IntegratedNutrientsManagementforFutureProduction:AReview

Abstract

AspertheestimatebytheUnitedNations,theworldpopulationwillincreaseto11billion,by2050.Thisrapidincreaseinthepopulationisofglobalconcern,creatingresponsibilitiesontheshouldersofthescientiststofetchtherapidlyincreasingpopulationalongwiththeproblemofreducedlandholding,suddenclimaticchallenges,andimbalancednutritioncoupledwithdeficienciesofnutrients.Itisnecessarytocontinuouslyreviewandmodifyagriculturalpracticesandtechnologiesinordertomeethumandemandswhilerespectingtheecologicalboundariesofourplanet.Amongthesetechnologiesarefertilizers,whosedevelopmentandapplicationhavebeencrucialforraisingcropyield,agriculturalproductivity,andfoodsecurity.However,usingfertilizershasanenvironmentalcost,andtheyhaven'tbeenaveryproductivefactorinhelpingmanypoorfarmersescapepovertyeconomically,especiallyinareaswhereapplyingfertilizerswithunbalancednutrientcompositionstopoorsoilshashadlittleeffectonyieldgrowth.Theuseefficiencyoffertilizerscanbeincreasedbyusingagronomicpracticestoapplyexistingmineralfertilizers,whichgenerallycontainN,P,andK,atthepropertime,place,amount,andcomposition.However,theoverallprogressmadeinminimizingthenegativeconsequencesisinsufficienttobringaboutthenecessarychangetowardsustainableagricultureinunderdevelopednations.Farmersmustintegratethemanagementofnutrientsandsoilfertilityintotheirfarmingpracticesinordertomeettheincreasingpopulation'sdemandforfood.Thispaperreviewstheconceptsofintegratednutrientmanagementinthecontextofitseco-friendlynatureandsustainability.

Keywords: Conventionalagriculture,Environmentalsafety,foodsecurity,Indianagriculture,Soilhealth,Soilproductivity

Introduction

Agricultureinthis21stcenturyfacessuperfluouschallenges,likethedeclineinproductivityanddegradationinsoilquality.Thatisprobablycausedbynumerousfactorslikeinsufficiencyofmoisture,deficiencyofplantnutrients,anddefectivemanagementofsoils.TheIndiansoilsexhibitatpresentverylowlevelofproductivityincomparisontoworldsoils.Toimprovesoilproductivity,theproperunderstandingofthesoilisunconditionallyrequired.InacountrylikeIndia,themostvitalchallengeistoprovidesufficientfoodfortheever-growingpopulationatreasonableandinexpensivepricesfromnonflexiblelandresources.Theuseandapplicationofagrochemicalshavegivenabundantriseinagricultureproductionatthecostofsoilhealthanditscondition.Toachievethispoorfertilizerapplicationimbalance,itisnecessarytoidentifyappropriateintegratedplantnutrientsupplysystemsforvariouscropsandtheircroppingsystems.Asfertilizersareexpensiveagri-inputs,theorderlyapproachtowardslucrativeagriculturewouldrecommendtheadditionaluseofplantnutrientsfromothersourcestocatertotherealneedofthesituation.Thefertilizerrecommendationforacropinaspecificregionmayentirelydifferfromthatina unlikeregionforanidenticalcrop.Anumberofsoiltestresultsgeneratedbyvarioussoiltestinglaboratoriesatthe stateaswellascentralgovernmentlevels,delivervaluableinformationaboutthedistributionpatternofplantnutrientsinsoils.Thedataonsoiltestingparametersofthefieldhelpedtheplanners,decisionmakersandfarmerstomaketheappropriateuseoffertilizers.Variationinthesoilnutrientcompositionisacommonsituationinagriculturalsystems.Undeniably,only30to50%ofappliedNitrogenfertilizersand10to20%ofPhosphaticfertilizersareusedbyplants**(AdesemoyeandKloepper,2009)**.Assessmentofnitrogeninthesoilismadeintermsoftheorganiccarboncontentofthesoil.Becauseofthetropicalclimateofthecountry,organicmatterisimmediatelydecomposedandsentofftotheatmosphere.Soilsare,poorinnitrogencontentastheamountofnitrogencontentinsoilisstraightforwardlyrelianton theamountoforganiccarboncontentinthesoil.Phosphorusstatusofcoursefoundlowinnearlyhalfofthearablelandofthecountry.Onlyafewdistrictsofthecountryarefoundtohavetherichstatusofavailablephosphorus,andtheremainingonesareinthemediumcategoryrange.However,potassiumdeficiencyismuchlesswidespreadthannitrogenandphosphorus,sincenearlythree-fourthsofthecountry'slandcomesunderthemediumtohighfertilityrange.Butatthesametime,ithasbeenbroughtoutthatalthoughaprofitableresponsetopotassiumapplicationhasnotalwaysbeenobserved,Indiansoilscannolongerbegeneralizedtoberichinavailablepotassium.ThemajorfarmingsysteminIndiaisricewheat,whichaccountsforover75%ofthecountry'stotalproductionoffoodgrains**(Mahajanetal.,2002)**.Thisapproachhasmadeasignificantcontributiontothesocioeconomicadvancementofthenation'sruralpeople.Themajoritypopulationinthenationdependsonwheatandriceastheirprimaryfoodsources.Eventhoughmanyfarmersarenowawareofthesustainabilityproblemsassociatedwiththerice-wheatcroppingsystem,includingyielddeclines,decreasedsoilfertility,physicalproperties,deteriorationofsoilbiologicalhealth,toxicityofheavymetals,anduptosomeextents,nitratecontaminationofgroundwater.Inlightoftheneedforfoodcommodities,whichisrisingquicklywiththeexpandingpopulation,theseimportantsustainabilityissuesmustbedistilleddown.Integratednutrientmanagement(INM)maybeanoptiontobolsteragriculturaloutputwhilesafeguardingtheenvironmenttfortheforeseeablefutureinasustainablemanner.Itisanapproachthatinvolvestheapplicationofbothorganicandinorganicplantnutrientsourcestoincreasecropoutput,protectthesoil,andcontributetomeetingfuturefoodneeds.Majorcropscannotachievetherequiredproductionimprovementsunlessplantsreceiveabalancedsupplyofnutrientsatsufficientlevels.

Theuseofchemicalfertilizers,organicmanure,andbiofertilizersincombinationwiththespecificaimofachievingsustainableandenvironmentallysustainablecropproductionwithoutdecreasingsoilhealthisreferredtoas"integratednutrientmanagementstrategies.Theconceptreliesonsoundcrophusbandry,harnessingthenaturalnutrientcapacitythroughbio-engineeringandminingofsoilreserves.Italsostressesonsearchformoreefficientnutrientnaturalresources.Itistheadmirableapplicationofchemical,organic,andbiologicalfertilizers.

HealthoftheIndianSoils

Degradationofsoilhealthisaseriousissueinthenation.Thelandareaofthecountry,whichis120.8Mhaandmakesup36.5%ofthetotalgeographicalarea(TGA),isdeterioratedasaresultofsoilerosion,salinity/alkalinity,soilacidity,waterlogging,andothercomplicatedissues**(NBSS&LUP,2008)**.Themainsourceofsoildegradation(82.6Mha)iswater-inducedsoilerosion,whichisfollowedbychemicaldegradation(24.7Mha).Indiaexperiencessoilerosionatarateof16.3tha^{-1}yr^{-1}onaverage,or5.34billiontonnes(Gt).Atotalof61%oferodedsedimentsisredistributedonland,whileabout29%arepermanentlylosttotheocean,and10%aredepositedinreservoirs,reducingtheirholdingcapacityby2%eachyear.Thesoilisalsodegraded,andabout8Mtofplantnutrientsarewashedawaywiththesediment.Degradedareashavetheabilitytocauseflashfloodsandsoilerosion.Theextentofnutrient-wisedeficienciesis89%N(63%low&26%medium),80%P(42%low&38%medium),50%K(13%low&37%medium),41%S,43.4%Zn,20.6%B,14.4%Fe,13%Mo,7.9%Mnand6.1%Cu**(ShuklaandPakhare,2015)**.Applyingexternallythelackingnutrientsthroughfertilizersisnecessarytomaintaincropproduction.

Impactoffertilizers

Fertilizersarestillthe'Kingpin'inthecurrentstructureofcommercialagriculture.However,thescientificandbalancedapplicationoffertilizersassumesvitalimportanceincommercialandsustai nablecropproduction.Efficientuseoffertilizerspaysbacktothefarmersmoreprofitperunitinvestment.Thisindicatesthatfertilizeristhekeyagri-inputforachievingtargetcommercialproduction.

FertilizerUseinIndia

Indiahashadconsistentgrowthinfertilizerapplicationandconsumption.Nutrient(N+P_2O_5+K_2O)consumptionincreasedfrom69,800tin1950-51to25.95Mtin2016-17.Indiaisthesecond-largestconsumerofnutrientsoverallintheworld,followingChina,anditrankssecondinNandP_2O_5consumptionandfourthinK_2Oconsumption.Theamountoffoodgrainproducedincreasedfrom50.8Mtin1950–1951to275.68Mtin2016–17.Thecumulativeannualgrowthrates(CAGR)ofnutrientintakeandfoodgrainproductionwere9.38and2.60%,respectively(Figure1);Itwaslargelyduetothisprogressiveuseoffertilizernutrientsthatthenationbecamefoodandnutritionself-sufficient.

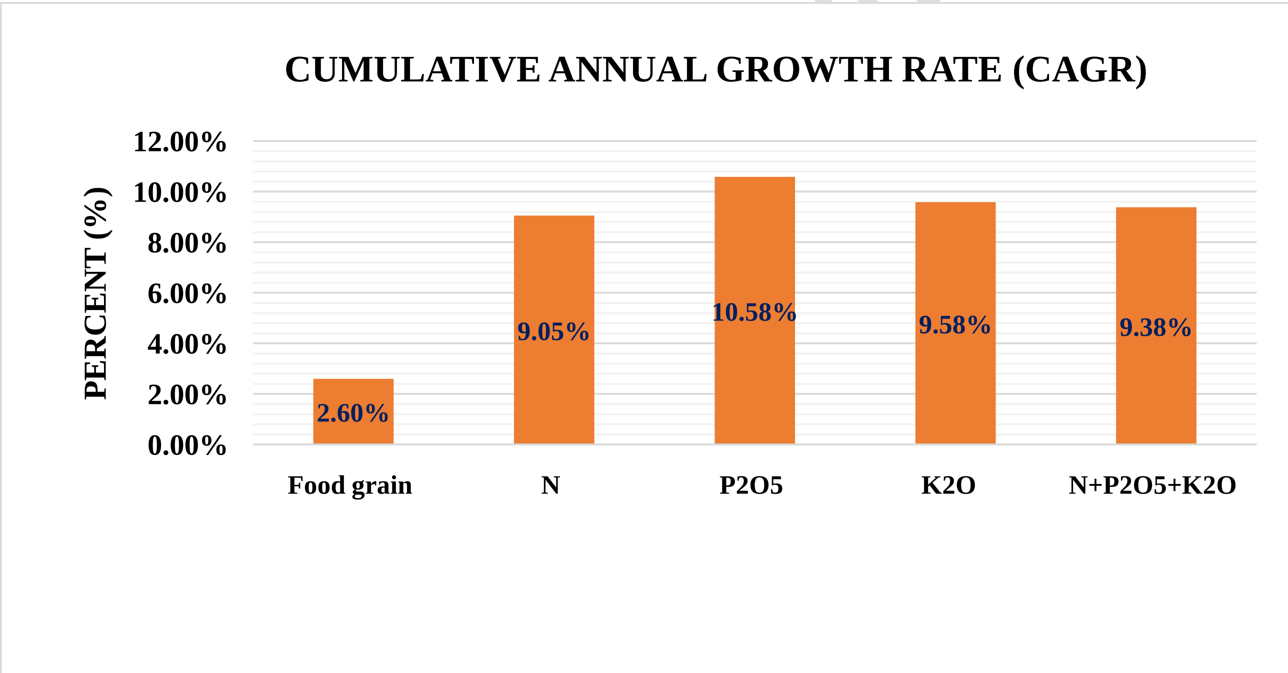

Fig.1CumulativeAnnualGrowthRate(CAGR)

Source:FAI(2016)andAnnualReviewofFertiliserProductionandConsumption(2016-17)

TheoptimalNPKuseratiois4:2:1,whilethecurrentNPKuseratio(withKasbase)for2016–17is6.7:2.7:1,whichisexcessivelyskewedinfavorofN.Fromtheperspectiveofagriculturalneedsaswellasasustainableproductivitygrowthaspect,thisisnotideal.TheglobalaveragefortheNPKusageratiois3.4:1.3:1.Regionaldifferencesintheuseratioaremoreobviousacrossthenation,withtheNorthhavingthebiggestdisparity(15.1:5.1:1)andtheSouthhavingthesmallest(4.2:1.9:1).Theseare7.1:3.1:1inWestand4.3:1.6:1inEast.Theperhectarenutrient(NPK)usevariedfrom93.4kgintheWestto178.3kgintheNorth.IntheNorthandWest,8.4kgha^{-1}ofKwereused,whileintheSouth,24.0kgha^{-1}wereused(Figure2).P_2O_5consumptionperhectarewashighestinthesouth(46.8kg)andlowestinth ewest(25.7kg).NitrogenconsumptionperhectarewashighestinNorth(127.3kgha^{-1})andlowestintheWest(59.3kgha^{-1}).Theratiosofnutrientsusedandconsumedvarygreatlybetweenstates.Ingeneral,southernstateshavethemostKuseperunitarea,whereasnorthernstateshavethelowest.Asaresult,statesinthesouthconsumelessNPKthanstatesinthenorth.

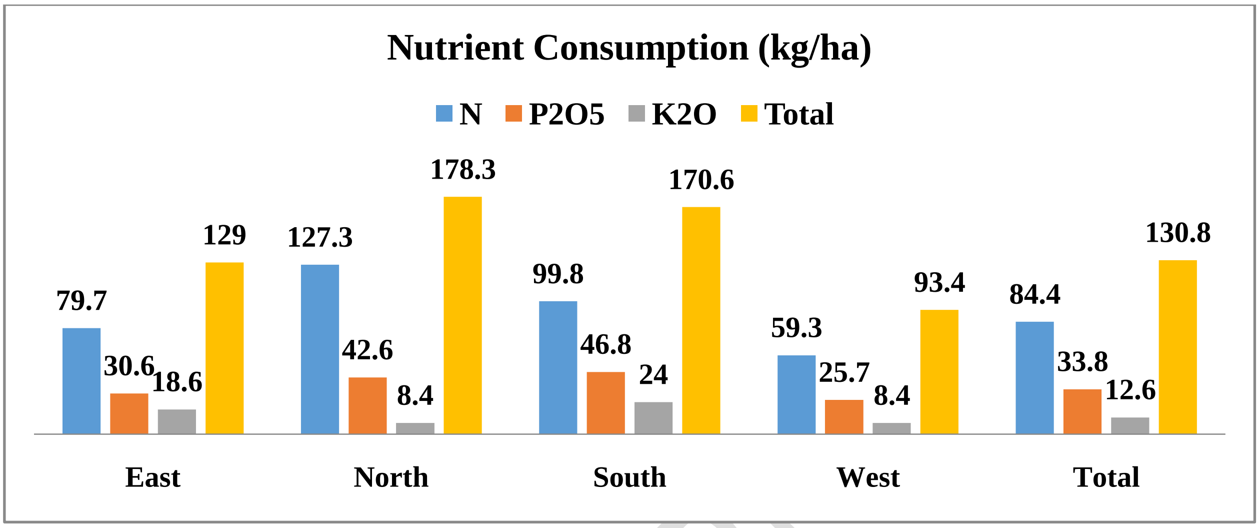

Fig.2NutrientconsumptioninzonesofIndia(2016-17)

Source:FAI.2017.FertilizerUseandEnvironmentalQuality.

ThequantityoffertilizeruseisdependentonfarmsizeasevidencedbytheAll-IndiaReportofInputSurvey(2011-12)whichshowsmoreuseoffertilizerbyfarmershavingsmallandmarginalsizeoflandholdingascomparedtofarmershavinglargeholding.Incontradiction,smallandmarginalfarmersuseabalanceddoseofNPKthanlargefarmers(table1).Forinstance,totalNPKconsumptioninirrigatedareaswas187kgha-1asopposedto82kgha^{-1}innon-irrigatedareas.Nutrient-wiseusewas115.7,51.9and19.4kgha^{-1}forN$_2$,P$_2$O$_5$andK$_2$Oinirrigatedareasandinnon-irrigatedareas,perhectareusewas48.8kgforN,24.4kgforP$_2$O$_5$and8.8kgforK$_2$O.

Table1.Useoffertilizerbylandholdingorfertilizerintensitybyvarioustypesoffarmers

Landholding	**NPKUsekgha^{-1}**	**NPKconsumptionratio**
Large	84.7	10.5:4.4:1
Marginal	188.7	5.6:2.3:1
Small	130.6	4.9:2.4:1
Semimedium	113	5.8:2.8:1
Medium	99.4	7.5:3.6:1

Source:AllIndiaReportofInputSurvey(2011-12)

Theterm"integratednutrientmanagement"(INM)referstotheprocessofmaximizingthebenefitsfromallpotentialsourcesoforganic,inorganic,andbiologicalcomponentsinacoordinatedmannerinordertomaintainsoilfertilityandplantnutrientsupplyatanoptimallevelformaintainingthedesi redproductivity.PlanningexperimentsinvolvingINMrevolvesaroundnitrogensinceratesofapplicationofvariousnutrientsourcesaredeterminedbytherelativecontributionsofNoriginatingfromthem.Intherice-wheatcroppingsystem,thecultivationofmoongbean(*vigna radiata*),togetherwiththefirstpod,shouldbereversedintothesoilafterselectingthefirstpod,itmaintainstheproductivityofthecrop(onaverageproduces1tmoongseedha^{-1})aswellasenriches40-120kgNha^{-1}inthesoil.Bio-fertilizerscontribute15-30kgNha^{-1}yr^{-1}inadditiontoprovidingancillarybenefitsincludingfosteringplantdevelopment,enhancingthequalityofseedsandfruits,andmaintainingthebiologicalhealthofthesoil**(Prasannaetal.,2014)**.Thecrop'sNUEwasraisedbythebalancedapplicationoftheidealNPK,anditwasfurtherimprovedbytheadditionof5to15tonnesofFYMperhectareeachyear(Table2).

Table2.Apparentrecoveryefficiency(ARE)ofnutrientsinmaize-wheatandrice-wheatsystemsasaffectedbylong-termnutrientsupplywithandwithoutFYM.

Soiltype	**Location**	**Crop**	**Treatments**			
			N	**NP**	**NPK**	**NPK+FYM**
		ApparentrecoveryefficiencyofN(%)				
Inceptisol	**Ludhiana**	Maize	16.7	23.5	36.4	40.2
		Wheat	32.0	50.6	63.1	67.8
Alfisol	**Palampur**	Maize	6.4	34.7	52.6	63.7
		Wheat	1.9	35.6	50.6	72.6
Mollisol	**Pantnagar**	Rice	37.5	40.7	44.4	61.7
		Wheat	42.4	46.1	48.4	47.9
		ApparentrecoveryefficiencyofP(%)				
Inceptisol	**Ludhiana**	Maize		10.3	21.4	26.3
		Wheat		20.6	30.7	34.8
Alfisol	**Palampur**	Maize		21.8	35.6	51.1
		Wheat		10.7	15.2	24.6
Mollisol	**Pantnagar**	Rice		18.2	23.3	53.0
		Wheat		11.2	10.4	23.3
		ApparentrecoveryefficiencyofK(%)				
Inceptisol	**Ludhiana**	Maize			43.8	58.2
		Wheat			88.1	112.8
Alfisol	**Palampur**	Maize			23.0	38.9
		Wheat			22.6	66.8
Mollisol	**Pantnagar**	Rice			34.5	108.3
		Wheat			13.7	35.8

N:recommendedN;NP:recommendedNandP;NPK:recommendedNPKtobothcrops;NPK+FYM:recommendedNPKtobothcrops+FYM(15tha^{-1}yr^{-1}upto2008-09and5tha^{-1}yr^{-1}thereafter)to*kharif*croponly.
Source:Singhet.al.(2012)

Changingscenarioofnutrientmanagement

Greateruseofcommercialfertilizersthedevelopmentofhigh-yieldingcultivarsandimprovedirrigationfacilitieshaveresultedinaspectacularincreaseinyieldofcrops.Therecentenergycrisesandconsequentpricehikeoffertilizerscoupledwithlowpurchasingpoweroffarmersinmasshaveagainreviewedtheinterestinorganicrecyclingthroughouttheworld.Nutrientmanagementhasgonethroughthreephasesofdevelopment.

PhaseI: Between1950and1965,therewasariseintheuseofchemicalfertilizersandacarefulexaminationoftheapplicationoforganicnutrientsourcesandgreenmanuring.

PhaseII: Beginninginthemiddleofthe1960s,the"GreenRevolution"ledtoanabruptincreaseintheusageofchemicalfertilizersandasteadyreductioninorganicfertilizersandgreenmanuring.Thisisevidentfromthefertilizerusegrowthfrom7.84lakhtonesin1965-66toabout15milliontonnesin1995-96and20.34milliontonnesin2005-06.

PhaseIII: Itcanbelinkedtothemid-1970s,themid-1980s,andtheyearssince1992whentheoilcriseswitnessedgloballywithadeficitoffertilizers,renewedtheinterestinIndiainpromotingintegratednutrientmanagementthatinvolvesmoreorganicwasterecyclinginagriculture.DependenceonINMgotgreaterinterestwiththeconcernofenvironmentalpollutionduetotheheavyuseofinorganicsforcommercialproduction.

UseofOrganicManures

WiththeintroductionoftheGreenRevolution,chemicalfertilizersreplacedwell-decomposedorganicmanuresincludingfarmyardmanure,digestedcowdung,andcompost(urbanandrural)asthemosteffectivesourceofplantnutrients.Revivingtheadditionofthesemanuresisnownecessary.Inadditiontomainandsecondarynutrients,organicmanuresalsocontainmicronutrientsintheformofcompoundsthatpromoteandinhibitgrowth.However,somematerialsusedtomakefarmyardmanure,ruralcompost,orurbanwastecompostcontainhazardouselementssuchtheheavymetals Ni,Cr,Cd,etc.,which,ifpresentinlargeenoughquantitiesintheorganicmanures,cannegativelyimpacttheplantgrowth.Itisimportanttonotethatwhileorganicmanuresimprovethephysical,chemical,andbiologicalcharacteristicsofsoils,theycannotreplacechemicalfertilizersduetotheirlowconcentrationofplantnutrientsandthehightransportcostsassociatedwiththeirbulkynature.ThealterationofthesoilprocessesbroughtaboutbytheadditionofOMandbiofertilizerincreasesthemetalsolubilityandavailability**(Kumaretal.,2017)**

GreenManureUse

Growinglegumesasgreenmanuretoimprovecropproductivityandsoilhealthisamongtheoldestpractices.Itgainsmoreadvantages,especiallyforlightsoilswithsandyandloamysandtextures,aswellassandyloamsoilsorsoilswithaloam/siltyloamtexture.Althoughtheymayserveotherpurposesaswell,greenmanuresarecropsplantedparticularlytoimproveandpreservethefertilityandstructureofthesoil.Inthesecircumstances,growingdhaincha(*Sesbaniaaculeata*)andburyingitinthesoilbeforethefloweringstageatthetimeoftransplantingricehasbeenfoundeffectiveinraisingtheyieldofbothriceandwheat**(Guptaetal.,2005)**.Greenmanuremostlyaffectsthesupplyofnitrogenandothernutrients.Abetterperiodforplantstoabsorbnutrientsfromdecomposinggreenmanuremaybeprovided,therebyimprovingnutrientuptakeefficiencyandcropyield(**PantaandParajulee.,2021)**

UseofRuralWastesandCropResidues

Thereisalotofopportunityforruralwastestobeusedasplantnutrients,includingpaddyandwheatstraw,aswellastheleftoversofothercropsincludingsorghum,pearlmillet,sugarcane,andpulses.However,giventhegrowingpopulation'sneedformorefoodgrainoutput,theiruseassuchorafercompostingcannotmatchthatofchemicalfertilizersinmaintainingriceandwheatyields.Theseorganicresidues'highC/Nratio,whichcanbeashighas100:1,isanotherrestriction.Nitrogenbecomesimmobilizedasaresultofthis.Asidefromtheaforementioned,sewageandindustrialeffluentsalsocontainvariousharmfulsubstancesaswellasvaryingamountsoforganicmatterandplantnutrientsdependingontheplaceoforigin**(Chhonkar,2003)**.Therearesignificantamountsofplantnutrientsinthewastewaterproducedbyvariouscorporations**(Chhonkar,2001)**.

UseofBio-Fertilizers

Thebiofertilizercontainsefficientlivecellsofmicroorganismsandisacarrier-basedmicrobialinoculant.Biofertilizersareabletomobilizenutrients,solubilizeinsolublenutrientsinthesoilsystem,fixatmosphericnitrogeninammoniaform,andreleaseplantgrowthhormonesthatar eneededbyplantsfordevelopmentandgrowth.Blue-greenalgae(BGA)andAzollaarethemajororganicfertilizersforricethatcanbeusedinplaceofchemicalfertilizers.BGAcanfixatmosphericnitrogen,especiallyinricesoilswithstandingwater,andtheycancreatechemicalsthatencouragegrowth**(Mahajanetal.,2003a)**.Azollaisafloatingfreshwaterfern.Itiswidelydispersedinfreshwaterbasinsandlowlandricefields.*Anabaenaazollae*,anitrogen-fixingBGA,isfoundinsidethefern.Itcanbeutilizedasabio-fertilizerinriceagricultureduetoitsprodigiousgrowthcharacteristicsandinteractionwithnitrogen-fixingBGA.Azollacanfix100–150kgNperhectareperyear**(Mahajanetal.,2003b)**.Fordirect-seededriceandwheatcrops,azotobacterculturemadefrom*azotobacterchroococcum*orotherspeciescanbeutilizedasabio-fertilizer**(Mahajanetal.,2008)**.

VermicompostUse

Vermicompostisanaturallyoccurringorganicmanuremadefromearthworms,sometimesknownastheearth'stillers.Wormcastingsandorganicdebris,suchashumus,liveearthworms,theircocoons,andothercreatures,arecombinedtocreatevermicompost.Theearthwormspeciesthatarenowbeingutilizedwidelyforvermicompostingare*Eiseniafoetida,EudrilusEugenia,Eudrilluseugeniae, Pheritimaelongata,*and*Perionyxexcavatus*.However,*Eiseniafoetida*isthespeciesthatismostfrequentlyusedglobally.Itisarichsourceofminerals,vitamins,andenzymes,aswellasmacronutrientsforplantslikeN,P,andK.Thecombineduseof100%recommendedfertilizerdosesofvermicompost,phosphatesolublebacteria(PSBs)andzinc(Zn)producedsignificantlyhigheramountsinwheatgrainandstrawyieldthantheequivalentof50%NPK,whetheraloneorincombinationwithfarmyardmanure(FYM),PSB,Znandvermicompost**(RatherandSharma,2009).**
EnrichedcompostwasmoresuccessfulthanintegrateduseofbiofertilizerandinorganicfertilizerinloweringthephytotoxicAlpoolandimprovingthenutritionalvalueofrice**(Patraetal.,2020).**

UseofbothOrganicsandInorganics

Asdiscussed,theuseofneitherorganicsalone(MahajanandSharma,2005)norinorganic(GuptaandSingh,2006)canhelpmaintainyield.AnotherstudyconductedbyIndianFarmersAccordingtoevidencefromtheFertilizerCo-operativeLimitedOrganizationandtheFoodandAgricultureOrganization,37.5%offarmersstrugglewiththeaccessibilityofcompostorfarmyardmanure.Inordertomeetthegrowingdemandforplantnutrients,itwillbenecessarytouseallorganicsources.Thetaskathandistocreateanappropriatetechnologyplatformthatwillfullyuseorganicmanuresandothersourcesinadditiontoinorganicstoincreasefoodoutputwithoutdegradingsoilhealth.Althoughsoilscontainacertainamountofinorganicandorganicnutritionsources,forimprovedplantperformance,thesearefrequentlysupplementedwithexternalfertilizerapplication**(WuandMa.,2015)**.Forplantstoflourish,itiscrucialtousenutrientsfrombothinorganicandorganicfertilizersinabalancedandoptimalmanner**(MaviandBenbi,2008)**

Nutrientsneedofintensifiedcommercialcroppingsystem

Thedevelopmentofanintegratedplantnutrientsupplysysteminvolvinganappropriatecombinationoforganics,biologicalNfixation,phosphatesolubilizingmicrobes,andneed-basedchemicalfertilizerswouldbecrucialforthesustainabilityofcommercialproduction.Cropproductionisthemostsignificantsourceofrenewablewealth.Intensivecroppinghaswidenedthescopeandneedforintegratednutrientmanagement.Asfarmingsystemshavebeenintensifiedandhigh-analysischemicalfertilizershavebeenusedmorefrequently,soilshavebeenmined,resultingindeficitsofsecondary(sulphur)andmicronutrients(Zn,Mn,Cu,B,andMo).**ShuklaandBehera,2019**reportedthatanalysisof2lacGIS-basedsoilsamplesshowedanastonishingtrendofshortagesinsulphur(S),zinc(Zn),iron(Fe),manganese(Mn),copper(Cu),andboron(B)inthenationinthelevelof40.5,36.5,12.8,7.1,4.2and23.2perce nt,respectively.Inarice-wheatsystem,INMhasalsoimprovedwateruseefficiencyandwater-holdingcapacity**(Sharmaetal.,2001)**.Inanintensiverice-wheatsystem,INMwiththeincorporationoforganicmaterialincreasessoilaggregation,structuralstability,andmacroaggregateCcontent**(Dasetal.,2014)**

Factsaboutintegratednutrientmanagement

- **Plantneedsseveralnutrientsforgrowthandproduction:**Thesenutrientscanbesuppliedtoplantsandvaryfordifferentsources.Themajorsourceincludesfertilizers.Whileorganicmanurealsoprovidesnutrients,itsamountisverylow.Thissupplycanalsobeincreasedbyusingafewsupplementalbio-fertilizersthatproducenutrients.
- **Integratednutrientsupplyemphasisontheuseofallresourcesforthesupplyofnutrients:**Themajorityoforganicmanureisofabio-origin(animalandhumanwaste,plantresidue,andbyproducts),whereasfertilizersareprimarilychemicalinnature.Citygarbageisnotstrictlybiodegradableandincludesdomesticwastessuchasurbancompost,sewage,andsludge.Theintegratednutrientsupplyalsoincludesgreenmanuringofbio-origin.
- **Fertilizersarethemoreconcentratedsourceforthesupplyofnutrientsthanorganicmanures:**Fertiliserscanmeetnutrientneedsforcropsatanylevelwithconsiderablylessmaterialthanorganicmanures,whichwouldrequirematerialtoprovidethesameamountofnutrients.
- **Organicmanurescontainseveralnutrientelements:**However,thusfaritistheirNvaluethathasreceivedthemajoremphasis.Researchresultshaveestablishedthatorganicmanures,particularlysecondaryandmicronutrientdeficits,havethepowertostopanumberofnutrientshortagesfromdeveloping.Anessentialtacticforpreventingtheoveruseofsoilresourcesonagriculturalfieldsandmaintainingsoilfertilityistheprovisionoforganicamendments**(Ranjanetal.,2020)**
- **ThegreatestchallengebeforeIndiahasalwaysremainedtoproducemorefoodtomeetthegrowingdemandcreatedbytheever-increasingpopulation:**Inmodernagriculture,fertilizershavecontributeduptoa50percentriseinfoodgrainoutput.Therefore,axingfertilizerusewillneverbeaviablestrategy.However,thereisalwaysaneedtomaximizetheefficiencyoffertilizerusewhichispresentlyquitelow(efficiencyislessthan50percentforNand10-30percentforP).
- **Thenutrientneedsforhigheryieldscannotbemetexclusivelythroughorganicsandbio-fertilizers:**Theorganicmanure'sslowandlownutrientsupplyisaproblem.Theseresourcesoughttobeviewedasasupplementtothesupplyofnutrientsfromchemicalfertilizersinanintegratednutrientsupply.Organicmanuredecompositionproductsmediateimprovementinsoilphysical,chemical,andbiologicalenvironmentsenhancefurtherthemeritofharmonizingtheuseofchemicalfertilizerandnaturalmanure.
- **Anintegratednutrientsupplyapproachiseconomicallyviableandenvironmentfriendly:**However,fertilizerswillcontinuetobethedominantcontributorformeetingthenutrientrequirementsofcropsinIndia.Utilizingchemicalfertilizeraswellasorganicsourcesofnutrientscontributestoenvironmentallyfriendlypracticesthatresultinthecomprehensivemanagementofthesoil-cropsystem**(Ranjanetal.,2020)**

Conclusion

Forcommercialagricultureproduction,consideringenvironmentalconservation,theintegratednutrientmanagementsystemseemstobethemostsustainablesystemofnutrientmanagement.However,itspackageofpracticesmayvaryfromregiontoregionandfromonefarmingsystemtoanotherfarmingsystem.Farmersmustintegratethemanagementofnutrientsandsoilfertilityintotheirfarmingpracticesinordertomeettheincreasingpopulation'sdemandforfood.Majoragriculturalyieldgain scannotbeachievedwithoutmakingsurethatplantsreceiveabalancedsupplyofnutrientsinsufficientquantities.Thegovernmentshouldaddressthisissuebydevelopingtestingandmonitoringmechanismsbecauseunless"nutrientcycles"arebetterunderstood,thisequilibriumcannotbeachieved.Byenablingplantstofurnishpartoftheirownnutrientsforimprovedgrowth,geneticengineeringmayalsoassistinmaintainingamorebalancednutrientsupply.Farmerswillneedassistanceadoptingnitrogen-fixingspecies,whichwillrequiretheassistanceofthegovernmentandextensionagencies.Additionally,thegovernmentmustcontinuetosupportthefarmers'broadandresponsibleuseoforganicandinorganicfertilizers.Theinitiativesincludenutrientdepletiontestingofthesoil,farmer-researchercollaboration,encouragingthemoreeffectiveuseoforganicnutrients,andurgingextensionagenciesandNGOstopayattentiontosoil-relatedconcerns.InvestmentstoincreasesoilfertilitymayalsobesupportedbygovernmentandNGOinitiatives.Manyoftheissuesthatpoor,smallholderfarmersinIndiaandothercountriesfacecanbesolvedbyintegratednutrientmanagement.However,thetimelyandcoordinatedeffortsofextensionprograms,thegovernment,NGOs,researchers,andthefarmersthemselvesareultimatelywhatdetermineINM'seffectiveness.

References

1. AdesemoyeAO,KloepperJW(2009)Plant-microbesinteractionsinenhancedfertilizeruseefficiency.ApplMicrobiolBiotechnol85:1–12.
2. ChhonkarP.K.(2001).ThestateofIndiansoilsciencesandchallengestobefacedduring21stcentury.*JournaloftheIndianSocietyofSoilScience*49(4):532–536.
3. ChhonkarP.K.(2003).Organicfarming–Scienceandbelief.*JournaloftheIndianSocietyofSoilScience*51(4):365–377.
4. FAI.2016.*FertiliserStatistics2015-16*,61thEdition.TheFertiliserAssociationofIndia,NewDelhi.
5. FAI.2017.FERTILISERUSEANDENVIRONMENTALQUALITY.TheFertiliserAssociationofIndia,NewDelhi.
6. GuptaR.D.andSinghH.(2006).Indiscriminateuseoffertilizerposeshealthhazards.*Farmers’Forum*6(9):20–24.
7. GuptaR.D.,KherD.andJalaliV.K.(2005).Organicfarming:ConceptanditsprospectiveinJammuandKashmir.*JournalofResearchSKUAST*4(1):25–37.
8. MahajanA.andSharmaR.(2005).Integratednutrientmanagement(INM)system–Concept,needandfuturestrategy.*AgrobiosNewsletter*4(3):29–32.
9. MahajanA.,BhagatR.M.andTrikhaA.(2003b).Fertilizingbio-fertilizers.*AgricultureToday*6(9):52–54.
10. MahajanA.,ChoudharyA.K.andBhagatR.M.(2002).Integratedplantnutrientmanagement(IPNM)systemforsustainabilityincerealbasedcroppingsystem.*IndianFarmers’Digest*35(7):29–32.
11. MahajanA.,ChoudharyA.K.,JaggiR.C.andDograR.K.(2003a).Importanceofbio-fertilizersinsustainableagriculture.*Farmers’Forum*3(4):17–19.
12. MahajanA.,GuptaR.D.andSharmaR.(2008).Bio-fertilizers–Awaytosustainableagriculture.*AgrobiosNewsletter*6(9):36–37.
13. PrasannaR.,DharD.W.andShivayY.S.2014.Significanceofbiofertilisersinintegratednutrientmanagement.In*TextbookofPlantNutrientManagement*(R.Prasad,D.Kumar,D.S.Rana,Y.S.Shivay,andR.K.Tewatia,Eds.),pp.231-248.IndianSocietyofAgronomy,IARI,NewDelhi.

14. SinghM.,DwivediB.S.andDattaS.P.2012.Integratednutrientmanagementforenhancingp roductivity,nutrientuseefficiencyandenvironmentalquality,In*SoilScienceintheServiceof Nation*(N.N.Goswamiet.al.,Eds)pp.55-67,ISSS,NewDelhi.
15. ShuklaA.K,andBeheraS.K.(2019).AllIndiaresearchprojectonmicro-andsecondarynutrientsandpollutantelementsinsoilsandplants:Researchachievementsan dfuturethrusts.*IndianJFert*.2019;15(5):522–543.
16. WuW.andMaB.,2015.Integratednutrientmanagement(INM)forsustainingcropproductiv ityandreducingenvironmentalimpact:Areview.*ScienceoftheTotalEnvironment*,*512*,pp.4 15-427.
17. MaviM.S.andBenbiD.K.,2008.Potassiumdynamicsunderintegratednutrientmanagemen tinrice-wheatsystem.*Agrochimica*,*52*(2),p.83.
18. SharmaM.P.,BaliS.V.,GuptaD.K.,2001.Soilfertilityandproductivityofrice(Oryzasativa) – wheat(Triticumaestivum)croppingsysteminanInceptisolasinfluencedbyintegratednutrie ntmanagement.IndianJ.Agric.Sci.71,82–86
19. DasB.,ChakrabortyD.,SinghV.K.,AggarwalP.,SinghR.,DwivediB.S.andMishraR.P.,20 14.Effectofintegratednutrientmanagementpracticeonsoilaggregateproperties,itsstabilit yandaggregate-associatedcarboncontentinanintensiverice–wheatsystem.*SoilandTillageResearch*,*136*,pp.9-18.
20. PantaS.andParajuleeD.,2021.IntegratedNutrientManagement(INM)inSoilandSustainab leAgriculture.*InternationalJournalofAppliedSciencesandBiotechnology*,*9*(3),pp.160-165.
21. RanjanA.,JhaC.K.andKumarN.,2020.AReviewonEffectofINMonSugarcaneGrowth,Yi eldandQuality.*Int.J.Curr.Microbiol.App.Sci*,*9*(1),pp.2597-2605.
22. RatherS.A.andSharmaN.L.,2009.EffectofIntegratedNutrientManagement(INM)onyiel dandeconomicsofwheat.*AsianJournalofSoilScience*,*4*(1),pp.15-17.
23. KumarA.,MauryaB.R.,RaghuwanshiR.,MeenaV.S.andTofazzalIslamM.,2017.Co-inoculationwithEnterobacterandRhizobacteriaonyieldandnutrientuptakebywheat(Tritic umaestivumL.)inthealluvialsoilundertheindo-gangeticplainofIndia.*JournalofplantgrowthRegulation*,*36*,pp.608-617.
24. PatraA.,SharmaV.K.,PurakayasthaT.J.,BarmanM.,KumarS.,ChobheK.A.,Chakraborty D.,NathD.J.andAnilA.S.,2020.Effectoflong-termintegratednutrientmanagement(INM)practicesonsoilnutrientsavailabilityandenzy maticactivityunderacidicInceptisolofNorth-EasternregionofIndia.*CommunicationsinSoilScienceandPlantAnalysis*,*51*(9),pp.1137-1149.
25. AllIndiaReportofInputSurvey.2011-12.AgricultureCensusDivision,DepartmentofAgriculture,CooperationandFarmersWelf are,MinistryofAgricultureandFarmersWelfare,NewDelhi2016.
26. NBSS&LUP,(2008).SoilsofKochBihardistrict,WestBengalforoptimizingLanduse,*NBS Spubl*,*No-1019*,*NBSS&LUP(ICAR)*,Nagpur,pp.1-70.
27. ShuklaA.K.andPakhareA.,2015.TraceElementsinSoil-PlantHumanContinuumIn:SoilScience:AnIntroduction(Eds.)Rattan,RK,etal.2015.