“Tostudy thedistributionof differentformsofsulphurand to determine thecorrelationbetweendifferentformsofsulphurin surfacesoil”.

YELLOW: Observational error and suggestion

BRIGHT GREEN: Ideal to be used

ABSTRACT

Sulphur isoneofthe essentialelementsforplantgrowth.Itisanimportantconstituentof manyenzymes andamino acids.Photosynthesisandnitrogenfixation areattributedtothetype ofsulphurlinkagepresent.Sulphurhasbeenfoundtohelpthesynthesisofaminoacidandhence increase proteincontentofplants,boosts the oil content.Today,theSSulfur (S)researchhasextendedto varioussoils,crops andcroppingsystems and differentsources ofsulphur.Severalsoilfactors influencetheavailabilityofsulphurandhencethestatusofdifferentformsofsulphur insoil varies widelywithsoiltypes.Keepinginview,Onehundredtwentyfive GPSbasedsurfacesoil samples (0-15cm)werecollectedfromfiveblocks(Mugavali, Chanderi, Ishagarh, Ashoknagar and Sadora)of AshoknagardistrictduringApril to May2016Soilswerestudiedfortheirphysical and chemicalcharacteristicsandstatusof differentformsofsulphur andtheirrelationshipwith differentsoil properties.Thedifferentformsofsulphur,i.e. that iswatersoluble,available,organicand total-Swereobservedintherangeof1.23–7.67,4.36–40.25,89.08–194.53and167.45–422.20mgkg-1underdifferentvillagesofinvestigatedareawiththeaveragevalueof4.09,14.68, 124.21and309.17 mgkg-1,respectively.Outof125surfacesamples,36samples(28.8%) were foundunderdeficient, 72(57.6%)undermediumand17(13.6%) sampleswasfoundinsufficient category. Availabilityofsulphur increasedwith anincreaseinorganiccarbonandclaycontentin soil. Thecorrelationstudyrevealedthat organiccarbonhadgreaterimpact ondifferent formsof sulphurfollowedbysoiltexture.Itsuggestedthat organicmatterwasmaincontributing factor affecting thesulphuravailabilityinsoil.TotalSmaintainedasignificantpositiveassociationwith alltheformsof sulphur. Suchrelationshipsuggeststhat sulphur exists inastateof dynamic equilibriuminthesesoils.

Keywords:Sulphur,photosynthesis, nitrogenfixation, organiccarbonandclaycontent.

INTRODUCTION

Sulphur(S)isthefourthmostimportantnutrientafternitrogen,phosphorusandpotassium forIndianagriculture.Itisessential forsynthesisofproteins,vitaminsandS-containingessential aminoacidsandisalso associatedwith(N)metabolism. Sulphurimprovesbothyieldandquality ofcrops.itisalsoconstituentofmanyenzymesandamino acidsand helpsintheincreasein oil percentage.Heavyremovalofsulphur byhighyieldingvarietiesparticularly oilseedscrop, intensivecropping withhighsulphurrequiring crops andlosses ofsulphurfromsoilthrough leaching anderosioncausesS-deficiencyin soil.ThemajorsourcesofS insoilsaresulphides, sulphatesand organiccombinationswithC andN contentsofsoils,thoughareflection ofparent materialfromwhichsoilsoriginated,is influencedbyclimateandmanagement practices. Consequently, differentsoils maintainawiderangeoftotal-S contentswhichhasbeenfoundto extendmorethanthreethousandppm.SincetotalS doesnotrelatewithplantgrowth, its plant availableforms emphasized more often.Mostlythesulphurinthesoilcan begroupedinto fourformsviz.total-S, organic-S, non-sulphate-S, andavailable-S. Inthesedifferent formsofsulphurorganicsulphurdominantlycontrolsthelevelsofplantavailablesulphur.
Theimportant factors whichinfluencethecontent andavailability of sulphur insoils are organicmatterandtextureofsoil.Sulphate-Srepresentsplantavailable-S,whichis

immediatesupplierof sulphateionstotherootsforabsorptionbyplants. InIndian agriculturetheinformationregardingdifferent forms of S isvery limited. Today, theS researchhasextendedtovarioussoils,cropsandcroppingsystemsanddifferentsources ofsulphur.

METHOD AND MATERIALS

The study was carried out during 2015-16 in the department of Soil Science, College ofAgriculture,Gwalior(M.P.).

(a)Location andextent:

Ashoknagar islocatedinthenorthernpartofMadhyaPradesh,betweenthe riversSindh andtheBetwa.Itcomesunderthenorthernpartof Malwaplateau,thoughmainpartofitsdistrict liesintheBundelkhandPlateau.TheCoordinatesofthedistrictare24°34′48″Nand77°43′ 48″Ewith averageelevation of 507 metres(1640ft)abovesealevel.

(b)Soils:

Soils oftheinvestigatedareaaregenerallyvariableincolour,depending onthetiming periodandsourcesofirrigationsystem.Inthisregion,themainclassesofsoil areblack, brown and bhatori (stony)soil.Thevolcanic,clay-likesoilofthe region owesitsblackcolourtothe high ironcontent ofthebasaltfromwhichitisformed.Thesoilrequireslessirrigationbecauseofits highcapacityformoistureretention. Theothertwosoiltypesarelighterandhaveahigher proportion ofsand.

(c)Collectionand preparation ofsoilsamples

Forthepresentstudy,125surface(0-15cm)soil samples(GPS basis,detailgivenin appendix)collectedfromcultivar'sfieldsof fiveblocks(namely; Mungaoli, Chanderi, Ishagarh, Ashoknagar andSadora) ofAshoknagardistrict.Therepresentativesoilsampleswerecollected withthehelpofsoilauger.Thesoilsampleswereputinthepolythenebagsproperly,labeledand carriedtothelaboratory. Aftercollection, thesamples werebrought toSoilScienceLaboratory, Collegeof Agriculture, Gwalior andsamples wereair dried, crushedandsievedthrough2mm plasticsieve.

Table1Detailsofsoilsamplescollectedfromvariousvillagesofdifferentblocksof Ashoknagardistrict.

S.No.	Block	Villagename	No.ofsamples	Total samples
1	Mungaoli	Aathaikheda	05	25
		Bilakhedi	05	
		Mudrakhana	05	
		Chamrai	05	
		Shyampur	05	
2	Chanderi	Barodiya	05	25
		Sangampur	05	
		Tarai	05	
		Mohalichak	05	

		Salona	05	
3	Isagarh	Korwas	05	25
		Kotharkhedi	05	
		Vijaypura	05	
		Pachlana	05	
		Bamnawar	05	
4	Ashoknagar	Mau	05	25
		Banyga	05	
		Diyadhari	05	
		Ratikheda	05	
		Ashoknagar	05	
5	Sadora	Kherai	05	25
		Bamuria	05	
		Parwai	05	
		Gugor	05	
		Bagulya	05	
Grandtotal		**25**	**125**	**125**

RESULTAND DISCUSSION

Watersoluble–S

Statusofwatersoluble-S(mgkg-1)inthesoils understudy areawas observedinthe rangeof1.23to7.67withanaveragevalueof4.09mgkg-1whichconstitutedonly1.32%content ofthetotal–S.TheresultsaresimilartothoseofPriyadarshi*etal.*(2004)whoreportedthatwater solublesulphurconstitutedonly2.2%oftotal sulphur in old alluvial soilsofNawada district.The averagemaximum(5.08mg kg-1)andminimum(2.83mg kg-1)valuesofwater solubleS was notedinBarodiyaandMohalichakvillagesofChanderiblock,respectively.Watersolublesulphur showed ahighlysignificantandpositivecorrelationwithorganiccarbonandtotal-Nofthe soilsofinvestigatedarea.Positiverelationshipbetweenwatersoluble-Sandclaycontent wasalsofoundwhichclearlyindicatedthatclaycontentincreasestheavailabilityofwater soluble-S. Significant andpositiverelationshipbetweenthesetwowas alsoreportedby KherandSingh(1993).BalanagoudarandSatyanarayana(1990)alsoobservedpositive andsignificantrelationshipbetweenwatersoluble-SandclaycontentinVertisols and Alfisols of northernKarnataka. Das*et al.*(2012)reportedthat alltheformsofsulphur gave significantlyand positivelycorrelated with organicC and claycontent

Table2Statusofwatersoluble sulphurin thesoilsof Ashoknagardistrict

S. No.	Block	NameofVillage	Water Soluble-S ($mgkg^{-1}$)	
			Range	**Mean**
1	**Mungaoli** (25)	Aathaikheda	1.52-5.41	3.68
		Bilakhedi	2.93-6.40	3.94
		Mudrakhana	3.63-6.19	4.74
		Chamrai	2.49-6.69	4.39
		Shyampur	2.39-5.02	3.84
		OverallBlock	**1.52-6.69**	**4.10**
2		Barodiya	3.89-6.53	5.08

	Chanderi (25)	Sangampur	1.23-4.78	3.09
		Tarai	2.78-5.45	4.31
		Mohalichak	1.48-3.56	2.83
		Salona	1.56-4.87	3.26
		OverallBlock	**1.23-6.53**	**3.72**
3	**Isagarh** (25)	Korwas	2.45-6.24	4.68
		Kotharkhedi	3.12-7.18	4.93
		Vijaypura	1.62-7.67	4.97
		Pachlana	2.56-7.18	4.52
		Bamnawar	2.81-6.41	4.46
		OverallBlock	**1.62-7.67**	**4.71**
4	**Ashoknagar** (25)	Mau	3.50-5.17	4.29
		Banyga	3.06-7.26	4.65
		Diyadhari	2.69-5.85	3.89
		Ratikheda	2.25-3.93	3.30
		Ashoknagar	2.93-5.20	389
		OverallBlock	**2.25-7.26**	**4.01**
5	**Sadora** (25)	Kherai	2.35-6.33	4.26
		Bamuria	2.34-5.77	4.27
		Parwai	1.34-5.34	3.38
		Gugor	2.56-5.78	3.88
		Bagulya	2.33-5.40	3.63
		OverallBlock	**1.34-6.33**	**3.89**
Wholedistrict			**1.23– 7.67**	**4.09**

Organic-S

Organic-S showedsignificantandpositivecorrelationwithorganiccarbon,clayandtotal nitrogen.Thismaybeduetothefactthatorganiccarbonisthemainsourceoforganic-S;therefore apositivesignificantcorrelationbetweenthetwoisexpected.Thesefindingareinconformitywith Sharma andJaggi(2001).The positive relationship oforganic-Swith organic carbon andtotal-N suggestedasimultaneousincreaseinthestatusofnitrogenandorganic-Sinsoilwithincrease in organiccarboninsoils.Theresultssuggestthattheorganicmatterinthesesoilscontainsulphur containing aminoacidswhichareresponsibleforcontributing totheorganicsulphurinsoils.A positivecorrelationoforganic-SwithorganiccarbonwasalsoreportedbyTrivedi*etal.* (2000) andBhatnagar*et al.*(2003)Theorganicsulphurwascorrelatedsignificantlyand positivelywith all theformsofsulphur. Similarrelationshipwasalso reportedbyJat andYadav(2006)

Table 3-Status oforganic sulphurinthe soils ofAshoknagar district

S. No.	Block	NameofVillage	Organic-S (mg kg^{-1})	
			Range	**Mean**
1	**Mungaoli** (25)	Aathaikheda	111.04–156.42	134.71
		Bilakhedi	89.08–126.28	107.85
		Mudrakhana	113.58–189.65	153.17
		Chamrai	104.82 -167.12	123.45
		Shyampur	90.87–127.31	108.45
		OverallBlock	**89.08–189.65**	**125.53**
2	**Chanderi** (25)	Barodiya	106.68–144.80	125.17
		Sangampur	100.37–131.80	114.34
		Tarai	106.79–155.54	138.41

		Mohalichak	100.70–130.89	117.22
		Salona	100.89–152.56	127.85
		OverallBlock	**100.37–155.54**	**124.60**
3	**Isagarh** (25)	Korwas	112.51–194.53	160.89
		Kotharkhedi	105.85–116.95	112.94
		Vijaypura	100.16–133.90	110.68
		Pachlana	102.52–134.71	118.16
		Bamnawar	99.23–113.27	106.59
		OverallBlock	**99.23–194.53**	**121.85**
4	**Ashoknagar** (25)	Mau	113.48–149.41	131.54
		Banyga	124.44–150.54	138.74
		Diyadhari	112.91–147.02	130.55
		Ratikheda	113.48–134.10	126.29
		Ashoknagar	113.89–146.11	134.11
		OverallBlock	**112.91–150.54**	**132.24**
5	**Sadora** (25)	Kherai	92.40–145.56	112.22
		Bamuria	108.07–145.0	120.79
		Parwai	105.04–136.12	114.62
		Gugor	100.77–166.74	125.04
		Bagulya	98.43–135.29	111.53
		OverallBlock	**92.40–166.74**	**116.84**
Wholedistrict			**89.08–194.53**	**124.21**

Total Sulphur

Ingeneral,the total-Scontentwasfoundsignificant andpositivelycorrelatedwithorganic carbon,clayandtotalnitrogen.Thesignificantandpositivecorrelationoftotal-Swithorganic carbonandclayandtotal-N hasalsobeenreportedbyAgarwalandNayyar(1998),Trivedi*etal.* (1998) andTrivedi*et al.*(2000). Totalsulphur appearstobeafunctionof soil organicmatter as botharesignificantlyand positivelycorrelated.Thisisalso duetothefactthatin mostofthesoil S isaconstituentoforganicmatter(Kumar*etal.*2002).KaurandJalali(2008)noticedthatthe total-Sexhibiteda positiveandhighlysignificantcorrelationwith organiccarbon (r=0.965)and finerfractionsofsoilviz.clay(r=0.470)andsilt(r=0.682).Thesulphate-S(available-S)was correlatedpositivelyandsignificantlywithsiltcontent(r=0.403).TotalSmaintainedasignificant positiveassociationwithalltheformsofsulphur.Suchrelationshipsuggeststhatsulphurexists in a state ofdynamicequilibrium in these soils. The results alsosuggestthat by proper management of organiccarboninsoilthepossibilityof soilsbecomedeficient maybeavoided. Positive relationbetweenorganic carbonandorganic sulphurand availablesulphurfurther indicatethat onmineralizationsof organiccarbonandorganicsulphur, underfevourablesoil conditions,thelevelofavailableS mayimprove.Positivecoefficientofcorrelationofclaywith availableandorganic –Sindicatethatsulphatesulphur(So4--)beingnegative(-ve) inchargeis retained byclayparticles thusleachingmaybecheeked.

Table4-StatusofTotalsulphur in the soilsof Ashoknagardistrict

S. No.	Block	NameofVillage	Total-S(mgkg^{-1})	
			Range	**Mean**
1	**Mungaoli** (25)	Aathaikheda	278.02–344.57	315.86
		Bilakhedi	167.45–305.52	264.01
		Mudrakhana	280.12-419.86	366.34
		Chamrai	275.68–379.09	308.88
		Shyampur	282.21–421.29	366.61
		OverallBlock	**167.45–421.29**	**324.34**
2	**Chanderi** (25)	Barodiya	235.58–397.84	313.39
		Sangampur	240.07-311.64	281.41
		Tarai	169.78–399.09	337.95
		Mohalichak	235.54–322.43	277.30
		Salona	239.07–312.48	288.41
		OverallBlock	**169.78–399.09**	**299.69**
3	**Isagarh** (25)	Korwas	277.62–422.20	371.17
		Kotharkhedi	283.75–389.19	312.40
		Vijaypura	244.37–278.30	265.82
		Pachlana	245.00–316.73	277.61
		Bamnawar	284.41–388.41	312.40
		OverallBlock	**244.37–422.20**	**307.86**
4	**Ashoknagar** (25)	Mau	286.07–398.31	328.29
		Banyga	310.96–377.98	333.91
		Diyadhari	278.20–394.80	338.76
		Ratikheda	280.05–388.79	321.62
		Ashoknagar	287.21–400.08	329.13
		OverallBlock	**278.20–400.08**	**331.14**
5	**Sadora** (25)	Kherai	183.91–398.93	285.51
		Bamuria	266.44–316.72	284.02
		Parwai	221.26–314.53	258.15
		Gugor	240.67–397.33	303.01
		Bagulya	266.57–315.67	283.42
		OverallBlock	**183.91–398.93**	**282.22**
Wholedistrict			**167.45–422.20**	**309.17**

Table5-Coefficientofcorrelation between differentformsofsulphur

	Watersoluble–S	Available–S	Organic-S	Total–S
W.S.–S	-	0.434**	0.546**	0.543**
Available – S	-	-	0.446**	0.379**
Organic-S	-	-	-	0.728**
Total–S	-	-	-	-

CONCLUSION

GlobalPositionSystem(GPS)basedonehundredTwentyfivesurfacesoil(0-15cm) sampleswerecollectedfromfiveblocks(Mungaoli,Chanderi,Ishagarh,AshoknagarandSadora) ofAshoknagardistrictduringAprilto May2016andwereanalysisstatus ofdifferentformsof sulphur(i.e.total-S,watersoluble-S,organic-Sandavailable–S).Theresultsaresummarized asfollows thatthedifferentformsofsulphur,i.e.watersoluble,available,organicandtotal-S wereobserved intherangeof1.23–7.67,4.36–40.25,89.08–194.53and167.45–422.20mg kg-1underdifferentvillagesofinvestigatedareawiththeaveragevalueof 4.09,14.68,124.21 and 309.17 mgkg-1,respectively.Outof125surfacesamples, 36samples(28.8%) werefound under deficient, 72(57.6%)undermediumand17(13.6%)sampleswasfoundinsufficient category.Statusofwater soluble-S(mgkg-1) inthesoilsunderstudyareawasobservedinthe rangeof1.23to7.67withanaveragevalueof4.09mgkg-1whichconstitutedonly1.32%content of thetotal–S. Watersolublesulphurshowedahighlysignificant andpositivecorrelationwith organiccarbonandtotal-Nofthesoils of investigatedarea.Available-S observedintherange of4.36to40.25 mgkg-1 understudied areawiththemeanvalue of 14.68 mgkg-1whichis4.75 percentoftheaveragetotal –Sstatusofthedistrictfoundunderstudy.Availablesulphurshowed significantandpositivecorrelationwithorganiccarbonandtotal nitrogen ofthesoils. Available-S wasshowedsignificant andnegativecorrelationwithcalciumcarbonatecontent of thesoils. Underdifferentformsofsulphur,Available-Swassignificantlyandpositivelycorrelatedwithtotal-Sandorganic-S.Statusof organic-Sobservedintherangeof 89.08–194.53mg kg-1under investigatedareawiththe averagevalue of 124.21mgkg-1whichis40.18%ofthetotal sulphur statusofthedistrict.Theaveragemaximum(160.89mg kg-1)andminimum(106.59mg kg-1) valuesoforganic-SwasobservedinKorwas andBamnawarvillageofIsagarhblock, respectively.

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