Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(2): 850-856

Received: 01-01-2018
Accepted: 02-02-2018

Humaira Ashraf
Division of Animal Nutrition, F.V. Sc & A.H, Shuhama, SKUAST-K, Srinagar, Jammu and Kashmir, India

HA Ahmed
Head, Division of Animal Nutrition, F.V. Sc & A.H, Shuhama, SKUAST-K, Srinagar, Jammu and Kashmir, India

AM Ganai
Division of Animal Nutrition, F.V. Sc & A.H, Shuhama, SKUAST-K, Srinagar, Jammu and Kashmir, India

ZA Pampori
Head, Division of Animal Physiology, F.V. Sc & A.H, Shuhama, SKUAST-K, Srinagar, Jammu and Kashmir, India

HM Khan
I/C Mountain Research Center for Sheep and Goat, Division of LPM, F.V. Sc & A.H, Shuhama, SKUAST-K, Srinagar, Jammu and Kashmir, India

I Hussain
Division of Veterinary Biochemistry, F.V. Sc & A.H, Shuhama, SKUAST-K, Srinagar, Jammu and Kashmir, India

Correspondence
Humaira Ashraf
Division of Animal Nutrition, F.V. Sc & A.H, Shuhama, SKUAST-K, Srinagar, Jammu and Kashmir, India

Multi-seasonal estimation of nitrogen, sulphur & nitrogen: Sulphur ratio in sub-alpine pasture grasses of Kashmir valley

Humaira Ashraf, HA Ahmed, AM Ganai, ZA Pampori, HM Khan and I Hussain

Abstract
The performance of plants can be maximized by N application only if S is adequate and, similarly, maximum response from S application will occur only if N is sufficient. In this study, the major plant species present in the pastures were collected; two pastures, Anderwan and Shuhama Pastures, during two seasons i.e., spring and autumn for their identification; in spring season 31 and in autumn season 32 palatable plant species were collected from both pastures respectively. The detailed Nitrogen, Sulphur content and N: S ratio of browse and grass species at Shuhama and Goabal (Anderwan) pastures during spring and autumn season were calculated. The mean of Nitrogen and Sulphur contents during the spring season in both pastures were more when compared to the mean of Nitrogen and Sulphur contents during autumn season.

Keywords: sub-alpine pasture plants, nitrogen, sulphur, N/S ratio

1. Introduction
Sulphur is an essential element for plants as well as animals. The animal products in diet owe this to plants, because the animals obtain S from these amino acids present in grasses, fodder and feeds. This is due to the fact that biosynthesis of organic S compounds takes place only in plants and bacteria [1]. Plants in turn obtain S from soil and adequate supply of available S is a necessary for successful production of agricultural and horticultural crops. Sulphur deficiency in soils is global and reported from various sites/countries in the world like China [2], Europe [3], USA [4], Canada [5] and India [6, 7].

Soil sulphur (S) analysis as an indicator for sulphur availability for plant growth proposed by some scientists of same field [8, 9]. The high mobility of sulphur in soil and the effects of many other factors such as the climate variation and the deepness of the water table, soil analysis is sometimes inadequate for predicting sulphur deficiencies at the parcel scale [10]. Balance (in-out) at the parcel level can also be used as an indicator of plant available sulphur [11]. Based on grass analyses, sulphur deficiency indicator can be a very complementary tool for methods predicting sulphur deficiency and can allow to have an information on the real sulphur nutrition of the plants and to evaluate the predicting methods without having to set up experimental trials with several sulphur treatments and yield measurements [12].

As plant sulphur deficiency indicators many parameters have been proposed such as total sulphur, sulphate, organic sulphur or ratios as, nitrogen (N): S, malate: sulphate, sulphate: total S; but, till date, no indicator has been chosen for grasses [13, 11, 14]. The most commonly used indicators are S content and N: S ratio. Literature reports that grasses with S content from 0.95 mg S g^{-1} DM [15] to 2.5 mg S g^{-1} DM [16] or N:S ratio from 14 [17] to 20 [16] responded positively to S fertilization. These indicators focus on critical value variation not only with the nitrogen nutrition of the plants [18] but during plant growth also. As for nitrogen (N) [19], phosphorus (P) and potassium (K) [20], S content and the critical values decrease during plant growth [21]. K and P nutrition status of grasses can be estimated by comparing K or P grass content to Index values taking into account a linear relationship between these elements and the grass N content [22]. S content also decreases during plant growth were considered [21] and such as for K, luxurious consumption of S occurs, to define an indicator method for diagnosing sulphur nutrition of grasses based on their S and N content is proposed.

2. Material and Methods

2.1 Study Area

The present study was carried out in the sub-alpine pastures of Goabal Sheep Breeding Farm (Anderwan Pasture) and Shuhama Pasture in District Ganderbal. The study was conducted at two pastures which are associated with two organized sheep farms viz; pastures of Govt. Sheep Breeding Farm Goabal, Ganderbal and pastures of Mountain Research Station for Sheep and Goat, Faculty of Veterinary Sciences and Animal Husbandry, SKUAST-K, Shuhama, in two different seasons i.e. spring and autumn.

The pasture of Goabal Sheep Breeding Farm (Anderwan Pasture) is situated at an average height of 2299.106 m AMSL. Shuhama pasture is located at an average height of 1798.93 m AMSL. The two pastures are on an average of 32 km away from each other; the vegetation is totally different probably due to greater human interference in Shuhama pasture than Anderwan pasture which is practically located in wild. The study was conducted in the month of May during spring when the temperature ranged from 20 ˚C to 24 ˚C and in the month of October during autumn season when the temperature ranged from 11˚C to 15 ˚C.

2.2 Identification of major pasture plant species

In this study, the major plant species present in the pasture were collected from the two pastures, Anderwan and Shuhama pastures, during two seasons i.e., spring and autumn for their identification. The samples were dried and a herbarium was made to record and proper identification of the plant species and the samples were identified by the experts of the Division of Taxonomy, University of Kashmir, Srinagar.

2.3 Estimation of Nitrogen

Total nitrogen was estimated by the micro-Kjeldahl method as per procedure suggested by AOAC [23].

2.4 Estimation of Sulphur

Available sulphur was determined by using 0.15% $CaCl_2$ solution [24].

3. Results

3.1 Plants identified in spring season

Palatable plants identified during spring season in both the pastures of Shuhama and Goabal pasture (Anderwan) are presented in table 1 and table 2 respectively. Some plants were exclusively present in the one pasture and absent in other, while some were present in both the pastures.

3.2 Plants identified in Shuhama pasture in spring season

The total of 18 palatable plant species were identified in Shuhama pasture which comprises of 12 grass species and 06 browse species. The browse species were *Berbaris lyceum, Indigofera hetrantha, Rosa brunonni, Rosa webbiana, Rubus spp., Zizyphus jujuba* and the grass species in Shuhama pasture were *Carpesium cernuum, Convolvulus arvensis, Cynadon dactylon, Gnaphalium affine, Lespedeza cuneata, Lolium temulentum, Medicago polymorpha, Plantago lanceolata, Sisymbriuim officinale, Trifolium pretense, Trifolium repens and Thymus linearis*.

3.3 Plants identified in Goabal pasture (Anderwan) in spring season

Total number of palatable plants identified in Goabal pasture (Anderwan) were 10 comprising of 03 browse species and 07 grass species. Palatable browse species in Goabal pasture (Anderwan) were *Berberis lyceum, Indigofera heterentha and Rosa brunonii* while palatable grass species were *Lolium perene, Medicago minima, Plantago lanceolata, Poa bulbosa, Poa perennis, Trifolium pratense,* and *Sisymbrium loeselii*.

3.4 Plants identified in autumn season

Palatable plant species identified during autumn season in the pastures of Shuhama and Goabal pasture (Anderwan) are presented in table 4 and 5, respectively. Some plants were exclusively present in one pasture and absent in other, while some were present in both the pastures.

3.5 Plants identified in Shuhama pasture in autumn season

The total of 18 palatable plant species were identified in Shuhama pasture, out of which 06 belonged to browse species and 12 belonged to grass species. Palatable browse species in Shuhama pasture includes *Astraglus grahamianus, Indigofera heterantha, Robinia pseudoacacis, Rosa brunonii, Rosa webbiania* and *Zizyphus jujuba* while palatable grass species were *Amaranthus caudatus, Cichorium intybus, Convolus arvensis, Cynodon dactylon, Daucus carrota, Lespedeza cuneata, Plantago major, Scrophularia decomposita, Trifolium pretense, Trifolium repens, Thymus linearis* and *Verbena officinalis*.

3.6 Plants identified in Goabal pasture (Anderwan) in autumn season

Total number of palatable plants identified in Goabal pasture (Anderwan) were 11 comprising of 10 browse species and only 01 grass species. Palatable browse species were *Berberis lyceum, Berberis pyracantha, Creatagus songarica, Euonymus hameltonianus, Indigofera hetrantha, Jasminum humile, Moras alba, Parrotiopsis jacquemontiana, Robinia pseudoacacis* and *Rosa brunonii* while palatable only grass species were *Juncus spp*.

3.7 Nitrogen, Sulphur status and Nitrogen: Sulphur ratio of pasture grasses for spring season

The detailed Nitrogen, Sulphur content and N: S ratio of browse and grass species at Shuhama pasture the during spring season are presented in table no. 5. Among the browse species, the highest Nitrogen content were found in *Indigofera heterantha* (2.804%) while the lowest Nitrogen content were found in *Rosa brunonii* (2.045%). Similarly, highest Sulphur content were found in *Indigofera heterantha* (0.194%) and lowest Sulphur content were found in *Berberis lycium* (0.156%). The N: S ratios were found optimum for the *Rosa webbiana* (12.82:1) and *Rosa brunonii* (12.25:1). Among the grass species, the highest Nitrogen content were found in *Convolvus arvensis* (4.384%) while the lowest Nitrogen content were found in *Lolium temulentum* (1.636%). Similarly, highest Sulphur content were found in *Convolvus arvensis* (0.210%) while the lowest Sulphur content were found in *Sisymbriuim officinale* (0.114%). The N: S ratios were found optimum for the *Cynadon dactylon* (11.68:1) and *Lolium temulentum* (11.44:1).

The detailed Nitrogen, Sulphur content and N: S ratio of browse and grass species at Goabal pasture (Anderwan) during spring season are presented in table no. 6. Among the browse species, the highest Nitrogen content were found in *Indigofera heterantha* (3.129%) while the lowest Nitrogen content were found in *Rosa brunonii* (2.083%). Similarly, highest Sulphur content were found in *Indigofera heterantha* (0.195%) and lowest Sulphur content were found in *Rosa*

brunonii (0.171%). The N: S ratios were found optimum for the *Rosa brunonii* (12.18:1). Among the grass species, the highest Nitrogen content were found in *Trifolium pretense* (2.788%) while the lowest Nitrogen content were found in *Sisymbriuim loeselii* (1.791%). Similarly, highest Sulphur content were found in *Trifolium pretense* (0.207%) while the lowest Sulphur content were found in *Sisymbriuim loeselii* (0.145%). The N: S ratios were found optimum for the *Sisymbriuim loeselii* (12.35:1) and *Lolium perene* (12.74:1).

3.8 Nitrogen, Sulphur status and Nitrogen: Sulphur ratio of pasture grasses for autumn season:

The detailed Nitrogen, Sulphur content and N: S ratio of browse and grass species at Shuhama pasture during autumn season are presented in table no. 7. Among the browse species, the highest Nitrogen content were found in *Robinia pseudoacacia* (3.043%) while the lowest Nitrogen content were found in *Astraglus grahamianus* (1.505%). Similarly, highest Sulphur content were found in *Robinia pseudoacacia* (0.186%) and lowest Sulphur content were found in *Astraglus grahamianus* and *Zizyphus jujube* (0.143%). The N: S ratios were found optimum for the *Astraglus grahamianus* (10.82:1), *Rosa brunonii* (10.30:1), *Rosa webbiania* (11.78:1) and *Indigofera heterantha* (12.65:1). Among the grass species, the highest Nitrogen content were found in *Trifolium repens* (3.530%) while the lowest Nitrogen content were found in *Cynadon dactylon* (0.993%). Similarly, highest Sulphur content were found in *Convolvus arvensis* (0.223%) while the lowest Sulphur content were found in *Cynadon dactylon* (0.102%). The N: S ratios were found optimum for the *Cichorium intybus* (11.02:1), *Amaranthus caudatus* (10.30:1), *Verbena officinalis* (10.57:1) and *Scrophularia decomposita* (11.10:1).

The detailed Nitrogen, Sulphur content and N: S ratio of browse and grass species at Goabal pasture (Anderwan) during autumn season are presented in table no. 8. Among the browse species, the highest Nitrogen content were found in *Robinia pseudoacacia* (3.202%) while the lowest Nitrogen content were found in *Creatagus songarica* (0.961%). Similarly, highest Sulphur content were found in *Indigofera heterantha* (0.197%) and lowest Sulphur content were found in *Creatagus songarica* (0.10%). The N: S ratios were found optimum for the *Berberis pyracantha* (12.82:1), *Berberis lyceum* (10.24:1), *Rosa brunonii* (11.20:1) and *Indigofera heterantha* (12.72:1). The only grass species, *Juncus spp.* Nitrogen content were found (1.626%), similarly, Sulphur content were found (0.143%). The N: S ratio of *Juncus spp.* were found optimum (11.32:1).

Table 1: Palatable plants identified during spring season in Shuhama pasture.

S. No	Scientific Name	Family	Plant Type	Local Name	English Name
1	*Berbaris lyceum*	Berberidaceae	Browse	Mazni Kund	Indian barberry
2	*Indigofera heterantha*	Fabaceae	Browse	Kech	Himaliyan Indigo
3	*Rosa brunonni*	Rosaceae	Browse	Kreed	Himalyan musk rose
4	*Rosa webbiana*	Rosaceae	Browse	Arval Posh	Thorny Rose
5	*Rubus spp.*	Rosaceae	Browse	-	-
6	*Zizyphus jujuba*	Rhamnaceae	Browse	Bare Kund	Jujube
7	*Carpesium cernuum*	Asteraceae	Grass	-	Nodding Carpesium
8	*Convolvulus arvensis*	Convolvulaceae	Grass	Thur	Field bindweed
9	*Cynadon dactylon*	Poaceae	Grass	Dramun	Bermuda grass
10	*Gnaphalium affine*	Asteraceae	Grass	-	Jersey cudweed
11	*Lespedeza cuneata*	Fabaceae	Grass	Jungle meth	Chinese bushclover
12	*Lolium temulentum*	Poaceae	Grass	Gasse	Rye grass
13	*Medicago polymorpha*	Fabaceae	Grass	-	Bur clover
14	*Plantago lanceolata*	Plantaginaceae	Grass	Guli	Lamb's tongue
15	*Sisymbriuim officinale*	Brassicaceae	Grass	-	Hedge mustard
16	*Trifolium pratense*	Fabaceae	Grass	Batak neur	Red clover
17	*Trifolium repens*	Fabaceae	Grass	Batak neur	White Clover
18	*Thymus linearis*	Lamiaceae	Grass	-	Himaliyan thyme

Table 2: Palatable plants identified during spring season in Goabal pasture (Anderwan).

S. No	Scientific Name	Family	Plant Type	Local Name	English Name
1	*Berberis lycium*	Berberidaceae	Browse	Mazni Kund	Indian barberry
2	*Indigofera heterantha*	Fabaceae	Browse	Kech	Himalyan Indigo
3	*Rosa brunonii*	Rosaceae	Browse	Kreed	Himalyan musk rose
4	*Lolium perene*	Poaceae	Grass	Gasse	Rye grass
5	*Medicago minima*	Fabaceae	Grass	Methi gasse	Little burclover
6	*Plantago lanceolata*	Plantaginaceae	Grass	Guli	Lamb's tongue
7	*Poa bulbosa*	Poaceae	Grass	-	Bluegrass
8	*Poa perennis*	Poaceae	Grass	-	-
9	*Trifolium pratense*	Fabaceae	Grass	Batak neur	Red clover
10	*Sisymbrium loeselii*	Brassicaceae	Grass	-	Tumbleweed mustard

Table 3: Palatable plants identified during autumn season in Shuhama

S. No	Scientific Name	Family	Plant Type	Local Name	English Name
1	*Astraglus grahamianus*	Papilionaceae	Browse	Chari kund	-
2	*Indigofera heterantha*	Fabaceae	Browse	Kech	Himaliyan Indigo
3	*Robinia pseudoacacia*	Fabaceae	Browse	Kikar	Black locust
4	*Rosa brunonii*	Rosaceae	Browse	Kreed	-
5	*Rosa webbiania*	Rosaceae	Browse	Arval Posh	Thorny Rose

6	*Zizyphus jujube*	Rhamnaceae	Browse	Bare Kund	Jujube
7	*Amaranthus caudatus*	Amaranthaceae	Grass	Ganhar	Pendant amaranth
8	*Cichorium intybus*	Asteraceae	Grass	Saze hande	Common chicory
9	*Convolus arvensis*	Convolvulaceae	Grass	Thur	Field bindweed
10	*Cynodon dactylon*	Poaceae	Grass	Dramun	Bermuda grass
11	*Daucus carrota*	Apiaceae	Grass	Mohar muj	Wild carrot
12	*Lespedeza cuneata*	Fabaceae	Grass	Jungle meth	Chinese bushclover
13	*Plantago major*	Plantaginaceae	Grass	Guli	Greater plantain
14	*Scrophularia decomposita*	Scrophulariaceae	Grass	Gande soi	Figwort
15	*Trifolium pretense*	Fabaceae	Grass	Batak neur	Red clover
16	*Trifolium repens*	Fabaceae	Grass	Batak neur	White Clover
17	*Thymus linearis*	Limaiceae	Grass	Jungle jayand	Himalyan thyme
18	*Verbena officinalis*	Verbenaceae	Grass	-	Holy Herb

Table 4: Palatable plants identified during autumn season in Goabal pasture (Anderwan)

S. No	Scientific Name	Family	Plant Type	Local Name	English Name
1	*Berberis lyceum*	Berberidaceae	Browse	Mazni Kund	Indian barberry
2	*Berberis pyracantha*	Berberidaceae	Browse	Kavdach	-
3	*Creatagus songarica*	Roaceae	Browse	-	Howthorn
4	*Euonymus hameltonianus*	Celastraceae	Browse	-	Hamilton's spindle tree
5	*Indigofera heterantha*	Fabaceae	Browse	Kech	Himaliyan Indigo
6	*Jasminum humile*	Oleaceae	Browse	-	Yellow jasmine
7	*Moras alba*	Moraceae	Browse	Shahtoot	Mulberry
8	*Parrotiopsis jacquemontiana*	Hamamelidaceae	Browse	Poshvi	Parrotia
9	*Robinia pseudoacacia*	Fabaceae	Browse	Kikar	Black locust
10	*Rosa brunonii*	Roseaceae	Browse	Kreed	Himalyan musk rose
11	*Juncus spp.*	Juncaceae	Grass	-	Rushes

Table 5: Estimation of nitrogen, sulphur and N: S ratio in plants of Shuhama pasture in spring season

S No.	Scientific name	N%	S%	N:S ratio
Browse species				
1.	*Zizyphus jujuba*	2.288	0.168	13.62:1
2.	*Indigofera heterantha*	2.804	0.194	14.45:1
3.	*Rosa webbiana*	2.103	0.164	12.82:1
4.	*Rosa brunonii*	2.045	0.167	12.25:1
5.	*Berberis lycium*	2.172	0.156	13.92:1
6.	*Rubus sp.*	2.248	0.172	13.07:1
Grass species				
1.	*Thymus linearis*	3.084	0.192	16.06:1
2.	*Gnaphalium affine*	1.957	0.132	14.83:1
3.	*Carpesium cernuum*	1.795	0.125	14.36:1
4.	*Cynadon dactylon*	1.763	0.151	11.68:1
5.	*Lolium temulentum*	1.636	0.143	11.44:1
6.	*Sisymbriuim officinale*	1.683	0.114	14.76:1
7.	*Lespedeza cuneata*	3.450	0.207	16.67:1
8.	*Trifolium pretense*	2.915	0.183	15.93:1
9.	*Trifolium repens*	3.604	0.199	18.11:1
10.	*Plantago lanceolata*	1.968	0.135	14.58:1
11.	*Medicago polymorpha*	2.470	0.156	15.83:1
12.	*Convolvus arvensis*	4.384	0.210	20.88:1

Table 6: Estimation of nitrogen, sulphur and N: S ratio in plants of Goabal pasture (Anderwan) in spring season

S No.	Scientific name	N%	S%	N:S ratio
Browse species				
1.	*Berberis lyceum*	2.326	0.174	13.37:1
2.	*Rosa brunonii*	2.083	0.171	12.18:1
3.	*Indigofera heterantha*	3.129	0.195	16.05:1
Grass species				
1.	*Medicago minima*	2.604	0.183	14.23:1
2.	*Poa perennis*	2.147	0.165	13.01:1
3.	*Plantago lancilata*	2.233	0.167	13.37:1
4.	*Poa bulbosa*	2.083	0.157	13.27:1
5.	*Lolium perene*	1.926	0.151	12.75:1
6.	*Trifolium pretense*	2.788	0.207	13.47:1
7.	*Sisymbrium loeselii*	1.791	0.145	12.35:1

Table 7: Estimation of nitrogen, sulphur and N: S ratio in plants of Shuhama pasture in autumn season

S No.	Scientific name	N%	S%	N:S ratio
Browse species				
1.	*Zizyphus jujuba*	1.874	0.143	13.10:1
2.	*Rosa brunonii*	1.741	0.169	10.30:1
3.	*Astraglus grahamianus*	1.505	0.143	10.52:1
4.	*Robinia pseudoacacis*	3.043	0.186	16.36:1
5.	*Indigofera heterantha*	2.29	0.181	12.65:1
6.	*Rosa webbiania*	1.885	0.160	11.78:1
Grass species				
1.	*Lespedeza cuneata*	3.195	0.187	17.09:1
2.	*Cichorium intybus*	1.796	0.163	11.02:1
3.	*Amaranthus caudatus*	1.555	0.151	10.30:1
4.	*Cynodon dactylon*	0.993	0.102	9.74:1
5.	*Trifolium repens*	3.53	0.191	18.48:1
6.	*Thymus linearis*	2.814	0.185	15.21:1
7.	*Daucus carrota*	3.231	0.206	15.68:1
8.	*Verbena officinalis*	1.395	0.132	10.57:1
9.	*Scrophularia decomposita*	1.154	0.104	11.10:1
10.	*Convolus arvensis*	3.222	0.223	14.45:1
11.	*Trifolium pretense*	3.076	0.192	16.02:1
12.	*Plantago major*	1.623	0.114	14.24:1

Table 8: Estimation of nitrogen, sulphur and N: S ratio in plants of Goabal pasture in autumn season

S No.	Scientific name	N%	S%	N:S ratio
Browse species				
1.	*Moras alba*	2.475	0.167	14.82:1
2.	*Berberis pyracantha*	1.82	0.142	12.82:1
3.	*Berberis lyceum*	1.382	0.135	10.24:1
4.	*Creatagus songarica*	0.961	0.100	9.61:1
5.	*Jasminum humile*	1.772	0.132	13.42:1
6.	*Robinia pseudoacacia*	3.202	0.188	17.03:1
7.	*Rosa brunonii*	1.938	0.173	11.20:1
8.	*Parrotiopsis jacquemontiana*	1.602	0.112	14.30:1
9.	*Indigofera heterantha*	2.505	0.197	12.72:1
10.	*Euonymus hameltonianus*	1.333	0.101	13.20:1
Grass species				
1.	*Juncus sp.*	1.626	0.143	11.37:1

4. Discussion

S and N plays central role in the synthesis of proteins, the supplies of these nutrients in plants are highly inter-related. In terms of dry matter and yield, Sulphur and nitrogen relationships were established in many studies in several crops [25-30]. Barney and Bush [31], while working on tobacco plant concluded that there was an apparent accumulation of one nutrient when the other nutrient was limited and that accumulated nutrient was used in protein synthesis when the treatment were reversed. A shortage in the S supply of the crops lowers the utilization of the available soil nitrogen, thereby increasing nitrate leaching [32]. O'Connor and Vartha [33] observed that large dose of gypsum reduced the yield of hay when N status in soil was unsatisfactory. Likewise, large dose of N created S deficiency [34]. It has been established that for every 15 parts of N in protein there is 1 part of S which implies that the N: S ratio is fixed within a narrow range of 15:1. The N: S ratio in the whole plant in general is 20: 1 [35]. Clarkson *et al.,* [36] while working on barley plants, demonstrated that at the whole plant level the apparent matching of supply to demand is accompanied by an apparent linkage of SO_4^{2-} to NO^{3-} uptake. Sulphur and nitrogen both are required for the synthesis of proteins; the ratio of total N to total S in plant tissue can reflect the ability of N and S in protein synthesis [37]. Thus, a change in the ratio of reduced-N to reduced-S (NR/SR), which is a reflection of the amount of S amino acids, suggests that protein metabolism has been significantly altered and has important implications for protein quality [38]. A number of studies on S requirement of the crop in relation to N have been reported [28, 29, 39, 40, 30]. There is a significant positive S x N interaction in relation to the oil content and yield. Adequate N: S ratio has been found to be 7.5:1 in grains, above which deficiency of S can be observed [41]. There is a strong relationship between S and N content in plants. The ratio of total N to total S and protein S determine the degree of availability of deficiency of S in protein. The N and S ratio is often preferred over concentration as a diagnostic criterion for S deficiency [42]. The total S content in plant tissues varies among plant species. In greenhouse trails with subterranean clover, N: S ratio was shown to be less variable with plant age and N supply than total S and total sulphate [43]. Experiments with rapeseed showed that the N:S ratio of rapeseed tops sampled at the rosette stage was very sensitive and changes due to change in sites, year and seed varieties and these changes were sometimes greater than differences between S deficient and S sufficient rapeseed [44]. Dev and Saggar [45] observed that S application lowered total N: total S ratios in soybean. It was also shown that at the S levels where consistency in total N and total S ratios was obtained, one part of S was required for every 14 and 16 parts of N in protein formation in different varieties of soybean. Dev *et al.,*[46] reported that application of 20 kg S ha^{-1} lowered N: S ratio in mustard seeds from a range of 14:1-16:1 to 11:1-12:1 and it was further reduced to 10:1, when S was applied at 40 kg ha^{-1}. Aulakh *et al.,* [47] found N: S ratio of 15.5:1 in plant tissue of

mustard to be critical, above which the inadequacy of S may cause a drastic reduction in grain yield.

5. Conclusion

Sulphur is an important nutrient for plant growth and development. Sulphur interactions with nitrogen nutrients are directly related to the alteration of physiological and biochemical responses of crops, and thus required to be studied in depth. This would help to understand nutritional behaviour of sulphur in relation to nitrogen nutrients and provide guidelines for inventing balanced fertilizer recommendations in order to optimise yield and quality of crops.

6. Acknowledgement

With reverence, I would like to acknowledge Dr. M. A. Alam, Incharge- Residue Analysis & Quality Control Laboratory, SKAUST-K Shalimar for providing laboratory to conduct this research work. Also acknowledge Dr. Qadrie ZL. For his continuous support and guidance during the period of work.

7. References

1. Parcell S. Sulfur in human nutrition and application in medicine. Alternative Med Rev. 2002; 7:22-44
2. Messick DL, Fan MX. Sulphur in balanced fertilization in China. In, Proc TSI-FAI IFA Workshop on Sulphur. In: Balanced Fertilization MC Sarkar, B C Biswas, S Das, S Dev (eds), The Fertiliser Association of India, New Delhi. 2007, 1-12
3. Messick DL. Sulphur fertilizers-A global perspective. Proc TSI-FAI-IFA Workshop on Sulphur In Balanced Fertilization (Sarkar MC, Biswas BC, Das S, Kalwe SP, Maity SK,eds), The Fertiliser Association of India, New Delhi. 2003, 1-7
4. Rehm G. Sulphur management for corn grown with conservation tillage. Soil Sci Am J. 2005; 69:709-717
5. Solberg ED, Malhi SS, Nyborg M, Henrique B, Gill KS. Crop responses to elemental Sulphur and sulphate S sources on sulphur deficient soils in Parkland region of Alberta and Saskatchewan. J Plant Nutr. 2006; 30:321-333
6. Singh MV. Importance of sulphur in balanced fertilizer use in India. Fertiliser News. 2001; 46(10):13-35
7. Tandon HLS. Sulphur in Soils, Crops and Fertilizers. Fertilizer Development and Consultation Organization (FDCO), New Delhi, 2011.
8. Scott NM. Evaluation of sulfate status of soils by plant and soil tests. Journal of the Science of Food and Agriculture. 1981; 32:193-199.
9. Zhao FJ. McGrath SP. Extractable sulphate and organic sulphur in soils and their availability to plants. Plant and Soil. 1994; 164:243-250.
10. Verlinden G. Sulphur dynamic in Belgian agricultural soils. Dissertationes de Agricultura. University of Leuven, 2002.
11. Schnug E, Haneklaus S. Diagnosis of sulphur nutrition. In: Schnug, E. (Ed.), Sulphur in Agroecosystems. Academic Publishers. The Netherlands. 1998, 1-38.
12. Mathot M, Thélier-Huché L, Lambert R. Sulphur and nitrogen content as sulphur deficiency indicator for grasses. European Journal of Agronomy. 2008; 28(4):655-658.
13. Dijkshoorn W, Van Wijk L. The sulphur requirement of plants as evidenced by the sulphur-nitrogen ratio in organic matter. A review of published data. Plant and Soil. 1967; 26:129-157.
14. Black Kalff M, Zhao FJ, McGrath P. Sulphur deficiency diagnosis using plant tissue analysis. In: Proceedings N° 503, International Fertiliser Society. York, 2002.
15. Helgadottir A, Palmason F, Björnsson H. The effect of sulphur fertilization on hay yield and its influence on sulphur content in grass. Journal of Agricultural Research in Iceland. 1977; 9:3-21.
16. Eppendorfer WH. Effects of varying amounts of sulphur and nitrogen on yield, N/S ratio and amino-acid composition of successive cuts of Italian ryegrass. Royal veterinary and agricultural university yearbook. 1976, 42-57.
17. Bolton J, Nowakowski TZ, Lazarus W. Sulphur-nitrogen interaction effects on the yield and composition of protein-N non-protein-N and soluble carbohydrates in perennial ryegrass. Journal of the Science of Food and Agriculture. 1976; 27:533-560.
18. Kowalenko CG. Variations in within season nitrogen and sulfur interaction effects on forage grass. Response to combinations of nitrogen, sulfur and boron applications. Communications in Soil Science and Plant Analysis. 2004; 35(5, 6):759-780.
19. Lemaire G, Salette J. Relation entre dynamique de croissance et dynamique de prélèvement d'azote pour un peuplement de graminées fourragères.Agronomie. 1984; 4(5):423-440. (In French).
20. Salette J. The role of fertilizers in improving herbage quality and optimization of its utilization. In: Proceedings of the 12th international Potash Institute Congress, 1982, 117-144.
21. Salette JE. Sulphur content in grasses during primary growth. In: An Foras Taluntais (Ed.), Sulphur in Forages, Proceedings of Symposium. 1978, 142-152.
22. Duru M, Thélier Huché LN, PK status of herbages: use for diagnosis of grasslands. Diagnostic procedures for crop N management. In: Inra (Ed.), Les colloques de l'Inra. 1997, 125-138.
23. AOAC, Official Method of Analysis. 16th Edn. Association of Official Analytical Chemists. Washington DC, 1995.
24. Williams CH, Steinbergs A. Soil sulphur fraction as chemical indices of available sulphur in some Australian soils. Australian Journal of Agricultural Research. 1959; 10:340-350.
25. Zhao FJ, Evans EJ, Bilsborrow PE, Syers JK. Influence of S and N on seed yield and quality of low glucosinolate oilseed rape (*Brassica nepus* L.). J Sci Food Agric. 1993; 63:29-37
26. McGrath SP, Zhao FJ. Sulphur uptake, yield response and the interactions between N and S in winter oilseed rape (*Brassica napus* L.) J Agric Sci. 1996; 126:53-62
27. Ahmad A, Abraham G, Gandotra N, Abrol YP, Abdin MZ. Interactive effect of nitrogen and sulphur on growth and yield of rapeseed-mustard (*Brassica juncea* [L.] Czern and Coss. and *Brassica campestris* L.). J Agron Crop Sci. 1998; 181:193-199
28. Jamal A, Fazli IS, Ahmad S, Abdin MZ, Yun SJ. Effect of sulphur and nitrogen application on growth characteristics, seed and oil yield of soybean cultivars. Korean J Crop Sci. 2005; 50(5):340-345
29. Jamal A, Fazli IS, Ahmad S, Abdin MZ. Interactive effect of nitrogen and sulphur on yield and quality of

groundnut (*Arachis hypogea* L.). Korean J Crop Sci. 2006a; 51(6):519-522
30. Jamal A, Moon YS, Abdin MZ. Enzyme activity assessment of peanut (*Arachis hypogea*) under slow-release sulphur fertilization. Aust J Crop Sci. 2010; 4(3):169-174
31. Barney Jr PE, Bush LP. Interaction of nitrate and sulphate reduction in tobacco.I. Influence of availibility of nitrate and sulphate. J Plant Nutr. 1985; 8:507-515.
32. Lakkineni KC, Abrol YP. Sulfur requirement of crop plants: Physiological Analysis. Fert News. 1994; 39:11-18
33. O'Conner KF, Vartha EW. Responses of grasses to sulfur fertilizers. Plant and Soil. 1969; 60(3):451-459
34. Eppendorfer WH. Effects of sulfur, nitrogen and phosphorous on amino acid composition of field beans (*Vicia faba*) and responses of the biological value of the seed protein and sulfur-amino acid content. J Sci Food Agric. 1971; 22:501-505
35. Cram WJ. Uptake and transport of sulphate. In: Rennenberg H (ed.) Sulphur Nutrition and Assimilation in Higher Plants. SPB Acadmic Publishing, The Hague, The Netherlands. 1990, 3-11.
36. Clarkson DT, Saker LR, Purves JV, Lee RB. Depration of nitrate and ammonium transport in barley plant with diminished sulphate status. Evidence of co-regulation of nitrogen and sulphate intake. J Expt Bot. 1989; 40:953-963
37. Brunold C, Suter M. Regulation of sulphate assimilation by nitrogen nutrition in the duckweek *Lemna minor* L. Plant Physiol. 1984; 76:579-583
38. Friedrich JW, Schrader LE. Sulphur deprivation and nitrogen metabolism in maize seedlings. Plant Physiol. 1978; 61:900-903.
39. Jamal A, Fazli IS, Ahmad S, Kim KT, Oh DG, Abdin MZ. Effect of sulfur on nitrate reductase and ATP sulfurylase activities in groundnut (*Arachis hypogea* L.). J Plant Biol. 2006b; 49(6):513-517
40. Jamal A, Ko K, Kim HS, Cho YK, Joung H, Ko K. Role of genetic factors and environmental conditions in recombinant protein production for plant molecular biofarming. Biotech Advan. 2009; 27:914-923.
41. Aulakh MS, Pasricha NS, Sahota NS. Yield, nutrient concentration and quality of mustard crops as influenced by nitrogen and sulphur fertilizers. J. Agric Sci Camb. 1980; 94:545-549
42. Stewart BA, Whitefield CJ. Effect of crop residuces, soil temp and sulfur on growth of winter wheat. Soil Sci Soc Am Proc. 1965; 29:752-755
43. Freney JR, Spencer K, Jones MB. On the constancy of the nitrogen to sulfur ratio in the protein subterranean clover tops. Soil Sci Plant Analysis. 1977; 8:241-249.
44. Maynard DG, Stewart JWB, Bettany JR. Use of plant analysis to predict sulphur deficiency in rapeseed (*Brassica napus*). Can J Soil Sci. 1983; 63:387-396
45. Dev G, Saggar. Effect of S fertilization on the N:S ratio in soybean varieties. Agron J. 1974; 66:454-456
46. Dev G, Sagar S, Bajwa MS. Nitrogen-sulfur relationship in raya (*Brassica juncea* L.) as influenced by sulfur fertilization. J Ind Soc Soil Sci. 1981; 29:397-399
47. Aulakh MS, Pasricha NS, Sahota NS. Nitrogen-sulfur relationship in brown sarson and Indian mustard. Ind J Agric Sci. 1977; 47:249-253