to be the best dose, economical, and cost-effective. This study will help a common farmer to manage their crop fertilization in combinations for targeted biological and quality of yield contents by efficient nitrogen use through slow releasing and reduced leaching in temperate hilly areas with average to below average organic matter.

Keywords: Fertilizer combinations, Garlic, Nitrogen, Poultry manure, Zeolite

To cite this article: Bibi, S., Tariq-Khan, M., Hamid, A., Jamil, M., & Shafqat, M. (2024). Interactive impact of zeolite with nitrogen sources on garlic yield under temperate agro-ecosystem of Azad Jammu and Kashmir. *Journal of Pure and Applied Agriculture, 9*(1), 91-97.

Introduction

Garlic (*Allium sativum* L.) is an important vegetable crop belonging to family Alliaceae, used as a daily culinary condiment and spices all over the world, especially in the sub-continent and Pakistan. Garlic has been used in China and India for more than 5000 years, and in Egypt since 2000 B.C. (Kamenetsky & Rabinowitch, 2001). It has extensive medicinal uses like flatulence, as an influencer on bronchial and pulmonary secretions, helps in the flow of menses, used as a relieving agent in case of colic pain and nervous headache. In modern research findings, it has antimicrobial, anti-hypersensitive, hypolipidemic, hepatoprotective, antidiabetic, insecticidal, immunomodulation, and antitumor properties (Yoshida et al., 1987; Singh et al., 2001). It is used as a tonic, carminative, stimulant and applied to the nose of hysteria patients during swooning. In routine medical practices, garlic is frequently used for the reduction of cholesterol in blood serum, as a rich source of organo-Sulphur like allicins, amino acid like L-cysteine sulfoxide (Lawson et al., 1991). At present time garlic tablets are used for their hypocholesterolemic action against high cholesterol levels (Augusti, 1977).

Indiscriminate use of inorganic fertilizers has resulted in the deterioration of soil texture, structure, reduction in microbial activities, subsoil water pollution, decrease in overall soil fertility and crop production. A desire and deserving need to concentrate the sound research work for this crop is required with a complete package of practices. Fertilizer dose optimization for garlic production in temperate areas to supply major and micronutrients on a regular basis is an important aspect to be explored. Fertilizer management will play an important role in its good growth, yield, and quality improvement (Badal et al., 2019). The importance of organic fertilizers like poultry manure cannot be ignored in garlic production, to improve growth, yield, and quality of produce. Nitrogen, phosphorus, and potassium are major, or macronutrients required by plants for vegetative growth and are abundant in organic matter. A sufficient amount of nitrogen is very important for the initiation of leaves and flower primordial in garlic crop (Tisdale et al., 1985). For high biological yield ample amount of nitrogen availability is imperative for plant growth which is available in the form of nitrate (NO_3^-) and ammonium (NH_4^+) through ammonification and mineralization. Nitrogen is supplemented to crops as synthetic fertilizers, organic matter, and some minerals like zeolite for sustainable yield. The application of nitrogen for garlic production may vary according to soil type and growing conditions throughout the growing season. Mineralization process starts during the first week of applications in porous soils, however, it is slow in the heavy and clay loam soils. Process is much faster in loamy soils, soils rich in organic matter with microbial abundance, and is used by soil microbes and crop plants (Burgos et al., 2006).

Zeolites are natural microporous, hydrated materials with 40 species having a more internal surface area required for plant growth. Zeolites are alumino-silicate minerals that hold on soil moisture contents and make N available to the plants due to large reactive surface area. Zeolites are used as fertilizer as they have high cation exchange capacity (CEC), soil water and moisture holding capacity, adsorption, hydration in the cultivation of cereals, fruit, and vegetables. It is also used in growth media to improve plant yield because it attracts and stores many nutrients in the soil and releases them gradually according to crop plants requirements. Zeolites are characterized for absorbing plant nutrients like NK from soil and slow release into the soil for plant uptake, increasing phosphorus availability to the crop. These are natural nitrogen transporters which enhance N uptake by plants. Optimum nitrogen uptake by crop plant and reduction in its leaching index and reduced extra phosphorus consumption limit economic losses (Savvas et al., 2004). Poultry manure enhances the water-holding capacity of soil along with 53% increased quantity of available nitrogen (Warren et al., 2006). Plant growth needs an increase in soil water and nutrient supply and is maximized before and after flowering. Poultry-manure and zeolite applications in combination with other nutrients have proved helpful in regulating the physiological processes in plants and leaves like maintaining relative water contents, catalase antioxidant enzyme activity, and reduction in proline accumulation under stress conditions (Zanjani et al., 2012).

Soil amendments with organo zeolite promote populations of nitrifying bacteria, which increase available cations to fulfill the crop plant requirements, limiting fertilizer losses (Leggo & Ledesert, 2001). Retaining of NH_4^+ by zeolite prevents the soil toxicity caused by excessive ammonia. Integration of organic and inorganic fertilizers can be advocated as one of the strategic solutions to maintain sustainable soil fertility and production. Amendments with naturally existing organo zeolite, organic manures, and inorganic fertilizers combination can be a workable solution for durable nitrogen supply in garlic crop which can reduce nitrogen losses with improved crop yield. Due to the importance of garlic and required nitrogen, the current study was designed, and targeted with soil amendments with poultry-manure (poultry wastes), zeolite, and urea, to assess crop yield responses and qualitative aspects against nitrogen sources combinations. Garlic crop productivity and quality was assessed and compared under diverse combinations and individual sources in temperate agro-ecosystem.

Materials and Methods

Experimental field layout, treatments and selection of planting material

Garlic (Lehsan-Gulabi), a local accession, was used as experimental plant material to test its performance against diverse nitrogen sources and their combinations with zeolite, poultry manure, and urea as nitrogen sources under field conditions of Rawalakot, Azad Jammu and Kashmir. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications of six rows having ten plants each.

Preparation of soil

Soil was prepared by thorough ploughing with the help of a tractor, 4 m^2 beds were prepared. Ten treatments, zero N fertilizer (Control), poultry manure (PM full) (1000 kg equivalent to urea nitrogen (UN) 120 kg/ha, zeolite (full) 1000 kg/ha, PM + Zeolite (60 + 500 kg/ha), UN (120 kg/ha), UN + PM (60 + 120 kg/ha), UN + zeolite (60 + 1000 kg/ha), UN + PM + Zeolite (60 + 250 + 330 kg/ha), UN + PM (60 + 60 kg/ha), UN + Zeolite (60 + 500 kg/ha) were applied as basel doze on the garlic crop (Table 1). Material was thoroughly mixed in each replication and each treatment.

Data collection

Ten plants from each replication (plot) were randomly selected and kept under observation from germination to harvesting of crop for different targeted parameters. Germination was estimated by germinated cloves per unit area with the reference to the number of sown cloves. Plant height, number of leaves, leaf area, average weight and diameter of bulbs, number of cloves per bulb.

Determination of qualitative parameters

Clove extract pH was measured by using a digital pH meter, by crushing the bulb in distilled water with 1:2.5 ratio. TSS (Total soluble solids) were measured by selection of 10 cloves of uniform size, ground vigorously and juice was extracted and put under refractometer and Brix were estimated.

Phenolic contents estimation

Total phenolic contents (TPC) were measured by Folin–Ciocalteau assay with little modification (Ainsworth & Gillespie, 2007). For estimation 100 µl from the extracted sample was mixed with FC agent in 200 µl eppendorf tube, vortexed for a few seconds for mixing, added 80 µl 700 mM Na_2CO_3, vortex again and kept at room temperature for 2 hours. Microplate Reader ElX800 waas used for content estimation at 765 nm and contents were estimated in µg per ml.

Ascorbic acid

Ascorbic acid (Vit C) was determined by using 2, 6 dichlorophenol indophenol dye. 5 ml of sample was taken in 100 ml of conical flask and 5 ml of 4% Meta phosphoric acid solution was added and titerated with dyne till the appearance of light pink color as end point.

Chlorophyll contents

Chlorophyll readings were taken with the help of a handheld dual wavelength meter (SPAD 502 chlorophyll meter, Minolta Camera Co., Ltd., Japan) at wave length of 645-663 nm. For chlorophyll analysis, leaves with an area of 1 cm^2 were taken and put in 4 ml of ethanol, and placed at room temperature for 24 hours. Samples were put in the chlorophyll meter and covered; readings were taken. Weight and diameter of ten randomly selected bulbs from each treatment were calculated after harvesting. Yield per unit area was determined by calculating and weighing the bulbs obtained from each plot and converted into kg per hectare.

Total antioxidants

DPPH (2, 2 diphenyl- picrylhydrazyl radical) assay was carried out for determination of antioxidants, with the help of spectrophotometry using protocol (Mimica-Dukić et al., 2003). Different concentrations of aliquot from juice extracted from the cloves was added to 5 ml 0.004% methanol solution of DPPH and incubated at 30 minutes at room temperature. Absorbance was read against 517 nm as 1% equal to 100 x and total antioxidants were expressed as IC µg ml^{-1}. Average shelf life for each replication was recorded by keeping the cloves at ordinary room temperature, and average yield per hectare for each treatment was computed.

Data analysis

Data was analyzed by using the analysis of variance (ANOVA) technique and differences among treatment means were compared by using DMRT (Duncan Multiple Range Test) to find significant differences among the mean value (Steel & Torrie, 1980).

Results

Experimental results from the garlic variety, "Lehsan-Gulabi" revealed the promising impact of various nitrogenous source combinations. Data shows the nonsignificant difference of various combinations but significantly different from individual nitrogen sources like UN, PM, and Zeolite. Garlic crop is multiplied by vegetative means, and experimental data computation results revealed improvement in various physiological parameters and yield of garlic crop under the influence of nitrogen sources combinations. Germination is the basic phenomenon of plant seed physiology where moisture plays a primary role and the whole crop stand depends on it. Various nitrogen sources individually enhanced the cloves germination percentage, while combinations increased plant height but are non-significant to individual sources and combinations (Table 1). Zeolite amendments improved the water-holding capacity of soil along with nitrate and phosphorus due to its highly reactive surface. It makes effective plant nutrient uptake especially NH_4^+ which is of prime importance during the germination phase of garlic cloves. These nutrients are also responsible for cell division which results in a high clove number. Poultry manure also provides nitrogen and micronutrients to the soil which are helpful in increasing the size and number of cloves. Yield increased significantly where nitrogen source combinations were applied as compared to only urea, poultry manure, and zeolite. It provides an opportunity for the farming community to look into the economic means of enhanced crop productivity with reduced fertilizer use. Maximum garlic production (8.7 t/ha, 43.8 g weight per bulb, and 8.45 cloves per bulb) was obtained where UN and PM combination at the rate of 60 + 60 kg/ha was applied; followed by 60 kg + 120 kg per ha of urea and PM with yield (7.816 t/ha, 30.73 g weight per bulb and 7.6 cloves per bulb). Urea, zeolite, and PM (60 + 250 + 250 kg/ha) application in combination yielded (7.67 t/ha, 23.51 g weight per bulb, and 8.8 cloves per bulb). The application of composite nitrogen sources resulted in a high yield significantly higher than the control (6.36 t/ha, 22.94 g bulb weight, and 7.1 cloves per bulb) (Table 2). Poultry Manure was found to increase the number of cloves per bulb and to some extent average bulb weight (Table 2). Maximum phenolic contents were produced under PM influence which are tools against biotic and abiotic stresses in garlic cloves were estimated and found highest 0.5310 mg/g where 120 kg of PM urea was used, 0.5233 mg/g ranked second where 60 kg UN and 60 kg PM nitrogen sources were used.

Zeolite with PM increased leaf area 62.4 cm^2 of garlic crop significantly higher than all other treatments, PM individually with 58.6 cm^2 ranked 2nd followed by and 57.9 cm^2 where 60 kg UN and 500 kg zeolite is applied. The individual and combined impact of nitrogen sources have a slight impact on total soluble solids (TSS) and ascorbic acid contents in cloves. TSS production where full doses of zeolite PM, and UN were applied was high (5.33; 5.33; 5.267 brix respectively) nonsignificant to each other, and highly significant in comparison to control with estimated 4.64 brix. The highest ascorbic acid 0.3% contents were estimated when 500 kg of PM and 500 kg of zeolite in combination were applied (Table 3). The highest antioxidants produced in cloves were estimated 0.3437 mg/100 g where 60 kg UN and 60 kg PM nitrogen sources were used, followed by 0.3130 mg/100 g where 500 kg zeolite and 60 kg PM were used (Table 4).

Table 1 Effect of various organic and inorganic nitrogen sources combined with zeolite on garlic growth and leaf characteristics

Treatment details	Germination (%)	Plant height (cm)	Leaves per plant	Leaf area (cm^2)
Control	82^{b}	43.5^{cd}	7.46^{cd}	43.0^{d}
Poultry manure (PM)	93^{a}	50.59^{a}	7.53^{cd}	58.6^{b}
Zeolite (Z)	92^{a}	43.42^{cd}	6.73^{e}	52.6^{c}
Z + PM	86^{b}	41.24^{e}	8.40^{b}	62.4^{a}
Urea Nitrogen (UN)	95^{a}	45.42^{bc}	9.30^{a}	56.5^{b}
UN + PM	86^{b}	43.29^{d}	8.16^{b}	57.1^{b}
UN + Z	92^{a}	49.18^{a}	9.46^{a}	56.5^{b}
UN + Z + PM	83^{b}	42.12^{de}	7.56^{cd}	57.2^{b}
UN + PM	85^{b}	43.89^{b}	7.7^{a}	57.6^{b}
UN + Z	85^{b}	46.61^{b}	7.2^{a}	57.9^{b}

Details of treatments (Nitrogen dose) per hectare and their combinations:1. Control (No fertilizer); 2. Poultry manure (PM) (120 kg); 3. Zeolite (Z) (1000 kg); 4. 50% Zeolite (500 kg) + 50% PM (60 kg); 5. Urea Nitrogen (120 kg); 6. ½ Urea N (60 kg) + P. Manure (120 kg); 7. ½Urea (60 kg) + Zeolite (120 kg); 8. ½UN (60 kg) + 25% Zeolite (250 kg) + 25% Poultry Manure (30 kg); 9. ½ UN (60 kg) + ½ PM (60 kg); 10. ½ UN (60 kg) + ½ Zeolite (500 kg); Full Dose: Poultry Manure (PM) equivalent of 120 urea N (UN); Zeolite (Z) 1000 kg; Urea equivalent to 120kg Nitrogen; Means at each column for each character, followed by similar letters are not significant at α 5% ($p < 0.05$) based on Duncan's multiple range tests (DMRT)

Table 2 Effect of various organic and inorganic nitrogen sources combined with zeolite on garlic bulb characteristics and yield

Treatment details	Bulb diameter (cm)	Bulb weight (g)	Cloves per bulb	Yield per hectare (kg)
Control	3.21^{d}	22.94^{e}	7.100^{e}	6358^{b}
Poultry manure (PM)	3.66^{bc}	41.56^{a}	8.867^{a}	7350^{ab}
Zeolite (Z)	4.18^{a}	28.24^{c}	8.400^{b}	6508.33^{b}
Z + PM	3.97^{b}	25.54^{d}	8.100^{c}	7491.7^{ab}
Urea Nitrogen (UN)	4.19^{a}	43.32^{a}	8.567^{b}	6816^{b}
UN + PM	3.81^{b}	30.73^{b}	7.600^{d}	7816^{ab}
UN + Z	4.16^{a}	27.98^{c}	7.767^{d}	6950^{b}
UN + Z + PM	3.22^{c}	23.51^{de}	8.800^{a}	7675^{ab}
UN + PM	3.99^{b}	43.80^{a}	8.467^{b}	8700^{a}
UN + Z	3.69^{bc}	32.88^{b}	7.700^{d}	7275^{ab}

Details of treatments (Nitrogen dose) per hectare and their combinations: 1. Control (No fertilizer); 2. Poultry manure (PM) (120 kg); 3. Zeolite (Z) (1000 kg); 4. 50% Zeolite (500 kg) + 50% PM (60kg); 5. Urea Nitrogen (120 kg); 6. ½ Urea N (60kg) + P. Manure (120kg); 7. ½Urea (60kg) + Zeolite (120kg); 8. ½UN (60 kg) + 25% Zeolite (250 kg) + 25% Poultry Manure (30 kg); 9. ½ UN (60 kg) + ½ PM (60 kg); 10. ½ UN (60 kg) + ½ Zeolite (500 kg); Full Dose: Poultry Manure (PM) equivalent of 120 urea N (UN); Zeolite (Z) 1000kg; Urea equivalent to 120kg Nitrogen; Means at each column for each character, followed by similar letters are not significant at α 5% ($p < 0.05$) based on Duncan's multiple range tests (DMRT)

Table 3 Effect of various organic and inorganic nitrogen sources combined with zeolite on chlorophyll contents, pH, total soluble solids and phenolics of garlic under temperate conditions

Treatment details	Chlorophyll contents (mg cm^{-2})	pH	Total soluble solids (TSS) (brix)	Phenolics (mg g^{-1})
Control	0.350^{ab}	5.653	4.637^{b}	2.042
Poultry manure (PM)	0.557^{ab}	5.767	5.333^{a}	0.5310
Zeolite (Z)	0.741^{ab}	5.660	5.333^{a}	0.4740
Z + PM	0.693^{ab}	5.687	4.667^{b}	0.4520
Urea Nitrogen (UN)	0.829^{a}	5.953	5.267^{a}	0.3907
UN + PM	0.659^{ab}	5.753	4.317^{c}	0.4940
UN + Z	0.772^{a}	5.713	5.100^{a}	0.4620
UN + Z + PM	0.749^{ab}	5.010	4.267^{c}	0.3870
UN + PM	0.774^{a}	5.653	4.350^{c}	0.5233
UN + Z	0.350^{b}	5.250	5.213^{a}	0.3490

Details of treatments (Nitrogen dose) per hectare and their combinations: 1. Control (No fertilizer); 2. Poultry manure (PM) (120 kg); 3. Zeolite (Z) (1000 kg); 4. 50% Zeolite (500 kg) + 50% PM (60kg); 5. Urea Nitrogen (120 kg); 6. ½ Urea N (60kg) + P. Manure (120kg); 7. ½Urea (60kg) + Zeolite (120kg); 8. ½UN (60 kg) + 25% Zeolite (250 kg) + 25% Poultry Manure (30 kg); 9. ½ UN (60 kg) + ½ PM (60 kg); 10. ½ UN (60 kg) + ½ Zeolite (500 kg); Full Dose: Poultry Manure (PM) equivalent of 120 urea N (UN); Zeolite (Z) 1000kg; Urea equivalent to 120kg Nitrogen; Means at each column for each character, followed by similar letters are not significant at α 5% ($p < 0.05$) based on Duncan's multiple range tests (DMRT)

Table 4 Effect of various organic and inorganic nitrogen sources combined with zeolite on antioxidant levels, ascorbic acid contents and shelf life of garlic under temperate conditions

Treatment details	Antioxidant (mg $100g^{-1}$)	Ascorbic acid	Shelf life
Control	0.2750	0.100^{b}	4.667
Poultry manure (PM)	0.2540	0.100^{b}	4.667
Zeolite (Z)	0.2487	0.100^{b}	4.667
Z + PM	0.3130	0.300^{a}	5.333
Urea Nitrogen (UN)	0.2917	0.1667^{b}	5.333
UN + PM	0.2597	0.200^{b}	5.000
UN + Z	0.2990	0.1667^{b}	5.333
UN + Z + PM	0.3097	0.200^{b}	4.667
UN + PM	0.3437	0.1667^{b}	5.000
UN + Z	0.2563	0.1667^{b}	5.333

Details of treatments (Nitrogen dose) per hectare and their combinations: 1. Control (No fertilizer); 2. Poultry manure (PM) (120 kg); 3. Zeolite (Z) (1000 kg); 4. 50% Zeolite (500 kg) + 50% PM (60kg); 5. Urea Nitrogen (120 kg); 6. ½ Urea N (60kg) + P. Manure (120kg); 7. ½Urea (60 kg) + Zeolite (120 kg); 8. ½UN (60 kg) + 25% Zeolite (250 kg) + 25% Poultry Manure (30 kg); 9. ½ UN (60 kg) + ½ PM (60 kg); 10. ½ UN (60 kg) + ½ Zeolite (500 kg); Full Dose: Poultry Manure (PM) equivalent of 120 urea N (UN); Zeolite (Z) 1000kg; Urea equivalent to 120kg Nitrogen; Means at each column for each character, followed by similar letters are not significant at α 5% ($p < 0.05$) based on Duncan's multiple range tests (DMRT)

Discussion

Nutrient management is an important and interesting aspect of crop production. Due to the increased amount of synthetic fertilizers, including nitrogen sources, phosphorus, and potassium, fertilizer losses, and luxury consumption need to be reduced by their economic impact and financial pressure. Nitrogen is frequently lost due to leaching and evaporation, which not only increases the cost of production but also increases soil and water pollution. Nitrogen use efficiency (yield increase per unit Nitrogen) and agronomic N use efficiency (AE) are the product of the plant nitrogen recovery efficiency (RE) or physiological efficiency (PE) from the applied fertilizer-N sources. In heavily irrigated fields this recovery is 20-40% while in upland crops normally recover about 40-60%. Despite of adequate supply of nitrogen in field conditions, the nitrogen uptake range in a farmer's field is approximately 36% in field crops (Cassman et al., 1993), further zeolite and its modified forms have the capacity to slowly release of phosphorus upto 1080 hours which is huge mileage in fertilizer use (Bansiwal et al., 2006). This produces a huge gap between the applied amount and the nitrogen recovered by the plants in the form of biological yield, which is a big challenge to be bridged. Garlic is an important vegetable crop that needs a high level of nitrogen for its economical yield.

Organic fertilizers such as animal or poultry manure (PM) are the best well-balanced means of plant nutrition for the garlic plants as well as any other economically important crop. Natural zeolites of sedimentary origin are widely used in the practice of plant growing both as substrate components for greenhouses and the basic material to prepare substitute fertilizers for application under field conditions (Tsitsishvili et al., 1993). Poultry manure (PM) and zeolite amendments improve nitrogen and phosphorus availability have been reported to increase over level 53% N and availability of macro and micronutrients for better plant growth (Yolcu, 2010). Nitrogen alone or in combination with zeolite increases chlorophyll contents which maximizes metabolic activities in plants; so the combinations of zeolite and other organic sources are recommended in vegetative crop production (Munir et al., 2011). Zeolite is a nitrogen transporter in soil which makes the nitrogen available to the plants and triggers the process of respiration in plants (Ferdous, 2011); zeolite decreases the leaching of nitrogen and phosphorus and makes the potassium slowly available to the plant according to the need (Gul et al., 2005). Zeolite is a nanoporous natural secondary mineral with large surface contact having excellent characteristics for nutrient desorption and adsorption. It is not biodegradable so it can benefit farmers for long-term nutrient cycling. Zeolite incorporation in soil reduces nitrogen leaching, because of its high retention of NH_4^+ (Ammonium) due to adsorption making a controlled release of NH_4^+ and its ability to minimize nitrate formation.

Urea on the other hand increased the chlorophyll contents 0.829 mg/cm^2 as compared to control 0.35 mg/cm^2 and other treatments during experiment observations were in accordance with previous studies (Pirzad et al., 2011). A study on nitrogenous source amendments with zeolite, UN, and PM in a soil medium with various combinations increased the productivity of the garlic crop. The question is still to address how long nutrients can be held by these amendments so that we can use them for sustainable production on an economic basis. In countries like Pakistan where synthetic fertilizers are very costly, the addition of zeolite in the fertilizer range can positively influence garlic crop productivity.

In this study, a total of ten treatments including individual sources and combinations of poultry manure (PM), zeolite, and urea (UN) at various levels were applied in temperate areas of Rawalakot on garlic crop for maximum nutrient use and yield response. Individual nitrogen sources were found less productive when compared to the combinations. Combination of PM and UN was found more yielding with 8.7 and 7.816 t/ha respectively both figures are significant and highly significant in comparison with the control 6.358 t/ha. However, all other combinations are nonsignificant to 7.816 t/ha value in the temperate climate of Rawalakot Azad Jammu and Kashmir with intensive sunlight during days. Poultry manure is a rich organic source of saw dust and poultry wastes need to be broken down.

Combinations of various nitrogen sources (zeolite, poultry manure with urea N) in soil medium result in the release of all types of nutrients in the soil rhizosphere by breaking down cellulose bonds helping garlic plant to maximize yield and increase microbial activity. Urea N and PM (60 kg + 60 kg equivalent to UN) application proved best with 8.7 t/ha yield in field conditions. Microbes present in PM with the help of urea degrade the cellulose present in the sawdust and decomposed resulting in the release of a variety of nutrients and minerals for plant growth, improvement of soil air, microbial activity and soil physical factors helped the garlic crop to perform best under this treatment. A combination of zeolite 500 kg and PM equivalent to 60 kg nitrogen application resulted in 7.491 t/ha garlic yield and improved the phenolic compound and antioxidant production which is a promising feature for good human health against diseases and carcinogenic disorders. Statistical differences between the highest and second to highest are found nonsignificant. Both the treatments have been found to their exceptional merit of yield and phenolics production; needs further exploration with reference to physiological parameters and disease resistance. Effects of zeolites on the productivity of garlic and other green vegetables showed that the addition of zeolite (clinoptilolite) containing tuffs increases the total productivity of crop. Some previous studies on corn and leafy vegetables like lettuce resulted in an increased amount of biomass almost twice in the substrate containing 90% of clinoptilolite (Gulshan et al., 2004; Janjghava et al., 2002). However; an increased amount of zeolite up to 90 Mg ha^{-1} resulted in low corn yield due to its sensitivity against Na present in clinoptilolite (Ippolito et al., 2011).

Soil amendments with zeolite decreased the water and fertilizer demand by up to 30% due to the adsorption of NH_4^+ reducing mineralization and increasing moisture holding capacity without any negative impact in the form of reduced yield making it a suitable source for crop productivity like cereals, vegetable, forage, wine, and fruits (Karam et al., 2009). Experimental results show that nutrient release and microbial activity in Rawalakot conditions are conducive to garlic production. PM is high in carbon contents and microbes present in soil and poultry litter are involved in the process of decomposition and nutrients are released along with mineralized ammonium ions which are adsorbed by the zeolite contents. The temperature in Rawalakot remains low during early summer during crop stand and the soil is loamy with improved soil structure which helps the nutrients to be effectively utilized. The zeolite application with PM amendments proved a significant mileage to sustainable N supply to garlic crop. Various doses from different nitrogen sources and zeolite as amendment in combinations were found high yielding as compared to individual sources. Combined application of urea N and zeolite alone exerts positive effects on bulb diameter and more carbohydrate accumulation (Zaman et al., 2011) that is due to reduced N leaching which can be achieved to 66% leaching reduction (Zwingmann et al., 2011).

Zeolite is known for its influence on catalase antioxidant enzyme production and its role as resistance to different oxidative stresses and disease when applied in combinations with other nutrients and nutrient sources as scavengers to reactive oxygen species (ROS) which are threats to plant cell health (Zanjani et al., 2012). Zeolite not only proved that it can be successfully used in the soils of temperate climates for bulb crop production as well but it can also increase crop value by enhancing the level of antioxidants. N use efficiency results in less synthetic N requirement reducing the price value, less groundwater contaminations, and a safe environment. Zeolite loaded with plant nutrients has a slow release mechanism, even if it is mixed directly with soil, it absorbs heavy metal pollution. Zeolite mixed with soil is effective in reducing the negative effects of salinity and drought stress on plants, furnishing positive effects in agricultural field (Aslan and Arslan, 2024). Awareness dispersal regarding zeolite and its application with various N source combinations like PM, animal dung, and dead decaying leaves can be a promising feature of garlic and other bulbous crop production. It can provide a new opportunity for maximum crop harvest with low fertilizer inputs resulting in a sustainable agricultural production system.

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