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A Study on the Growth of Magnesium Demanding *Allium cepa* using Bittern Effluent from Puthalam Saltpan of Kanyakumari

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Abstract

The use of bittern, a concentrated brine solution, as a fertilizer has garnered interest due to its high nutrient content. However, the impact of bittern concentration on plant growth and development remains unclear. This study seeks to investigate the effects of varying bittern concentrations on plant growth, exploring potential benefits and drawbacks. High salt concentrations can be detrimental to plant growth, yet certain species have adapted to thrive in saline environments. This study aims to investigate the optimal bittern concentration that promotes plant growth and explore its potential applications as a fertilizer. Globally, approximately 60% of the total salt produced is utilized by chemical industries, while the remaining portion is consumed by humans through their diet. During the salt production, equal quantity of unwanted and unavoidable toxic material, i.e., bittern is being discharged. As the bittern is enriched with magnesium, sulphate, calcium, potassium etc. and also trace metals other than the usual ions like sodium and chloride, it can either be used as such as fertilizer or can be transformed into various useful solid fertilizers. As predominantly having magnesium, bittern was tried as a fertilizer as such and in the form of solid fertilizer to magnesium demanding crop like onion (*Allium cepa*).

***Key words*:** Common salt, Salt-pan, Bittern concentration, Onion, Fertilizer, Plant growth

Plants can synthesize their own food through photosynthesis. However, for the healthy growth of plants, incorporation of fertilizers is mandatory. Indeed, while plants have the remarkable ability to synthesize their own food through photosynthesis, relying only on sunlight, carbon dioxide, and water to produce glucose and oxygen, their nutritional requirements go beyond what they can produce internally [1]. For robust and healthy growth, plants also need essential minerals and nutrients from the soil, which they cannot synthesize on their own. This is where fertilizers play a crucial role [2]. Regarding fertilizers, NPK is considered as the major nutrients, which are needed for a healthy growth [3]. Along with NPK, it is in need of secondary nutrients like magnesium, calcium, sulphate, molybdenum etc. [4]. Fertilizers supply vital nutrients that are often insufficient in natural soil, especially in intensive farming scenarios where repeated cropping depletes soil nutrient levels. In many agricultural settings particularly those involving intensive farming practices soils are subjected to continuous cropping without adequate recovery periods. This repeated cultivation extracts large quantities of essential nutrients from the soil, leading to nutrient imbalances and a gradual decline in soil fertility. Without replenishment through fertilizers, the nutrient-depleted soils are unable to support healthy plant growth, resulting in reduced crop yields and lower produce quality. Thus, the application of fertilizers becomes indispensable for restoring soil nutrient levels, sustaining agricultural productivity, and ensuring long-term soil health. While plants primarily use photosynthesis for energy production, they require several macro and micronutrients to support various physiological processes essential for development and resistance to stress [5]. Trace elements like, iron, manganese, copper, zinc, boron, cobalt etc. also plays a crucial role in providing a steady growth for the plants [6]. As agricultural systems intensify, the need for a balanced micronutrient profile becomes even more critical. Trace elements help plants build resistance to environmental stressors, reduce the need for chemical pesticides, and contribute to higher quality and yield [7]. They are an important part of sustainable agriculture practices, enabling growers to produce nutrient-rich crops that support both ecosystem health and food security. While needed in small quantities, trace elements are indispensable to plant growth and development. Their roles in enzyme activation, chlorophyll synthesis, and disease resistance highlight their importance, underscoring the need for balanced micronutrient management in soil and plant care [8]. These metals are extremely essential, but in large quantities, they may cause physiological disorders [9]. To avoid trace metal toxicity, practices such as regular soil testing and targeted fertilization are essential. In cases where soil tests reveal high levels of a particular metal, techniques like liming

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to adjust soil pH, adding organic matter, and using balanced fertilizers can help buffer plants from toxic levels [10]. Crop rotation and selecting plants with specific tolerances can also help mitigate issues in soils with high metal content. While trace metals are crucial in small amounts, managing their levels carefully is vital for plant health [11]. Excessive amounts can lead to toxicity, impairing growth, reducing yields, and ultimately affecting the sustainability of agricultural practices. The unwanted and unavoidable commodity during salt making i.e., bittern is enriched with almost all the above nutrients [12]. Therefore, bittern which is discharged as a by-product in solar salt-pans can be utilized directly as a fertilizer or it can be further converted into different solid fertilizers, which can be used for various magnesium demanding crops like ladies' finger, onion, tomato, green chillies, radish etc.

MATERIALS AND METHODS

The study deals with the effect of bittern as a fertilizer on onion by growing the plants in various pots. Bittern, an unavoidable material formed during salt production was found to be toxic when released in concentrated form [13]. However, bittern is rich in magnesium, sulphate and traces of calcium, sodium, potassium, trace metals like iron, manganese, copper, and zinc [14]. Regarding the bittern samples used for the study, it was collected from Puthalam salt-pan of Kanyakumari district, Tamil Nadu. All the pots were one feet high and 30 cm wide. Soil, sand and organic mixture was mixed in the ratio 1:1:1 and this mixture was filled 3/4th in all pots. This mixture is the humus fraction, which improves the soil structure, and texture. Five pots were utilized for the study. This experimental set-up was kept in the open terrace so that all the pots can have the same exposure of sunlight. Seeds were sown and were watered daily for 2 times a day. The number of days for germination was even in all the pots and the entire experiment was carried out for sixty days. The maximum tiller height, number of tillers having maximum height, total number of tillers, number of bulbs and total weight of bulbs of onion in the five pots were recorded. A dilute metacid (2ml in one litre of water) solution was applied using a hand-sprayer once in every fifteen days to eliminate harmful pests.

Experimental set-up

Five pots were used and labelled as O-C, O-1, O-2, O-3, and O-4

O-C – Control pot containing the soil mixture alone
O-1 – Soil mixture + 5 ml of bittern evenly mixed
O-2 – Soil mixture + 10 ml of bittern evenly mixed
O-3 – Soil mixture + 15 ml of bittern evenly mixed
O-4 – Soil mixture + 20 ml of bittern evenly mixed

In each pot, two onion bulbs of approximately equal weight were planted. The selected onion bulbs were healthy and minimum water was sprinkled daily since heavy accumulation of water may lead the onion bulbs to decay. The germination of all the bulbs took nine days and the entire experiment was carried out for a period of 60 days. The total number of tillers, maximum tiller height and number of tillers having maximum height were recorded once in 30 days in all the five different pots. After 60 days, the onion with tillers were rooted out and the number of bulbs and total weight of bulbs in all the different pots were recorded.

Ash analysis

The well matured leaves of the five different pots were cut off and dried well at room temperature for 3 to 4 days. Of the dried leaves, 3 gm of each was weighed and further dried in an oven at a temperature of 110ºC to 140ºC and were made to ash in silica crucibles. The ash was weighed and transferred to 250 ml beakers for triple acid digestion with HNO_3, H_2SO_4 and $HClO_4$ in the ratio 7:2:1. After 2 hours, the contents were transferred into crucible, heated in sand-bath and were allowed to cool in desiccators. The extract was made up in 25 ml S.M. Flask with double distilled water [15]. The five different ash samples were subjected to various analysis viz., percentage of calcium, magnesium and potassium by standard methods [16]. Atomic Absorption Spectrophotometer analyzed the trace metals like iron, manganese, zinc and copper.

RESULTS AND DISCUSSION

In pot-culture studies, a mixture of soil, sand and organic mixture in the ratio 1:1:1 is used, since these provide the necessary primary nutrients such as nitrogen, phosphorus and potassium to plants for healthy growth. Organic mixture is humus fraction which improves soil structure and texture [17]. This mixture is prepared by dumping cattle dung, crop residue and other biological wastes in an open place which contain all plant nutrients [18]. Moreover, the addition of organic mixture to soil enhances biological activity and enriches the soil [19]. A trial experiment was conducted with 0,20,40,60 and 80 ml of bittern in five different pots of onion and green chillies. It resulted in scorching of leaves in onion and green chilliies in all pots except the control pot because of excess chlorides present in bittern [20]. So, the quantity of bittern added was reduced to 0,5,10, 15 and 20 ml for the five different pots of onion.

First monitoring on 31th day

The germination of onion seeds in all the five different pots were uniform i.e., on the tenth day. O-C had a total of 12 tillers, of which 2 tillers had the maximum height of 21 cm. O-1 had 15 tillers of which 3 tillers had the maximum height of 21.2 cm. Eighteen tillers were observed for O-2, of which 5 tillers had a maximum height of 21.6 cm. O-3 had 22 tillers of which 5 tillers had the maximum height of 22.0 cm. But O-4 had the maximum number of tillers i.e., 24 and 6 tillers had the maximum height of 22.3 cm. (Table 1, Fig 1).

Table 1 Measurements recorded on 31st day

Classification	Maximum tiller height (cm)	Number of tillers having maximum height	Total number of tillers
O-C	21.0	2	12
O-1	21.2	3	15
O-2	21.6	5	18
O-3	22.0	5	22
O-4	22.3	6	24

Second monitoring on 61st day

During this period, an increase in the number of tillers were observed. O-C had minimum number of tillers i.e., 16, of which 4 had the maximum height of 27.2 cm. O-1 had 18 tillers, of which 5 had the maximum height of 27.6 cm. Twenty tillers were observed in O-2, of which 6 had the maximum height of

27.9 cm, while for O-3, it was 22 tillers with 7 tillers had the maximum height of 28.2 cm. A maximum of 25 tillers was observed for O-4, of which 8 had the maximum height of 29.0 cm (Table 2).

Table 2 Measurements recorded on 61st day

Classification	Maximum tiller height (cm)	Number of tillers having maximum height	Total number of tillers
O-C	27.2	4	16
O-1	27.6	5	18
O-2	27.9	6	20
O-3	28.2	7	22
O-4	29.0	8	25

Further monitoring was impossible, as the tillers cannot stand erect. Therefore, the tillers with bulbs of all the experimental pots were rooted out. The 3/4th portion of tillers of the different pots were cut and made into ash and subjected to chemical analysis. Number and total weight of the bulbs were also recorded.

Yield report

The onion bulbs from all the five different pots were carefully removed from the soil. O-C had minimum number of bulbs i.e., 9 and the total weight of the bulbs was 12.2g. O-1 had 12 bulbs with a weight 16.8g while O-2 had 14 bulbs with a weight of 18.5g. O-3 had 16 bulbs, weighing 22.4g. But, O-4 had the maximum number of bulbs i.e., 18 weighing 28.2g (Table 3). The above data comprising the total number of tillers, maximum tiller height and number of tillers having the maximum height, number of bulbs and the total weight of bulbs of the five different classifications clearly indicated that the increased addition of bittern has increased the fertilizer value and in turn increased the yield of onion. But excess of bittern leads to curling of tillers since bittern has excess chlorides in the form of magnesium chloride and potassium chloride.

Table 3 Onion: Yield report

Classification	Number of bulbs	Total weight of bulbs (gm)
O-C	9	12.2
O-1	12	16.8
O-2	14	18.5
O-3	16	22.4
O-4	18	28.2

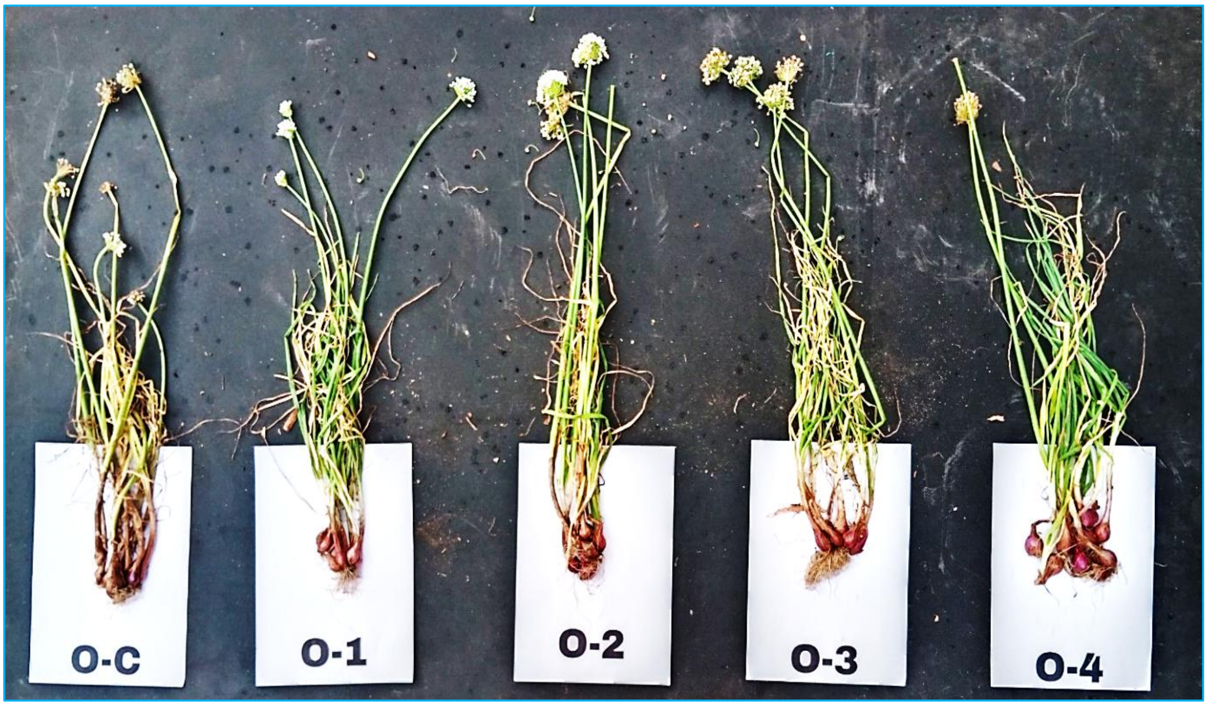

Fig 1 Onion harvested using bittern as fertilizer

Ash analysis

Ash samples from the five different pots were analyzed for various chemical parameters and the percentage of all ions gradually increased from O-C to O-4. O-C had the minimum ash percentage. i.e., 8.05% and for O-1, O-2 and O-3, they were 8.12%, 8.21% and 8.35% respectively. Maximum ash percentage of 8.45% was observed for O-4 (Table 5). The percentage of calcium was minimum for O-C i.e., 1.22% and for O-1, O-2 and O-3, it was 1.28%, 1.36% and 1.43% respectively. But a maximum value of 1.52% was observed for O-4. (Table 4). From the earlier observations, it was learnt that the sufficient quantity of calcium required for onion is 1.00% - 2.00% (Table 5). Despite, the soil mixture provided the necessary calcium, the addition of bittern increased calcium intake, resulting in a gradual increase from O-C to O-4. The percentage of magnesium also increased from O-C to O-4 significantly. A minimum value of 0.21% was observed from O-C and for O-1, O-2 and O-3, it was 0.35%, 0.38% and 0.45% respectively. Maximum value of 0.52% was observed for O-4 (Table 4). From the earlier observations, the sufficient quantity of magnesium required for onion is known to be 0.25% to 0.40% (Table 5). Despite the soil mixture provided some magnesium, the total requirement was exclusively supplied by bittern and so there was a significant increase from O-C to O-4.

The value of sulphate also increased significantly from O-C to O-4 due to the increased dosage of bittern. The sufficient quantity of sulphate required was exclusively provided by bittern. O-C had minimum percentage of sulphate i.e., 0.16% and for O-1, O-2 and O-3, it was 0.34%, 0.52% and 0.70% respectively. Maximum value of 0.92% was observed for O-4 (Table 4). From the earlier observations, it is known that the sufficient requirement of sulpahte was 0.50- 1.005% (Table 5).

The percentage of potassium was found to increase gradually from O-C to O-4. Though the required potassium was supplied by the soil mixture, the increased addition of bittern activated the intake of potassium. O-C had the minimum percentage of potassium i.e., 3.70% and O-1, O-2 and O-3 had the values of 3.82%, 3.92% and 4.04% respectively. But, a maximum value of 4.16% was observed for O-4 (Table 4). From the earlier observations, the sufficient requirements of potassium were found to be 4.00% - 5.50% (Table 5). The values of various elements like calcium, magnesium, sulphate and potassium of the different ash samples were in agreement with the established data. The trace metals of the different samples were also found to increase marginally from O-C to O-4. Regarding iron, a minimum value of 9.18 mg/L was observed for O-C and for O-1, O-2 and O-3, it was 9.31 mg/L, 9.47 mg/L and 9.68 mg/L respectively. But a maximum value of 9.91 mg/L was observed for O-4 (Table 4).

O-C had minimum value of manganese i.e., 3.22 mg/L and for O-1, O-2 and O-3, it was 3.31 mg/L, 3.41 mg/L and 3.65mg/L respectively. Maximum value of 3.87 mg/L was observed for O-4 (Table 4). Minimum value of copper was recorded for O-C i.e., 5.17 mg/L and for O-1, O-2 and O-3, it was 5.33 mg/L, 5.46 mg/L and 5.65 mg/L respectively. Maximum value of 5.86 mg/L was observed for O-4 (Table 4). Zinc was found to be minimum for O-C i.e., 5.14 mg/L and for O-1, O-2 and O-3, it was 5.24 mg/L, 5.36 and 5.53 mg/L respectively. Maximum value of 5.72 mg/L was recorded for O-4 (Table 4). Though the soil mixture provided the required trace metals to plant, the increased addition of bittern activated the intake of various micronutrients and so a gradual increase in the values of various elements were observed from O-C to O-4.

Despite the gradual increase in the percentage of all nutrients viz., calcium, magnesium, sulphate, potassium and micronutrients viz., iron, manganese, copper and zinc, the percentage of magnesium and sulphate increased statistically in the ash samples of onion as the addition of bittern increased. This is because bittern is enriched with magnesium and sulphate than other elements (Table 4). The standard requirement table comprising low, sufficient and high values regarding the percentage of calcium, magnesium, sulphate and potassium for onion, recorded by earlier workers [21] are represented in (Table 5).

Table 4 Onion: Ash analysis

Classification	Weight of dry tillers (gm)	Ash %	Calcium %	Magnesium %	Sulphate %	Potassium %	Iron mg/L	Manganese mg/L	Copper mg/L	Zinc mg/L
O-C	2	8.05	1.22	0.21	0.16	3.70	9.18	3.22	5.17	5.14
O-1	2	8.12	1.28	0.35	0.34	3.82	9.31	3.31	5.33	5.24
O-2	2	8.21	1.36	0.38	0.52	3.92	9.47	3.41	5.46	5.36
O-3	2	8.35	1.43	0.45	0.70	4.04	9.68	3.65	5.65	5.53
O-4	2	8.45	1.52	0.52	0.92	4.16	9.91	3.87	5.86	5.72

Table 5 Onion: Standard requirement of nutrients

Ions	Low	Sufficient	High
Ca (%)	0-80 – 0.99	1.00 – 2.00	> 2.00
Mg (%)	0.22 – 0.24	0.25 – 0.40	> 0.40
SO_4^{2-} (%)	0.30 – 0.49	0.50 - 1.00	> 1.00
K (%)	3.50 - 3.99	4.00 – 5.50	> 5.50

CONCLUSION

The present study reveals that bittern which is a by-product formed during salt production can be used as a useful fertilizer for magnesium-demanding crops as it is rich in magnesium and other trace elements. The growth of *Allium cepa* was studied using different volumes of bittern. While excessive bittern resulted in scorching of leaves, lower amount of bittern resulted in increased growth rate and yield. Ash analysis was performed and the results were found to be satisfactory. So, bittern which is discarded as a waste material can be used as a useful fertilizer for crops like *Allium cepa* in lower concentrations. The study demonstrated that incorporating bittern into a standard pot-culture soil mixture comprising soil, sand, and organic matter (1:1:1) can significantly enhance onion growth and yield. The initial trial with higher bittern volumes (20–80 ml) resulted in phytotoxicity due to chloride excess, necessitating a revised dosage range (0–20 ml). Monitoring over 61 days revealed a consistent increase in tiller number, maximum tiller height, bulb count, and total bulb weight with increasing bittern concentration. Chemical analysis of ash from harvested onion tillers indicated a progressive rise in essential macro- and micronutrients, particularly magnesium and sulphate, reflecting bittern's mineral composition. While the soil mixture provided baseline nutrition, bittern notably supplemented magnesium and sulphate beyond sufficiency levels, enhancing nutrient uptake and plant vigor. However, the study also highlights the need to regulate bittern application, as excessive chlorides can impair plant health. Overall, controlled use of bittern shows promise as a supplementary fertilizer, particularly for magnesium- and sulphate-deficient soils in onion cultivation.

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