Vegetable Science (2017) 44 (1) : 98-102

Plant nutrient status of cabbage and various soil characteristics as influenced by different sources and levels of sulphur

R Bhat[1], N Jabeen[2], MA Chattoo[3], S Mufti[4], Z Rashid[5], Shahid B Dar*[6], B Afroza[7] and R Rasool[8]

Received: March 2017 / Accepted: July 2017

Abstract

A field experiment was conducted during *Rabi* 2012-13 and 2013-14 to study the influence of different sources and levels of sulphur on plant nutrient status of cabbage and various soil characteristics. The experiment was laid in a randomized block design with three replications. Three sources of sulphur i.e., gypsum, elemental sulphur and potassium sulphate with three levels i.e., 40, 70 and 100 kg S ha^{-1} for each source were given in the experiment. Potassium sulphate as a source of sulphur recorded highest nitrogen (3.3%), phosphorus (0.017%), potassium (2.15%) and sulphur (0.41%) in cabbage. Increasing levels of sulphur up to 70 kg ha^{-1} significantly increased the nitrogen (2.9%), potassium (2.1%) and sulphur (0.41%) in cabbage. However, there is a non-significant effect of levels of sulphur on phosphorus content. Elemental sulphur as a source of sulphur recorded the highest available sulphur (12.7 kg ha^{-1}) followed by gypsum and potassium sulphate. Increasing levels of sulphur upt o 100 kg ha^{-1}, there was a significant increase in the electrical conductivity (0.142 d Sm^{-1}), organic carbon (0.99%), available nitrogen (318.3 kg ha^{-1}), available phosphorus (24.5 kg ha^{-1}), available potassium (168.6 kg ha^{-1}) and available sulphur (11.5 kg ha^{-1}) status of the soil. Maximum head yield and seed yield were recorded with potassium sulphate as a source and increase in level, increased yield up to 100 kg S ha^{-1}.

Keywords: Cabbage, Seed yield, Quality, Sulphur and Fertilizer

Introduction

Cabbage (*Brassica oleracea* var. *capitata*) is the second most important cole crop after cauliflower, which was originated in Europe and in the Mediterranean region, evolved from a leafy mustard herb "Caboche" a French word believed to be the root of the English name of cabbage. Cabbage falls under cole group and all cole crops have one common trait i.e., genetic potential to thicken various parts. Cabbage is distinguished by its swollen heads which is formed by thickening of edible buds with tightly packed overlapping leaves manifesting a large head. The shape of head may be round, conical, oblong or flat depending on the variety. Cabbage is famous for its nutritional values, medicinal effects, and other therapeutic properties. It is consumed throughout the country by every class of people as fresh vegetables or raw as salad. To know the countless benefits of this vegetable nutritional experts all over the world have established the health benefits of cabbage. The head is an excellent source of vitamins, minerals and dietary fibers. Having high fibre content, it also helps in regular bowel movement. Fresh cabbage juice can relieve abdominal pain, indigestion, headache, bronchitis, and asthma. Studies have shown that cabbage also prevents the development of cancer cells. Glucosinolates present in cabbage are a class of nitrogen and sulphur containing compounds shown to have cancer preventing properties. They have been shown to inhibit the activity of some chemical carcinogens. The plant enzyme myrosinase is released upon consumption of glucosinolate containing vegetables and catalyses glucosinolate hydrolysis (Fenwick et al. 1983). The iron and sulphur contents present in cabbage are factors making it effective in cleaning our digestive system. Dietitians regarded it as a wholesome tonic for maintaining health. It is a source of Indole-3-carbinol, or 13C, a compound used as an adjuvant therapy for recurrent respiratory papillamatosis, a disease of the head and neck caused by human papillomavirus that causes growth in the airway that can lead to death. In addition to N, P and K nutrients, sulphur has been found to be very much beneficial (Hara and Sonoda 1981). Sulphur is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium (Jamal et al. 2010). Sulphur is best known for its role in the synthesis of proteins,

[1]Division of Vegetable Sciences, [2]Division of Agronomy, and [3]Division of Soil Science, Sher-e-Kashmir University of Agricultural Sciences & Technology, Kashmir- 191121, J&K
*Corresponding author, Email: sbd.agron@gmail.com

oils, vitamins and is associated with the production of superior nutritional and market quality, and glucosinolates in Brassica crops. Hence keeping this necessity in view different sources and levels were used to study their effect on plant nutrient status and various soil characteristics

Materials and Methods

Field experiments were carried out at Vegetable Experimental Farm, Division of Vegetable Science *Rabi* season of2012-13 and 2013-14 located at 34.1^0N and 74.8^0 E at an altitude of 1587 m above MSL, in order to work out the optimum level and source of sulphur for obtaining higher growth, yield and seed yield in cabbage. The soil (0-15 cm) of experimental site was well drained silty clay loam in texture with pH 7.00, high in organic carbon (0.97%), medium in available N (242.6 kg/ha), available P (21.5 kg/ha), available K (165.6 kg/ha) and available S (22.6 kg/ha). The experiment was laid in a randomized block design with three replications having 10 treatments comprising different combinations of sulphur levels and sulphur sources *viz*, 40 kg S ha^{-1} through Gypsum (T_1), 70 kg S ha^{-1} through Gypsum (T_2), 100 kg S ha^{-1} through Gypsum(T_3), 40 kg S ha^{-1} through Elemental sulphur (T_4), 70 kg S ha^{-1} through Elemental sulphur (T_5), 100 kg S ha^{-1} through Elemental sulphur (T_6), 40 kg S ha^{-1} through Potassium sulphate (T_7), 70 kg S ha^{-1} through Potassium sulphate (T_8), 100 kg S ha^{-1} through Potassium sulphate (T_9) and control (T_{10}). A uniform dose of nitrogen @150 kg N ha^{-1}, Phosphorus @ 60 kg P_2O_5 ha^{-1}, Potassium @ 60 kg K_2O kg ha^{-1} and FYM @ 30 t ha^{-1} was applied to each plot. Sulphur through different sources and levels as per treatment was applied as basal dose. Elemental sulphur was applied 15 days prior to transplanting of seedlings. Cabbage cv. Golden Acre was transplanted at 60 × 45 cm spacing during first fortnight of April and harvested at fully matured stage. Selected and tagged plants were left in the field for seed production during winter. All other cultural practices were followed as per standard recommendations. Observations were recorded on various aspects from 10 randomly selected plants from each plot. Sulphur in cabbage head was estimated by turbidity method as out lined by Chesnin and Yien (1951). Soil samples (0–15 cm) were collected from each plot after harvest of crop. These samples were analyzed (Table 1) for pH (1:2.5 soil: water suspension), organic carbon by rapid titration method (Walkley and Black, 1934), available N by alkaline permanganate method (Subbiah and Asija, 1956), available P by Olsen's method (Olsen et al 1954), and available K by ammonium acetate extraction method (Jackson 1973). The data were analyzed as per the standard procedure for Analysis of Variance (ANOVA) as described by Gomez and Gomez (1984). The difference in the treatment mean was tested by using CD at 5% level of probability.

Table 1: Details of treatment combinations

T_1	:	40 kg S ha^{-1} through Gypsum
T_2	:	70 kg S ha^{-1} through Gypsum
T_3	:	100 kg S ha^{-1} through Gypsum
T_4	:	40 kg S ha^{-1} through Elemental sulphur
T_5	:	70 kg S ha^{-1} through Elemental sulphur
T_6	:	100 kg S ha^{-1} through Elemental sulphur
T_7	:	40 kg S ha^{-1} through Potassium sulphate
T_8	:	70 kg S ha^{-1} through Potassium sulphate
T_9	:	100 kg S ha^{-1} through Potassium sulphate
T_{10}	:	Control

Results and Discussion

Nutrient status of plant: The results of present investigation have shown that both the sources and levels of sulphur significantly influenced the nutrient status of cabbage under study. The data presented in (Table-2), indicated that all the sources of sulphur had a significant influence on the Nitrogen, Phosphorus, Potassium and Sulphur in cabbage. Potassium sulphate as a source of sulphur recorded highest Nitrogen (3.3%), Phosphorus (0.017%), Potassium (2.15%) and Sulphur (0.41%) in cabbage. The lowest Nitrogen (1.96%), Phosphorus (0.01%), Potassium (1.84%) and Sulphur (0.36%) was recorded under control. The superiority of potassium sulphate as a source of sulphur in inducing the increase in yield attributes of cabbage could be attributed to highly soluble nature and readily available sulphur ($S0_4$) in potassium sulphate as compared to Gypsum and Elemental sulphur. Similar observations have been reported by Skwierawska et al. (2008) in cabbage.

Further study of the data , revealed that the application of increasing levels of sulphur up to 70 kg ha^{-1} significantly increased the Nitrogen (2.9%), Potassium (2.1%) and Sulphur (0.41%) in cabbage. However, there is a non significant effect of levels of sulphur on phosphorus content. The positive influence of sulphur fertilization on concentration of any nutrient in plant seems to be due to improved nutritional environment both in the rhizosphere and the plant system. Thus, increased availability of nutrients in the root zone coupled with increasing metabolic activity at the cellular level probably might have increased the nutrient uptake and their accumulation in vegetative plant parts. Higher nitrogen in head is directly responsible for higher protein because it is a primary component of amino acids which constitute the basis of protein. The content of nitrogen increased significantly with the application of sulphur

Table 2: Plant nutrient status and yield as influenced by different sources and levels of sulphur (Pooled data of two years)

Treatment	Nitrogen content (%)	Phosphorus content (%)	Potassium content (%)	Sulphur content (%)	Head yield (q ha^{-1})	Seed yield (q ha^{-1})
Sulphur sources						
Gypsum	2.90	0.014	2.07	0.40	338.10	4.10
Elemental sulphur	2.10	0.012	1.8	0.39	310.00	3.30
Potassium sulphate	3.30	0.017	2.15	0.41	408.40	4.80
Graded levels of sulphur ha^{-1}						
40 kg	2.60	0.015	1.97	0.39	314.60	3.65
70 kg	2.90	0.014	2.10	0.41	370.20	4.2
100 kg	2.80	0.015	2.03	0.40	371.90	4.4
Control versus rest control mean	1.96	0.01	1.84	0.36	234.60	2.25
Sources CD (p ? 0.05)	0.05	0.001	0.06	0.004	3.20	0.05
Levels	0.05	NS	0.06	0.004	3.20	0.05
Control vs Rest	0.02	0.0007	0.02	0.001	1.40	0.02

and is attributed to application of sulphur which in turn provides vigorous root and shoot growth resulting in greater absorption of nitrogen from the soil, this is further supported by the fact that sulphur deficiency prevents utilization of nitrogen and also brings about an accumulation of soluble nitrogen within the plants The increased accumulation of nitrogen in plants thus checks further absorption of nitrogen leading to decrease in nitrogen content in plants. The interaction between nitrogen and sulphur was synergistic and hence application of sulphur increases the concentration and uptake of nitrogen and vice versa (Kumar et al. 2002 and Sharma et al. 1990). Application of sulphur in the absence of nitrogen decreases the concentration of nitrogen in mustard but when sulphur was added the effect was synergistic (Dev and Kumar 1982). Application of sulphur and nitrogen increased their respective uptake in rapeseed. However, the effect of nitrogen rate on sulphur uptake varied with sulphur application rate. Sulphur application had no appreciable effect on nitrogen uptake at low nitrogen application rates but significantly enhanced dry matter produced (Janzen and Bettany 1984).

Application of sulphur significantly increased the content and uptake of potassium and other micronutrients, it also influenced physical, chemical and biological properties of soil resulting in change like drop in soil pH. Release of nutrients in available form and other physical properties might have influenced the availability of other nutrients leading to their absorption, thereby showing a higher content with application of sulphur. There is a positive interaction between sulphur and potassium reported in mustard by Chandal and Virmani (1983). Increase in sulphur dose showed no significant effect on phosphorus content because of the interaction between two anions (SO^{2-}& PO^{2-}) for adsorption sites on the soil. Similar observations have been reported by Skwierawska et al. (2008) and Rosen et al (2005) in cabbage and Chippa (2005) in cauliflower.

The interaction effect between sources and levels of sulphur on sulphur percentage during 2013-14 and in pooled data was found significant (Table 3). The sulphur percentage varied significantly among different sulphur sources when fertilizer sulphur was applied as Gypsum, Elemental sulphur and Potassium Sulphate. Similarly at 40, 70, and 100 kg S ha^{-1}, sulphur content in head varied significantly among different sulphur levels. Significantly higher sulphur content 0.43% during both the years and in pooled data was recorded with treatment combination 70 kg S ha^{-1} as potassium sulphate which was statistically superior to all other treatment combination. Potassium sulphate as a source of sulphur recorded highest head yield and seed yield per hectare[1]. The superiority of potassium sulphate as a source of sulphur in inducing the increase in seed yield attributes of cabbage could be attributed to highly soluble nature and readily available sulphur (sulphate) in potassium sulphate as compared to Gypsum and Elemental sulphur (Tandon and Messick 2002). Further, the application of increasing levels of sulphur up to 100 kg ha^{-1} significantly increased the head yield and seed yield.

Table 3: Interaction effect of sources and levels of sulphur on sulphur content (%) in cabbage

Treatment	Sulphur Levels (kg ha^{-1})								
	2012-2013			2013-2014			Pooled		
Sulphur sources	40	70	100	40	70	100	40	70	100
Gypsum	0.40	0.43	0.41	0.40	0.42	0.40	0.40	0.42	0.40
Elemental sulphur	0.38	0.40	0.40	0.38	0.40	0.41	0.38	0.40	0.41
Potassium sulphate	0.41	0.43	0.42	0.41	0.43	0.42	0.41	0.43	0.42
CD (p ? 0.05)		0.001			0.003			0.002	

Soil characteristics: The results revealed that the sources of sulphur have a non significant effect on various soil characters as soil pH (Table 4), Electrical conductivity (d Sm^{-1}), Organic carbon (%). However, soil pH decreases with the application of sulphur, available nitrogen (kg ha^{-1}), available phosphorus (kg ha^{-1}), and available potassium (kg ha^{-1}). However, source of sulphur have a significant influence on available sulphur (kg ha^{-1}) status of the soil (Table-3). Elemental sulphur as a source of sulphur recorded the highest Available sulphur (12.7kg ha^{-1}) followed by gypsum and potassium sulphate. This is due to the fact that, less utilization of elemental sulphur for various processes undergoing in plants resulted in highest availability in the soil as compared to potassium sulphate and gypsum. Similar observations have been reported by Fatech Karimi et al. (2012) in canola. Further, levels of sulphur significantly influenced the nutrient status of the soil under study. The data presented in (Table-3) indicated that increasing levels of sulphur up to 100 kg ha^{-1} there is a significant increase in the Electrical conductivity (0.142 d Sm^{-1}), Organic carbon (0.99%), Available Nitrogen (318.3 kg ha^{-1}), Available phosphorus (24.5 kg ha^{-1}), Available potassium (168.6 kg ha^{-1}) and Available sulphur (11.5 kg ha^{-1}) status of the soil. Application of sulphur increases the availability of sulphur which results in higher content in the crop of mustard (Isapiri et al. 2012). Application of sulphur reduces soil pH due to the formation of sulphuric acid. Decrease in pH and increase in dry weight and phosphorus concentration and uptake with the application of sulphur have been reported by Erdal et al. (2006). Increase in Electrical conductivity might be due to increase in solubility of salts present in the soil due to formation of sulphuric acid which acts as a solvent for soil minerals. Salts become more soluble and conduct more electric current. Availability of nutrients in the soil increased by application of sulphur have been reported by Besharati et al. (2007) and Kaya et al. (2009) and attributed to decrease in soil pH. Higher levels of sulphur increased the availability of nutrients in the soil by reducing pH due to formation of sulphuric acid (Marok and Dev 1980). Similar observations have been reported by Jaggi and Dixit (1995) in cauliflower and Fatereh Karimi et al. (2012) in canola. The interaction effect (Table 5) between sources and levels of sulphur on available sulphur (kg ha^{-1}) during 2013-14 and in pooled data was found significant (Table 4). The available sulphur (kg ha^{-1}) varied significantly among different sulphur sources when fertilizer sulphur was applied as Gypsum, Elemental sulphur and Potassium Sulphate. Similarly at 40, 70, and 100 kg S ha^{-1}, available sulphur (kg ha^{-1}) varied significantly among different sulphur levels. Significantly higher available sulphur 32.6 kg ha^{-1} 32.0 kg ha^{-1} and 32.0 kg ha^{-1} during both the years and in pooled data was recorded with treatment combination of 100 kg S ha^{-1} as elemental sulphur which was statistically superior to all other treatment combination. From the study it is conclude that potassium sulphate as a source of sulphur and increase in sulphur up to 70

Table 4: Soil characteristics as influenced by different sources and levels of Sulphur (pooled data of two years)

Treatment	pH	EC (d Sm^{-1})	OC	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})	Available sulphur (kg ha^{-1})
Sulphur sources							
Gypsum	6.71	0.141	0.983	312.00	23.40	167.30	21.00
Elemental sulphur	6.74	0.141	0.984	312.10	23.40	167.10	28.40
Potassium sulphate	6.72	0.141	0.985	312.20	23.40	167.20	17.90
Graded levels of sulphur ha^{-1}							
40 kg	6.74	0.140	0.978	305.20	22.30	166.00	20.30
70 kg	6.7	0.141	0.984	312.80	23.50	167.00	21.20
100 kg	6.71	0.142	0.99	318.30	24.50	168.60	25.70
Control versus rest control mean	6.80	0.141	0.97	291.00	20.40	161.30	15.60
Sources CD (p ? 0.05)	NS	NS	NS	NS	NS	NS	0.15
Levels	NS	0.0004	0.004	0.80	0.08	0.19	0.15
Control versus rest	0.02	0.0001	0.001	0.34	0.03	0.08	0.06

Table 5: Interaction effect of sources and levels of sulphur on Available sulphur (kg ha^{-1}) in soil

Treatment	Sulphur levels (kg ha^{-1})								
	2012-2013			2013-2014			Pooled		
Sulphur sources	40	70	100	40	70	100	40	70	100
Gypsum	17.9	18.1	27.3	17.6	17.9	27.1	17.6	17.9	27.3
Elemental sulphur	25.9	27.5	32.6	25.5	27.5	32.0	25.7	27.5	32.0
Potassium sulphate	17.9	18.0	18.5	17.9	17.9	18.1	17.9	17.9	18.1
CD (p?0.05)	0.08			0.10			0.09		

kg ha^{-1} improved nutrient status of cabbage plant. However, there is a non-significant effect of levels of sulphur on phosphorus content. Elemental sulphur as a source of sulphur recorded the highest available sulphur followed by gypsum and potassium sulphate. Increasing levels of sulphur up to 100 kg ha^{-1}, there was a significant increase in the electrical conductivity, organic carbon, available nitrogen, available phosphorus, available potassium and available sulphur status of the soil.

सारांश

पत्ता गोभी में पोषक तत्वों व विभिन्न मष्दा गुणों के चारित्रिक स्तर पर गंधक के विभिन्न स्रोतों एवं स्तरों के प्रभाव को ज्ञात करने के लिये एक प्रक्षेत्र प्रयोग वर्ष 2012–13 में किया गया। प्रयोग रेण्डोमाइज्ड ब्लाक डिजाईन में तीन प्रतिकृतियों में लगाया गया। गन्धक के स्रोतों जैसे– जिप्सम, गंधक तत्व व पोटैशियम सल्फेट को तीन स्तरों जो 40, 70 एवं 100 किग्रा/हे. प्रत्येक स्रोत से प्रदान किये गये। गन्धक स्रोत में पोटैशियम सल्फेट द्वारा उच्चतम नत्रजन (3.3 प्रतिशत), फास्फोरस (0.017 प्रतिशत), पोटैशियम (2.10 प्रतिशत) व गन्धक (0. 41 प्रतिशत) पत्ता गोभी में पाया गया। गन्धक के स्तर में 0.70 किग्रा/हे. वृद्धि करने पर सार्थक रूप से नत्रजन (2.9 प्रतिशत), पोटैशियम (2.10 प्रतिशत) व गन्धक (0.41 प्रतिशत) पत्ता गोभी में वृद्धि पायी गयी जबकि गन्धक के प्रयोग का प्रभाव फास्फोरस की मात्रा पर कोई सार्थक प्रभाव नही पाया गया। गंधक तत्व के रूप में गन्धक के स्रोत से सबसे अधिक उपलब्ध गन्धक (12.7 किग्रा/हे.) रहा तथा इसके उपरान्त जिप्सम व पोटैशियम सल्फेट का स्थान पाया गया। गन्धक का स्तर 100 किग्रा/हे. वष्द्धि करने पर विद्युत चालकता (0.142 डी/वर्ग मीटर), कार्बनिक कार्बन (0.99 प्रतिशत), उपलब्ध नत्रजन (318.3 किग्रा/हे.) उपलब्ध फास्फोरस (24.5 किग्रा/हे.), उपलब्ध पोटैशियम (168.6 किग्रा/हे.) व उपलब्ध गंधक (11.5 किग्रा/हे.) का सार्थक वृद्धि मृदा में पायी गयी। अधिकतम शीर्ष व बीज उपज पोटैशियम सल्फेट को स्रोत रूप में अपनाने पर पाया गया तथा स्तर वृद्धि पर उपज में 100 किग्रा. एस/हे. से वृद्धि हुई।

References

Besharati H, Atashnama K and Hatami S (2007) Effect of sulphur application on nutrient availability of soil. African J (11): 1325- 1329.

Chandal RS and Virmani SM (1983) Sulphur nutrition on oilseeds. Indian J Agril Sci 43: 731-733.

Chesnin L and Yien CH (1951) Turbidity determination of available sulphur. Soil Sci Soc Amer Proc 15: 149-151.

Dev G and Kumar V (1982) Secondary nutrients in review of soil research in India, Part I, 12th International Congress of Soil Science, New Delhi, pp 342-36.

Erdal I, Kepenek K and Kýzýlgoz (2006) Effect of different levels of sulphur on growth, yield and quality of cauliflower. Bio Agri Hort 23: 263-272.

Fatereh Karimi, Mohammad Ali Bahmanyar and Shahabi M (2012) Investigation the effects of sulphur and cattle manure application on micronutrient availability in calcareous soil and accumulation in leaf and seed of canola. European J Expl Bio 2(3): 836-842.

Fenwick GR, Heaney RK and Mullin WJ (1983) Glucosilnolates and their break down products in food and food plants. Crit Rev Food Sci Nutr 18: 123-201.

Gomez KA and Gomez AA (1984) Statistical Procedures for Agricultural Research. 2nd edition. John Wiley and Sons, Inc. New York.

Hara T and Sonoda Y (1981) The role of macro-nutrients in cabbage head formation. Soil Sci Plant Nutr 27(1): 45-54.

Issa Piri, Ali R, Abolfazl T, Fatemeh R and Mahdi B (2012). Effect of sulphur fertilizer on sulphur uptake and forage yield of *Brassica juncea* in conditions of different regimes of irrigation. African J Agric Res 7(6): 958-963.

Jackson ML (1973) Soil chemical analysis. Prentice Hall of India Pvt, New Delhi.

Jaggi C and Dixit SP (1995) Response of cauliflower to sulphur and molybdenum in vegetable growing area of Palam Valley. J Indian Soc Soil Sci 43(2): 229-231.

Jamal A, Moon YS and Abdin MZ (2010). Sulphur- A general overview and interaction with nitrogen. Aus J Crop Sci 4: 523-529.

Janzen HH and Bettany JR (1984) Sulfur nutrition of rapeseed. Influence of fertilizer nitrogen and sulfur rates. Amer J 48: 100-107.

Kaya M, Kucukyumuk Z and Erdal I (2009) Effect of different levels of sulphur on soil health. African J Biotech 8(18): 4481-4489.

Kumar P, Tripathi N and Singh R (2002) Response of Indian mustard to sources and levels of sulphur in partially reclaimed salt affected soil. Indian J Agril Sci 72: 21-23.

Marok A and Dev S (1980). Response of sunflower to sulphur application and evaluation of the sulphur status of soil. Jawaharlal Nehru Agric Bull 8:100-102.

Olsen SR, Coleman CW, Watnate FS and Dean LA (1954) Estimation of available phosphorus with sodium bicarbonate. United States Department of Agriculture Circular 939: 19.

Rosen CJ, Fritz VA, Gardner GM, Hecht SS, Carmella SG and Kenne PM (2005) Cabbage yield and glucosinolate concentration as affected by nitrogen and sulphur fertility. Horti Sci 40(5): 1493-1498.

Sharma UC, Gangwar, MS and Srivastava PC (1990) Effect of Zinc and sulphur on nutrient uptake and yield of mustard. J Indian Soc Soil Sci 38: 696-701.

Skwierawska M, Zawartka L and Zawadzki B (2008) The effect of different rates and forms of applied sulphur on nutrient composition of planted crops. Plant Soil Environ 54: (5): 179-189.

Subbiah BV and Asija GL (1956) A rapid procedure for the estimation of available nitrogen in soils. Curr Sci 25: 259-260.

Tandon HL and Messick S (2002) Practical sulphur guide. Connecticut Avenue, N.W, Suite 612 Washington DC, pp 2-19.

Walkley A and Black JA (1934) An estimation of the method for determining soil organic carbon and a proposed modification of the chemical acid titration method. Soil Sci 37: 29-39