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Effect of various Sulphur levels on concentration and uptake of nitrogen, phosphorus and potash of soybean [*Glycine max* (L.)] varieties

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Abstract
A pot experiment was conducted at Department of Agricultural Chemistry and Soil Science, College of Agriculture, Junagadh Agricultural University, Junagadh to study the "Varietal Response of Soybean [*Glycine max* (L.) Merrill] to Sulphur in Medium Black Calcareous Soils during *kharif* 2012.The pot experiment comprising 20 treatment combinations, each replicated four time was laid out in factorial concept of CRD design with four different levels of Sulphur- Cosawet Sulphur (0, 5, 10 and 15 mg kg^{-1}) and five soybean varieties *viz.*, V_1 (GS-1), V_2 (GS-2), V_3 (GJ-335), V_4 (PK-472), V_5 (GJS-3) were tested in the experiment, in respect of yield and yield attributes, content and uptake of nuutrient (NPK) by plant parts & their total uptake at different growth stages of soybean crop and status of soil available nuterint(NPK) at harvest. The experimental soil was *vertic haplustepts* medium black calcareous, clayey in nature which was slightly alkaline in reaction $pH_{2.5}$ (7.8) and $EC_{2.5}$ (0.58 dSm^{-1}), low in available nitrogen (242 kg ha^{-1}), medium in available phosphorus (39.20 kg ha^{-1}), high in available potasium (320 kg ha^{-1}) and medium in available Sulphur (21.50 kg ha^{-1}).The concentration of nitrogen, phosphorus, potassium in leaves, shoot and root at 45 DAS and leaves, shoot, root and seed at harvest was remain unaffected. Almost, the maximum uptake of nitrogen, phosphorus and potassium by leaves and shoot and their total uptake at 45 DAS and at harvest were recorded with variety V5 (GJS-3). Similar trend was also observed in case of the uptake of NPK by seed at harvest. The availability of NPK in soil at harvest did not influenced significantly by varieties of soybean. The application of sulpur @ 15 mg kg^{-1}also produced beneficial effect on uptake of nutrients (NPK) by plant parts and their total uptake at 45 DAS and at harvest. Application of Sulphur @ 15 mg kg^{-1}gave significantly higher uptake of NPKS by leaves, shoot and root and their total uptake at 45 DAS and at harvest over that of lower Sulphur levels. Similarly, the maximum uptake of NPKS by seed recorded at Sulphur applied @ 15 mg kg^{-1}. Similarly, the interaction effect of variety and Sulphur also found in respect of uptake of K and S by seed and registered significantly higher with variety V_5 (GJS-3) at Sulphur level of 15 mg kg^{-1}.

Keywords: *kharif* soybean**,** Sulphur levels, nutrient content, uptake and total uptake, mg kg^{-1}

1. Introduction
Soybean [*Glycine max* (L.) Merrill] is considered a miracle crop because of its dual qualities, *viz*., high protein and oil content in seed. In India, soybean cultivation was started in 1977. It has high yield potential, wide adaptability, short duration and very high nutritional value having a vast multiplicity of uses as food and industrial products. Being a legume, it fixes a large amount of atmospheric nitrogen in soil. Therefore, soybean crop is known as "Golden Bean", "Miracle Crop", "Wonder Crop" and "Gold of Soil". The soybean crop is one of the remarkable success stories in Indian agriculture. It was promoted in the mid 80's as one of the strategies to boost edible oil production in the country. It was introduced in Gujarat by ex Baroda State as early as 1934. In recent years, great interest has been evidenced in the cultivation and the use of soybean, mainly on account of its dietic, industrial and agricultural importance. In India it occupies fourth position in respect of area and fifth in production among the nine oilseed crops. *viz*. Groundnut, castor, safflower, rapeseed, mustard, sesamum, soybean, sunflower, and niger in the world. In India, area under soybean cultivation was 9.73 million hectares and yield was 1024 kg ha^{-1} with total production of 9.96 million tonnes during year 2009-10. The major growing states are Madhya Pradesh, Uttar Pradesh, Maharashtra and Karnataka. In Gujarat, the area under soybean was 63,100 ha and yield was 804 kg ha^{-1} with total production of 50,700 MT (Anonymous, 2012) [1]. The introduction of high yielding varieties, increase in cropping intensity and use of high analysis fertilizer increased the crop

production tremendously but in the course of time deficiencies of micro and secondary nutrients become critical for sustaining optimum productivity of crops in several soils (Singh, 1999) [13]. In that Sulphur fertilizers are most critical for grain yield and oil and protein synthesis, and improvement of quality of soybean through enzymatic and metabolic efforts (Kumar *et al*. 1981) [8].

Materials and Methods

A pot experiments was conducted during *kharif* - 2012, to study the "Varietal response of soybean [*Glycine max* (L.) Merrill] to Sulphur in medium black calcareous soils" at the Department of Agricultural Chemistry and Soil Science, College of Agriculture, Junagadh Agricultural University Junagadh. The details of the methodology followed during the course of study are as below.

Experimental details

A pot experiment was carried out during the period of July to Nov, 2012. The details of experiment are given into sub-parts as follows:

1	Location	:	Department of Agriculture Chemistry and Soil Science, College of Agriculture, JAU, Junagadh
2	Season and Year of experiment	:	*Kharif*-2012
3	Pot size	:	Pot Experiment (Wt. of soil = 12 kg / pot)
4	Experimental design	:	CRD (Factorial)
5	Replications	:	4 (Four)
6	Crop and variety	:	Soybean and Five varieties as per treatment.
7	Seed rate	:	Sow seven (7) seed each pot and finally maintain 5 plant per pot.

Treatment detailed

Four levels of Sulphur and five varieties were studied in the present investigation are described as under.

Varieties Sulphur Level (mg kg^{-1})

V_1 = GS – 1 S_1 = 0
V_2 = GS – 2 S_2 = 5
V_3 = JS – 335 S_3 = 10
V_4 = PK – 472 S_4 = 15
V5 = GJS – 3

Thus in all, there were 20 treatment combinations, each replicated for four times.

Note:-Total replication four, out of four replication, plants were uprooted at 45 DAS from two replication. Hence, the two replication were accounted for all observation.

All possible Treatment combination

Sr No	Treatment	Sr No	Treatment
1	V_1S_1	11	V_3S_3
2	V_1S_2	12	V_3S_4
3	V_1S_3	13	V_4S_1
4	V_1S_4	14	V_4S_2
5	V_2S_1	15	V_4S_3
6	V_2S_2	16	V_4S_4
7	V_2S_3	17	V_5S_1
8	V_2S_4	18	V_5S_2
9	V_3S_1	19	V_5S_3
10	V_3S_2	20	V_5S_4

Results and discussion

Content of nutrient (NPK)

Effect of Variety

The perusal of the data in table 1, 2 and 3 revealed that the concentration of nitrogen, phosphorus, potassium and Sulphur in leaves, shoot and root at 45 DAS and leaves, shoot, root and seed at harvest did not influence by tested varieties of soybean.

Effect of Sulphur

It can be seen from the result (Table 1, 2 and 3) that the concentration of Sulphur in the leaves, shoot and root at 45 DAS as well as in leaves, shoot, root and seeds part of soybean at harvest increased with increasing levels of Sulphur application. These results are in line with those obtained by Dhillon and Dev, (1978) [3], Singh and Raj, (1988) [14], Vijayapriya *et al*. (2005) [16].

The application of Sulphur did not show any significant effect on content of N, P and K in leaves, shoot and root at 45 DAS and in leaves, shoot, root and seed at harvest. Vaghani *et al*. (2010) [15] reported that the application of Sulphur did not produce any significant effect on the content of N, P and K in seed and stover of sesame.

Interaction effect of Variety and Sulphur

The interaction between variety and Sulphur did a not effect on the concentration of NPKS in leaves, shoot and root at different growth stages and in seed at harvest (Table 1, 2 and 3).

Uptake of nutrient (NPK).

The soil is a dynamic system, the uptake and requirement of nutrient influence by several factors like crop and variety, physico-chemical properties of soil, nutrient supply and management practices etc. Even though, nutrient concentration and their uptake by plant parts have been used to evaluate fertilizer practices and to investigate the problem of poor growth. Hanway and Weber, (1971) [6] studied on the effect of fertilizer application on noduleting and non-noduleting soybean and of varieties on the amount of N,P and K accumulation in above ground plant parts of soybean at successive stages of plant development. Total accumulation of N, P and K in the plant followed patterns similar to that of dry matter accumulation. Rate of accumulation was slow early in the season, but became rapid and the nutrients accumulation at constant daily rate. Approximately 79% of total accumulation of these nutrient occurred up to 46 days period. Approximately half of the N, P and K in the mature seeds were translocated from other plant parts, and the remaining half taken up from the soil and nodules during seed development. Fertilizer application increased the amount of N, P and K accumulation in the plants.

Effect of Variety

The uptake of nitrogen, phosphorus, potassium and Sulphur by leaves, shoot and root part of plant at different growth stages and by seed at harvest as well as their total uptake by soybean was significantly influenced by varieties of soybean except uptake of nitrogen, phosphorus and potassium by shoot at 45 DAS and at harvest, and Sulphur uptake by leaves, shoot and root parts of plant at harvest, total uptake of P at 45 DAS, K and S at harvest (Table 4, 5, and 6). Almost, the maximum uptakes of nitrogen, phosphorus, potassium and Sulphur by leaves and shoot and their total uptake at 45 DAS and at harvest were recorded with variety V_5 (GJS-3). Similar trend

was also observed in case of the uptake of NPKS by seed at harvest, whereas the uptake of NPKS by root was registered higher with variety V_2 (GS-2). The uptake is arithmatic output of content and dry matter yield. Varieties differ significantly among themselves in respect of the NPKS uptake by plant parts and their total uptake because of total dry matter production and it partitioning between organs (Billore *et al*., 2009) [2]. Similar finding were also reported by Patil, (2000) [10], for N, P, K uptake by groundnut cultivars and Sharma *et al*. (2006) [12] for N, P, K uptake by soybean cultivars.

Table 1: Effect of varieties and Sulphur on nitrogen content (%) in plant parts of soybean

Treatments	45 DAS			At harvest			
	Leaves	Shoot	Root	Leaves	Shoot	Root	Seeds
Variety (V)							
V_1 GS-1	0.438	1.026	0.668	0.231	0.721	0.544	5.689
V_2 GS-2	0.434	0.988	0.708	0.238	0.714	0.599	5.614
V_3 JS-335	0.463	1.038	0.679	0.231	0.730	0.608	5.941
V_4 PK-472	0.428	1.006	0.706	0.222	0.720	0.626	5.795
V_5 GJS-3	0.466	0.990	0.798	0.240	0.786	0.655	5.606
S.Em.+	0.011	0.034	0.032	0.011	0.032	0.028	0.112
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS
Sulphur level (S)							
S_1-0 mg kg^{-1}	0.409	0.985	0.664	0.204	0.731	0.575	5.588
S_2-5 mg kg^{-1}	0.404	0.984	0.699	0.213	0.764	0.601	5.662
S_3-10 mg kg^{-1}	0.430	1.027	0.732	0.221	0.696	0.628	5.676
S_4-15 mg kg^{-1}	0.540	1.041	0.752	0.292	0.746	0.621	5.990
S.Em.+	0.010	0.030	0.028	0.010	0.028	0.025	0.100
C.D. (P=0.05)	0.029	NS	NS	0.029	NS	NS	0.284
Vx S Interaction							
S.Em.+	0.023	0.067	0.063	0.023	0.064	0.056	0.223
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS
C.V.%	7.135	9.433	12.58	13.937	12.236	13.055	5.514

Table 2: Effect of varieties and Sulphur on phosphorus content (%) in plant parts of soybean

Treatments	45 DAS			At harvest			
	Leaves	Shoot	Root	Leaves	Shoot	Root	Seed
Variety (V)							
V_1 GS-1	0.218	0.229	0.210	0.124	0.160	0.190	0.499
V_2 GS-2	0.228	0.224	0.204	0.136	0.180	0.197	0.545
V_3 JS-335	0.240	0.230	0.187	0.134	0.170	0.208	0.528
V_4 PK-472	0.213	0.222	0.211	0.138	0.165	0.202	0.550
V_5 GJS-3	0.10	0.234	0.196	0.149	0.178	0.226	0.536
S.Em.+	0.010	0.010	0.010	0.008	0.007	0.009	0.018
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS
Sulphur level (S)							
S_1-0 mg kg^{-1}	0.208	0.213	0.186	0.125	0.156	0.193	0.500
S_2-5 mg kg^{-1}	0.232	0.230	0.205	0.132	0.179	0.215	0.537
S_3-10 mg kg^{-1}	0.222	0.222	0.199	0.142	0.170	0.204	0.532
S_4-15 mg kg^{-1}	0.240	0.246	0.217	0.147	0.177	0.207	0.558
S.Em.+	0.009	0.009	0.009	0.007	0.007	0.008	0.016
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS
Vx S Interaction							
S.Em.+	0.020	0.021	0.019	0.015	0.015	0.018	0.036
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS
C.V.%	12.77	12.93	13.44	15.720	12.58	12.73	9.48

Table 3: Effect of varieties and Sulphur on potassium content (%) in plant parts of soybean

Treatments	45 DAS			At harvest			
	Leaves	Shoot	Root	Leaves	Shoot	Root	Seed
Variety (V)							
V_1 GS-1	0.869	1.126	0.649	0.324	0.539	0.225	1.605
V_2 GS-2	0.885	1.035	0.655	0.326	0.524	0.250	1.576
V_3 JS-335	0.879	1.104	0.651	0.341	0.530	0.218	1.636
V_4 PK-472	0.860	1.051	0.625	0.364	0.539	0.246	1.633
V_5 GJS-3	0.870	1.089	0.683	0.355	0.525	0.218	1.634
S.Em.+	0.034	0.052	0.021	0.022	0.019	0.011	0.019
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS
Sulphur level (S)							
S_1-0 mg kg^{-1}	0.856	1.010	0.634	0.313	0.523	0.225	1.601
S_2-5 mg kg^{-1}	0.869	1.094	0.647	0.332	0.536	0.235	1.623
S_3-10 mg kg^{-1}	0.879	1.102	0.644	0.344	0.503	0.215	1.608
S_4-15 mg kg^{-1}	0.886	1.118	0.685	0.355	0.563	0.250	1.635
S.Em.+	0.030	0.046	0.019	0.022	0.019	0.010	0.017
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS
Vx S Interaction							
S.Em.+	0.068	0.103	0.042	0.027	0.043	0.022	0.038
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS
C.V.%	11.02	13.46	9.15	11.45	11.45	13.41	3.34

Effect of Sulphur

The uptake of nitrogen, phosphorus, potassium and Sulphur by leaves, shoot and root, (Table 4, 5, and 6) at different growth stage and seed at harvest and their total uptake by soybean increasing trend was observed with Sulphur level. Application of Sulphur @ 15 mg kg^{-1}gave significantly higher uptake of NPKS by leaves, shoot and root and their total uptake at 45 DAS and at harvest over that of lower Sulphur levels. Similarly, the maximum uptake of NPKS by seed recorded at Sulphur applied @ 15 mg kg^{-1}. Sharma *et al*. (2004) [11] reported that the application of Sulphur @ 30 kg ha^{-1}gave significantly higher uptake of N, P, K and S by soybean. These finding are in agreement with those by Ijgude and Kadam, (2005) [7], Gokhale *et al*. (2005) [4] and Nagar *et al*., (2011) [9].

Interaction effect of Variety and Sulphur

The interaction effect of variety and Sulphur was found non-significant on the uptake of NPKS by leaves, shoot and root part of plant and their total uptake by plant at different growth stages except K and S uptake by seed (Table 4, 5, and 6). The uptake of K and S by seed was registered significantly higher with variety V_5 (GJS-3) at Sulphur level (15 mg kg^{-1}). Accumulation of K in soybean at maturing was varied with variety due to genetic variation and recovery of K by soybean (Billore *et al*., 2009) and also availability of K increased by Sulphur levels which might be increased the uptake of K by seed. The uptake of S by seed was recorded significantly higher with variety JS-335 at 40 kg ha^{-1} (Gokhale *et al*., 2004) [5].

At 45 DAS

Effect of Variety

The uptake of potassium by leaves and root part of the plant significantly influenced by various varieties of soybean at 45 DAS. The uptake of potassium by leaves was recorded higher with variety V_5 (GJS-3) with value of 23.90 mg plant^{-1}. It was remained at par V_2 (GS-2), V_3 (JS-335) and V_4 (PK-472).While potassium uptake by root recorded higher with variety V_2 (GS-2) with value of 2.74 mg plant^{-1}. It was also remained at par with V_3 (JS-335), V4 (PK-472) and V_5 (GJS-

3). The uptake of potassium by shoot was found non-significant.

Effect of Sulphur

The application of Sulphur produced significant effect on potassium uptake by leaves and shoot parts of the plant at 45 DAS. While, the uptake of potassium by root was unaffected due to the Sulphur application. Significantly higher value of potassium uptake by leaves (24.29 mg plant^{-1}) and shoot (30.16 mg plant^{-1}) were recorded with Sulphur applied @ 15 mg kg^{-1} (S_4) which was also found at par with S_3 (10 mg S kg^{-1}) in respect of potassium uptake by shoot and leaves.

Interaction effect of Variety and Sulphur

The interaction effect of Sulphur and variety found to be non significant in respect of potassium uptake by leaves, shoot and root at 45 DAS.

At harvest

Effect of Variety

The uptake of potassium by leaves, root, and seed was significantly affected by different varieties of soybean but potassium uptake by shoot was found non- significant. The uptake of potassium by leaves (10.4 mg plant^{-1}) with variety V_4 (PK-472), root (1.22 mg plant^{-1}) with variety V_2 (GS-2) and seed (110.69 mg plant^{-1}) with V_5 (GJS-3) recorded higher as compared remaining varieties. It was also found at par with V_5 (GJS-3) for uptake of K by root and V_4 (PK-472) for potassium uptake by seed.

Effect of Sulphur

The uptake of potassium by leaves, shoot, and root and seed part of the plant was significantly influenced by various levels of Sulphur. The application of Sulphur @ 15 mg kg^{-1}(S_4) gave significantly higher value of potassium uptake by leaves (11.27 mg plant^{-1}), shoot (32.41 mg plant^{-1}), root (1.20 mg plant^{-1}) and seed (85.74 mg plant^{-1}) over that of lower dose of Sulphur. It was also found at par with S_3 (10 mg S kg^{-1}) by potassium uptake seed.

Interaction effect of Variety and Sulphur

The K uptake by seed of soybean at harvest significantly influenced due to combined effect of variety and Sulphur. Significant higher value of K uptake by seed (122.46 mg plant^{-1}) was obtained with variety V_5 (GJS-3) at10mg kg^{-1}, it was also at par withV_5 (GJS-3) X S_4 (15 mg kg^{-1}).

Table 4: Effect of varieties and Sulphur on nitrogen uptake (mg plant^{-1}) by dry matter of plant parts of soybean

Treatments	45 DAS			At harvest			
	Leaves	Shoot	Root	Leaves	Shoot	Root	Seed
Variety (V)							
V_1 GS-1	8.35	21.81	2.04	5.19	36.96	1.99	193.02
V_2 GS-2	11.33	25.20	3.00	6.96	39.53	2.94	209.40
V_3 JS-335	11.46	24.23	2.36	6.31	38.75	2.52	257.06
V_4 PK-472	10.71	23.26	2.56	6.32	38.35	2.68	382.97
V_5 GJS-3	12.96	25.69	2.86	7.50	44.00	2.80	380.14
S.Em.+	0.77	1.12	0.19	0.50	1.71	0.18	9.47
C.D. (P=0.05)	2.19	NS	0.53	1.42	NS	0.51	26.94
Sulphur level (S)							
S_1-0 mg kg^{-1}	8.78	21.48	2.32	4.86	37.28	2.19	261.97
S_2-5 mg kg^{-1}	9.10	21.83	2.35	5.45	39.80	2.47	275.85
S_3-10 mg kg^{-1}	11.01	24.87	2.74	6.13	37.93	2.73	286.95
S_4-15 mg kg^{-1}	14.49	27.97	2.85	9.31	43.05	2.96	313.31
S.Em.+	0.69	1.00	0.17	0.45	1.53	0.16	8.47
C.D. (P=0.05)	1.95	2.84	0.47	1.27	4.36	0.45	24.10
Vx S Interaction							
S.Em.+	1.54	2.24	0.37	1.00	3.43	0.36	18.93
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS
C.V.%	19.84	13.17	20.40	21.94	12.26	19.47	9.41

Table 5: Effect of varieties and Sulphur on phosphorus uptake (mg plant^{-1}) by dry matter of plant parts of soybean

Treatments	45 DAS			At harvest			
	Leaves	Shoot	Root	Leaves	Shoot	Root	Seed
Variety (V)							
V_1 GS-1	4.17	4.88	0.63	2.76	8.24	0.70	16.94
V_2 GS-2	5.94	5.79	0.86	3.97	10.01	0.96	20.43
V_3 JS-335	5.97	5.38	0.66	3.62	9.08	0.86	22.82
V_4 PK-472	5.75	5.18	0.77	3.82	8.81	0.87	36.36
V_5 GJS-3	5.92	6.12	0.71	4.58	9.92	0.97	36.33
S.Em.+	0.58	0.42	0.05	0.25	0.48	0.05	1.13
C.D. (P=0.05)	NS	NS	0.15	0.71	NS	0.15	3.22
Sulphur level (S)							
S_1-0 mg kg^{-1}	4.48	4.64	0.64	2.95	7.98	0.73	24.11
S_2-5 mg kg^{-1}	5.31	5.18	0.69	3.40	9.36	0.88	25.88
S_3-10 mg kg^{-1}	5.67	5.39	0.75	3.99	9.29	0.89	27.09
S_4-15 mg kg^{-1}	6.73	6.66	0.82	4.66	10.21	0.98	29.22
S.Em.+	0.52	0.37	0.05	0.22	0.43	0.05	1.01
C.D. (P=0.05)	1.47	1.06	NS	0.63	1.21	0.13	2.87
Vx S Interaction							
S.Em.+	1.16	0.84	0.11	0.50	0.95	0.10	2.26
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS
C.V.%	22.28	21.64	20.60	18.72	14.60	17.02	12.04

Table 6: Effect of varieties and Sulphur on potassium uptake (mg plant^{-1}) by dry matter of plant parts of soybean

Treatments	45 DAS			At harvest			
	Leaves	Shoot	Root	Leaves	Shoot	Root	Seed
Variety (V)							
V_1 GS-1	16.65	23.87	1.96	7.23	27.67	0.84	54.44
V_2 GS-2	22.91	26.42	2.74	9.41	29.09	1.22	58.81
V_3 JS-335	21.44	25.82	2.27	9.29	28.18	0.90	70.71
V_4 PK-472	20.77	24.82	2.26	10.04	28.75	1.06	107.84
V_5 GJS-3	23.90	28.58	2.52	10.01	29.56	0.93	110.69
S.Em.+	1.23	1.91	0.17	0.62	1.34	0.07	2.31
C.D. (P=0.05)	3.49	NS	0.49	0.62	NS	0.21	6.57
Sulphur level (S)							
S_1-0 mg kg^{-1}	18.46	22.12	2.22	7.37	26.71	0.86	75.80
S_2-5 mg kg^{-1}	19.58	24.40	2.16	8.53	28.05	0.97	78.31
S_3-10 mg kg^{-1}	22.20	26.91	2.44	9.60	27.43	0.93	82.14
S_4-15 mg kg^{-1}	24.29	30.16	2.57	11.27	32.41	1.20	85.74
S.Em.+	1.10	1.71	0.15	0.55	1.20	0.07	2.06
C.D. (P=0.05)	3.12	4.85	NS	1.56	3.40	0.18	5.87
Vx S Interaction							
S.Em.+	2.45	3.82	0.34	1.23	2.67	0.15	4.62
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	13.14
C.V.%	16.42	20.80	20.60	18.94	13.20	21.20	8.11

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