

Research Article

Assessment of polyhalite fertilization on nutrient uptake and post-harvest soil nutrient balance in onion (*Allium cepa* L.) var Co (on) 6

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Abstract

The application of potassium and secondary nutrients through polyhalite significantly enhances the growth, yield of tomatoes and cluster beans etc. Polyhalite is a highly useful nutrient source for maintaining soil health, particularly in terms of soil fertility. In view of above facts, the present investigation was carried out on evaluation of polyhalite on nutrient uptake and post-harvest soil nutrient status in onion var Co (on) 6 at a farmer's field in Maattiyampatti village Kaarimangalam taluk, Dharmapuri district, Tamil Nadu. The experimental soil was sandy loam in texture, with a pH of 7.56 and an EC of 0.24 dS m⁻¹. The experiment was laid out in a randomized block design consisting of 12 treatments and 3 replications. The polyhalite and muriate of potash were used as a potassium source at different levels (10 to 50 kg K₂O ha⁻¹). The recommended doses of nitrogen (60 kg ha⁻¹) and phosphorus (60 kg ha⁻¹) were applied as urea and single super phosphate, respectively, in all treatments except the absolute control. The results of the study clearly showed that the application of polyhalite performed better than muriate of potash across all parameters. The highest plant and bulb nutrient uptake of N, P, K, S, Ca and Mg (96.5, 49.8, 97.1, 52.2, 22.3, 19.3 kg ha⁻¹ in bulb respectively) at all growth stages and maximum soil available nutrient status in post-harvest soil were recorded under application of potassium through polyhalite as 40 kg K₂O ha⁻¹ recommended dose of nitrogen and phosphorus (T₁₁). The minimum values were observed in the absolute control (T₁).

Key words: Muriate of potash, Nutrient uptake, Onion, Polyhalite, Soil nutrient status

INTRODUCTION

Onions are incredibly nutrient-dense veggies that may help balance blood sugar, support heart health, and support bone density. Onions belong to the flowering plant genus *Allium*. They contain a variety of beneficial vitamins, minerals, and plant chemicals and are tasty, adaptable and reasonably priced. Onions are classified as biennials but are typically grown as annuals for their

edible bulbs (Gnanasundari *et al.*, 2022). Globally, onion production reached approximately 110 million metric tons, cultivated across 5.9 million hectares (FAO, 2022). India and China are the leading producers, accounting for roughly half of the world's total output. India has the largest area under onion cultivation. According to the latest record, onion production dropped by 19.84% amounting to 242.15 lakh tones in the 2023-24, as compared to 2022-23 amounting of 302.08 lakh

tones (Department of Agriculture and Farmers Welfare of India, First Advance Estimates of horticultural crops for 2023-24). The area under onion cultivation was estimated at 1.79 million hectares. Maharashtra is the leading onion producer, followed by Madhya Pradesh and Gujarat (Singh *et al.*, 2024).

Potassium, calcium, magnesium, and sulfates are major components of polyhalite, a naturally occurring mineral with the chemical formula $K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$. Usually created by the evaporation of ancient seawater in sedimentary basins, it is a rather uncommon evaporate mineral. As a multi-nutrient fertilizer, polyhalite is becoming increasingly significant worldwide because it contains four vital plant nutrients in sulfate form, which is readily absorbed by plants (Karthikeyan *et al.*, 2025). Polyhalite is promoted as a low-chloride fertilizer suitable for chloride-sensitive crops. With little environmental impact, it supports sustainable agriculture by supplying several vital nutrients in a single application. Significant polyhalite deposits are found in the United Kingdom (particularly in North Yorkshire), China, and parts of the Middle East. The largest known deposit lies deep beneath the North Sea off the UK coast and is currently being mined by companies such as Anglo American (Mulder *et al.*, 2011). The onion crop removes large quantities of nutrients from the soil, which must be replenished to maintain soil fertility. In this context, a comparative study was conducted on potassium fertilization in onion. Muriate of potash is almost the sole source of potash fertilization, used by the farmers. But some other sources of potash would perform better than muriate of potash. Based on the potassium sources, the present investigation is conducted to compare the effects of polyhalite and Muriate of potash on nutrient uptake and post-harvest soil nutrient status in onion.

MATERIALS AND METHODS

The present investigation was carried out at a farmer's field in Maattiyampatti village Kaarimangalam taluk, Dharmapuri district, Tamil Nadu to study the polyhalite fertilization on nutrient uptake and post-harvest soil nutrient balance in onion (*Allium cepa* L.) var Co (on) 6. The experimental soil was a sandy loam (Typic Ustropept) in the vannapatti series. The experimental soil had a neutral pH (7.12). It was low in organic carbon (6.5 g kg^{-1}), low in available nitrogen (181 kg ha^{-1}), medium in available phosphorus (14.1 kg ha^{-1}), available potassium (117 kg ha^{-1}), available sulphur (12.1 mg kg^{-1}), exch. calcium ($5.78 \text{ C mol (p+) kg}^{-1}$) and exch. magnesium ($2.49 \text{ C mol (p+) kg}^{-1}$). The twelve treatments were replicated three times in a randomized block design. The treatment details were T₁: Absolute control, T₂: control (N, P alone), T₃: 10 kg K₂O ha⁻¹ as MOP, T₄: 20 kg K₂O ha⁻¹ as MOP, T₅: 30 kg K₂O ha⁻¹ as MOP, T₆: 40 kg K₂O ha⁻¹ as MOP, T₇: 50 kg K₂O ha⁻¹ as MOP, T₈:

10 kg K₂O ha⁻¹ as polyhalite, T₉: 20 kg K₂O ha⁻¹ as polyhalite, T₁₀: 30 kg K₂O ha⁻¹ as Polyhalite, T₁₁: 40 kg K₂O ha⁻¹ as polyhalite, T₁₂: 50 kg K₂O ha⁻¹ as Polyhalite. The recommended doses of nitrogen (60 kg ha⁻¹) and phosphorus (60 kg ha⁻¹) were applied to all treatments except the absolute control. The nutrient uptake, viz., nitrogen (Microkjeldhal method by Humphries, 1956), phosphorus (Vanadomolybdate yellow colour method by Jackson, 1973), potassium (flame photometer method by Jackson, 1973), calcium, magnesium (Versenate method by Jackson, 1973), and sulphur (Turbidimetric method by Chesnin and Yien, 1951), was calculated from nutrient content and dry matter production. The post-harvest soil nutrient status viz, available nitrogen (Alkaline permanganate method by Subbiah and Asija, 1956), phosphorus (Ascorbic acid blue method by Watanabe and Olsen, 1965), potassium (Neutral normal ammonium acetate extraction by Stanford and English 1949), calcium, magnesium (Versenate method by Jackson, 1973) and sulphur (Turbidimetric method by Chesnin and Yien, 1951) were analyzed as per the standard procedure and recorded. The assumptions of normality and homogeneity of variances were examined using residual diagnostics and were found to be satisfactory at the 5% significance level. Statistical analyses were performed using AGRIS software version 25.2.0

RESULTS AND DISCUSSION

Nutrient uptake

The effect of applying potassium as muriate of potash and polyhalite resulted in a significant increase in nutrient uptake. Among the different potassium sources used, polyhalite showed the highest nutrient uptake compared to muriate of potash. Regarding the levels, application of potassium, either as muriate of potash or polyhalite, at 40 kg K₂O ha⁻¹ was significantly superior to other treatments at all growth stages. The maximum nitrogen uptake of 46.8, 74.2, 96.5 kg ha⁻¹, phosphorus uptake of 20.9, 32.8, 49.8 kg ha⁻¹, potassium uptake of 44.9, 69.2, 97.1 kg ha⁻¹, calcium uptake of 11.21, 15.6, 22.3 kg ha⁻¹, magnesium uptake of 7.11, 11.3, 19.3 kg ha⁻¹ and sulphur uptake of 22.4, 33.1, 52.2 kg ha⁻¹ at 30, 60 DAT and in bulb respectively (Table 1 and 2) were observed in application of potassium through polyhalite @ 40 kg ha⁻¹ along with recommended dose of nitrogen and phosphorus. This might be due to the application of polyhalite, which supplies four major nutrients to plants (Sacks *et al.*, 2017). The present investigation shows that polyhalite application resulted in the highest nutrient uptake compared with muriate of potash.

The increase in uptake might be associated with the balanced supply of nutrients to soil, which is required during crop growth. This balanced nutrient profile ad-

Table 1. Effect of muriate of potash and polyhalite on nitrogen, phosphorus and potassium uptake in onion

Treatments details	Nitrogen uptake (kg ha ⁻¹)			Phosphorus uptake (kg ha ⁻¹)			Potassium uptake (kg ha ⁻¹)		
	30 DAT	60 DAT	Bulb	30 DAT	60 DAT	Bulb	30 DAT	60 DAT	Bulb
T ₁ - Absolute control	27.2	43.3	57.1	6.10	13.9	21.3	26.5	40.8	63.5
T ₂ - K=0	31.3	47.8	62.3	8.10	17.0	24.8	29.3	45.0	67.3
T ₃ - 10 kg of K ₂ O ha ⁻¹ as MOP	33.0	51.5	66.3	9.50	19.0	27.8	31.2	47.7	71.2
T ₄ - 20 kg of K ₂ O ha ⁻¹ as MOP	36.5	57.0	73.5	12.3	22.6	33.5	34.6	53.0	77.3
T ₅ - 30 kg of K ₂ O ha ⁻¹ as MOP	39.8	62.3	80.5	15.0	25.8	38.5	37.7	58.0	83.3
T ₆ - 40 kg of K ₂ O ha ⁻¹ as MOP	44.1	69.6	90.2	18.6	30.2	45.4	42.1	64.8	91.7
T ₇ - 50 kg of K ₂ O ha ⁻¹ as MOP	43.1	67.6	87.4	17.7	29.0	43.3	40.9	63.8	89.1
T ₈ - 10 kg of K ₂ O ha ⁻¹ as Polyhalite	34.7	54.3	69.8	10.9	21.0	30.9	33.0	50.3	74.3
T ₉ - 20 kg of K ₂ O ha ⁻¹ as Polyhalite	38.1	59.6	77.1	13.6	24.2	36.0	36.1	55.4	80.3
T ₁₀ - 30 kg of K ₂ O ha ⁻¹ as Polyhalite	41.4	64.9	84.0	16.3	27.4	40.9	39.3	60.4	86.1
T ₁₁ - 40 kg of K ₂ O ha ⁻¹ as Polyhalite	46.8	74.2	96.5	20.9	32.8	49.8	44.9	69.2	97.1
T ₁₂ - 50 kg of K ₂ O ha ⁻¹ as Polyhalite	45.7	72.2	93.6	20.0	31.8	47.8	43.6	67.2	94.6
SEd	0.74	1.20	1.59	0.59	0.70	1.10	0.69	1.10	1.30
CD (p=0.05)	1.5	2.5	3.2	1.2	1.4	2.2	1.4	2.2	2.7

Table 2. Effect of muriate of potash and polyhalite on sulphur, calcium and magnesium uptake in onion

Treatment details	Sulphur uptake (kg ha ⁻¹)			Calcium uptake (kg ha ⁻¹)			Magnesium uptake (kg ha ⁻¹)		
	30 DAT	60 DAT	Bulb	30 DAT	60 DAT	Bulb	30 DAT	60 DAT	Bulb
T ₁ - Absolute control	7.70	14.5	22.6	2.11	3.55	8.00	1.92	2.95	6.01
T ₂ - K=0	9.50	17.3	26.6	3.37	4.97	10.3	2.86	3.85	7.99
T ₃ - 10 kg of K ₂ O ha ⁻¹ as MOP	11.2	19.0	29.4	4.22	5.99	11.5	3.38	4.67	9.20
T ₄ - 20 kg of K ₂ O ha ⁻¹ as MOP	13.9	22.5	35.1	6.18	8.17	14.2	4.28	6.33	11.6
T ₅ - 30 kg of K ₂ O ha ⁻¹ as MOP	16.6	25.9	40.6	7.82	10.4	16.7	5.17	7.96	14.1
T ₆ - 40 kg of K ₂ O ha ⁻¹ as MOP	20.1	30.3	47.7	10.0	13.6	20.1	6.40	9.99	17.3
T ₇ - 50 kg of K ₂ O ha ⁻¹ as MOP	19.2	29.1	45.6	9.76	12.9	19.2	6.15	9.59	16.5
T ₈ - 10 kg of K ₂ O ha ⁻¹ as Polyhalite	12.6	20.8	32.4	5.20	7.02	12.9	3.86	5.55	10.4
T ₉ - 20 kg of K ₂ O ha ⁻¹ as Polyhalite	15.3	24.2	37.9	7.04	9.31	15.4	4.74	7.15	12.9
T ₁₀ - 30 kg of K ₂ O ha ⁻¹ as Polyhalite	17.9	27.5	43.1	8.80	11.7	17.9	5.70	8.78	15.3
T ₁₁ - 40 kg of K ₂ O ha ⁻¹ as Polyhalite	22.4	33.1	52.2	11.21	15.6	22.3	7.11	11.3	19.3
T ₁₂ - 50 kg of K ₂ O ha ⁻¹ as Polyhalite	21.4	31.9	50.2	10.90	14.9	21.4	6.85	10.8	18.6
SEd	0.57	0.70	1.14	0.29	0.46	0.53	0.18	0.33	0.50
CD (p=0.05)	1.1	1.4	2.3	0.60	0.97	1.1	0.38	0.70	1.05

dresses multiple aspects of plant nutrition. Potassium is crucial for overall plant growth, sulfur is essential for amino acid and protein synthesis, magnesium is a component of chlorophyll, and calcium contributes to cell wall structure. The presence of these nutrients in right proportions supports a wide range of physiological processes, enhancing nutrient uptake efficiency. Polyhalite is known for its slow-release characteristics.

This slow-release feature ensures a sustained, prolonged supply of nutrients to plants, reducing the risk of nutrient leaching and making them available when black gram plants need them (Karthikeyan *et al.*, 2023). It provides a more consistent nutrient availability, promoting efficient uptake by plant roots. Polyhalite can contribute to soil structure improvement (Vale and Giroto, 2022). It helps to enhance soil aeration, water

retention, and nutrient-holding capacity. Improved soil structure provides a favorable environment for root development and nutrient uptake by plants (Karthikeyan *et al.*, 2025). It ensures that the nutrients are distributed more uniformly in root zone, making them more accessible to plant roots. In polyhalite, Ca and Mg are present in sulphate form and hence have greater mobility than when supplied as carbonates, allowing them to occupy deeper soil layers, enabling the root system to grow in depth and volume and improving nutrient uptake in all types of crops (Fernandez and Hoefft, 2009). However, additional calcium fertilization has been shown to have beneficial effects on leaf senescence, plant growth regulator activities, and nutrient mobility in the sugarcane crop (Gokul *et al.*, 2023). Magnesium is involved in the synthesis of proteins and adenosine triphosphate, and is needed for the transport of carbohydrates. Magnesium is also the central atom of the chlorophyll molecule, and as such is essential for photosynthesis. Similar to calcium, magnesium is associated with disease resistance in plants (Huber and Jones, 2013) and can enhance nitrogen uptake (Potarzycki, 2011; Szulc, 2010).

Polyhalite, multi nutrient fertilizer mitigate the nutrient antagonistic though its balanced nutrient composition. This characteristic improves soil nutrient content and further promotes nutrient uptake. Sulphur supplied through polyhalite expected to exhibit positive nitrogen, which regulate nitrogen assimilation and utilization. Further an improved potassium status promoted the

nitrogen and sulphur uptake in onion (Ozkan *et al.*, 2018). The nutrient uptake observed with polyhalite application might be due to additional K nutrition from polyhalite. Polyhalite, a naturally occurring mineral, promotes microbial activity, root growth, and nutrient uptake by plants and bulbs. This is similar to the findings of Karthikeyan *et al.* (2023), who reported that the application of polyhalite increased nutrient uptake in the plant, seed, and haulm of black gram.

Soil fertility status

The present investigation indicates that polyhalite and muriate of potash applications significantly influenced soil fertility. Application of potassium @ 40 kg K₂O ha⁻¹ through polyhalite recorded highest availability of nutrients viz., nitrogen (233 kg ha⁻¹), phosphorus (16.3 kg ha⁻¹), potassium (212 kg ha⁻¹), sulphur (20.2 mg kg⁻¹), calcium (8.08 c mol kg⁻¹) and magnesium (3.23 c mol kg⁻¹) in post-harvest soil of onion (Table 3). The increase in availability might be due to the supply of nutrients in the soil through fertilizers, viz., polyhalite. Polyhalite a naturally occurring fertilizers contains oxides of Ca, Mg, K and S, these salts promote flocculation of soil aggregates and improve the physical properties of soil. The cations, of these minerals, such as Ca²⁺, Mg²⁺ and K⁺, replace Al³⁺ on soil colloids and neutralize H⁺ in soil solution, thereby improving the soil pH and regulating the dissolution of mineral and increase the soil nutrient availability (Zhao *et al.*, 2022). Polyhalite has a lower water solubility than other potassium sources; it

Table 3. Effect of muriate of potash and polyhalite on post-harvest soil nutrient status in onion

Treatments	Available nitrogen (kg ha ⁻¹)	Available phosphorus (kg ha ⁻¹)	Available potassium (kg ha ⁻¹)	Available sulphur (mg kg ⁻¹)	Exch. Ca (c mol kg ⁻¹)	Exch. Mg. (c mol kg ⁻¹)
T ₁ - Absolute control	134	10.3	126	12.4	3.84	1.54
T ₂ - K=0	148	11.0	139	13.6	4.40	1.76
T ₃ - 10 kg of K ₂ O ha ⁻¹ as MOP	157	11.7	148	14.3	4.84	1.94
T ₄ - 20 kg of K ₂ O ha ⁻¹ as MOP	175	12.4	164	15.6	5.71	2.28
T ₅ - 30 kg of K ₂ O ha ⁻¹ as MOP	195	14.0	180	17.1	6.55	2.62
T ₆ - 40 kg of K ₂ O ha ⁻¹ as MOP	219	15.4	200	19.2	7.51	3.01
T ₇ - 50 kg of K ₂ O ha ⁻¹ as MOP	214	15.1	196	18.5	7.39	2.96
T ₈ - 10 kg of K ₂ O ha ⁻¹ as Polyhalite	166	12.4	156	14.9	5.29	2.11
T ₉ - 20 kg of K ₂ O ha ⁻¹ as Polyhalite	186	13.5	172	16.4	6.14	2.46
T ₁₀ - 30 kg of K ₂ O ha ⁻¹ as Polyhalite	205	14.6	188	17.8	6.95	2.78
T ₁₁ - 40 kg of K ₂ O ha ⁻¹ as Polyhalite	233	16.3	212	20.2	8.08	3.23
T ₁₂ - 50 kg of K ₂ O ha ⁻¹ as Polyhalite	228	16.0	208	19.9	7.93	3.17
SEd	3.97	0.23	3.44	0.29	0.12	0.04
CD (p=0.05)	8.0	0.40	7.00	0.60	0.24	0.12

provides nutrients like K, S, Ca, and Mg for a longer time required for plant growth (Yermiyathu *et al.*, 2017). Polyhalite's slow-release characteristics contribute to prolonging the availability of nutrients for crop improvement, reducing the leaching of nutrients, especially sulphur (Jiang *et al.*, 2016). Yermiyathu *et al.* (2017) reported that polyhalite application influences the low transport and leachate in soil than equivalent sulphate salts. These prolonged releases supply energy for the growth of microbes, which increase nutrient availability in soil. Muriate of potash as K source increases chloride content in soils and reduces sulphate content, also, K^+ in muriate of potash gets fixed more strongly to clay particles, than does K released from polyhalite, due to competition between monovalent (K^+) and divalent (Ca^{2+} , Mg^{2+}) cations, which improve the nutrient availability in soil. K^+ adsorbs less strongly to mineral soil surfaces than Ca^{2+} or Mg^{2+} , and the total adsorption capacity of soil increases as the clay mineral concentration increases (Pavuluri *et al.*, 2017).

Conclusion

Polyhalite application in the present study significantly increased nutrient uptake and post-harvest soil nutrient status under onion cultivation. Application of potassium @ 40 kg K_2O ha^{-1} through polyhalite, along with the recommended dose of nitrogen and phosphorus, resulted in the maximum nutrient uptake by plants and increased the fertility status of the experimental soil. In the future, research may focus on the effects of polyhalite on growth stimulation, nutritional efficiency, optimal polyhalite dosage, and shelf-life improvement in onion in Tamil Nadu. Furthermore, the results are most applicable to conditions similar to the study area, and multi-location trials are recommended to confirm broader applicability.

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

- Chesnin, L. & Yien, C.R. (1951). Turbidimetric determination of available sulphates. *Soil Sci. Soc. Amer. Proc.*, 15, 149-151.
- Fernandez, F.G. & Hoefft, R.G. (2009). Managing soil pH and crop nutrients. *Illinois agronomy handbook.*, 24: 91-112.
- Gnanasundari, K., Srivignesh, S., Krishna, K. R., Kumar, M. & Kumar, A.R. (2022). Integrated nutrient management in onion-a review. *Ecol. Environ. Conser.*, 28, 182-192. <http://dx.doi.org/10.53550/EEC.2022.v28i07s.030>
- Gokul, D., Karthikeyan, P.K., Poonkodi, P., Babu, S., Imas, P., Perelman, A. & Sriramachandrasekharan, M.V. (2023). Effect of polyhalite and muriate of potash on quality attributes of sugarcane (*Saccharum officinarum* L.) in Inceptisols. *J. Appl. Nat. Sci.*, 15(4), 1326-1331. <https://doi.org/10.31018/jans.v15i4.4953>
- Huber, D.M. & Jones, J.B. (2013). The role of magnesium in plant disease. *Plant Soil J.*, 368, 73-85. <http://dx.doi.org/10.1007/s11104-012-1476-0>
- Humphries, E.C. (1956) Mineral components and ash analysis. Modern methods of plant analysis, Springer-Verlag Berlin., 1, 468-502
- Jackson, M.L. (1973) Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi, 498.
- Jiang, L., Young, S.D., Broadley, M.R., Bailey, E.H., Graham, N.S. & Mc-Grath. S.P. (2016). Dissolution rate of selected sulphur fertilizers; understanding selenate - sulphate competition. In: Compendium of polysulphate scientific research. *ICL Fertilizers, St. Louis.*, MO: 149.
- Karthikeyan, P.K., Ranjani, R., Bhuvanewari, R., Rameshkumar, S., Gokul, D., Swetha Reddy, K. & Muralleedharan, A. (2023). Polyhalite as a source of potassium on dry matter production and nutrient uptake of black gram Cv. ADT 5. *Res. J. Agri. Sci.*, 14(1), 122-126.
- Karthikeyan, P.K., Vijay, P., Gokul, D., Swetha Reddy, K. & Bhuvanewari, R. (2025). Effect of potassium through polyhalite on growth and yield of onion Var. CO (ON) 6. *J. Appl. Nat. Sci.*, 17(1), 39. <https://doi.org/10.31018/jans.v17i1.6123>
- Mulder, V.L., De Bruin, S., Schaeppman, M.E. & Mayr, T.R. (2011). The use of remote sensing in soil and terrain mapping - A review, *Geoderma*, 162(1-2): 1-19. <http://dx.doi.org/10.1016/j.geoderma.2010.12.018>
- Ozkan, C.F., Anac, D., Eryuce, N., Demirtas, E.L., Asri, F.O., Guven, D., Simsek, M. & Ari, N. (2018). Effect of different potassium and sulfur fertilizers on onion (*Allium cepa* L.) yield and quality. *Int. Potash Inst., (e-ifc)* 53, 16-24.
- Pavuluri, K., Malley, Z., Mzimhiri, M.K., Lewis, T.D. & Meakin, R. (2017). Evaluation of polyhalite in comparison to muriate of potash for corn grain yield in the Southern Highlands of Tanzania. *Afr. J. Agron.*, 5, 325-332.
- Potarzycki, J. (2011). Effect of magnesium or zinc supplementation at the background of nitrogen rate on nitrogen management by maize canopy cultivated in monoculture. *Plant Soil Environ.*, 57(1): 19-25. <https://doi.org/10.17221/77/2010-PSE>
- Sacks, Gantz, M.S., Mezuman, U., Peled, L. & Imas, P. (2017). Polyhalite a multi- nutrient fertilizer preventing Ca and Mg deficiencies in greenhouse tomatoes under desalinated irrigation water. *Int. J. Potash Inst.*, 51, 34- 41. <https://www.ipipotash.org/publications/eifc-418>
- Singh, P.L., Singh N P.K., Singh, O.P., Shiva Seth, Debashish Kumar & Satyam Raj. 2024. Assessment of trend for area, production, productivity and post-harvest losses of onion and potato in Uttar Pradesh, India. *Economic Affairs.*, 69(02). 865-871.
- Stanford, D. & English. L. (1949). Use of flame photometer in rapid soil tests of K and Ca. *Agron. J.*, 4, 446-447.
- Subbiah, B.V. & Asija, L.C. (1956). A rapid method of estimation of available nitrogen in soils. *Curr. Sci.*, 25, 258 -260.
- Szulc, P. (2010). Effects of differentiated levels of nitrogen fertilization and the method of magnesium application the utilization of nitrogen by two different maize culti-

- vars for grain. *Pol. J. Environ. Stud.*, 19(2), 407-412.
20. Vale, F. & Girotto, E.S. (2022). Fertilization efficiency with polyhalite mineral: a multi-nutrient fertilizer. *Int. Potash Inst., (e-ific)* 66, 12-43.
21. Watanabe, I. & Olsen, S.R. (1965). Test of ascorbic acid methods for determining phosphorus in water and NaHCO₃ extracts from soil. *Soil Sci. Soc. Am. Proc.*, 29, 677- 678.
22. Yermiyathu, U., Ziporia, I., Faingold, I., Yusopova, L., Fausta, N. & Bar-Talb, A. (2017). Polyhalite as a multi nutrient fertilizer – potassium, magnesium, calcium and sulphate. *Isr. J. Plant Sci.*, 64(3-4), 145-157. <http://dx.doi.org/10.1163/22238980-06401001>
23. Zhao, X., Ma, X., Chen, B., Shang, Y. & Song, M. (2022). Challenges toward carbon neutrality in China: Strategies and countermeasures. *Resour. Conserv. Recycl.*, 176: 105959. <http://dx.doi.org/10.1016/j.resconrec.2021.105959>