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Research Article

Preparation of Valuable Solid Fertilizers from Bittern in Salt-Pans of Kanyakumari District, Tamil Nadu, India

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ABSTRACT

Common salt, also known as sodium chloride, is widely distributed on earth, especially in the form of seawater, which is an inexhaustible source. Common salt is economical and an excellent supplier of balanced nutrients, viz., sodium, iron, calcium, potassium, magnesium, etc., and even trace elements. Today majority of the farmlands are being depleted of minerals because of unwanted agricultural practices. Therefore, the soil has to be made fertile by the addition of nutrients in the form of different fertilizers. The organic mixture is the humus fraction, which improves soil structure and texture. One of the important sources for the synthesis of such fertilizers is the bittern, which is an unavoidable toxic material being let off from solar salt pans after crystallizing common salt. As this bittern is highly corrosive and poses transportation problems, it can be transformed into solid fertilizers through various improved methods.

Keywords: Sodium chloride, Salt-pans, Bittern, Nutrients, Fertilizers.

INTRODUCTION

Common salt is predominant in deciding the world's economy. Most of the earth's surface is covered with water, in which 2.5% of common salt is present.[1,2] Of the total salts produced in the world, nearly 60% is meant for chemical industries and the remaining is being utilized by humans through their dietary habits. Solar salt production involves fractional crystallization of different salts by which the purest form of common salt can be made.[3] After removing the crystallized common salt, they let out mother liquor, i.e., bittern, which is an unavoidable commodity that can be converted into different useful fertilizers. The addition of an organic mixture to soil enhances biological activity and enriches the soil with available nitrogen, phosphorous and potassium.[4] Since bittern is enriched with different chemicals, it can be used as the raw material to generate a variety of fertilizers that can be applied to plants to have better and healthier growth. The requirements of various elements differ depending on the nature of the soil conditions.[5] This unavoidable and unwanted toxic bittern is enriched with various ions like magnesium, calcium, potassium, chloride, sulfate and iodide.[6]

MATERIALS AND METHODS

Bittern samples were collected from different pans like Swamithoppu and Puthalam of Kanyakumari district. The samples collected were used to synthesize the solid fertilizers, which are being utilized for magnesium-demanding crops like Surinum spinach. Four different methods were adopted for the synthesis of the solid fertilizers and here, for this study, only one method is taken into consideration.

Method for the preparation of solid fertilizer

About 10 mL of bittern was taken in a 250 mL conical flask and added with 10 mL of dilute hydrochloric acid. To this mixture, 2 mL of orthophosphoric acid and the required quantity of ammonia solution were added by stirring continuously to get a clear solution. A white precipitate was formed, which was then poured into a polypropylene petri dish and allowed to dry at room temperature for 7 days. Utmost care was taken to remove the residual traces of the water molecules by drying the precipitate in an air oven at 80°C for 3 hours. The precipitate was stored in a vacuum desiccator to avoid moisture absorption until further use.

Yield: Swamithoppu – 6.89 g

Puthalam – 6.51 g

The fertilizer value of bittern was studied by analyzing the biomass production of magnesium-demanding crops like surinum spinach (*Talinum fruticosum*) and its impact on solid fertilizer concentration in different pots.

Experimental setup

The pots were uniformly sized, measuring 1 feet in height and 30 cm in width. The soil, sand and organic mixture were mixed in a 1:1:1 ratio and filled 3/4th in all pots. The experimental setup was maintained on an open terrace to ensure uniform sunlight exposure for all pots. In each pot, two small pieces of spinach stems were planted and watered daily in the morning and evening. The number of days for germination was even in all five different pots and the entire experiment was carried out for 90 days. The height, stem width,

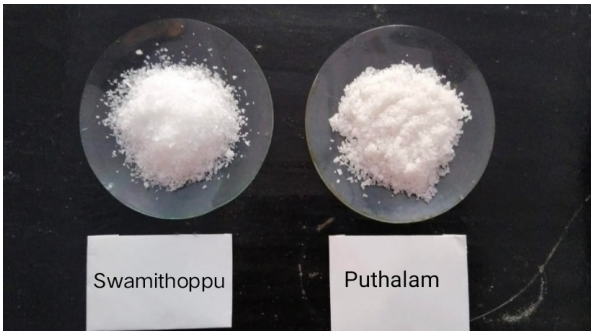

Fig. 1: Solid fertilizers prepared from Swamithoppu and Puthalamsalt pans

maximum leaf width and total number of leaves in the plants of the five different pots were recorded. A dilute metacid (2 mL in one liter of water) solution was applied using a hand sprayer once every 15 days to eliminate harmful pests. Throughout the study, the sprouting of flowers and enlarging of leaves were not uniform in all the five pots, and the total number of leaves was recorded on the 91st day.

Ash analysis- procedure

The well matured leaves of the plants were carefully cut off and dried at room temperature for 3 to 4 days. Of the dried leaves, 3 g of each was weighed and further dried in an oven at a temperature of 110° −140°C and were made to ash in silica crucibles. The ash of the five different samples was then digested with triple acid, i.e., HNO_3, H_2SO_4 and $HClO_4$, in the ratio of 7:2:1. The content in the crucible was heated in a sand-bath and was made up to25 ml in S.M Flask with double distilled water.[7]

The five different samples were subjected to various analyses, viz., percentages of calcium, magnesium, potassium, iron, manganese, zinc and copper by standard methods.[8,9]

RESULTS AND DISCUSSION

The solid fertilizers that were prepared using different bittern samples from Swamithoppu and Puthalam are presented in Fig. 1. These fertilizers were added to magnesium-demanding crops like Surinum spinach. The observed growth of plants in various pots is presented in Figs 2(a) and 2(b).

Mode of Application of Solid Fertilizer to Plants

Five pots were labelled as S-Control, S-a, S-b, S-c and S-d. (Fig. 2a)
S-Control- Control pot containing the soil mixture alone
S-a – Soil mixture + 2 g of solid fertilizer evenly mixed
S-b – Soil mixture + 4 g of solid fertilizer evenly mixed
S-c – Soil mixture +6 g of solid fertilizer evenly mixed
S-d – Soil mixture + 8 g of solid fertilizer evenly mixed
Five pots were and labelled as P-Control, P-a, P-b, P-c and P-d. (Fig 2b)
P-Control- Control pot containing the soil mixture alone
P-a – Soil mixture + 2 g of solid fertilizer evenly mixed
P-b – Soil mixture + 4 g of solid fertilizer evenly mixed
P-c – Soil mixture +6 g of solid fertilizer evenly mixed
P-d – Soil mixture + 8 g of solid fertilizer evenly mixed
S denotes Swamithoppusalt-pan
P denotes Puthalam salt-pan

Figure 2a: Surinum spinach plants grown using solid fertilizer from Swamithoppu bittern

Figure 2(b): Surinum spinach plants grown using solid fertilizer from Puthalam bittern

Growth analysis

The various parameters like the plant height (cm), stem width (cm), maximum leaf width (cm), number of leaves having maximum leaf width and total number of leaves were recorded on the 91th day.

Final monitoring on 91st day—Swamithoppu

A minimum plant height of 45.2 cm was observed for S-control and for S-a, S-b and S-c, it was 45.6, 46.4 and 47.3 cm, respectively. A maximum plant height of 49.2 cm was observed for S-d.

The stem width also increased gradually from S-Control to S-d. A minimum stem width of 2.4 cm was observed for S-Control and for S-a, S-b and S-c it was 2.8, 3.1 and 3.6 cm, respectively. A maximum stem width of 4.5 cm was observed for S-d.

Eighteen leaves were observed for S-Control, of which five leaves had a maximum width of 6.1 cm. S-a had 24 leaves and five leaves had the maximum width of 6.5 cm. For S-b, the total number of leaves was 36, of which six leaves had a maximum leaf width of 7.0 cm. 45 leaves were observed in S-c, of which seven leaves had a maximum leaf width of 7.3 cm. But, a total number of 68 leaves were observed for S-d, of which 9 leaves had a maximum width of 8.1 cm (Table 2).

Final monitoring on 91st day— Puthalam

A minimum plant height of 39.2 cm was observed for P-control and for P-a, P-b and P-c, it was 43.2 cm, 45.3 cm and 48.6 cm, respectively. A maximum plant height of 55.2 cm was observed for P-d (Table 2).

The stem width also increased gradually from P-Control to P-d. A minimum stem width of 2.2 cm was observed for P-Control and for P-a, P-b and P-c it was 2.6, 2.9 and 3.3 cm, respectively. A maximum stem width of 4.5 cm was observed for P-d.

Table 1: Growth analysis of Surinum spinach after the addition of the solid fertilizer prepared from Swamithoppu bittern

Classification	*Plant height (cm)*	*Stem-width (cm)*	*Maximum leaf-width (cm)*	*Number of leaves having maximum leaf width*	*Total number of leaves*
S-Control	45.2	2.4	6.1	5	18
S-a	45.6	2.8	6.5	5	24
S-b	46.4	3.1	7.0	6	36
S-c	47.3	3.6	7.3	7	45
S-d	49.2	4.5	8.1	9	68

Table 2: Growth analysis of Surinum spinach after the addition of solid fertilizer prepared from Puthalam bittern

Classification	*Plant height (cm)*	*Stem-width (cm)*	*Maximum leaf-width (cm)*	*Number of leaves having maximum leaf width*	*Total number of leaves*
P-Control	39.2	2.2	5.8	3	15
P-a	43.2	2.6	6.1	4	20
P-b	45.3	2.9	6.8	5	30
P-c	48.6	3.3	7.0	5	41
P-d	55.2	4.5	7.7	7	61

Fifteen leaves were observed for P-Control, of which, three leaves had a maximum width of 5.8 cm. P-a had 20 leaves, and four leaves had a maximum width of 6.1 cm. For P-b, the total number of leaves was 30, of which five leaves had a maximum leaf width of 6.8. A total leaves of 41 were observed for P-c, of which five leaves had a maximum leaf width of 7.0 cm. But, a total number of 61 leaves were observed for P-d, of which seven leaves had a maximum width of 7.7 cm.

Ash analysis- swamithoppu

Samples from the five different pots were analyzed for various parameters, viz., the percentage of calcium, sodium, sulfate, potassium, iron, manganese, copper and zinc. A gradual increase in the values of all the nutrients from S-Control to S-d was observed (Table 3).

The percentage of potassium was found to increase marginally from S-Control to S-d. A minimum value of 2.51% was observed in S-Control. For S-a to S-d it was 2.53, 2.55, 2.56 and 2.59%, respectively. From the earlier observations, it was found that the sufficient requirement of potassium for spinach was 2.50 to 3.50%. (Table 3).

The percentage of calcium in all five different ash samples was found to increase gradually from S-Control to S-d. S-Control had the minimum value of calcium i.e., 0.71% and for S-a, S-b and S-c it was 0.73, 0.75 and 0.78%, respectively. A maximum value of 0.82% was observed for S-d. From the earlier observations, it was known that the sufficient requirement of calcium for spinach is 0.71 to 1.21%.

The percentage of magnesium was found to increase significantly from 1.0 to 1.6%. S-Control had the minimum percentage of magnesium, i.e., 1.0%. But for S-a, S-b and S-c it was 1.2, 1.3 and 1.5% respectively. A maximum value of 1.6% was observed for S-d. These values were found to be correlate with the earlier observations that 1.0 to 1.6% magnesium is sufficient for spinach.

The percentage of sulfate also increased markedly from S-Control to S-d. S-Control had a minimum percentage of sulphate i.e., 0.21% and for S-a, S-b and S-c it was 0.23, 0.25 and 0.27%, respectively. But S-d recorded the maximum percentage of sulfate, i.e., 0.32%. The above results were in agreement with earlier observations that 0.20 to 1.0% of sulfate is sufficient for spinach.

The trace metals present in the five different samples were also analyzed and a marginal increase was observed from S-Control to S-d (Table 3).

S-Control had a minimum value of iron, i.e., 69 ppm and for S-a, S-b and S-c it was 78, 87 and 111 ppm, respectively. A maximum value of 122 ppm was observed for S-d.

Regarding the values of manganese, it is minimum for S-Control i.e., 72 ppm and for S-a, S-b and S-c it was 76, 89 and 119 ppm, respectively. Maximum value was observed in S-d i.e., 131 ppm.

S-Control had a minimum value of zinc, i.e., 22 ppm for S-a, S-b and S-c it was 26, 29 and 32 ppm. S-d was found to have a maximum value of 35 ppm.

Similarly, the value of copper increased gradually from S-Control from S-d. S-Control had minimum value of 26 ppm. For S-a, S-b and S-c it was 30, 36 and 48 ppm, respectively. S-d had a maximum value of 52 ppm.

Ash analysis- puthalam

Samples from the five different pots were analyzed for various parameters such as the percentage of calcium, sodium, sulfate, potassium, iron, manganese, copper and zinc. A gradual increase in the values of all the nutrients from P-Control to P-d was observed (Table 3).

The percentage of potassium was found to increase marginally from P-Control to P-d. A minimum value of 2.49% was observed in P-Control. For P-a to P-d it was 2.50, 2.51, 2.52 and 2.57%, respectively. From the earlier observations, it was known that the

Table 3: Ash analysis of leaves grown by Swamithoppu fertilizer

Classification	K^+ *(%)*	Ca^{2+} *(%)*	Mg^{2+} *(%)*	SO_4^{2-} *(%)*	*Fe (ppm)*	*Mn (ppm)*	*Zn (ppm)*	*Cu (ppm)*
S-Control	2.51	0.71	1.0	0.21	69	72	22	26
S-a	2.53	0.73	1.2	0.23	78	76	26	30
S-b	2.55	0.75	1.3	0.25	87	89	29	36
S-c	2.56	0.78	1.5	0.27	111	119	32	48
S-d	2.59	0.82	1.6	0.32	122	131	35	52

Table 4: Ash analysis of leaves grown by Puthalam fertilizer

Classification	K^+ *(%)*	Ca^{2+} *(%)*	Mg^{2+} *(%)*	SO_4^{2-} *(%)*	*Fe (ppm)*	*Mn (ppm)*	*Zn (ppm)*	*Cu (ppm)*
P-Control	2.49	0.66	0.94	0.17	64	68	18	21
P-a	2.50	0.68	0.96	0.18	74	73	21	28
P-b	2.51	0.70	0.98	0.20	82	83	23	31
P-c	2.52	0.72	1.0	0.22	101	104	29	40
P-d	2.57	0.74	1.2	0.23	113	125	33	49

sufficient requirement of potassium for spinach was 2.50 to 3.50% (Table-4).

The percentage of calcium in all five different ash samples was found to increase gradually from P-Control to P-d. P-Control had the minimum value of calcium i.e., 0.66% and for P-a, P-b and P-c it was 0.68, 0.70 and 0.72%, respectively. A maximum value of 0.74% was observed for P-d. From the earlier observations, it was observed that the sufficient requirement of calcium for spinach is 0.70 to 1.21%.

The percentage of magnesium was found to increase significantly from 0.94 to 1.2%. P-Control had the minimum percentage of magnesium i.e., 0.94%. But for P-a, P-b and P-c it was 0.96, 0.98 and 1.0%, respectively. A maximum value of 1.2% was observed for P-d. These values were found to be in correlation with the earlier observations that 1.0 to 1.6% magnesium is sufficient for spinach.

The percentage of sulphate also increased markedly from P-Control to P-d. P-Control had a minimum percentage of sulphate, i.e., 0.17% and for P-a, P-b and P-c it was 0.18, 0.20 and 0.22%, respectively. But P-d recorded the maximum percentage of sulphate i.e., 0.23%. The above results were in agreement with earlier observation that 0.20 to 1.0% of sulfate is sufficient for spinach.

The trace metals present in the five different samples were also analyzed and a marginal increase was observed from P-Control to P-d (Table 4).

P-Control had a minimum value of iron, i.e., 64 ppm and for P-a, P-b and P-c it was 74, 82 and 101 ppm, respectively. A maximum value of 113 ppm was observed for P-d.

The value of manganese is minimum for P-Control i.e., 68 ppm and for P-a, P-b and P-c it was 73, 83 and 104 ppm, respectively. Maximum value was observed in P-d, i.e., 125 ppm.

P-Control had a minimum value of zinc, i.e., 18 ppm. For P-a, P-b and P-c it was 21, 23 and 29 ppm. P-d was found to have a maximum value of 33 ppm.

Similarly, the value of copper increased gradually from P-Control from P-d. P-Control had a minimum value of 21 ppm. For P-a, P-b and P-c it was 28, 31 and 40 ppm, respectively. P-d had a maximum value of 49 ppm (Table 5).

Table 5: Standard requirements for Surinum spinach

Classification	*Low value*	*Sufficient value*	*High value*
K^+ (%)	2.0–2.49	2.50–3.50	>9.99
Ca^{2+} (%)	0.50–0.69	0.70–1.21	>5.0
Mg^{2+}(%)	0.40–0.99	1.0–1.60	>3.0
SO_4^{2-} (%)	0.1–0.19	0.20–1.0	>1.0
Fe (ppm)	50–59	60–201	>600
Mn (ppm)	20–29	30–251	>700
Zn (ppm)	20–24	25–61	>300
Cu (ppm)	3–4	5–26	>100

The U.S Department of Agriculture (USDA) National Nutrient Database fo Standard Reference[9]

CONCLUSION AND FUTURE STUDIES

Since bittern is rich in magnesium, sulfate and traces of calcium, sodium, potassium and also trace metals like iron, manganese, copper and zinc, it was tried as a fertilizer for a magnesium-demanding crop like Surinum spinach. When salts are added to soil in reasonable amounts, they feed plants but are not toxic to them. As the addition of solid fertilizer was increased, the growth of Surinum spinach was also found to increase gradually. The intake of all nutrients such as calcium, magnesium, sulfate and potassium was observed in the plants after the addition of solid fertilizer and it was determined by ash analysis. The growth and solubility were found to be satisfactory. Therefore, it is recorded proof that the fertilizers obtained from the bittern samples of the salt pans can be used effectively for plants like suriunum spinach to have a better yield.

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