EFFECT OF N, P, K, Zn AND B NUTRIENTS ON GROWTH, YIELD AND QUALITY OF ONION (*ALLIUM CEPA* L.) AND FERTILITY STATUS OF SOIL IN ALFISOLS OF SOUTHERN TAMIL NADU, INDIA

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Abstract. This research work was experimented at Agriculture College and Research Institute, Killikulam, Tamil Nadu, India during *rabi* season of 2019-20 and 2020-21 to study the effect of soil test crop response (STCR) application of macronutrients in addition to boron and zinc on the growth performance, yield attributes, quality of onion and soil fertility. Experiment was laid out in randomized block design (RBD) replicated thrice using onion variety CO (On) 5 as a test crop. The performances were significantly influenced by the application macro nutrients with micro nutrients *viz.*, zinc and boron based on STCR. Application of STCR as 106:97:54 kg of NPK ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1} + 0.5% foliar spray significantly influenced the growth with tallest plant (55.2 cm), maximum number of leaves (17.2), and yield attributes of maximum polar diameter (3.35 cm), bulb lets (6.4/clump), bulb weight (85.2 g/plant) and bulb yield (16.85 t ha^{-1}). The quality parameters and soil fertility status were also improved for the same treatment. The lowest growth, yield characters, bulb yield and quality with lower fertility status were observed in absolute control. TheSTCR recommendation as 106:97:54 kg of NPK ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1} with 0.5% foliar spray was found to be the best for onion production and sustaining soil health in the semi-arid tract of southern Tamil Nadu, India.
Keywords: *STCR, nutrients, growth parameters, quality attributes, available nutrients, economics*

Introduction

Onion (*Allium cepa* L.), often referred to as the “Queen of Kitchen,” is a significant commercial vegetable crop extensively cultivated in India, belonging to the Alliaceae family. As a cool-season crop, onion thrives in a variety of agro-climatic conditions, with optimal growth occurring at temperatures between 25°C and 35°C and rainfall ranging from 500 to 750 mm. The edible parts include green leaves and both immature and mature bulbs. Onions possess a strong flavor due to sulfur-containing compounds, specifically volatile oils like allyl propyl disulfide, which contribute to their distinctive smell and pungency. Historically, onions have been cultivated for food, medicine, and culinary purposes (Khatemenla et al., 2018).

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India ranks second in global onion production, following China, with 1.29 million hectares cultivated and a production of 2017.18 tons as of 2016-17. In Tamil Nadu, onions are grown over 34.08 thousand hectares, yielding 10.18 tons per hectare (AGRI INDIASTAT (2020). The average marketable yield potential during the *rabi* season is up to 41.5 tons per hectare, while the national average stands at 30.3 tons per hectare. Low onion production can often be attributed to improper fertilizer application and the cultivation of unsuitable varieties for specific agro-climatic conditions. Therefore, optimizing fertilizer use and selecting appropriate varieties are crucial for enhancing onion yields.

Among the key factors limiting productivity, imbalanced nutrition is a primary concern (Bhat et al., 2018). Micronutrients play a vital role in various plant metabolic processes, including cell wall development, respiration, photosynthesis, chlorophyll formation, enzyme activity, and nitrogen fixation. They significantly influence growth, yield, and quality **(**Dhar et al., 2019). Micronutrients incorporation in soil during the growth period can effectively correct deficiencies and enhance the mineral concentration in plant biomass.

Zinc is required in small amounts for plant growth and development. It plays a crucial role in chlorophyll and carbohydrate formation and is involved in various enzyme systems (Tisdale et al., 2015). The application of micronutrients across various soil types has shown significant improvements in onion growth and yield (Saeed and Dizayee, 2023).

However, there is limited information on the effects of zinc and boron in conjunction with inorganic fertilizers for onion cultivation in the semi-arid regions of southern Tamil Nadu. Given this context, further investigation into these practices is warranted to optimize onion production in the region.

Materials and methods

The investigation was conducted at Agricultural College and Research Institute, Killikulam, Tamil Nadu, during the *rabi* seasons of 2019-20 and 2020-21 using the onion variety CO (On) 5. This location lies in the semi-arid region of Thoothukudi district at 80°46’ latitude and 77°42’ longitude, at an altitude of 40 m above MSL. The mean annual rainfall is 750 mm, with temperatures ranging from 26.3°C to 35°C during the growing season.

STCR-based nutrient application

The Soil Test Crop Response (STCR) approach considers the soil’s available nitrogen (N), phosphorus (P), and potassium (K) to determine fertilizer requirements for a targeted yield of 17 t ha^{-1} for onion variety CO (On) 5. Fertilizer prescription equations were derived from calibration experiments and prescribed by the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India (Ramamoorthy et al., 1969). Fertilizers were calculated as half doses of N and full doses of P, K, Zn and B, applied at transplanting, with the remaining nitrogen applied as top dressing. Foliar sprays of Zn and B were administered at vegetative and bulb formation stages (30 and 45 days after transplanting, DAT).

Fertilizer estimation under STCR

Crop	Soil available nutrients (kg ha^{-1})	Targeted yield (t ha^{-1})	Required fertilizers (kg ha^{-1})
Onion	236 (N), 16.8 (P), 245 (K)	17	106 (N), 97 (P_2O_5), 54 (K_2O)

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The experimental soil was nearly neutral with permissible electrical conductivity, characterized as reddish-brown sandy clay loam with low organic carbon, available nitrogen, medium available phosphorus, and available potassium (*Table 1*). Zinc and boron levels were deficient. The experiment comprised eight treatments in a randomized block design with three replications (*Table 2*). Treatments were based on STCR recommendations for the targeted yield of 17 t ha^{-1}, with a STCR dose of 106:97:54 kg of NPK ha^{-1}. Zinc sulfate and borax were used for zinc and boron, respectively. Nitrogen was applied in two equal split doses at 30 and 45 DAT, with foliar applications occurring at the same intervals. Standard practices for onion cultivation were followed, and harvesting occurred in the last week of March in both years. Growth, yield characters, and bulb yield were recorded.

Table 1. *Initial soil properties of experimental filed and preferable ranges*

Parameter	Value of type	Preferable ranges
Soil texture	Scl (sandy clay loam)	Loam
pH	6.68	6.5-7.5
EC (dS/m)	0.22	<1.0
SOC (%)	0.36	>0.5
Available N (kg/ha)	236	>280
Available P (kg/ha)	16.8	>11.0
Available K (kg/ha)	245	>118
Available Zn (mg/kg)	0.78	>1.20
Available Cu (mg/kg)	1.01	>1.20
Available Mn (mg/kg)	3.84	>2.0
Available Fe (mg/kg)	7.55	>3.6
Available B (mg/kg)	0.23	>0.5

Table 2. *Soil test crop response (STCR) based treatment details*

Sl. No	Treatment details
T1	STCR as 106:97:54 kg of NPK ha^{-1}
T2	STCR + $ZnSO_4$ @ 25 kg ha^{-1}
T3	STCR + $ZnSO_4$ @ 0.5% foliar spray
T4	STCR + $ZnSO_4$ @ 25 kg ha^{-1} + 0.5% foliar spray
T5	STCR + Borax @ 10 kg ha^{-1}
T6	STCR + Borax @ 0.5% foliar spray
T7	STCR + Borax @ 10 kg ha^{-1} + 0.5% foliar spray
T8	Absolute Control

Representative plant samples (twenty plants) were collected for biochemical and nutritional analysis. Samples were dried at 105°C until a constant weight was reached, ground through a 2 mm sieve, and analyzed for nutrients. Nutrient analysis followed tri-acid and di-acid digestion methods; phosphorus was analyzed by the vanadomolybdate method, potassium by flame photometry (Jackson, 1973), zinc by atomic absorption spectrophotometry (Piper, 1966), and boron by the azomethene-H method (Berger and

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Truog, 1939). The nutrient analysis of plant samples were carried out in accordance with the methods reported by Page et al. (1982). Nutrient uptake was calculated by multiplying nutrient concentration by dry matter yield.

Soil samples (0-15 cm) were collected post-harvest using an auger for analysis. Soil analyses followed standard procedures: organic carbon (Walkley and Black, 1934), available nitrogen (Subbiah and Asija, 1956), available phosphorus (Olsen, 1954), available potassium (Stanford and English, 1949), available zinc (DTPA extractant using AAS, Lindsay and Norvell, 1978), and available boron (hot water extraction, Berger and Truog, 1939).

Fresh onion bulbs were analyzed for protein, total soluble solids (TSS), pyruvic acid, and ascorbic acid content. Protein was estimated using the micro-Kjeldahl method (Humpries, 1956), TSS using a hand refractometer (Ranganna, 1986), pyruvic acid via modified dinitrophenyl hydrazine (DNPH) method (Schwimmer and Weston, 1961), and ascorbic acid by the dye method (Roe and Kuether, 1943).

Statistical analysis

Soil and plant sample analyses were statistically evaluated using analysis of variance (ANOVA) and Tukey's multiple comparison test as per the methods outlined by Pinto et al. (2010). The analyses were performed using SPSS 26. Significant differences were indicated by ** for a 1% probability level and * for a 5% probability level, while non-significant comparisons were marked as NS.

Results and discussion

The growth characteristics such as plant height, number of leaves, yield attributes, and bulb yield were significantly influenced by the application of soil test crop response (STCR) with N: P: K @ 106:97:54 kg/ha along with zinc and boron (*Table 3*).

Table 3. *Effect of STCR fertilizer along with Zinc and Boron on growth, yield attributes and bulb yield (pooled data of two years)*

Treatments	Plant height (cm)	Number of leaves/plant	Polar diameter (cm)	Equatorial diameter (cm)	Bulb lets/clump	Bulb weight (g/plant)	Bulb yield (t/ha)
T1	45.5	12.8	2.12	1.94	4.3	62.8	12.42
T2	50.2	15.2	2.74	2.41	5.6	77.6	15.14
T3	48.4	14.1	2.53	2.32	5.1	69.8	13.73
T4	55.2	17.2	3.35	2.98	6.4	85.2	16.85
T5	49.5	14.3	2.58	2.37	5.3	73.7	14.30
T6	46.6	13.4	2.45	2.18	5.1	66.6	13.23
T7	52.2	16.2	2.97	2.62	6.1	81.5	15.92
T8	40.3	9.6	1.65	1.45	3.2	56.5	9.67
SEd	0.67	0.43	0.10	0.12	0.12	1.74	0.35
CD ($p = 0.05$)	1.47	0.90	0.22	0.25	0.26	3.54	0.74

The treatment with STCR as N:P:K @106:97:54 kg/ha + $ZnSO_4$ @ 25 kg/ha + 0.5% foliar spray (T4) demonstrated superior results, yielding maximum plant height (55.2 cm), number of leaves (17.2), and yield attributes including polar diameter of bulb

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(3.35 cm), equatorial diameter (2.98 cm), bulb lets per clump (6.4), bulb weight (85.2 g), and bulb yield (16.85 t/ha). The next best treatment, STCR as N:P:K@106:97:54 kg/ha + Borax @ 10 kg/ha + 0.5% foliar spray (T7), achieved plant height (52.2 cm), number of leaves (16.2), polar diameter of bulb (2.97 cm), equatorial diameter (2.62 cm), bulb lets per clump (6.1), bulb weight (81.5 g), and bulb yield (15.92 t/ha). In contrast, the application of STCR as N:P:K @106:97:54 kg/ha alone (T1) yielded lower results: plant height (45.5 cm), number of leaves (12.8), polar diameter of bulb (2.12 cm), equatorial diameter (1.94 cm), bulb lets per clump (4.3), bulb weight (62.8 g), and bulb yield (12.42 t/ha). The absolute control (T8) showed the lowest values: plant height (40.3 cm), number of leaves (9.6), polar diameter of bulb (1.65 cm), equatorial diameter (1.45 cm), bulb lets per clump (3.2), bulb weight (57.8 g), and bulb yield (9.67 t/ha). The increase in bulb yield for T4 over T1 was 35.66%, and over absolute control (T8) it was 74.25%. This indicates that the soil was deficient in zinc and boron, and their external application positively enhanced onion growth. These findings align with the results of Geetha Kumari et al. (2022) and Manna et al. (2016), further corroborated by Bhat et al. (2018), which suggest that high yield reflects vigorous vegetative growth. Similar findings have also been reported in onion by Mandal et al. (2020); Kaur et al. (2019) and Laxmi et al. (2019).

Quality parameters such as total soluble solids (TSS), ascorbic acid, protein, and pyruvic acid contents were also significantly influenced by the application of STCR-recommended NPK with Zn and B (*Figs. 1–4*). The highest TSS (16.5 °Brix), ascorbic acid (16.23 mg/100 g), protein (9.12%), and pyruvic acid (5.12 µmole/g) were recorded for T4, followed by T7, which yielded TSS (14.3 °Brix), ascorbic acid (14.88 mg/100 g), protein (8.21%), and pyruvic acid (4.52 µmole/g). These two treatments were comparable. The increase in quality parameters was attributed to the combined application of macro and micronutrients readily available to the plants (Singh, 2022; Maisura et al., 2019). In contrast, T1 recorded lower values: TSS (10.3 °Brix), ascorbic acid (9.72 mg/100 g), protein (7.3%), and pyruvic acid (3.12 µmole/g). The absolute control (T8) had the lowest TSS (8.25 °Brix), ascorbic acid (7.92 mg/100 g), protein (6.40%), and pyruvic acid (2.82 µmole/g). The lower content of quality parameters in these treatments can be attributed to the absence of micronutrients compared to their application through soil and foliar methods. Previous studies indicated that micronutrients combined with macronutrients enhance quality parameters in onion bulbs. Zinc's role in activating enzymes like carbonic anhydrase, fructose-1,6-bisphosphate, and aldolase is essential for improving total soluble solids, as these enzymes function within the chloroplasts and cytoplasm during photosynthesis (Mandal et al., 2019; Mondal et al., 2020; Ramal Yusuf et al., 2023; Vijay et al., 2017).

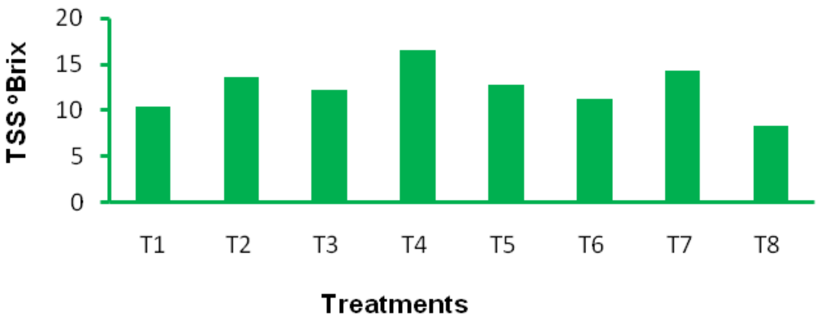

***Figure 1.** Effect of treatments on total soluble solid (TSS) content (°Birx) in onion bulb*

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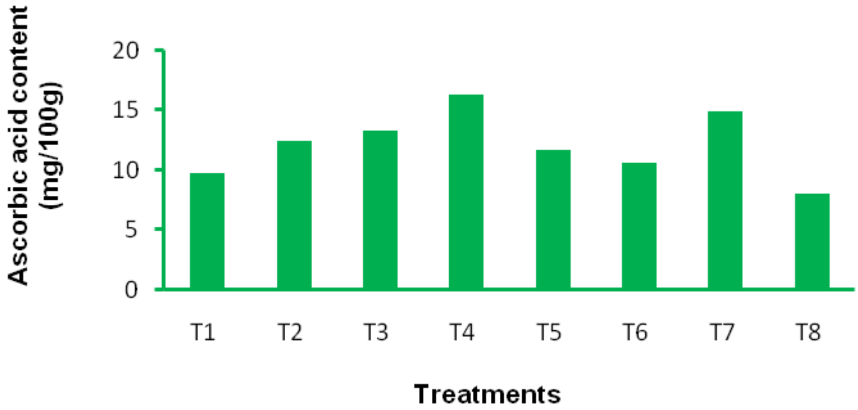

Figure 2. *Effect of treatments on ascorbic acid content (mg/100 g) in onion bulb*

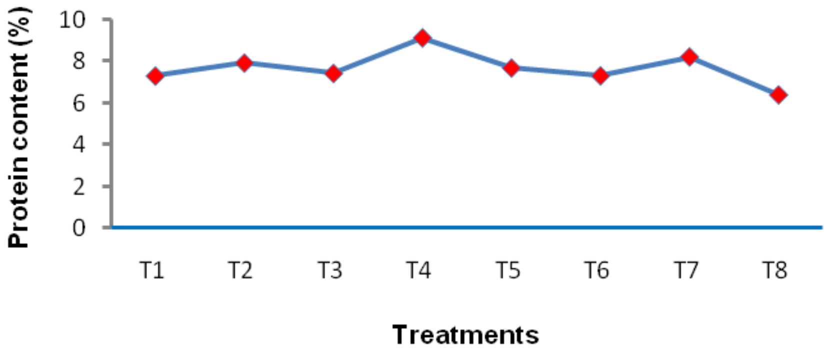

Figure 3. *Effect of treatments on protein content (%) in onion bulb*

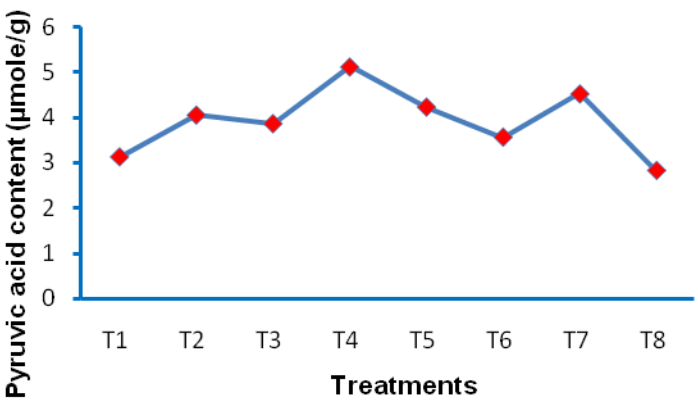

Figure 4. *Effect of treatments on pyruvic acid content (µmol/g) in onion bulb*

Nutrient content and uptake in onion plants and bulbs improved significantly with the STCR-recommended doses of NPK with zinc and boron fertilization (*Table 4*). The T4 treatment recorded the highest content of N, P, K, and Zn at 1.41%, 0.29%, 1.64%, and 18.56 mg/kg, respectively, along with the highest uptake of these nutrients (106.67 kg/ha of N, 20.01 kg/ha of P, 112.32 kg/ha of K, and 122.68 g/ha of Zn). Boron applied with balanced level of NPK resulted in higher content and uptake. These finding are in agreement with observation of Khokhar (2019). T7 exhibited the highest boron

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content (12.84 mg/kg) and uptake (81.49 g/ha). The increased nutrient content and uptake resulted from the synergistic effects of zinc and nitrogen, which enhanced nitrogen content and uptake in onion bulbs. This was due to the availability of nutrients at all growth stages and increased dry matter production with crop age (Sharma et al., 2021; Singh et al., 2019).

Table 4. *Effect of STCR fertilizer along with Zinc and Boron on nutrient content and uptake (pooled data of 2 years)*

Treatments	Nutrient content (%)			Nutrient content (mg/kg)		Nutrient uptake (kg/ha)			Nutrient uptake (g/ha)	
	N	P	K	Zn	B	N	P	K	Zn	B
T1	0.89	0.16	1.03	11.10	7.43	35.37	7.12	41.45	52.50	30.47
T2	1.19	0.22	1.45	17.76	7.99	76.45	15.60	87.61	109.23	50.26
T3	1.15	0.20	1.26	16.27	8.28	58.66	11.25	60.60	83.25	40.98
T4	1.41	0.29	1.64	18.56	8.89	106.67	20.01	112.32	122.68	55.67
T5	1.12	0.21	1.38	12.52	12.62	65.31	13.31	76.20	63.47	71.63
T6	1.01	0.19	1.25	11.80	11.62	43.65	10.61	54.12	59.13	52.02
T7	1.26	0.27	1.53	13.00	12.84	90.92	17.16	103.35	81.56	81.49
T8	0.72	0.11	0.96	9.73	6.97	26.08	5.57	36.07	37.99	25.06
SEd	0.049	0.009	0.032	0.36	0.26	2.52	0.61	2.48	2.71	1.57
CD (p = 0.05)	0.151	0.029	0.084	1.09	0.81	7.78	1.88	7.63	8.34	4.84

Soil fertility status significantly improved with STCR application of N: P: K at 106:97:54 kg/ha, zinc, and boron (*Table 5*).

Table 5. *Effect of STCR fertilizer along with zinc and boron on soil available nutrient status after harvest of crop (pooled data of 2 years)*

Treatments	pH	SOC (%)	N	P	K	Zn	B
			(kg/ha)			(mg/kg)	
T1	6.68	0.34	174	10.9	172	0.61	0.32
T2	6.81	0.54	191	12.7	192	1.01	0.34
T3	6.77	0.41	182	13.3	184	0.68	0.33
T4	6.85	0.66	208	15.4	201	1.09	0.48
T5	6.78	0.45	190	13.0	176	0.64	0.61
T6	6.75	0.40	180	12.4	172	0.67	0.53
T7	6.82	0.58	197	13.1	195	1.01	0.65
T8	6.65	0.32	169	10.9	165	0.48	0.28
SEd	NS	0.017	2.84	0.48	2.65	0.016	0.022
CD (p = 0.05)	NS	0.053	8.75	1.49	8.18	0.048	0.068

Although soil pH remained unchanged after harvest, T4 recorded the highest fertility values: organic carbon (0.66%), N, P, K (208, 15.4, 201 kg/ha, respectively), and Zn (1.09 mg/kg). T7 showed organic carbon (0.58%), N, P, K (197, 13.1, 195 kg/ha, respectively), and Zn (1.01 mg/kg). The highest available boron (0.65 mg/kg) was found in T7. All treatments significantly improved organic carbon content from initial

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values of 0.36%. This increase is attributed to the enhanced root biomass and vegetative growth of onions (Maurya et al., 2018). The absolute control (T8) had the lowest fertility values: organic carbon (0.32%), N, P, K (169, 10.9, 165 kg/ha, respectively), and Zn and B (0.48 and 0.28 mg/kg). The soil available N, P, K, Zn and B status showed that the soil N, P, K, Zn and B status after harvest was maintained in all the treatments. Besides plant nutrient addition, as soil test crop response of N, P, K with Zn and B conserve and enhance the native soil nutrients. The earlier report of Singh et al. (2019) also supported this finding.

Conclusion

In conclusion, the findings suggest that applying soil test crop response N, P, K, along with zinc and boron significantly improves plant growth, yield parameters, quality, nutrient content, and soil fertility status. The best practice for sustaining productivity and soil health involves the combined application of STCR (106:97:54 kg NPK/ha) + ZnSO4 @ 25 kg/ha with 0.5% foliar spray, making it a viable strategy for growers in the semi-arid regions of southern Tamil Nadu.

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REFERENCES

[1] Agriculture Statistical Year Book (2020): Government of India Ministry of Statistics and programme Implementation. – http://mospi.nic.in/statistical-year- book-india/2017/177.

[2] Berger, K., Truog, E. (1939): Boron determination in soils and plants. – Industrial & Engineering Chemistry Analytical Edition 11(10): 540-545.

[3] Bhat, T. A., Chattoo, M. A., Mushtaq, F., Akhter, F., Mir, S. A., Zargar, M. Y., Wani, K. P., Shah, M. D., Ejaz, Parry, A. (2018): Effect of zinc and boron on growth and yield of onion under temperate conditions. – Int. J. Curr. Microbiol. App. Sci. 7(4): 3776-3783.

[4] Dhar, M., Mandal, J., Maity, T. K., Mohanta, S. (2019): Evaluation of kharif onion (*Allium cepa* L.) varieties under different planting dates. – Journal of Pharmacognosy and Phytochemistry. 8(2): 1317-1329.

[5] Geetha Kumari, B. N., Salimath, S. B., Onkarappa, S., Thippeshappa, G. N., Thippesha, D. (2022): Effect of different NPK levels and intervals of fertigation on growth and yield of onion (*Allium cepa* L.) in the central dry zone of Karnataka. – The Pharma Innovation Journal 11(3): 2266-2269.

[6] Gomez, K. A., Gomez, A. A. (1984): Statistical Procedures for Agricultural Research. – 2 Ed. John Wiley and sons, NewYork.

[7] Humphries, E. (1956): Mineral Components and Ash Analysis. – In: Paech, K., Tracey, V. (eds.) Moderne Methoden der Pflanzenanalyse/Modern Methods of Plant Analysis. Springer, Berlin, pp. 468-502.

[8] Jackson, M. (1973): Estimation of Phosphorus Content. Soil Chemical Analysis. – Printer Hall, New Delhi.

[9] Kaur, A., Raturi, H. C., Kachwaya, D. S., Singh, S. K., Singh, T. (2019): Effect of fertigation on growth and fruit yield of cucumber (*Cucumis sativus* L.) grown under open ventilated polyhouse condition. – J Pharmacogn. Phytochem 202-204.

[10] Khatemenla, Singh, V. B., Tengse, T., Sangma, A., Maiti, C. S. (2018): Effect of zinc and boron on growth, yield and quality of onion (*Allium cepa* L.) cv. agrifound dark red. – Int. J. Curr. Microbiol. App. Sci. 7(4): 3673-3685.
[11] Khokhar, K. M. (2019): Mineral nutrient management for onion bulb crops—a review. – The Journal of Horticultural Science and Biotechnology. DOI: 10.1080/14620316.2019.1613935.
[12] Laxmi, M. P., Hadimani, H. P., Vijayalakshmi, P., Biradar, I. B., Prasanna, S. M., Revanappa (2019): Influence of sulphur, zinc and boron on yield and quality of onion. – Int. J Chem. Stud. 7(4): 16-22.
[13] Lindsay, W. L., Norvell, W. A. (1978): Development of a DTPA soil test for zinc, iron, manganese, and copper. – Soil Science Society of America Journal 42(3): 421-428.
[14] Maisura, Nurdin, M., Muslina (2019): Effect of manure and NPK fertilizers on growth and production of onion (*Allium cepa* L.). – Journal of Tropical Horticulture 2(1): 16-18.
[15] Mandal, J., Ajgalley, R., Saha, D., Mohanta, S. (2019): Growth, yield and quality of some onion (*Allium cepa* L.) cultivars under Lateritic Belt of Eastern India. – Veg. Sci. 46(1&2): 129-131.
[16] Mandal, J., Acharyya, P., Bera, R., Mohanta, S. (2020): Response of onion to NPK, S and micronutrients. – Int. J. Curr. Microbiol. App. Sci. 9(6): 1137-1144.
[17] Manna, D., Maity, T. K. (2016): Growth, yield and bulb quality of onion (*Allium cepa*L.) in response to foliar application of boron and zinc. – J. of Plant Nutrition 39(3): 438-441.
[18] Maurya, P. K., Yadav, L. M., Thakur, G., Patel, P. (2018): Effect of micronutrient application on growth and yield of kharif onion (*Allium cepa* L.). – Int. J. Curr. Microbiol. App. Sci 7(3): 601-608.
[19] Mondal, S., Ghosh, G. K., Mandal, J. (2020): Effect of graded levels of sulphur as magnesium sulphate on yield and quality of onion (*Allium cepa* L.) in red and lateritic soils of West Bengal, India. – International Journal of Current Microbiology and Applied Sciences 9(4): 1-9.
[20] Olsen, S. R. (1954): Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. – United States Department of Agriculture, Washington.
[21] Page, A. L., Miller, R. H., Keeney, D. R. (1982): Methods of Soil Analysis 2. Chemical and Microbiological Properties. – American Society of Soil Science, Madison, WI.
[22] Pinto, M., Cordon, J. A., Gómez Díaz, R. (2010): Thirty years of information literacy (1977–2007) A terminological, conceptual and statistical analysis. – Journal of librarianship and information science 42(1): 3-19.
[23] Piper, C. S. (1966): Soil and Plant Analysis: A Laboratory Manual of Methods for the Examination of Soils and the Determination of the Inorganic Constituents of Plants. – Hans Publications, Bombay.
[24] Ramamoorthy, B., Narasimham, R. L., Dinesh, R. S. (1969): Fertilizer application for specific yield target of Sonora 64. – Indian Fmg. 17(5): 43-45.
[25] Ranganna, S. (1986): Handbook of Analysis and Quality Control for Fruit and Vegetable Products. – Tata McGraw-Hill Education, Ahmedabad.
[26] Roe, J., Kuether, C. (1943): Estimation of ascorbic acid. – J Biol Che. 147: 3999.
[27] Saeed, D. F., Dizayee, A. T. R. (2023): The effect of various levels of nitrogen, phosphorus and potassium on production of local red onion (*Allium cepa* L.). – Bionatura Latin American Journal of Biotechnology and Life Sciences. 3(8): 20-38.
[28] Schwimmer, Sand Weston, W. J. (1961): Onion flavor and odor, enzymatic development of pyruvic acid in onion as a measure of pungency. – Journal of Agricultural and Food Chemistry 9(4): 301-304.
[29] Sharma, A., Asati, K. P., Yaday, S. S., Namdeo, K. N. (2021): Impact of organic and inorganic fertilizers on growth, yield and economics of garlic (*Allium sativum* L.). – Annals of Plant and Soil Research 23(4): 477-480.

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DOI: http://dx.doi.org/10.15666/aeer/2302_21372146

[30] Singh, H., Singh, V., Singh, J. P. (2019): Effect of organic and inorganic nutrient sources on productivity profitability and soil fertility in onion (*Allium cepa*) under Entisoil. – Indian Journal of Agricultural Sciences 89(5): 851-855.
[31] Singh, U. N., Pandey, M., Singh, O. P. (2020): Soil sulphur status and response of onion (*Allium cepa*) to sources levels of sulphur. – Annals of Plant and Soil Research 22(2): 115-118.
[32] Singh, V. (2022): Impact of integrated nutrient management on soil fertility and yield of onion (*Allium cepa*) on an alluvial soil. – Annals of Plant and Soil Research 24(2): 337-341 https://doi.org/10.47815/apsr.2022.10172.
[33] Stanford, G., English, L. (1949): Use of the flame photometer in rapid soil tests for K and Ca. – Agronomy Journal 41(9): 446-447.
[34] Subbiah, B., Asija, G. (1956): A rapid method for the estimation of nitrogen in soil. – Current Science 26: 259-260.
[35] Tisdale, S. L., Nelson, W., Land Beaten, J. D. (1984): Zinc. Soil Fertility and Fertilizers. Fourth Ed. – Macmillan Publishing Company, New York, pp. 382-391.
[36] Vijay, A., Jain, P., Lal, N., Shiurkar, G. (2017): Effect of micronutrients on yield, quality and storability of onion cv. Bhima Super. – Trends in Biosciences 10:(6): 1354-1358.
[37] Walkley, A., Black, I. A. (1934): An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. – Soil Science 37(1): 29-38.
[38] Yusuf, R., Syakur, A., Kalaba, Y., Randi, R. (2023): Role of seaweed extract and NPK on the growth and yield of onion (*Allium wakegi* L.). – IOP Conf. Ser. Earth Environ. Sci. 373:03020.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_21372146