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Sulfur Uptake and Transport According to its Status Either Organic or Inorganic Form

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Abstract

The objective of this study was to investigate the effects of different sources of sulfur fertilizer either organic as plant residue (composite tea), animal residue (chicken manure) or inorganic fertilizer (potassium sulfate) or industrial waste water on the ionic contents of potassium , sodium , calcium , magnesium, and iron in roots and shoots of broccoli plants (*Brassica oleracea* L. var. italic). As well as sulfur interactions: sulfur content, sulfur requirement, sulfur uptake, rate of transport sulfur from root to shoot and distribution of sulfur in broccoli plants. The obtained results showed that the potassium, sodium, calcium, magnesium, and iron contents in growing plants in different types of soil is closely linked to the stage of plant growth as well as the plant organ and the type of soil used and also on the type and concentration of various fertilizers. The sulfur interactions included changes: in the total sulfur content, sulfur requirements, sulfur uptake and rate of sulfur transport from root to shoot. As well as, the change in the distribution of the sulfur in different plant organs: roots and shoots. Above parameters relied mainly on the soil type and various treatments.
Keywords: Sulfur; Uptake; Transport; Organic; Inorganic; Fertilizers; Broccoli.

1. Introduction

Plant nutrients are importance for producing sufficient and healthy food for the world's expanding population. Plant nutrients are therefore a vital component of any system of sustainable agriculture. Moreover, enhanced flows of plant nutrients are required by agricultural intensification to crops and higher uptake of those nutrients by crops. The decreasing of nutrient stocks in the soil, which is occurring in many developing countries, is a major but often hidden form of land degradation. On the other hand, environmental problems can be caused by excessive applications of nutrients, or inefficient management, especially if large amounts of nutrient are lost from the soil/crop system into water or the air [1] .

Sulfur in the soil can be found as part of organic matter, elemental sulfur (S) and as sulfate (SO_4^{2-}), which is the primary form taken up by plants. Most of the sulfur in the soil is in the soil organic matter and is unavailable for plant uptake until the organic matter is mineralized, which is a slow process. Other sources of sulfur include rainfall (acid rain), plant residue breakdown and manure addition. The addition of sulfur through rainfall has significantly decreased over time, as fewer sulfur-containing fuels are used, especially coal, and from the change to low-sulfur fuels for transportation. Sulfur historically had been added as a byproduct of certain fertilizers, but now more concentrated materials are used without the sulfur byproduct. The reduced atmospheric deposition and use of sulfur-containing fertilizers, combined with increased crop yields, has led to higher incidence of sulfur deficiency.

Sulfur (S) is a significant component of complete and balanced crop nutrition, and has justifiably gained more attention in recent years. Sulfur has long been recognized as a vital element for plant growth and development. Researchers observed Crop responses to applied sulfur in a wide range of soils in many parts of the world [2]. Sulfur has become more important as a limiting nutrient in crop production, clearly show a growing sulfur deficit in the soils of many regions of the world [3] for several seasons .The main reasons for sulfur deficiency are (1) low organic matter content of the soil; (2) unfavorable soil environment cause decrease in mineralization rate of organic matter; (3) depletion of soil reverse due to intensive cultivation and the applied sulfur free fertilizers; (4) declining sulfur reserves on soil due to accelerated rate of soil erosion; (5) use of high rates of nitrogen and potassium fertilizers, which demand high rate of sulfur; (6) the decreased use of S-containing pesticides and fungicides; (7) depletion of sulfur from soils by volatilization and leaching; (8) areas where soil parent materials are low in sulfur; (9) areas of sandy soils with humid and sub humid climates [4]. Sulfur also is a vital nutrient for crops, animals, and

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people. Sulfur occurs naturally in the environment and is the thirteenth most available element in the earth's crust. Following nitrogen, phosphorus, and potassium, sulfur is an essential plant nutrient, necessary for growth and metabolism [5].

2. Sources of Sulfur

Most of the sulfur is contained in organic matter but some is adsorbed on clay particles. So these sources can be summarized as: (1) organic matter, (2) soil minerals, and (3) sulfur gases in the atmosphere. In addition, sulfur is provided also by irrigation water. Sulfur found in the environment in many oxidative states that range from (sulfide S^{2-}) in its most reduced form to (S^{6+}) in its most oxidized form (sulfate- $SO_4{}^{2}$(sulfate- $SO_4{}^{2-}$) [5]. Sulfur dioxide (SO_2), mainly, and hydrogen sulfide (H_2S) are liberated to the atmosphere as a result of volcanic activity. All sulfur compounds are in fixed flux (termed global sulfur cycle) between oxidized and reduced forms through the action of living organisms and chemical processes. Plants use sulfate for the synthesis of diverse primary and secondary metabolites. The first organic compound produced in the sulfate assimilatory mechanism is cysteine (Cys). It is a necessary amino acid incorporated into various proteins, and a precursor of several significant compounds such as methionine, S-adenosylmethionine (SAM), S-methyl methionine, [Fe/S] clusters, hormones, vitamins and enzyme cofactors. Some cys- including metabolites, involving glutathione (GSH) and thionins function in response versus environmental stresses. Organic compounds containing sulfur are also responsible for the special taste and odor of vegetables and herbs used in the kitchen or in traditional medicine [5].

2.1. Sulfur Input to Soils

Atmospheric precipitation, fertilizer addition or mineralization of soil by organic S may be produced by soil sulfate, which is the main sulfur fraction currently, main inputs to soils from mineral fertilizers might be via NPK fertilizers. S-quantities also may be provided by organic manures [6].

2.2. Sulfate Uptake by Plants

Sulfate is taken up by the roots that have high affinity. The uptake of sulfate by the roots and its transport to the shoot is strictly controlled. The plasma membrane of the root cells actively absorb sulfate and transport it to the shoot. On the other hand, the uptake and transport of sulfate is energy dependent (driven by a proton gradient generated by ATPases) Chen and Gallie [7]. Sulfur nutritional status of the plants control regulation and expression of the majority of sulfate transporters [8]. Plants take up SO_2 directly from the air through their stomata. If the concentration is too high photosynthesis is disturbed resulting in chlorosis and necrosis. The severity of this effect depends on a number of factors including temperature, light, plant water content, humidity, duration and level of SO_2 pollution, and plant species [5].

2.3. Sulfur Metabolism

Sulfur (S) has to be reduced to sulfide before it is further assimilated. Root plastids include all sulfate reduction enzymes; however, the reduction of sulfate to sulfide and its subsequent synthesis into cysteine (Cys) occur predominantly in the shoot in the chloroplast [9]. Cysteine and methionine are highly important in the structure; conformation and role of proteins (see the following scheme). Plants contain a large variety of other organic sulfur compounds which act an important role in physiology and protection against environmental stress [10]. Sulfur limitations will result in the loss of plant production, fitness and resistance to environmental stress and pests**.**

2.4. Strategy of Plants Adapted to a Variable or Fluctuating Sulfur Supply

Sulfur uptake is regulated by plants which are able to adapt to a variable or fluctuating sulfur supply [11] for example:

2.4.1. Acquisition when Sulfur is in Short Supply

This is probably a common scenario in many environments, and increasingly a situation occurring in agro-ecosystems if there is no sulfur fertilizer is supplied.

2.4.2. Redistribution throughout the Plant

Re-mobilization of reserves and redistribution around the plant are employed to maximize the usefulness of a lower resource. Requirement to redistribute nitrogen drive the redistribution of protein sulfur however, in some cases, redistribution can occur as a direct result of sulfur deficiency. Redistribution is important if the overall application is limiting or if the supply is intermittent.

2.4.3. Avoiding Excess Uptake

This is a well-studied scenario in the laboratory which at cellular level includes the repression of uptake and assimilation. This is not always successful as with a high external sulfate application, homeostasis may be overwhelmed. In some plants, for example in Brassica, there is a high requirement for sulfur, and the sulfate content of vegetative tissues tends to be high.

3. Use of Chemical Fertilizers

Mineral fertilizers are operated in liquid or solid form, usually in industrial operations. They can provide main nutrients, secondary nutrients, micronutrients or mixtures of nutrients. One nutrient only is provided by straight fertilizers while complex fertilizers supply several. The terms chemical or industrial fertilizers often used for these products but are misleading because the nutrients provided by mineral fertilizers are the same as those applied by the mineralization of organic material through soil micro-organisms. Many agricultural soils of the world are deficient in one or more of the necessary nutrients required for supporting healthy plants. The entire world suffers from food shortage problem as a result of a huge increment of population and the huge loss of agricultural soils due to desertification and erosion problems. Therefore, it is very essential to increase crop productivity by improving the crop ability to mitigate environmental stress conditions including low water availability, soil salinity and nutrients deprivation. The increase of agricultural food production worldwide over the past four decades has been associated with a remarkable increase in the use of fertilizers [12]. Fertilization is the most important and controllable factor affecting the nutritional value of vegetables. The type and value of fertilizer and the level of application directly influence the level of nutrients available to plants and indirectly influence plant physiology and the biosynthesis of secondary compounds in plants. Secondary compounds in plants are known as secondary metabolites or phytonutrients [13]. Commercial fertilizer is a source of plant nutrients that can be provided to soil to nourish crops when the soil cannot supply crop requirements. When a nutrient in the soil is low certain amount of that nutrient is recommended to be applied to provide the total demand of the crop and yield. Fertilizer is the normal and major method of applying the nutrient although animal manures and sludge may be used.

Potassium fertilizer is supplied to improve the yield and quality of plants growing in soils that are lacking a proper supply of this necessary nutrient. The word “potash” is a general term that most frequently means potassium chloride (KCl), but it is also used to all other K-containing fertilizers, such as potassium sulfate (K_2SO_4), commonly referred to as sulfate of potash or SOP [14]. Potassium is a relatively available element in the earth’s crust and production of potash fertilizer occurs in every inhabited continent. Instead it is naturally mixed with salts containing Mg, Na, and Cl. These minerals require additional processing to separate their components. K_2SO_4 is formed by reaction of KCl with sulfuric acid**.** Foliar spray of K_2SO_4 is a convenient way to supply additional K and S to plants, providing the nutrients withdrawn from the soil [15]. Complex system of biogeochemical cycles has often negatively affected the use of chemical fertilizers to increase soil fertility and crop productivity. For example, fertilizer use has caused leaching and runoff of nutrients, especially N and P, resulting in environmental degradation**.** It is also the requirement of the development of organic and ecologicaly friendly agriculture. The intrinsic adaptation mechanisms achieved by plants, under natural and stressed conditions they grow in association with a number of soil microorganisms [16].

3.1. Use of Organic Fertilizers

Soil and underground water are contaminated due to uncontrolled application of chemical fertilizers in agricultural practices production. The movement of agrochemicals through soil to groundwater or their discharge to surface waters represents an ecological risk. It is also accumulated in food chain causing hazardous effects [17]. It is suggested to use organic fertilizers such as compost which are low in cost and friendly environmental amendments. The integrated plant nutrient supply and management system aims at sustaining productivity with minimum deleterious effect on soil health and environment. The system enhances nutrient use efficiency, maintains soil health, enhances yield and reduces cost of cultivation [18]. Some plant tissue can be used as green manure (fresh) that is act in the soil without composting or eating by animals. Compost tea (CT), water-based compost extracts containing large population of beneficial microbes and enhance of soil fertility. Composts or compost extracts used as an organic fertilizer have significant effects on plant growth and considered as a valuable soil amendment [19]**.** According to Litterick, *et al.* [20], consumers of organic food tend to prefer their fruit and vegetables to be organic compared to other food groups because of the perception that these products are more nutritious. Litterick, *et al.* [20], pointed that aerobic compost extract increased strawberry yield meanwhile anaerobic compost extract had no effect. Compost tea sprayed on leaf typically alters the set of organisms on foliage through both inoculation of the organisms from the tea and through supply of nutrient that help support survival of leaf colonizing organisms. Organic fertilizers can therefore be used to lower the amount of toxic compounds produced by conventional fertilizers in vegetables like lettuce. Increased consumer attention of food safety issues and environmental interests has contributed to the development of organic farming over the last few years [21]. However, organic farming is still applied to very small sector of agriculture. Chicken manure is often known as suitable local organic fertilizer. It contains high levels of nutrients, as N, P and high content of organic matter [22]. According to recent studies, the usage of chicken manures (CKM) can be an effective instead of chemical fertilizers. Organic fertilizers should be used in adequate amounts to achieve suitable yield. Nowadays, consumers are requiring higher quality and safer food and highly interested in organic products [23].

Farm income will also increase when farmers use less money on fertilizers and pesticides for growing crops. There is an increase in demand of organically produced vegetables in view of its health and nutritional benefits [24]. Organic fertilizers are increasingly playing a more important role as substitutes to chemical fertilizers, where most organic fertilizers are made of many kinds of agricultural wastes such as animal dung and plant residues [25]. Organic manure can act as an alternative practice to mineral fertilizers for improving soil structure [26] and microbial biomass. It can play a direct function in plant growth as a source of all vital macro and micronutrients in available forms during mineralization and improves physical and chemical properties of soils [27].

3.2. Use of Waste Water

Today, world is facing the challenge of water scarcity. Limitation of water sources has attracted attention of researchers to proper use of unconventional water sources such as brine water and urban and industrial effluents. Due to urban development and increase in water consumption, a large volume of water is produced from raw waste water and treated effluents [28].

A great deal of water used by major cities is converted to urban waste water. Many arid and semiarid areas are exposed to scarcity of water sources, and water demands for irrigation are high. Under these conditions, usage of low quality water sources is being considered. On the other hand, the urbanized areas produced huge amounts of waste water, the inappropriate disposal of which poses environmental problems to the surrounding areas. In this context, [29] investigate that, pollution discharged to the aquatic environment comes mainly reported urban waste water, industrial facilities, animal breeding and agricultural inputs. During last century, water consumption rate increased heavily. Increase in consumption per capita and unplanned use of water sources has led to qualitatively and quantitatively critical conditions of water. Hence, usage of unconventional water sources including urban waste waters, particularly in agriculture, which is the main consumer of water, is of special importance. Many developing countries are not capable to use detailed waste water treatment plans. Millions of farmers in these regions do the farming by using waste water or waste water-polluted sources, where there is no alternative for wastewater [30]. Application of urban waste waters in irrigation has been recommended as a rich source of fertilizing elements in many countries. Waste water can compromise human health through incidence of bacteriological, viral, protozoan and parasitic diseases [31]. Soil pollution is a major cause of change in the quality of the soil. Industrial effluents are responsible for serious water [32] and soil pollution**,** which is considered as one of the major factors responsible for low productivity of crops. Polluted water directly affects soil not only in industrial areas but also in agricultural fields and river beds, creating secondary sources of pollution [33].

Industrial waste has been a major cause in reducing soil fertility and causing great damage because effluent are being added to the neighboring soil and water (used for irrigation) continuously. The harmful nature of industrial effluents in relation to plant growth and development is well recognized owing to the presence of toxic chemicals at a relatively high level [34]. Agricultural production in many countries is being severely affected by the reckless discharge of these effluents to the water bodies near the industrial establishments which are the main source of irrigation. In addition to providing large quantities of water, some effluents contain considerable amount of essential nutrients, which may prove beneficial for plants. Irrigation with waste water is taken into consideration as an option to offset shortage of available water. In this case, it is necessary to assess impacts of using urban waste water on physical and chemical properties to achieve sustainable development [35].

4. Materials and Methods

Pure strain of broccoli (*Brassica oleracea* L. var. *italica*) seeds was kindly supplied by the agriculture research center, ministry of agriculture, Giza, Egypt. Seed beds were well prepared, watered early in the morning with sprinkler till germination and seedling development. After 45 days, uniform plants were transplanted into plastic pots (35 cm in diameter) arranged in green house and filled with different types of soil. Each pot contains 10 kg soil.The area of the experimental plot was 25 m^2 consisted of many rows, each row consist of 5 pots. The plant distance was 50 cm a part on one side; pots were directly irrigated by normal irrigation system. Agricultural management, diseases and pest control program were followed according to the recommendation of the Egyptian ministry of agriculture. The following treatment was used as a source of Sulphur fertilization; industrial waste water as an effluents from El Delta Company for fertilizers of chemical industries (ASMEDA) at a distance of 1 Km from the factory in Talkha region from El- Dakhlia governorate as a source of inorganic sulpher for irrigation (20 mg SO_4^{--} /L); K_2SO_4 (5 ,12.5 and 50 mg/pot) according to Christa, *et al.* [36] and use of compost tea (1 CT : 3 water) according to Hegazi and Algharib [37], chicken manure (CKM 52.3 gm/ 10Kg soil according to Ouda and Mahadeen [38] as a source of organic fertilizers beside to control (without treatment). A preliminary experiments were carried out to test the

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Table-1. Some physical and chemical properties of the used soil with different ratios of clay to sand

Soil characters / Soil type	Soluble ions (mg /100g dry weight soil)												Available (mg\kg)		
	PH	EC	O.C (%)	Ca^{+2}	Mg^{++}	Na^{+}	K^{+}	TSS	$CaCO_3$	HCO_3^- (%)	Cl^- (%)	SO_4^{-2} (%)	N	P	K
100 % clay	7.1	153.4	1.78	26.82	13.85	517.2	81.35	551.2	0.6	0.18	0.143	1.66	48.7	5.92	375
(1:1) (clay : sand v/v)	6.94	146.7	1.72	24.62	12.95	379.8	57.67	360.1	4.9	0.14	1.12	1.45	32.8	4.05	253
(1:2) (clay : sand v/v)	7.4	147.0	1.42	22.41	11.25	242.9	48.27	414.0	3.2	0.12	0.83	1.44	30.4	3.71	241
(1:3) (clay : sand v/v)	6.96	129.5	1.28	20.01	11.13	211.7	36.52	204.7	2.5	0.11	0.67	1.44	29.5	3.52	235
(1:4) (clay : sand v/v)	7.1	144.2	1.18	19.61	10.04	201.6	29.47	404.9	1.2	0.09	0.47	0.91	24.1	3.07	198
100 % sand	7.3	133.6	0.88	18.81	9.52	191.2	22.91	311.5	0.8	0.06	0.28	0.87	22.9	2.93	194

Throughout the growth of plants, sampling was carried out at the three different stages of plant growth first, (14 days old), second (63 days old), third (98 days old) from the transplanting date.

4.1. Determination of Ionic Contents

At the time of sampling, the plant roots were rinsed in distilled water for 30 seconds to remove the soil particles from the root surface and blotted lightly. Thereafter, plants were separated into shoots and roots. Samples were dried in an oven at 80°C till constant dry weight and dry weights of samples were recorded. The dried matter was digested in concentrated HNO_3 and made up to volume with deionized distilled water as described by Motsara and Roy [39]. K^+ and Na^+ concentrations in the plants were measured by Flame-Emission Spectrophotometer. Ca^{+2}, Mg^{+2} and Fe^{+2} concentrations were measured by Atomic Absorption Spectrophotometry (PHF 80B biology Spectrophotometer). Data were calculated as μ mol g^{-1} dry weight.

4.2. Sulfur Content

Approximately 0.5 g of plant sample was pre-digested in 7 ml of HNO_3 for 1h. Then 3.5 ml of 70% $HClO_4$ were added and the contents of the closed Teflon vessel digested at 100% power for 3 min and at 40% for a further 20 min. The samples were made up to 30 ml volume, filtered through a Whatman No.1 filter paper and analyzed by an ARL 3580 ICP spectrometer. Digestion was *accomplished* in a CEM microwave oven (model MDS 2000) as described by Soon, *et al.* [40].

4.3. Sulfur Requirement

The requirement of sulfate by roots and its reduction and further assimilation in the shoot is calculated according to Durenkamp and De Kok [41].

The overall sulfur requirement:

$S_{requirement}$ (μ mol g^{-1} plant day^{-1}) = RGR (% day^{-1}) × $S_{content}$ (μ mol g^{-1} plant)

Where RGR represent the relative growth rate and S content the total plant tissue sulfur content. The RGR can be estimated as follows:

$RGR = (\ln W_2 - \ln W_1)(t_2 - t_1)$

where W_1 and W_2 represent the total weight (g) at time t_1 and t_2, respectively, and t_2-t_1 the time interval (days) between harvests.

4.4. Sulfur Uptake

The rate of sulfate uptake by the roots necessary to meet the plants' sulfur requirement for growth can be estimated according to Castro, *et al.* [42] as follows:

S_{uptake} (μ mol g^{-1} root day^{-1}) = $S_{requirement}$ (μ mol g^{-1} plant day^{-1}) × (S/R_{ratio} +1)

Where S/R_{ratio} represent the shoot (S) to root (R) biomass partitioning of the plant.

4.4.1. The Rate of Sulfur Transport from Root to Shoot

The rate of transport of elements from root to shoot was estimated as:

$J_j = (M_{s2} - M_{s1}) / (W_{r2} - W_{r1}) \times RGR$

Where J_j is the transport of ion J from root to shoot, (M_{s2}- M_{s1}) is the change in ion content of the shoot from time 1 to time 2, (W_{r2}- W_{r1}) is the change in dry weight of the root from time 1 to time 2. RGR represent the relative growth rate of the root on dry weight basis over this period. These were calculated according to Shukry, *et al.* [43].

All the data were subjected to statistical analysis according to the procedures reported by Snedecor and Cochran [44] and means were compared by SPSS multiple ranges tests at 5 % level of probability.

5. Results and Discussion

5.1. Ionic Content

With the forecasts of increasing sulfur deficit in plant production and the need to maintain a high yield quality, one must consider that element in the fertilization not only for the highest-sulfur-requirements of plants. As a result it is necessary to perform research into the effects of sulfur fertilizer application on the chemical composition of yields, especially the content of macroelements. It was demonstrated that fertilizer supplementation into the soil (all used soils) either in organic or inorganic form as well as the application of waste water for irrigation, as compared with control showed a significantly better effect on the content of all tested elements (K^+, Na^+ , Ca^{++} , Mg^{++} and Fe^{++}), as shown in tables (2,3,4,5,6,7). This may be due to , that , the organic manure (CKM and CT) improved the ionic status of soil and make most of ions more available to broccoli plants .These results are in accordance with those obtained by Bvoungyeul, *et al.* [45], who found that, organic composts increased CEC (cation exchange capacity). El-Bassiouny and Shukry [46] found that , the supplementation of soil in the Nubaria region in Egypt with either chicken manure (CKM) or farmyard manure (FYM) increased the accumulation of inorganic solutes (K, Na, Ca, Mg, Zn, Fe, and Cu) in leaves and seeds of cowpea plants. In this respect, Shukry [47] stated that, cattle manure is a valuable fertilizer and soil amendment , and is traditionally applied to the land to increase fertility of calcareous soil. With respect to the effect of the application of the organic fertilizers, it was noticed that, CKM induced, in general, a high increase in the content of K^+, Na^+, Ca^{++}, Mg^{++} and Fe^{++} compared with CT. Plant roots can absorb some larger organic molecules, but their rate of absorption is slow. From a plant root perspective, it makes little difference if the nutrient originally came from different organic fertilizers. In addition, application of chicken manure to soil enhances concentration of water soluble salts in soil [48] which become more available to plants with a reflection effect on the plant growth as obtained in the present results (unpublished), where the treated plants with CKM recorded the best growth than in treatment with CT. In this respect**,** Mufwanzala and Dikinya [49] found that, the utilization of chicken manure as an organic fertilizer is essential in improving soil productivity and crop production. Similarly, organic wastes are also being advocated by different environmental organizations world-wide to preserve the sustainability of agricultural systems. Furthermore, chicken manure is preferred amongst other wastes because of its high concentration of macro-nutrients [50]. Organic residues differ in composition which affects its decomposability. Residues can be decomposed fast or slow. If decomposition is fast, the effect on soil biota is temporary and, for this short time, large, during which many nutrients will become available for plant growth. If decomposability is slow, effects on soil biota is less big but will be maintained for a longer time, nutrients will become available to plants to a limited extent, and organic matter content will be raised for a longer time [51]. Minor improvements in soil fertility were observed with aerated compost tea (ACT) [52]. In the present study, the potassium ion content in both root and shoot of untreated and variously treated broccoli plants showed some variations through three stages of growth. Potassium ion content was increased with the age of plants from first to second stage, then decreased at third stage which may be due to remobilization of potassium to heads of plants. Similar results were obtained by Ouda and Mahadeen [38]. In this respect, Nasreen and Huq [53] stated that, the uptake of potassium by plant components of sunflower with different levels of sulfur showed significant differences over the growth stages. On the other hand, uptake of potassium by stem, was increased over time across the treatments, which was associated with the increase in stem dry matter as recorded in our data (unpublished). The increasing trend of potassium uptake by head including seed was further accelerated by the application of sulfur irrespective of growth stages. Potassium ion contents were more increased by the elemental sulfur form (K_2SO_4) than the organic form in either CT or CKM. In this context Knap, *et al.* [54] stated that, potassium content was higher in conventionally grown basil, cherry, pear, apple, carrot, cucumber, raseperry, pepper, tomato, cherry tomatoes and beet root. The highest potassium content was measured in the conventional beet root with the value of 51.300 mg/ kg. The lowest content had organic apple (5.310 mg/kg). Most crops in this study had higher potassium content produced in conventional farming what is in accordance with Kristl, *et al.* [55] but it is not in agreement with the findings of Roussos and Gasparatos [56]. There was an increase in K content of shoot and root of broccoli with increasing the concentration of K_2SO_4, the higher the rates of applied sulfur, the higher the uptake of potassium (Tables 2,3,4,5,6,7) In this regard, Barczak, *et al.* [57] stated that, the application of 20 kg $S{\cdot}ha^{-1}$ increased Potassium accumulation in lupin plants, as compared with the control treatment, by 11.8%, while the use of 60 kg $S{\cdot}ha^{-1}$ increased by 19.9%. In addition, the potassium ion content in both shoot and root in treatment with K_2SO_4 at low concentration (2.5 mg/ pot) was more or less similar with the treatment by waste water (Tables 2,3,4,5,6,7) Similar results were obtained by Roy, *et al.* [58] who stated that, waste water may supply organic matter and mineral nutrients to soil that are beneficial to crop production, and reduce the cost of fertilizer application. When i grouped samples the order from the highest to the lowest potassium content was as follows: $K_2SO_{4\ (2.5\ mg/pot)} \geq$ waste water > (CKM) > CT, similarly as in Knap, *et al.* [54].

Table-2. Effect of organic and inorganic fertilizers on minerals content of Brassica oleracea plant in 100 % clay soil

Stage	Treatment	K		Na		K/Na		Ca		Fe		Mg	
		Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
I	Initial	129.2	297.9	41.7	58.6	3.1	5.1	53.7	74.2	0.77	1.09	11.6	21.8
	Tap water (control)	165.9	498.2	41.3	61.4	4.02	8.11	67.9	98.3	1.22	3.83	27.6	45.6
	Waste water	173.8	526.4	52.4	79.8	3.32	6.60	78.5	123.9	1.38	4.19	37.9	59.1
	Composite tea	168.7	508.2	45.6	66.2	3.70	7.68	69.8	106.4	1.33	4.12	30.3	54.3
	CKM	171.4	518.7	49.8	72.5	3.44	7.15	74.3	114.8	1.36	4.15	34.1	49.5
	K_2SO_4 (2.5 mg/pot)	176.1	533.9	63.4	95.3	2.78	5.60	91.8	137.2	1.31	4.05	48.9	70.9
	K_2SO_4 (12 mg/pot)	179.4	539.5	59.9	89.9	2.99	6.00	87.1	132.6	1.27	3.96	45.3	66.7
	K_2SO_4 (50 mg/pot)	181.7	547.3	57.5	85.3	3.16	6.42	82.8	128.7	1.25*	3.89	41.4	63.8
	LSD at 5%	0.04	0.05	0.04	0.09	0.11	0.10	0.02	0.06	0.04	0.20	0.12	0.06
II	Tap water (control)	247.2	658.7	120.4	178.4	2.05	3.69	176.9	197.9	1.65	5.11	78.6	130.4
	Waste water	272.3	709.4	138.6	207.9	1.96	3.41	204.1	237.8	1.74	5.33	97.5	159.1
	Composite tea	255.3	666.5	133.5	199.6	1.91	3.34	194.3	228.5	1.68	5.18	91.7	149.5
	CKM	264.4	693.1	135.9	203.7	1.95*	3.40	199.2	232.4	1.70	5.27	94.3	155.3
	K_2SO_4 (2.5 mg/pot)	279.2	701.6	130.1	195.1	2.15*	3.60	189.6	221.8	1.79	5.49	88.6	144.5
	K_2SO_4 (12 mg/pot)	285.6	724.6	126.7	190.4	2.25	3.81	185.8	213.5	1.78	5.44	86.5	138.9
	K_2SO_4 (50 mg/pot)	291.9	750.3	122.8	186.8	2.38	4.02	181.2	205.4	1.77	5.37	81.4	134.7
	LSD at 5%	0.06	0.22	0.09	0.06	0.14	0.01	0.09	0.07	0.01	0.05	0.04	0.03
III	Tap water (control)	222.1	551.7	111.3	165.7	1.99	3.33	152.1	184.4	1.46	4.25	77.1	121.0
	Waste water	280.7	699.0	143.1	218.1	1.96*	3.20	197.4	236.4	1.82	6.00	99.2	162.1
	Composite tea	190.9	640.1	112.4	173.2	1.70	3.70	182.2	229.6	1.63	4.98	89.1	122.2
	CKM	251.1	653.2	120.7	189.0	2.08	3.46	187.7	230.0	1.64	5.1	91.4	130.4
	K_2SO_4 (2.5 mg/pot)	267.0	699.3	129.9	190.1	2.06	3.68	175.1	220.9	1.52	5.31	81.3	129.3
	K_2SO_4 (12 mg/pot)	282.2	710.4	123.0	182.3	2.29	3.90	170.0	213.6	1.49*	5.12	74.2	127.5
	K_2SO_4 (50 mg/pot)	287.3	731.0	119.2	179.4	2.41	4.07	168.5	204.1	1.40	4.94	72.0	122.6
	LSD at 5%	0.03	0.06	0.03	0.07	0.04	0.04	0.02	0.07	0.05	0.08	0.05	0.06

Table-3. Effect of organic and inorganic fertilizers on minerals content of Brassica oleracea plant grown in (1:1) (clay: sand v/v) soil

Stage	Treatment	K		Na		K/Na		Ca		Fe		Mg	
		Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
I	Initial	129.2	297.9	41.7	58.6	3.1	5.1	53.7	74.2	0.77	1.09	11.6	21.8
	Tap water (control)	241.1	580.2	54.6	96.5	4.42	6.01	84.1	120.0	1.56	4.90	42.9	75.1
	Waste water	274.4	651.3	82.5	154.4	3.33	4.22	121.0	184.1	3.14	7.01	65.2	112.2
	Composite tea	254.3	510.9	74.4	133.9	3.42	3.82	110.5	162.9	2.90	5.80	50.0	98.0
	CKM	269.5	648.1	79.0	149.2	3.41	4.34	119.2	170.0	2.95	6.92	58.1	100.4
	K_2SO_4 (2.5 mg/pot)	279.0	710.4	62.3	125.1	4.48*	5.68	104.9	152.3	2.87	5.81	48.7	87.7
	K_2SO_4 (12 mg/pot)	286.2	747.5	60.9	119.0	4.70	6.28	97.3	149.2	1.99	5.60	46.5	72.9
	K_2SO_4 (50 mg/pot)	291.1	762.7	59.1	112.3	4.93	6.79	91.0	140.8	1.81	5.41	39.4	64.8
	LSD at 5%	0.05	0.03	0.04	0.07	0.11	0.08	0.5	0.05	0.07	0.09	0.03	0.1
II	Tap water (control)	269.7	621.2	73.0	111.1	3.69	5.59	210.4	198.2	2.24	5.12	88.3	121.7
	Waste water	326.0	781.6	121.1	341.2	2.69	2.29	340.2	370.0	3.20	7.60	135.4	192.2
	Composite tea	291.8	710.0	108.9	291.3	2.68	2.44	290.7	311.9	2.91	6.10	119.1	152.4
	CKM	319.3	762.1	119.8	310.5	2.67	2.45	299.2	320.2	2.91	7.52	126.2	163.5
	K_2SO_4 (2.5 mg/pot)	341.3	780.3	94.7	284.4	3.60*	2.74	280.3	310.3	2.39	6.20	108.5	141.1
	K_2SO_4 (12 mg/pot)	352.0	791.5	82.5	271.9	4.27	2.91	274.5	291.4	2.20*	6.00	100.0	132.0
	K_2SO_4 (50 mg/pot)	367.7	801.6	80.4	263.0	4.57	3.05	250.6	274.0	2.19*	5.78	98.7	120.9
	LSD at 5%	0.07	0.11	0.07	0.08	0.13	0.06	0.2	0.6	0.07	0.08	0.04	0.09
III	Tap water (control)	262.2	612.1	70.3	100.2	3.73	6.1	206.1	187.1	2.19	5.10	82.0	121.2
	Waste water	328.9	790.7	123.2	335.7	2.67	2.36	339.5	362.9	3.41	7.43	124.9	187.7
	Composite tea	284.4	690.2	100.6	282.0	2.83	2.45	281.6	290.8	2.77	6.07	110.0	140.5
	CKM	310.2	740.9	110.5	300.4	2.73	2.47	278.4	291.2	2.61	7.32	120.2	132.0
	K_2SO_4 (2.5 mg/pot)	362.0	784.7	93.1	262.8	3.89	2.99	272.3	300.4	2.27	6.11	100.8	122.8
	K_2SO_4 (12 mg/pot)	374.1	804.0	79.0	259.0	4.74	3.10	261.7	240.6	2.19*	5.84	97.6	115.1
	K_2SO_4 (50 mg/pot)	387.5	819.3	74.0	244.1	5.24	3.36	224.0	221.7	2.08	5.49	87.1	109.7
	LSD at 5%	0.05	0.10	0.06	0.09	0.11	0.08	0.09	0.04	0.05	0.08	0.03	0.12

*Non-significant LSD at 5%

Table-4. Effect of organic and inorganic fertilizers on minerals content of Brassica oleracea plant grown in (1: 2) (clay: sand v/v) soil

Stage	Treatment	K		Na		K/Na		Ca		Fe		Mg	
		Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
I	Initial	129.2	297.9	41.7	58.6	3.1	5.1	53.7	74.2	0.77	1.09	11.6	21.8
	Tap water (control)	209.0	531.8	52.0	87.8	4.02	6.06	79.1	100.0	1.49	4.32	32.6	62.3
	Waste water	324.3	694.3	70.4	114.7	4.61	6.05*	102.2	164.2	2.53	7.04	52.4	84.2
	Composite tea	288.9	517.2	64.6	99.1	4.47	5.22	89.6	147.9	2.15	6.71	42.3	61.4
	CKM	319.2	670.4	68.7	110.4	4.65	6.07*	97.5	159.1	2.41	6.86	49.3	79.5
	K_2SO_4 (2.5 mg/pot)	335.1	699.4	62.1	90.3	5.40	7.75	87.4	138.3	1.89	6.60	38.9	59.9
	K_2SO_4 (12 mg/pot)	342.7	706.1	60.3	90.0	5.68	7.85	83.3	131.4	1.74	6.42	35.4	54.7
	K_2SO_4 (50 mg/pot)	355.2	714.0	58.3	89.0	6.09	7.94	79.0*	130.5	1.62	5.14	31.0	48.4
	LSD at 5%	0.04	0.09	0.05	0.12	0.04	0.06	0.12	0.03	0.01	0.04	0.08	0.13
II	Tap water (control)	262.3	620.9	104.3	188.5	2.51	3.29	182.7	166.7	1.75	5.07	84.2	141.8
	Waste water	381.2	682.0	165.4	311.8	2.30	2.19	314.8	315.4	3.01	8.10	111.5	197.0
	Composite tea	310.9	590.7	143.5	289.1	2.17	2.04	291.9	276.1	2.29	7.41	98.8	175.1
	CKM	363.1	672.2	159.9	299.0	2.27	2.25	298.7	309.0	2.91	7.92	100.7	182.0
	K_2SO_4 (2.5 mg/pot)	396.3	710.8	140.3	272.7	2.82	2.61	281.8	241.2	2.71	7.15	89.7	164.8
	K_2SO_4 (12 mg/pot)	406.4	721.0	137.2	269.9	2.96	2.67	276.2	239.3	2.66	7.09	84.1	160.2
	K_2SO_4 (50 mg/pot)	411.7	737.3	134.9	265.3	3.05	2.78	270.2	227.6	2.40	6.98	76.9	158.3
	LSD at 5%	0.05	0.08	0.05	0.11	0.03	0.03	0.10	0.04	0.01	0.06	0.06	0.12
III	Tap water (control)	260.2	617.2	102.7	181.6	2.53	3.40	177.9	154.2	1.64	4.96	80.0	132.5
	Waste water	390.1	687.8	167.4	316.3	2.33	2.17	312.7	306.7	3.04	8.13	116.4	190.2
	Composite tea	310.7	584.1	137.7	283.4	2.26	2.06	281.4	264.9	2.27	7.32	94.2	164.7
	CKM	359.3	670.7	142.6	282.2	2.52*	2.38	274.3	302.8	2.87	7.74	97.3	171.9
	K_2SO_4 (2.5 mg/pot)	399.6	712.3	131.2	267.5	3.05	2.66	270.0	235.0	2.64	7.06	82.2	142.4
	K_2SO_4 (12 mg/pot)	415.2	729.0	130.8	257.0	3.17	2.84	266.1	221.2	2.57	6.87	79.9	151.1
	K_2SO_4 (50 mg/pot)	441.0	741.5	128.5	253.1	3.43	2.93	258.7	219.1	3.31	6.64	74.5	150.0
	LSD at 5%	0.07	0.06	0.04	0.09	0.03	0.05	0.08	0.06	0.03	0.05	0.06	0.10

Table-5. Effect of organic and inorganic fertilizers on minerals content of Brassica oleracea plant grown in (1: 3) (clay: sand v/v) soil

Stage	Treatment	K		Na		K/Na		Ca		Fe		Mg	
I		Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
	Initial	129.2	297.9	41.7	58.6	3.1	5.1	53.7	74.2	0.77	1.09	11.6	21.8
	Tap water (control)	201.9	524.3	49.0	84.0	4.12	6.24	72.3	102.3	1.43	4.52	31.1	64.3
	Waste water	265.5	610.0	74.6	129.9	3.56	4.70	92.1	176.7	2.49	6.14	54.9	92.9
	Composite tea	220.4	481.0	62.4	101.1	3.53	4.76	82.9	150.2	2.09	5.41	46.2	73.2
	CKM	241.3	597.9	62.7	118.2	3.85	5.06	90.2	164.3	2.41	5.92	50.0	89.1
	K_2SO_4 (2.5 mg/pot)	271.3	624.1	59.9	98.8	4.53	6.32	81.8	143.4	1.90	5.40	42.4	67.0
	K_2SO_4 (12 mg/pot)	282.9	630.2	55.2	91.3	5.13	6.90	75.1	137.5	1.87	5.31	39.7	58.8
	K_2SO_4 (50 mg/pot)	294.4	635.7	50.1	87.7	5.88	7.25	76.9	129.0	1.74	5.27	36.3	50.7
	LSD at 5%	0.07	0.04	0.04	0.13	0.04	0.08	0.12	0.02	0.03	0.08	0.06	0.11
II	Tap water (control)	252.2	614.6	92.3	187.2	2.73	3.28	179.0	204.2	1.96	5.66	90.9	135.3
	Waste water	314.5	661.7	141.3	309.5	2.23	2.14	301.1	320.9	2.96	7.09	121.7	196.4
	Composite tea	284.8	512.9	136.9	290.8	2.08	1.76	281.2	298.1	2.11	6.82	108.2	182.0
	CKM	293.4	646.5	139.6	308.6	2.10	2.09	290.4	309.9	2.77	6.91	119.9	190.1
	K_2SO_4 (2.5 mg/pot)	325.1	667.1	132.7	264.7	2.45	2.52	270.7	255.8	2.08	5.72*	98.2	172.2
	K_2SO_4 (12 mg/pot)	337.0	689.7	126.9	261.4	2.66	2.64	264.6	247.2	2.00*	5.63*	97.3	169.2
	K_2SO_4 (50 mg/pot)	344.2	711.0	124.8	258.3	2.76	2.75	249.8	238.4	1.95	5.42	84.9	161.4
	LSD at 5%	0.05	0.08	0.03	0.12	0.03	0.05	0.15	0.04	0.08	0.09	0.10	0.13
III	Tap water (control)	251.3	610.2	89.2	183.0	2.82	3.33	164.7	200.2	1.81	5.42	86.2	124.1
	Waste water	315.3	665.1	144.4	310.2	2.18	2.14	306.5	323.6	2.94	7.12	120.4	190.0
	Composite tea	281.0	509.2	132.1	274.1	2.13	1.86	280.3	274.8	2.07	6.81	105.5	179.7
	CKM	290.7	642.1	138.5	300.0	2.10	2.14	272.8	292.7	2.65	6.74	110.1	182.9
	K_2SO_4 (2.5 mg/pot)	326.1	681.3	130.7	253.5	2.50	2.69	264.2	243.1	2.00	5.66	87.4	165.3
	K_2SO_4 (12 mg/pot)	349.7	704.0	121.8	249.0	2.87	2.83	260.9	242.0	1.87*	5.41*	80.3	159.8
	K_2SO_4 (50 mg/pot)	352.9	721.1	119.9	246.0	2.94	2.93	232.1	229.0	1.76*	5.31	79.8	141.5
	LSD at 5%	0.07	0.07	0.04	0.10	0.04	0.05	0.13	0.05	0.07	0.05	0.07	0.12

Table-6. Effect of organic and inorganic fertilizers on minerals content of Brassica oleracea plant grown in (1: 4) (clay: sand v/v) soil

Stage	Treatment	K		Na		K/Na		Ca		Fe		Mg	
I		Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
	Initial	129.2	297.9	41.7	58.6	3.1	5.1	53.7	74.2	0.77	1.09	11.6	21.8
	Tap water (control)	172.1	499.9	52.0	69.0	3.31	7.24	79.9	110.1	1.42	4.18	35.3	62.1
	Waste water	186.4	640.4	74.1	95.1	2.52	6.73	93.4	192.0	1.94	6.25	62.0	81.0
	Compositetea	176.3	599.0	62.4	86.2	2.83	6.95	83.1	179.3	1.73	5.84	59.2	75.5
	CKM	184.0	631.3	69.3	90.3	2.66	6.99	90.2	185.2	1.86	5.99	61.1	79.7
	K_2SO_4 (2.5 mg/pot)	189.2	742.9	64.2	84.7	2.95	8.77	89.3	142.4	1.54	4.00	51.4	72.3
	K_2SO_4 (12 mg/pot)	190.0	746.5	60.8	83.8	3.13	8.91	87.9	140.7	1.49	3.92	49.5	70.4
	K_2SO_4 (50 mg/pot)	193.5	759.9	60.9	80.9	3.18	9.39	84.0	138.9	1.38	3.72	47.9	69.9
	LSD at 5%	0.06	0.05	0.02	0.12	0.05	0.06	0.11	0.02	0.01	0.03	0.07	0.12
II	Tap water (control)	250.7	664.4	133.1	197.1	1.88	3.37	190.5	215.8	1.81	7.12	84.7	165.5
	Waste water	290.9	791.4	210.7	240.0	1.38	3.30	251.4	264.2	2.14	9.52	115.2	194.4
	Compositetea	275.4	752.2	199.4	220.2	1.38	3.42	215.2	252.1	1.99	8.64	99.9	186.1
	CKM	282.2	764.9	206.0	235.4	1.37	3.25	248.2	260.4	2.01	9.39	110.0	189.0
	K_2SO_4 (2.5 mg/pot)	310.2	804.3	200.2	219.4	1.55	3.67	198.0	235.5	1.89	7.42	94.1	182.2
	K_2SO_4 (12 mg/pot)	312.0	825.1	199.0	216.5	1.57	3.81	196.1	230.3	1.83*	7.31	92.9	181.9
	K_2SO_4 (50 mg/pot)	325.1	861.0	188.3	210.3	1.73	4.09	183.2	221.0	1.79*	7.29	89.4	181.7
	LSD at 5%	0.04	0.09	0.04	0.12	0.04	0.02	0.11	0.03	0.03	0.07	0.09	0.11
III	Tap water (control)	235.3	635.0	125.9	172.2	1.87	3.69	187.3	210.0	1.70	6.15	82.3	152.0
	Waste water	292.4	777.1	198.7	251.0	1.47	3.09	253.7	266.2	2.15	9.60	119.0	196.9
	Compositetea	270.2	749.9	170.3	211.7	1.59	3.54	214.4	250.1	1.92	8.60	99.2	182.1
	CKM	279.3	764.7	187.2	231.9	1.49	3.30	242.8	259.9	1.98	9.31	109.7	184.4
	K_2SO_4 (2.5 mg/pot)	330.4	790.2	161.0	211.4	2.18	3.74	192.9	225.7	1.74*	7.31	90.3	178.3
	K_2SO_4 (12 mg/pot)	352.1	794.8	154.1	209.1	2.28	3.80	189.0	219.4	1.72*	7.26	89.4	169.5
	K_2SO_4 (50 mg/pot)	369.9	811.4	143.4	199.1	2.58	4.08	180.1	211.3	1.70*	7.14	87.2	165.6
	LSD at 5%	0.08	0.07	0.03	0.08	0.02	0.04	0.07	0.05	0.07	0.02	0.04	0.13

Table-7. Effect of organic and inorganic fertilizers on minerals content of Brassica oleracea plant grown in 100 % sand soil

Stage	Treatment	K		Na		K/Na		Ca		Fe		Mg	
I		Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
	Initial	129.2	297.9	41.7	58.6	3.1	5.1	53.7	74.2	0.77	1.09	11.6	21.8
	Tap water (control)	141.1	312.0	45.4	61.5	3.11	5.07	65.1	82.1	0.92	1.74	20.3	30.7
	Waste water	152.3	425.1	56.8	68.0	3.68	6.25	72.9	110.0	1.32	3.19	47.1	62.0
	Composite tea	132.0	370.4	49.9	66.1	2.65	5.60	60.2	97.4	1.19	2.74	37.9	47.2
	CKM	143.2	389.3	51.6	65.4	2.78	6.09	69.5	100.0	1.24	2.99	38.2	59.8
	K_2SO_4 (2.5 mg/pot)	157.4	430.0	50.0	63.3	3.15*	6.79	54.4	94.2	1.11	2.65	27.4	37.5
	K_2SO_4 (12 mg/pot)	169.5	451.9	48.1	62.2	3.52	7.27	50.3	90.3	1.9	2.44	25.0	35.4
	K_2SO_4 (50 mg/pot)	170.9	509.7	44.6	62.4	3.83	8.17	48.2	87.5	1.2	1.98	22.3	30.9*
	LSD at 5%	0.08	0.03	0.03	0.12	0.04	0.09	0.11	0.04	0.09	0.06	0.08	0.14
II	Tap water (control)	140.2	420.8	62.0	72.3	2.26	5.82	71.0	103.0	1.14	2.29	41.5	74.3
	Waste water	155.3	540.6	94.3	92.1	1.65	5.87*	100.4	145.1	1.49	4.00	62.7	103.0
	Composite tea	137.4	499.0	82.8	83.0	1.66	6.01	84.7	110.4	1.23	3.00	46.9	88.2
	CKM	149.5	511.1	89.1	89.9	1.68	5.69	92.1	132.0	1.35	3.17	59.6	93.1
	K_2SO_4 (2.5 mg/pot)	160.0	608.3	79.4	79.7	2.02	7.63	79.9	106.2	1.20	2.91	39.8	89.3
	K_2SO_4 (12 mg/pot)	169.9	624.2	78.9	80.4	2.15	7.76	75.3	105.5	1.17*	2.87	40.2	87.0
	K_2SO_4 (50 mg/pot)	174.1	681.4	70.7	75.2	2.46	9.06	73.5	103.7	1.15*	2.80	38.0	80.5
	LSD at 5%	0.06	0.08	0.04	0.14	0.02	0.06	0.13	0.03	0.04	0.05	0.03	0.12
III	Tap water (control)	132.3	413.3	50.9	69.5	2.60	5.95	70.2	77.2	1.09	2.18	40.2	69.3
	Waste water	155.0	531.0	82.2	97.3	1.89	5.46	89.1	139.3	1.39	3.72	64.1	107.8
	Composite tea	129.9	480.7	74.4	79.2	1.75	6.07	79.4	101.4	1.18	2.65	33.4	72.0
	CKM	131.7	491.5	78.0	80.0	1.69	6.15	84.3	122.1	1.32	2.80	42.3	84.4
	K_2SO_4 (2.5 mg/pot)	156.4	577.5	61.1	76.3	2.56	7.57	78.1	98.0	1.11*	2.54	30.0	74.8
	K_2SO_4 (12 mg/pot)	160.2	609.2	58.3	70.1	2.75	8.69	76.7	84.8	1.09*	2.42	22.6	70.9
	K_2SO_4 (50 mg/pot)	166.1	671.4	58.6	70.4	2.83	9.54	69.0	82.9	1.09*	2.38	20.3	69.1
	LSD at 5%	0.08	0.06	0.04	0.11	0.02	0.05	0.10	0.04	0.07	0.02	0.04	0.10

Potassium is needed to complete many essential functions in plants, such as activating enzyme reactions, synthesis of proteins, starch, sugars regulating water flow in plant tissues cells and leaves. Potassium sulfate is an excellent source of nutrition for plants [59, 60].

The changes in the contents of Na^+ ion (Tables 2,3,4,5,6,7) revealed that, different treatments under investigation induced a significant increase in Na ion content of broccoli root and shoots comparing with the control throughout the three experimental growth stages. Regarding the different treatments, the waste water induced the highest values followed by organic fertilizers (CKM > CT) and inorganic fertilizers in all used soils except in clay soil at first stage, where inorganic fertilizers recorded the highest values than the other treatments. In general, a gradual increase in K_2SO_4 concentration followed by a decrease in Na^+ ion content of broccoli shoots and roots, this may be due to continuous supply of minerals from waste water during experimental period, similarly, this increase in Na was probably due to the high Na contents in the irrigation with waste water, and consequently in the soil.

Consequently, there were variations in K/Na ratio of broccoli plants in different used soils with different treatments according to variation in both contents of K^+ and Na in shoots and roots. It was obvious that (Table 4), the highest K/Na ratio was obtained in the used soil (1: 2 clay: sand v/v) and sandy soil for root and shoot respectively. Meanwhile the higher values over the experimental period were obtained in plants treated with K_2SO_4 except in clay soil, the control in first stage showed the higher values.

The influence of different treatments applied to different used soils on Ca^{++} ion content revealed that, there was a significant increase in Ca^{++} content of broccoli roots and shoot comparing with the control. Organic fertilizer achieved the higher values in Ca^{++} content than that of inorganic one except in 100% clay soil at first stage. This in agreement with those obtained with Knap, *et al.* [54]. Calcium content in crops was in the most cases quite uniform regarding different methods of farming. Basil, parsley, and celery had higher content of Ca^{++} in organic samples as compared to conventional one. On the other hand, calcium content was higher in the conventionally grown broccoli and cucumber as compared to organic ones. Likewise, Ca^{++} content of egg plants, tomatoes and beetroots were quite higher in conventionally grown crops. Regardless many authors [56, 61] reported higher contents of minerals (Ca^{++}, K^+ and P^{+++}) in the crops from organic farming , meanwhile the superior values, at all, achieved by using (100%)waste water [62].

For Mg^{++} ion content, there was a significant increase in shoots and roots of treated broccoli plants in response to organic fertilizers and waste water in all the used soils. Meanwhile the treatments with K_2SO_4, induced a significant decrease at moderate and high concentrations (12.5 and 50 mg/Pot) in roots and in treatment with high concentration (50 mg/Pot) in shoot of most of the used soils, with the exception of the used soil (1:4) (clay: sand v/v) which recorded a significant increase in all treatments in both shoots and roots through stages of growth. It was claimed that a good supply of sulfur decreases the contents of calcium and magnesium [63].

In this concept, Worthington [21] compared results from 1240 studies and found that organic fruits and vegetables contained more minerals than conventionally grown crops. Likewise, Wszelaki, *et al.* [64] found more K, Mg, P, S and Cu in organically grown potatoes in comparison to the conventional potatoes. Widely excepted reason is that organic matter in soil makes minerals, due to slower release less prone to leaching and thus more available to be absorbed by the roots [65]. Soil's pH has been shown to modulate the uptake of the macronutrient Ca^{++} and Mg^{++}.

There was , in general a significant increase in Fe^{++} content in all treatments over control (Tables 2,3,4,5,6,7) this in accordance with those obtained by Ouda and Mahadeen [38] who stated that, each increase in organic manure and inorganic fertilizers dosages resulted in an increase in Fe, Mn and Zn leaf contents of broccoli plants. Meanwhile, there was a significant decrease in the content of these elements in shoot of broccoli plants of the used soil (1: 4) (clay: sand v/v) in treatment with different concentrations of inorganic fertilizers. A non-significant change was observed in roots of most different used soils at different stages in treatments with moderate and the highest concentrations (12.5 & 50 mg/pot) of K_2SO_4. Waste water treatment significantly recorded the highest content of iron compared with other treatments.

In this respect, Ouda and Mahadeen [38] stated that, the differences in some cases were found non-significant. The highest content of Fe^{++}, Mn^{++}, and Zn^{++} in broccoli leaf was observed by application of the highest dosages of inorganic fertilizer, whereas the lowest leaf content was observed by control treatment [66]. The effect of organic manure on Fe^{++} uptake, may be due to the reason that organic carbon acts as a source of energy for soil microorganism, which upon mineralization releases organic acids that decreased soil pH and improves availability of Fe^{++} [67].

5.2. Interaction of Sulfur

5.2.1. Sulfur Content

For economic and environmental reasons, optimization of S fertilization is required, and several diagnostic tools to enable evaluation of plant S status have been proposed. However, due to spatial and temporal soil variability, S or SO_4^{-2} concentrations in the soil are not usually considered appropriate [68]. The results reported in the present investigation (Tables 8,9,10,11,12,13) show that , broccoli (*Brassica oleracea* L. var italica) plants have a general increase of sulfur in both root , shoot and consequently the total sulfur content owing to application of organic (CT or CKM) or inorganic fertilizers (K_2SO_4 at all concentrations) as well as the irrigation with industrial waste water. *Brassica oleracea* belongs to brassicaceae (the mustard family; [69] are characterized by a high growth rate and a high sulfur requirement [70, 71]. In most of the used soils, the CKM- treated plants recorded the highest content of sulfur than that treated with CT. This may be due to that the decomposition of organic S and its mineralization to inorganic sulfate anion in CKM may be was faster than in CT. Sulfate, like most anions, is somewhat mobile in soils and therefore subject to leaching. Soil conditions where S is most likely to be deficient include low organic matter levels, coarse (sandy) texture with high drainage. Meanwhile, in the used soil 100% sand the reverse situation was occurred, where the content of total sulfur of broccoli plants in response to CT was higher than CKM. Sulfur content in both roots and shoots as well as total sulfur in the treated plants with K_2SO_4 concentrations (2.5 , 12 and 50 mg/pot), was significantly increased comparing with the control except in 100% clay soil at third stage, and 1:4 (clay :sand v/v) soil at second and third stages and in 100% sand soil at first stage , where the total sulfur content was decreased significantly by all concentrations of K_2SO_4 (2.5 , 12 and 50 mg/ Pot), comparing with the control , meanwhile there was a decrease at high concentration (50 mg/pot) at first stage in the used soils (1:2 , 1:3 clay : sand v/v) and at moderate and high concentrations (12 and 50 mg/pot) at third stage in the used soil (1:4) (clay :sand v/v). This may be due to variation in the availability of sulfur in the different used soils as recorded in (Table 1), where the capacity of soils to adsorb SO_4^{-2} is dependent on a number of physical and chemical properties. Factors affecting SO_4^{-2} adsorption include pH, type of cation present, presence of competing anions, extractable Al^{+3} and Fe^{+3} fractions, extractable SO_4^{-2}, organic C, clay content, and soil horizon type [72]. Hoeft, *et al.* [73], reported that the inclusion of pH with extractable S significantly improved the prediction of S response. Although most soils contain, with, a sufficiently high amount of sulfur (0.01 to 0.05 %), not all soils meet the plants' needs of sulfur. To be suitable as a plant nutrient, sulfur not only must be available in the soil at the proper concentration, but also in the proper form. Thus, the nutritional status of a plant for sulfur is determined by both the availability of sulfate to the roots and the availability of volatile sulfur to the leaves [74]. In the present investigation, in general, an increase of sulfur application tended to increase the content of sulfur in plants comparing with the control, especially in the second growth phase and following the application of S- SO_4^{-2}. This in accordance with those obtained by Skwierawska, *et al.* [75] who stated that, an increase of sulfur rates tended to increase the content of sulfates in plants, especially in the juvenile growth phase and following the application of S- SO_4^{-2} The maximum doses of sulfur caused its luxury uptake, particularly in the second and third year of the experiment on cabbage, onion and barley plants. Similar correlations were detected by Sud, *et al.* [76].

Table-8. Effect of organic and inorganic fertilizers on sulfur parameters of Brassica oleracea plant grown in 100 % clay soil

Stage	Treatments	S content in root	S content in shoot	(S+R)
	Initial	74.1	100.0	174.1
I	(control)	78.9	105.4	184.3
	Waste water	99.8	130.7	230.5
	Composite tea	91.2	115.6	206.8
	CKM	97.1	125.3	222.4
	K_2SO_4 (2.5 mg/pot)	89.9	114.5	204.4
	K_2SO_4 (12 mg/pot)	86.8	109.4	196.2
	K_2SO_4 (50 mg/pot)	84.9	107.3	192.2
	LSD at 5%	0.09	0.05	0.11
II	(control)	101.9	290.4	392.3
	Waste water	128.5	409.1	537.6
	Composite tea	122.6	398.6	521.2
	CKM	125.7	403.8	529.5
	K2SO4 (2.5 mg/pot)	119.0	345.7	464.7
	K2SO4 (12 mg/pot)	112.3	310.8	423.1
	K_2SO_4 (50 mg/pot)	104.8	302.7	407.5
	LSD at 5%	0.06	0.03	0.15
III	(control)	100.9	227.9	328.8
	Waste water	129.7	297.5	427.2
	Composite tea	121.5	232.0	353.5
	CKM	120.3	284.7	405.0
	K_2SO_4 (2.5 mg/pot)	115.5	198.2	313.7
	K_2SO_4 (12 mg/pot)	110.0	187.9	297.9
	K_2SO_4 (50 mg/pot)	98.0	184.1	282.1
	LSD at 5%	0.04	0.04	0.13

*Non-significant LSD at 5%

Table-9. Effect of organic and inorganic fertilizers on sulfur parameters of Brassica oleracea plant grown in (1:1) (clay: sand v/v) soil

Stage	Treatments	S content in root	S content in shoot	(S+R)
	Initial	74.1	100.0	174.1
I	(control)	99.9	121.3	221.2
	Waste water	135.1	242.0	377.1
	Composite tea	117.2	197.9	315.1
	CKM	129.0	221.4	350.4
	K_2SO_4 (2.5 mg/pot)	112.3	193.3	305.6
	K_2SO_4 (12 mg/pot)	110.7	189.2	299.9
	K_2SO_4 (50 mg/pot)	100.9	178.7	279.6
	LSD at 5 %	0.08	0.06	0.14
II	(control)	147.4	143.1	290.5
	Waste water	282.4	312.2	594.6
	Composite tea	264.9	277.4	542.3
	CKM	275.3	300.3	575.6
	K_2SO_4 (2.5 mg/pot)	260.2	249.5	509.7
	K_2SO_4 (12 mg/pot)	253.0	234.6	487.6
	K_2SO_4 (50 mg/pot)	249.0	227.2	476.2
	LSD at 5 %	0.07	0.03	0.14
III	(control)	143.2	139.7	282.9
	Waste water	287.7	311.8	599.5
	Composite tea	251.6	244.8	496.4
	CKM	264.2	291.1	555.3
	K_2SO_4 (2.5 mg/pot)	261.5	232.2	493.7
	K_2SO_4 (12 mg/pot)	243.1	215.0	458.1
	K_2SO_4 (50 mg/pot)	239.0	209.0	448.0
	LSD at 5 %	0.03	0.05	0.012

*Non-significant LSD at 5%

Table-10. Effect of organic and inorganic fertilizers on sulfur parameters of Brassica oleracea plant grown in (1: 2) (clay: sand v/v) soil

Stage	Treatments	S content in root	S content in shoot	(S+R)
	Initial	74.1	100.0	174.1
I	(control)	92.0	109.3	201.3
	Waste water	106.1	181.0	287.1
	Composite tea	86.9	124.9	211.8
	CKM	98.5	132.7	231.2
	K_2SO_4 (2.5 mg/pot)	84.7	131.8	216.5
	K_2SO_4 (12 mg/pot)	81.9	129.4	211.3
	K_2SO_4 (50 mg/pot)	80.7	117.8	188.6
	LSD at 5 %	0.07	0.04	0.13
II	(control)	98.3	272.7	371.0
	Waste water	210.2	420.6	630.8
	Composite tea	178.0	358.5	536.5
	CKM	198.1	411.1	609.2
	K2SO4 (2.5 mg/pot)	173.5	409.4	582.9
	K2SO4 (12 mg/pot)	165.4	396.2	561.6
	K_2SO_4 (50 mg/pot)	161.3	387.2	548.5
	LSD at 5 %	0.06	0.03	0.14
III	(control)	97.1	268.0	365.1
	Waste water	211.2	421.3	632.5
	Composite tea	165.3	387.2	552.5
	CKM	190.4	410.4	600.8
	K_2SO_4 (2.5 mg/pot)	172.1	402.5	574.6
	K_2SO_4 (12 mg/pot)	163.9	372.7	536.6
	K_2SO_4 (50 mg/pot)	161.0	370.9	531.9
	LSD at 5 %	0.04	0.04	0.13

*Non-significant LSD at 5%

Table-11. Effect of organic and inorganic fertilizers on sulfur parameters of Brassica oleracea plant grown in (1: 3) (clay: sand v/v) soil

Stage	Treatments	S content in root	S content in shoot	(S+R)
	Initial	74.1	100.0	174.1
I	(control)	95.3	112.3	207.6
	Waste water	107.2	196.0	303.2
	Composite tea	86.9	139.9	226.8
	CKM	99.0	146.7	245.7
	K_2SO_4 (2.5 mg/pot)	85.9	137.2	223.1
	K_2SO_4 (12 mg/pot)	82.1	135.4	217.5
	K_2SO_4 (50 mg/pot)	81.5	119.5	201.0
	LSD at 5 %	0.07	0.05	0.14
II	(control)	99.3	265.3	364.6
	Waste water	215.2	399.2	614.4
	Composite tea	181.-0	372.0	553.0
	CKM	192.1	379.1	589.2
	K_2SO_4 (2.5 mg/pot)	180.2	364.5	544.7
	K_2SO_4 (12 mg/pot)	179.6	359.7	539.3
	K_2SO_4 (50 mg/pot)	172.7	342.2	514.9
	LSD at 5 %	0.05	0.03	0.13
III	(control)	97.0	260.0	357.0
	Waste water	217.1	401.2	618.3
	Composite tea	180.3	361.8	542.1
	CKM	190.2	395.4	585.6
	K_2SO_4 (2.5 mg/pot)	177.4	341.9	519.3
	K_2SO_4 (12 mg/pot)	172.5	339.7	512.2
	K_2SO_4 (50 mg/pot)	170.0	337.6	507.6
	LSD at 5 %	0.04	0.04	0.13

*Non-significant LSD at 5%

Table-12. Effect of organic and inorganic fertilizers on sulfur parameters of Brassica oleracea plant grown in (1: 4) (clay: sand v/v) soil

Stage	Treatments	S content in root	S content in shoot	(S+R)
	Initial	74.1	100.0	174.1
I	(control)	75.3	103.1	178.4
	Waste water	93.0	127.9	220.9
	Composite tea	84.1	113.7	197.8
	CKM	90.4	125.1	215.5
	K_2SO_4 (2.5 mg/pot)	82.7	112.8	195.5
	K_2SO_4 (12 mg/pot)	80.5	108.0	188.5
	K_2SO_4 (50 mg/pot)	79.9	105.2	185.1
II	(control)	95.0	242.5	337.5
	Waste water	125.1	395.9	521.0
	Composite tea	119.4	291.7	411.1
	CKM	120.9	391.0	511.9
	K_2SO_4 (2.5 mg/pot)	112.7	225.1	337.8
	K_2SO_4 (12 mg/pot)	109.8	214.4	324.2
	K_2SO_4 (50 mg/pot)	102.1	209.3	311.4
III	(control)	94.2	222.1	316.3
	Waste water	127.3	294.3	421.6
	Composite tea	117.7	231.0	348.7
	CKM	119.0	282.2	401.2
	K_2SO_4 (2.5 mg/pot)	110.9	194.4	305.3
	K_2SO_4 (12 mg/pot)	105.4	189.9	295.3
	K_2SO_4 (50 mg/pot)	100.3	183.7	284.0

*Non-significant LSD at 5%.

Table-13. Effect of organic and inorganic fertilizers on sulfur parameters of Brassica oleracea plant in 100 % sand soil

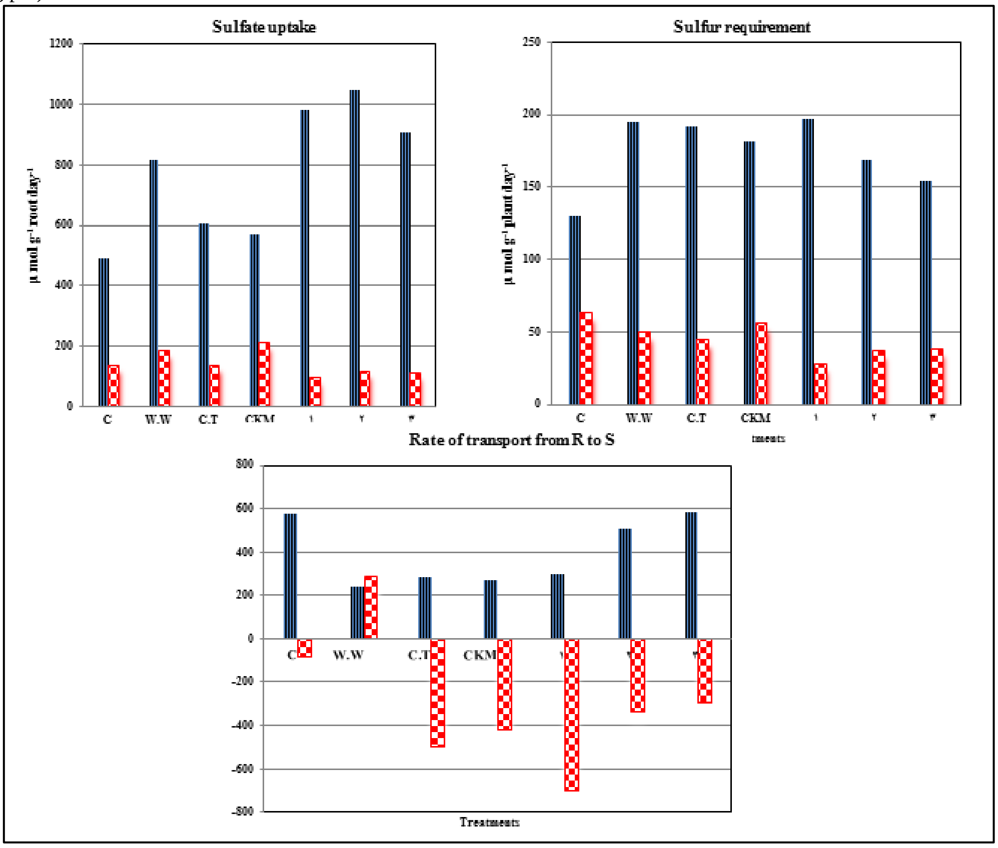
Stage	Treatments	S content in root	S content in shoot	(S+R)
	Initial	74.1	100.0	174.1
I	(control)	40.9	101.3	142.2
	Waste water	53.2	112.1	165.3
	Composite tea	42.4	109.9	152.3
	CKM	46.3	111.0	157.3
	K_2SO_4 (2.5 mg/pot)	42.2	92.8	135.0
	K_2SO_4 (12 mg/pot)	39.1	90.7	129.8
	K_2SO_4 (50 mg/pot)	34.0	82.3	116.3
	LSD at 5%	0.04	0.04	0.10
II	(control)	41.5	124.1	165.6
	Waste water	56.6	172.1	228.7
	Composite tea	41.4	152.6	194.0
	CKM	48.3	141.5	189.8
	K2SO4 (2.5 mg/pot)	45.7	136.2	181.9
	K2SO4 (12 mg/pot)	42.9	130.1	173.0
	K_2SO_4 (50 mg/pot)	40.2	121.6	161.8
	LSD at 5%	0.03	0.02	0.11
III	(control)	37.1	120.9	158.0
	Waste water	55.2	164.8	220.0
	Composite tea	37.0	144.7	181.7
	CKM	31.9	137.0	168.6
	K_2SO_4 (2.5 mg/pot)	32.0	129.9	161.9
	K_2SO_4 (12 mg/pot)	29.3	121.6	150.9
	K_2SO_4 (50 mg/pot)	21.6	111.5	133.1
	LSD at 5%	0.03	0.02	0.10

*Non-significant LSD at 5%

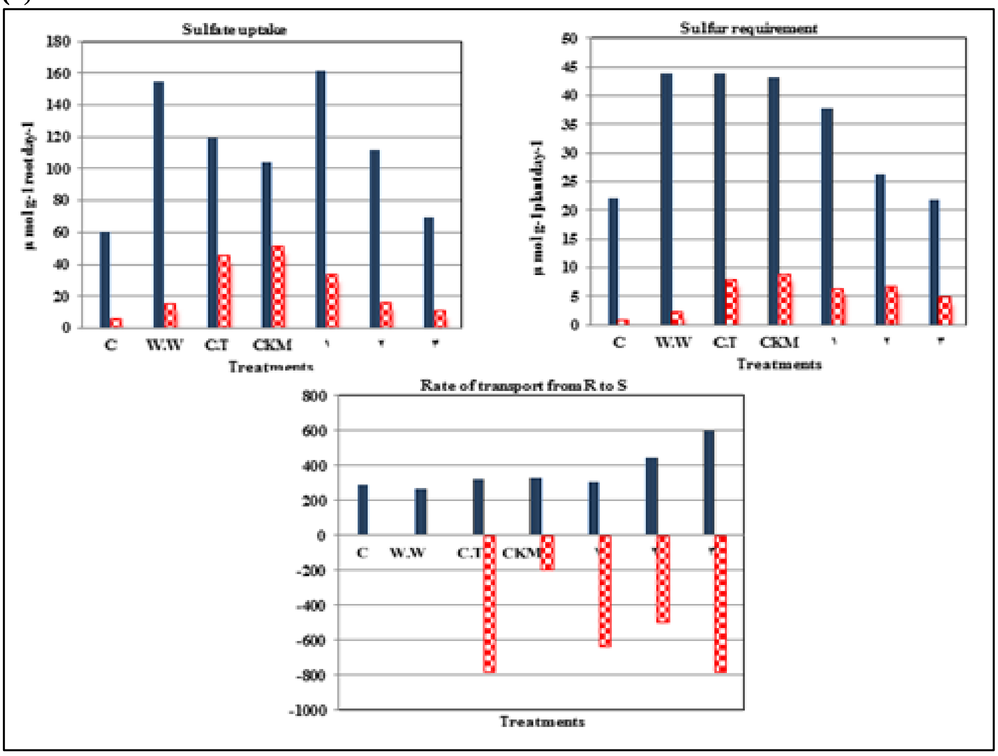
5.2.2. Sulfur Requirement

The requirement of a crop for S can be defined as the minimum amount of S in the crop associated with the maximum yield. Data reported in figure 1 (a – f) suggested that , the sulfur requirements in all used soils under all treatments organic; CT or CKM, inorganic fertilizers; K_2SO_4 at all concentrations, as well as use industrial waste water showed that , there was a general increase in sulfur requirements during second stage than at the third stage except in the used soil (1:4 clay: sand v/v) under treatment with K_2SO_4 at all used concentrations, where the sulfur requirement during these two stages was more or less similar in soil 100% sand where the sulfur requirements during the third stage recorded the highest values than the second stage in control and in treated plants with the used K_2SO_4 concentrations. A variation in sulfur requirements may be due to different used soils and different amount of sulfur in different treatments. Increasing K_2SO_4 concentrations induce further lowering sulfur requirements in broccoli plants. Treatments with waste water induced the highest values in sulfur requirements in the used soils 100% clay, 1:1 and 1:4 (clay: sand v/v). CKM induce a highest value for sulfur requirements in soils (1:2, 1:3 clay: sand v/v and 100% sand). However, this requirement may be higher when quality aspects are considered. In this respect, [77] stated that, it is obvious that the size of the requirement is related to crop yield in wheat plants.

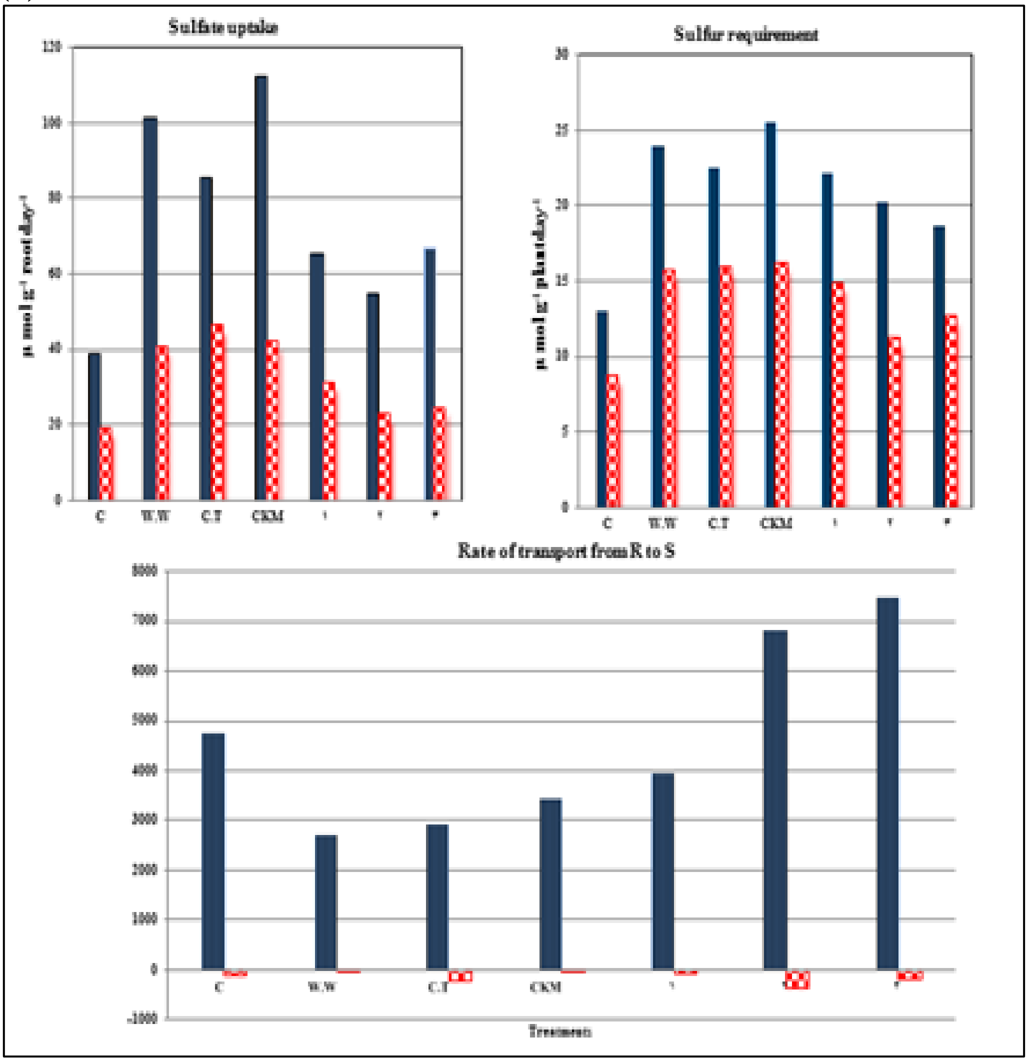
Figure-1. (a - f): Effect of organic and inorganic fertilizer on sulfur uptake (µ mol g-1 root day-1), sulfur requirement (µ mol g-1 plant day-1) and rate of sulfur transport from root to shoot of Brassica oleracea in (100 % clay (a) ; 1:1(b) ; 1:2(c) ; 1:3(d) ; 1:4(e) clay: sand v/v)& (100% sand (f)) soil, where C: control, W.W: waste water, CT: composite tea, CKM: chicken manure, (1): K2SO4 (2.5 mg/pot), (2): K2SO4 (12 mg/pot), (3): K2SO4 (50 mg/pot).



(b)

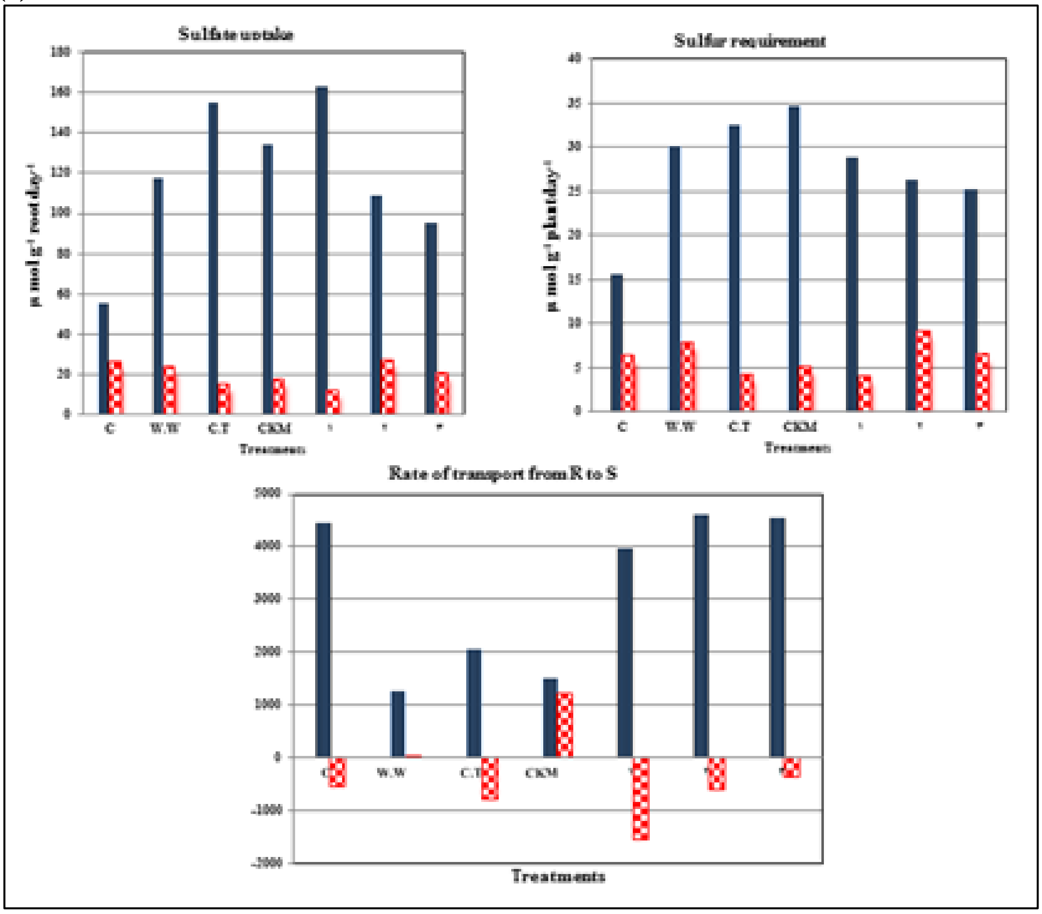


(C)



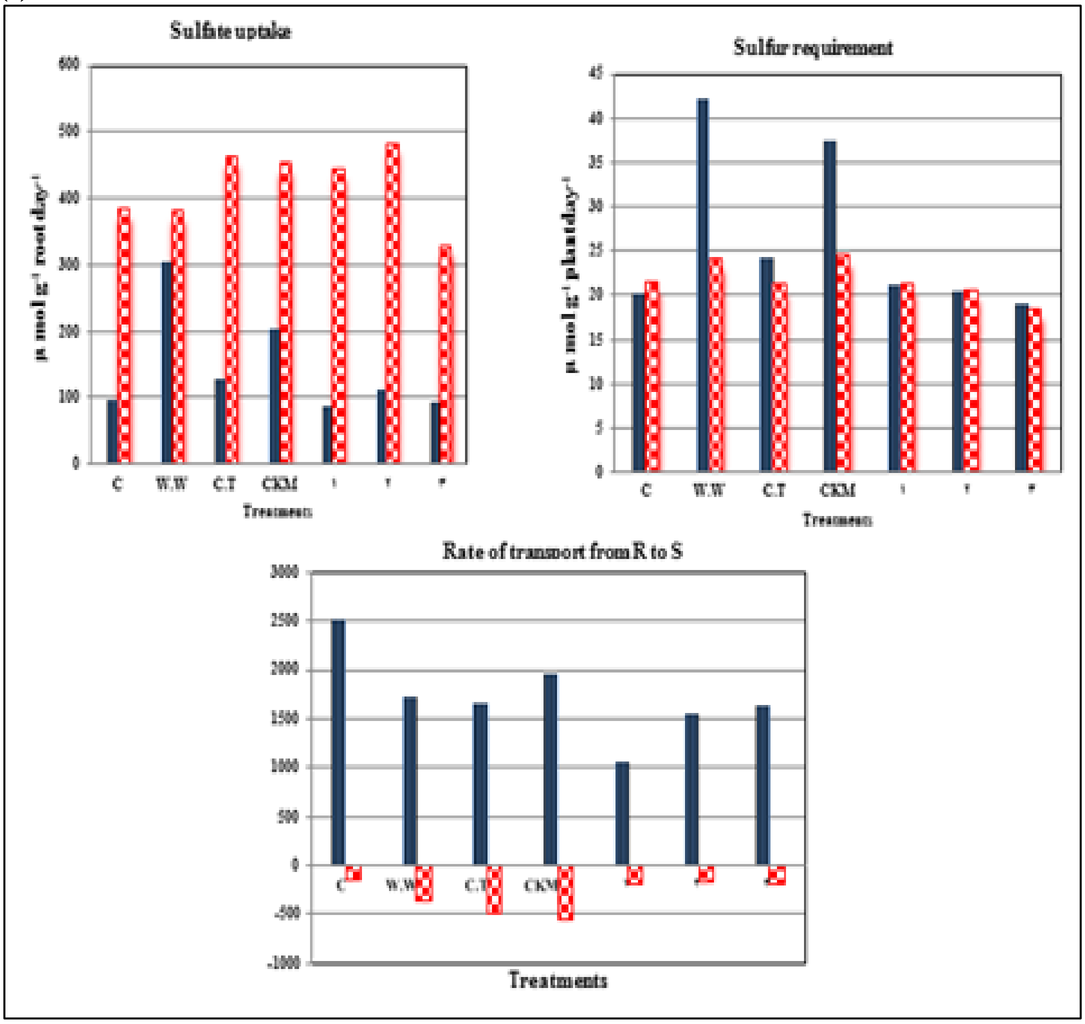
Sulfate uptake
μ mol g⁻¹ root day⁻¹
Sulfur requirement
μ mol g⁻¹ plant day⁻¹
Rate of transport from R to S
C
W.W
C.T
CKM
Treatments

(d)

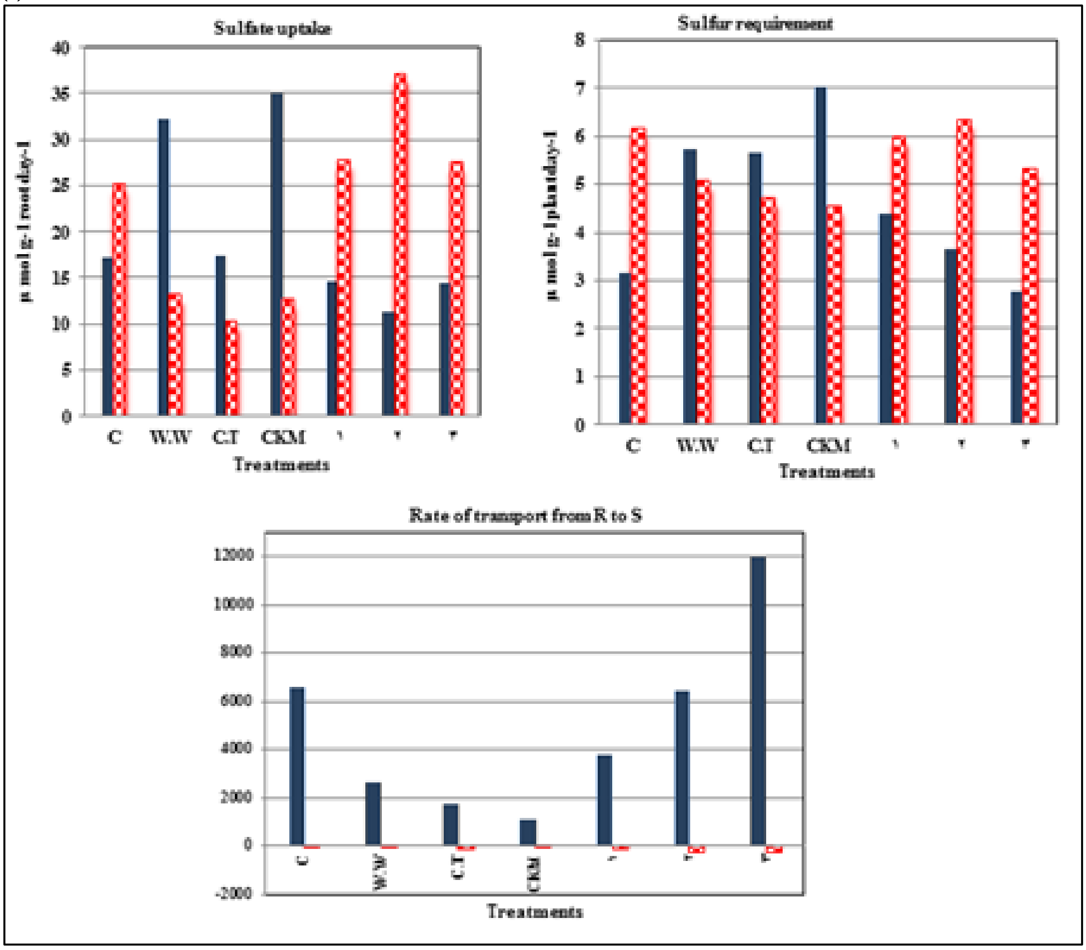


Sulfate uptake
μ mol g⁻¹ root day⁻¹
Sulfur requirement
μ mol g⁻¹ plant day⁻¹
Rate of transport from R to S
C
W.W
C.T
CKM
Treatments

(e)


Sulfate uptake
μ mol g⁻¹ root day⁻¹
C
W.W
C.T
CKM
Treatments
Sulfur requirement
μ mol g⁻¹ plant day⁻¹
Rate of transport from R to S
Treatments

(f)


Sulfate uptake
μ mol g-1 root day-1
C
W.W
C.T
CKM
Treatments
Sulfur requirement
μ mol g-1 plant day-1
Rate of transport from R to S
Treatments

5.2.3. Sulfur Uptake

The growth of broccoli plants in the six different used soils led to marked changes in the uptake of sulfur by the plants treated either with organic (CT and CKM) or with inorganic fertilizers (K_2SO_4 at all concentrations) or irrigated with industrial waste water (figure 1 (a – f) Thus, in general, the sulfur uptake in second stage recorded the high values than in the third stage except in (1:4 clay: sand v/v) soil, a reverse situation was obtained in response to all treated and control plants. The same trend was observed in the used soil 100% sand in response to treatment with K_2SO_4 at all concentrations and in control. In this connection, Sulfur enters the plant predominantly via the root from the soil solution in the form of sulfate [77]. Sulfate is actively transported into root cells across the plasma membrane through a proton/sulfate co-transport ($3H^+$/ SO_4^{-2}) mediated by sulfate transporters and driven by a proton gradient generated by ATP ases [11, 78]. Subsequently sulfate is transported into the stele where it is loaded into the xylem and distributed to the shoot. Sulfate has to be reduced to sulfide before it is further metabolized into cysteine, the precursor and sulfur donor for the majority of other organic sulfur compounds present in plants [11]. Root plastids contain all enzymes of the assimilatory sulfate reduction pathway, but the major proportion of the sulfate is reduced in the chloroplasts in the shoot [79]. Also, Plants have evolved a network of sulfate transporters with different affinity, localization and regulation enabling efficient uptake and distribution of sulfur from root cells into sink organs according to the availability of sulfur and the plant's requirements [80]. The uptake of sulfate into roots is mainly a metabolic process mediated bay carrier proteins [81]. In *Triticum aestivum* a small part of the influx of sulfate into root cells was found to be non-metabolic, including carrier-mediated, passive transport and diffusion as well [82].

5.3. Rate of Sulfur Transport from Roots to Shoots

The experimental results revealed that, the rate of sulfur transport from root to shoot through the third stage was less than the second stage in all used soils figure 1 (a – f). It was recorded a passive transport through the second stage and an active transport through the third stage with few exceptions in treated plants with waste water in 100% clay soil and with waste water and CKM in the used soil (1:3) (clay: sand v/v), where the rate of transport was passively at the two stages. Sulfate transport appears to be carefully controlled by a set of additive and non-additive gene effects [83]. Mechanisms regulating synthesis and degradation of carriers control the availability of transport entities. The sulfate carriers present may subject to negative feedback control of their activity by the intracellular sulfate concentration and by reduction products of sulfur metabolism [84]. In spring wheat roots, negative cooperatives between a minimum numbers of four interacting allosteric binding sites for sulfate on each carrier entity has been reported [82]. Active as well as passive influx of sulfate seems to be controlled by this allosteric inhibition and may therefore be mediated by the same carrier system [82]. Because it is not known to what extent sulfate is taken up by rhizodermal tissue and transported in the symplast and to what extent it is taken up by endodermal tissue after apoplasmic transport**.** The observation of an active and a passive influx [82] may still reflect different uptake systems at different sites of the root. The bulk of the sulfate was localized in the vacuoles. In carrot root cells and in lemna, sulfate is actively transported at both plasmalemma and tonoplast, with the plasmalemma influx being considerably higher than the tonoplast influx [83]. Both influxes are accompanied by a passive efflux of sulfate [83], possibly mediated by the same carriers as the influxs. The rate of sulfate reduction is much smaller than both the plasma lemma and the tonoplast fluxes; therefore, it would not be limited by either transport system [83]. However, only the tonoplast influx of sulfate appears to be regulated by internal sulfate. With increasing concentrations of sulfate in the vacuole, the active influx of sulfate into the vacuole will decrease and the efflux by facilitated diffusion will increase until both fluxes are equal. When vacuolar fluxes of sulfate do not remove net amounts of sulfate from the cytoplasm, substantial amounts of sulfate will accumulate in the cytoplasm until equilibrium between active influx and passive efflux is obtained.

5.4. Sulfur Distribution

The results obtained (Table 14) showed a clear difference in the distribution of S between different organs of broccoli (*Brssica oleracea* L. var. italica) plants either in root , stem or leaves were grown on different used soils which was treated with low concentration of K_2SO_4 (2.5 mg/pot) or irrigated with waste water through first stage of growth. At all used soils , root S contents were recorded the lowest amount of sulfur than the shoot system , either in the stem or in the leaves .This may be due to the shoot system (stem or leaves) was consider as a sink organs for sulfur , meanwhile root act as source tissues, exporting S . The sulfur content in the roots of fertilized plants with K_2SO_4 or treated with waste water increased steadily than the control, where sulfate taken up by the roots is a primary sulfur source for plants. Sulfate is actively transported into root cells across the plasma membrane through a proton/sulfate co-transport ($3H^+$/ SO_4^{-2}) mediated by sulfate transporters and driven by a proton gradient generated by ATP ases [11]. Subsequently sulfate is transported into the stele where it is loaded into the xylem and distributed to the shoot. Root plastids contain all enzymes of the assimilatory sulfate reduction pathway, but the major proportion of the sulfate is reduced in the chloroplasts in the shoot [79, 85]. As Saito [85] already reported that, sulfate is further taken up by roots and translocated via the xylem to shoot tissues where it is reduced to cysteine (Cys) and either converted to methionine (Met) or incorporated into proteins or Cys containing peptides such as glutathione. In this context, Lappartient and Touraine [86] consider that, the shoot is the major sink for sulfur and the necessity of demand-driven signaling from the shoot to root has been proposed. Glutathione, the end product of sulfur assimilation, essential in the storage and transport of reduced sulfur, was suggested as an important inter-organ signal compound of the sulfur status from the shoot to the root [87].

Table-14. Effect of inorganic fertilizer K2SO4 and waste water on the distribution of sulfure within *Brassica oleracea* plant grown for 14 days. Old in different type of soil. Each value is the mean of 3 samples, represented as µM/g dry weigh

Soil type	Treatments	Root	Stem	L1	L2	L3	L4	L5	L6	L7	L8	Bud
100 % clay	(control)	80.2	410.5	89.2	166.1	274.4	299.5	363.2	409.1	475.7	-	480.0
	Waste water	91.4	520.2	99.7	216.2	253.0	387.9	416.1	481.5	535.2	567.0	571.9
	K_2SO_4 (2.5 mg/pot)	88.3	380.0	90.5	204.7	265.1	317.5	387.2	440.4	493.0	-	504.7
	LSD at 5 %	0.12	0.11	0.19	0.13	0.14	0.13	0.16	0.13	0.13	-	0.29
(1:1)(clay : sand v/v)	(control)	80.4	297.6	86.9	150.2	214.8	270.2	311.1	-	-	-	351.2
	Waste water	82.9	382.1	94.1	190.2	215.4	299.0	350..0	417.1	-	-	470.3
	K_2SO_4(2.5 mg/pot)	81.6	420.8	88.0	120.7	209.3	287.8	338.1	410.7	461.0	-	508.3
	LSD at 5 %	0.11	0.13	0.15	0.12	0.12	0.13	0.16	-	-	-	-
(1:2)(clay : sand v/v)	(control)	73.7	391.7	77.8	150.9	224.9	293.5	341.3	398.7	430.0	-	488.1
	Waste water	85.0	503.0	94.5	191.3	231.0	314.1	400.5	457.2	504.9	540.2	550.7
	K_2SO_4(2.5 mg/pot)	79.3	396.4	86.4	123.4	216.0	310.6	339.4	411.3	-	-	420.2
	LSD at 5 %	0.13	0.14	0.17	0.15	0.14	0.12	0.13	0.12	0.17		0.23
(1:3)(clay : sand v/v)	(control)	80.7	400.1	84.2	143.0	218.9	290.2	329.0	390.1	420.5	-	398.5
	Waste water	83.9	510.1	90.4	178.5	224.3	318.1	380.1	446.0	517.7	534.9	546.0
	K_2SO_4(2.5 mg/pot)	80.9	487.4	85.3	122.9	200.4	275.2	311.1	380.0	491.1	500.3	574.8
	LSD at 5 %	0.11	0.12	0.14	0.15	0.18	0.11	0.12	0.13	0.28		0.33
(1:4)(clay : sand v/v)	Tap water (control)	73.6	382.6	79.5	152.1	239.0	295.9	351.2	401.9	-	-	450.2
	Waste water	94.5	490.7	97.4	219.3	242.9	375.6	408.7	466.5	523.6	-	561.7
	K_2SO_4 (2.5 mg/pot)	86.4	430.9	88.9	201.8	249.5	315.7	372.1	419.0	-	-	480.0
	LSD at 5 %	0.14	0.14	0.17	0.19	0.15	0.17	0.19	0.18	-		0.23
100 % sand	(control)	58.4	240.2	63.2	132.1	162.5	197.9	226.0	257.3	-	-	281.7
	Waste water	70.0	339.2	72.4	112.0	186.2	249.3	261.7	302.1	340.1	-	372.9
	K_2SO_4(2.5 mg/pot)	59.9	260.1	63.9	120.2	180.4	243.1	265.0	-	-	-	305.6
	LSD at 5 %	0.12	0.13	0.13	0.19	0.14	0.17	0.14	0.10	-	-	0.22

*Non-significant change at 5% level

In shoot system , the oldest leaf (L1) contain the least amount of sulfur , whereas the youngest one contain the high amount of sulfur, and the distribution of sulfur to the bud is more obvious. Buds clearly acted as sink tissues throughout the first stage of experiment as their S content increased whatever the S supply. However, S limitation (control) in all used soils decreased the remobilization of S to younger leaves comparing with other treatments, while greatly increasing it to the buds, which became the main sink tissue.

The remobilization of endogenous S from or to different plant tissues as shown in table (5), in 100 % clay soil the youngest leaf (L8) in treatment with waste water contain nearly 6 fold than the oldest one (L1) , meanwhile in treatment with K_2SO_4, the youngest one (L7) contain about 5 fold than the oldest one (L1). For the used soil 1:1 (clay: sand v/v) in treatments with waste water (L6) contain about 4 fold than (L1), meanwhile in in the treated plants with K_2SO_4, (L7) contain about 5 fold than (L1). In the used soil 1:2 (clay: sand v/v) in treated with waste water (L8) contain about 6 fold than (L1), meanwhile in response to treatment with K_2SO_4, (L6) contain about 5 fold than (L1). While in the used soil 1:3(clay: sand v/v) the youngest leaf (L8) of the plants treated with waste water and K_2SO_4 contain about 6 fold than oldest one (L1). In the used soil 1:4 (clay: sand v/v) in response to the treatment with waste water (L7) contain about 5 fold than (L1), meanwhile in the plants treated with K_2SO_4, (L6) contain nearly about 5 fold than (L1). For the used soil 100% sand in treated plants with waste water (L7) contain nearly about 5 fold than (L1) , meanwhile in the treated plants with K_2SO_4, (L5) contain about 5 fold than (L1), meanwhile in treatment with waste water, (L8) contain about 4 fold than (L1). The overall results showed that, S remobilization was maintained from older leaves, to young ones to maintain its growth rate especially during its early development (i.e. leaf expansion) at the beginning of the experiment. It can be conclude that most of the sulfate entering mature leaves is rapidly loaded into the phloem and translocated to sinks elsewhere in the plant. The ultimate accumulation of most of the sulfur in the developing leaf must therefore require translocation of sulfur. Several studies, with a variety of plants, show that sulfur is translocated in phloem as inorganic sulfate or sulfite (after exposure of plants to SO_2 [88] or as reduced organic sulfur, principally glutathione [89, 90]. It was suggested that the differential accumulation of sulfur in developing leaves was due to sulfate metabolism and incorporation of sulfur into amino acids and protein. Similarly Abd Allah, *et al.* [91] found that, the S taken up was mostly allocated to the leaves (55%) and to the roots (27%) in *Brassica napus* L. Moreover; the total S content of LB8 and LB10 strongly decreased indicating a large remobilization of S compounds from the soluble fraction, principally as sulfate, which was reported to be mainly stored within the vacuole [92-94]. Moreover, this redistribution of S compounds to young developing leaves was without any acceleration of leaf senescence processes [95]. The authors suggested that, this would maintain photosynthetic capacities of shoot tissues as i obtained in my results (Fig. $7_{(a\text{-}f)}$) and subsequent metabolic activities within the whole plant (i.e. including uptake processes in the root).

Differences in sulfur content in leaves in different used soils were due to differences in availability of nitrogen in different soil (Table 1). This is in accordance with Lim, *et al.* [96].

6. Conclusion

It was showed that the potassium , sodium , calcium , magnesium, and iron contents in growing plants in different types of soil is closely linked to the stage of plant growth as well as the plant organ and the type of soil used and also on the type and concentration of various fertilizers.

* The sulfur interactions included changes: in the total sulfur content, sulfur requirements, sulfur uptake and rate of sulfur transport from root to shoot. As well as, the change in the distribution of the sulfur in different plant organs: roots and shoots. Above parameters relied mainly on the soil type and various treatments.
* Organic materials differ in their efficiency as fertilizers according to their origin, chemical composition and processing techniques. It was found of vital interest to study the use of chicken manure.

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