E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(8): 737-740
Received: 02-05-2024
Accepted: 05-06-2024

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Effect of nutrients (Secondary and micronutrients) and humic acid on growth and bulb yield of garlic (*Allium sativum* L.)

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i8Sj.1357

Abstract
A field experiment was conducted to study the effect of nutrients (Secondary and micronutrients) and humic acid on growth and bulb yield of garlic during *rabi* season of 2022-23 and 2023-24 and the experiment was laid out in Factorial Randomized Block design with three replications. The results from the pooled data revealed that, among the four different nutrient treatments, soil application of secondary nutrients with foliar spray of micronutrients (N_3) recorded significantly higher growth and yield attributes. Among two different methods of application of humic acid, foliar spray of humic acid @ 0.2% (H_2) was resulted significantly higher growth and yield attributes. Among the interactions, N_3H_2 (Secondary nutrients + Micronutrients + Foliar spray of humic acid @ 0.2%) had significantly higher growth and yield attributes and yielded higher bulb yield per hectare (6.54 t ha^{-1}) compared to other interactions.

Keywords: Secondary nutrients, micronutrients and humic acid

Introduction
Garlic (*Allium sativum* L.) is a underground bulb crop belongs to Amaryllidaceae family having chromosome number 2n=16. Other related crops in the family are onion (*Allium cepa* L.), shallot (*Allium asacloncum* L.), leek (*Allium porrum* L.), chive (*Allium schoenoprasum* L.), welsh onion and Chinese onion. It is the second most widely used and cultivated bulb crop after onion. The bulb can be consumed as spice or condiment in the form of garlic paste, pickle, chutney, curried vegetables, curry powders and meat preparation, *etc*. Value-added products of garlic are garlic powder, flavours, flakes and volatiles. In Unani and Ayurvedic systems of medicine, garlic is used as carminative and gastric stimulant. It helps in digestion and absorption of food.
During 2022, world production of garlic was 28.5 million tonnes, with China alone accounting for 71 per cent of the total production. India at second position accounting for about 5 per cent of the total production with production of 3253 thousand metric tonnes from 363 thousand hectares area with productivity 8.03 tonnes per hectare. Madhya Pradesh recorded the highest production of garlic in India, accounting to over 2016.13 thousand metric tonnes (Anon., 2023a) [2]. In Karnataka (Rank's 11th in India), garlic is being cultivated over an area of 3.267 thousand hectares with production of 24.601 thousand metric tonnes with productivity of 7.53 tonnes per hectare. Haveri, Belagavi, Dharwad, Vijayapura, Bidar and Kalaburagi are the important garlic growing districts in Karnataka (Anon., 2023b) [3].
The Indian soils which are more deficient in micronutrient such as Zn, B, Cu, Mo and others. Micronutrients are just as important as the major nutrients in plant nutrition required for crop growth and development and they are used in smaller quantities. Even though, micronutrients are needed by the plants in a minor quantity but they involved in a wide variety of metabolic processes as well as cellular functions within the plants. In general, micronutrients play an active role in the plant metabolic process starting from cell wall development to respiration, photosynthesis, chlorophyll formation, enzyme activity, nitrogen fixation *etc*. (Ballabh *et al*., 2013) [4]. Humic acid is particularly used for increasing the nutrient availability.

Moreover, humic substances can chelate most metals present in the soil, thereby increasing their availability to plants. Humic substances also influence the growth of roots and root hairs. The increase of the root surface caused by humic substances promotes the uptake of elements such as phosphorus (P), potassium (K) and iron (Fe). Humic substances have a very profound influence on the growth of plant roots and used as a seed treatment and foliar application in agricultural field. The mechanism of possible growth promoting effect, usually attributed to hormone-like impact, activation of photosynthesis and improved nutrient uptake (Shafeek *et al*., 2015) [12].

The experiment was objectivated to know the response of garlic for varied crop geometry and planting periods, to standardize the suitable crop density and planting period for garlic and to workout economics of garlic for varied crop geometry and planting periods.

Materials and Methods

The experiment was conducted at Herbal Garden, Department of Horticulture, College of Agriculture, Raichur during the year 2022-23 and 2023-24, which falls under the Agro-Climatic Zone-II (North-Eastern dry zone) of Karnataka. Raichur located at 16° 12' N latitude, 77° 35' E longitude and 407 meters altitude above mean sea level. The soil of the experimental site was red loam to clay loam.

The experiment was laid out in Factorial Randomized Block Design (FRBD) design and consisted of four nutrient combinations and three humic acid application methods comprising of 12 treatment combinations and replicated thrice.

Treatment Details

Factor A: Nutrients

1. N_1: Secondary nutrients (Ca-15%, Mg-3% and S-15%) @ 125 kg ha^{-1}
2. N_2: Micronutrients (Zn-3%, Fe-2.5%, Mn-1%, Cu-1%, B-0.5%, Mo-0.1%) @ 0.5%
3. N_3: Secondary nutrients + Micronutrients
4. N_4: No nutrients application

Factor B: Humic acid

1. H_1: Clove treatment with humic acid @ 0.2%
2. H_2: Foliar spray of humic acid @ 0.2%
3. H_3: No application of humic acid

Well decomposed FYM (20 t ha^{-1}) was applied at the time of land preparation for both the experimental plots. Recommended NPK (125:62.5:62.5 kg ha^{-1}) was applied in the form of urea, DAP and MOP as soil application and secondary nutrients (SPIC Keerthi) having Ca-15%, Mg-3% and S-15% @ 125 kg ha^{-1} also applied to the soil before sowing as per the treatment. Micronutrients (Zn-3%, Fe-2.5%, Mn-1%, Cu-1%, B-0.5%, Mo-0.1%) @ 0.5% and humic acid @ 0.2% were applied as foliar spray at 30, 60 and 90 DAP. Clove treatment with humic acid @ 0.2% was done by soaking of garlic cloves for 1 hour.

Observations were recorded on five randomly selected and labelled plants for growth parameters such as plant height (cm), number of leaves per pant, leaf length (cm), leaf width (mm), leaf area (cm^2), neck thickness (mm) (At harvest) and yield parameters such as average bulb weight (g), bulb diameter (cm), bulb length (cm), number of cloves per bulb, average clove weight (g), weight of 100 cloves (g) and bulb yield per hectare (t ha^{-1}).

Results and Discussion

Nutrients

Among the four different nutrient combinations, application of secondary nutrients with micronutrients (N_3) in garlic performed significantly better than other nutrients application. This was followed by the soil application of secondary nutrients in garlic (N_1).

Application of secondary nutrients with micronutrients (N_3) in garlic observed to have significantly higher values of growth parameters like plant height (43.21 cm), number of leaves per plant (9.28), leaf length (36.84 cm), leaf width (13.91 mm), leaf area (187.24 cm^2) and neck thickness (11.54 mm) (Table 1).

The treatment N_3 (Secondary nutrients + Micronutrients) recorded significantly higher values of yield parameters like average bulb weight (15.28 g), bulb diameter (3.14 cm), bulb length (2.72 cm), number of cloves per bulb (12.19), average clove weight (1.29 g), weight of 100 cloves (147.07 g) and bulb yield per hectare (6.39 t ha^{-1}) (Table 2).

Significantly increased growth and yield parameters in the N_3 (Secondary nutrients + Micronutrients) treatment in garlic might be due to the application of secondary nutrients which might have helped in enhancing photosynthesis, supporting cell division and elongation, root development, improving nutrient and water uptake and ensuring efficient protein and enzyme synthesis, which are crucial for bulb development. Secondary nutrients like calcium and magnesium contributed to the structural integrity and metabolic processes that support the development of larger garlic bulbs. In the nutrient treatments, the micronutrients are also needed for various physiological processes like enzyme activation, cell wall formation and chlorophyll production, which is necessary for photosynthesis. Micronutrients support healthier root systems, enhancing the plant's ability to absorb water and nutrients, which are crucial for bulb growth. Some micronutrients act as chelating agents, improving the availability and uptake of other essential nutrients. Iron and other micronutrients enhance chlorophyll production, boosting photosynthesis and providing more energy for bulb development. Similar findings have also been reported by Rajaneesh *et al*. (2022) [11], Bhashkar and Devi (2021) [6] and Pooja *et al*. (2020) [10].

Table 1: Effect of nutrients (Secondary and micronutrients) and humic acid on growth parameters of garlic

Treatments	Plant height (cm)	Number of leaves	Leaf length (cm)	Leaf width (mm)	Leaf area (cm^2)	Neck thickness (mm)
Nutrients						
N_1	41.77	8.72	34.56	13.15	166.31	10.75
N_2	40.58	8.20	33.33	12.74	155.15	10.24
N_3	43.21	9.28	36.84	13.91	187.24	11.54
N_4	37.27	6.69	29.21	11.38	121.49	8.79
Mean	40.71	8.22	33.48	12.80	157.55	10.33
S. Em. ±	1.02	0.42	1.33	0.44	11.70	0.49
C.D. @ 5%	2.98	1.24	3.89	1.30	34.32	1.43
Humic acid						

H_1	41.14	8.45	33.91	12.96	161.60	10.53
H_2	42.23	8.91	35.56	13.48	175.50	11.12
H_3	38.75	7.31	30.98	11.94	135.55	9.33
Mean	40.71	8.22	33.48	12.80	157.55	10.33
S. Em. ±	0.88	0.37	1.15	0.38	10.13	0.42
C.D. @ 5%	2.58	1.08	3.37	1.12	29.72	1.24
Interactions						
N_1H_1	41.76	8.89	34.76	13.26	169.11	10.91
N_1H_2	43.59	9.49	36.69	13.88	185.16	11.57
N_1H_3	39.96	7.77	32.23	12.31	144.65	9.78
N_2H_1	41.36	8.44	34.03	12.93	160.08	10.48
N_2H_2	42.46	9.16	35.69	13.58	176.24	11.22
N_2H_3	37.94	7.00	30.27	11.71	129.15	9.01
N_3H_1	44.16	9.77	37.68	14.29	196.32	12.00
N_3H_2	44.93	9.99	39.58	14.77	211.65	12.52
N_3H_3	40.55	8.07	33.25	12.67	153.77	10.11
N_4H_1	37.27	6.67	29.15	11.37	120.88	8.75
N_4H_2	37.97	6.99	30.28	11.71	128.94	9.19
N_4H_3	36.57	6.41	28.19	11.08	114.65	8.43
Mean	40.71	8.22	33.48	12.80	157.55	10.33
S. Em. ±	1.76	0.73	2.30	0.77	20.27	0.85
C.D. @ 5%	5.17	2.15	6.74	2.24	59.44	2.48

Table 2: Effect of nutrients (Secondary and micronutrients) and humic acid on yield parameters of garlic

Treatments	Average bulb weight (g)	Bulb diameter (cm)	Bulb length (cm)	Number of cloves per bulb	Average clove weight (g)	Weight of 100 cloves (g)	Bulb yield (t ha^{-1})
Nutrients							
N_1	13.96	2.98	2.59	11.76	1.25	140.51	6.25
N_2	12.96	2.82	2.46	11.42	1.19	134.49	6.14
N_3	15.28	3.14	2.72	12.19	1.29	147.07	6.39
N_4	9.92	2.27	2.07	10.43	1.00	115.69	5.74
Mean	13.03	2.80	2.46	11.45	1.18	134.44	6.13
S. Em. ±	0.71	0.13	0.10	0.40	0.05	7.58	0.10
C.D. @ 5%	2.09	0.37	0.29	1.18	0.16	22.24	0.30
Humic acid							
H_1	13.46	2.88	2.52	11.59	1.21	137.83	6.18
H_2	14.53	3.03	2.63	11.94	1.26	145.01	6.30
H_3	11.10	2.50	2.23	10.82	1.08	120.48	5.90
Mean	13.03	2.80	2.46	11.45	1.18	134.44	6.13
S. Em. ±	0.62	0.11	0.09	0.35	0.05	6.57	0.09
C.D. @ 5%	1.81	0.32	0.26	1.02	0.14	19.26	0.26
Interactions							
N_1H_1	14.30	3.06	2.64	11.88	1.28	144.31	6.30
N_1H_2	15.55	3.22	2.76	12.29	1.32	149.52	6.44
N_1H_3	12.02	2.68	2.36	11.11	1.15	127.70	6.03
N_2H_1	13.45	2.93	2.54	11.59	1.23	137.28	6.21
N_2H_2	14.86	3.13	2.69	12.06	1.30	145.07	6.37
N_2H_3	10.56	2.39	2.16	10.61	1.05	121.13	5.83
N_3H_1	16.30	3.28	2.83	12.53	1.34	151.81	6.50
N_3H_2	16.78	3.31	2.86	12.68	1.34	156.03	6.54
N_3H_3	12.76	2.83	2.46	11.37	1.19	133.37	6.12
N_4H_1	9.78	2.24	2.05	10.38	0.99	117.90	5.72
N_4H_2	10.92	2.46	2.20	10.71	1.08	129.44	5.87
N_4H_3	9.07	2.11	1.96	10.19	0.94	99.72	5.63
Mean	13.03	2.80	2.46	11.45	1.18	134.44	6.13
S. Em. ±	1.23	0.22	0.17	0.69	0.09	13.14	0.18
C.D. @ 5%	3.62	0.64	0.51	2.04	0.27	38.52	0.52

Humic acid

Among the different methods of application of humic acid in garlic, foliar spray of humic acid @ 0.2% (H_2) performed significantly better than other methods of application. This was followed by the treatment in which garlic cloves treated with humic acid @ 0.2% (H_1).

Results revealed that significantly higher growth parameters *i.e.*, plant height (42.33 cm), number of leaves per plant (8.91), leaf length (35.56 cm), leaf width (13.48 mm), leaf area (175.50 cm^2) and neck thickness (11.12 mm) were recorded when garlic crop sprayed with humic acid @ 0.2% (H_2) (Table 1).

The foliar application of humic acid @ 0.2% (H_2) exhibited significantly higher yield parameters *i.e.*, average bulb weight (14.53 g), bulb diameter (3.03 cm), bulb length (2.63 cm), number of cloves per bulb (11.94), average clove weight (1.26 g) and weight of 100 cloves (145.01 g) and bulb yield per hectare (6.30 t ha^{-1}) (Table 2).

Foliar spray of humic acid @ 0.2% (H_2) in garlic significantly

enhanced the overall growth of garlic by improving nutrient uptake, stimulating growth hormones, enhancing photosynthesis and mitigating stress. These combined effects led to increased growth rates and greater overall growth parameters. Humic acid can increase chlorophyll content in leaves, which enhances photosynthesis and provides more energy for the plant to produce carbohydrates, which are necessary for bulb development and weight accumulation. The results of the earlier researchers are in accordance with the present findings of Balmori *et al*. (2019) [5], Moustafa *et al*. (2016) [8] and Al-Shamary *et al*. (2021) [1].

Interactions

Among the interaction between application of nutrients and humic acid in garlic, application of secondary and micronutrients along with the foliar spray of humic acid @ 0.2% (N_3H_2) has significantly recorded higher growth and yield attributes.

Among the treatments, garlic crop applied with secondary and micronutrients along with the foliar spray of humic acid @ 0.2% (N_3H_2) resulted in significantly higher growth and yield components, comprising growth parameters like plant height (44.93 cm), number of leaves per plant (9.99), leaf length (39.58 cm), leaf width (14.77 mm), leaf area (211.65 cm^2) and neck thickness (12.52 mm) (Table 1).

Application of secondary and micronutrients with foliar spay of humic acid @ 0.2% (N_3H_2) in garlic resulted in significantly higher yield parameters like average bulb weight (16.78 g), bulb diameter (3.31 cm), bulb length (2.86 cm), number of cloves per bulb (12.68), average clove weight (1.34 g) and weight of 100 cloves (156.03 g) and bulb yield per hectare (6.54 t ha^{-1}) (Table 2).

Growth and yield parameters were found to be significantly higher under the treatment interaction N_3H_2 (Secondary nutrients + Micronutrients + Foliar spray of humic acid @ 0.2%) might be due to beneficial effect of the nutrients and humic acid. The calcium, magnesium and sulphur which improve the uptake and utilization of essential nutrients such as nitrogen, phosphorus and potassium led to growth and development throughout the garlic growing cycle. Secondary nutrients influence the development of yield components such as bulb size, number of cloves per bulb and overall biomass accumulation. The significant increase in growth and yield parameters of garlic with the application of micronutrients is primarily due to the combined effects of enhanced enzyme activities, improved photosynthetic efficiency, optimized nutrient uptake, regulation of hormonal balance and stress tolerance. Foliar spray of humic acid helps in the combined effects of enhanced nutrient uptake, improved metabolic processes, hormonal regulation and stress tolerance contribute to a significant increase in garlic bulb yield per hectare. Similar results were noticed by Jagat *et al*. (2022) [7], Nahar *et al*. (2020) [9] and Moustafa *et al*. (2016) [8].

Conclusion

Application of secondary nutrients with micronutrients (N_3) had resulted in vigorous growth, more bulb yield of good quality for *rabi* season garlic crop. The foliar spray of humic acid @ 0.2% had resulted in increased bulb yield of good quality bulbs from vigorous crop of garlic. The interaction N_3H_2 (Secondary nutrients + Micronutrients + foliar spray of humic acid @ 0.2%) resulted in higher growth and yield parameters.

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