Review Article

Impact of Integrated Nutrient Management sustainable Wheat production: An overview

Abstract

The adequate and balanced supply of plant nutrients is of critical importance in improving the productivity of wheat crop. Due to prohibitive cost of chemical fertilizers, Indian farmers, mostly marginal and small, do not supply the recommended doses of nutrients to these energy rich crops, indigenously available organic sources of nutrients have been recorded to enhance the efficiency and reduce the requirement of chemical fertilizers. The nutrients (N, P, K and Zn) can be supplied through fertilizers, organic manures, bio-fertilizers, bio-stimulants and their combined applications under integrated nutrient management. Wheat varieties differ in their phenology, requirement of thermal and photoperiod units and growth habits which cumulatively determine the varietaladaptation at different locations and sowing times. Therefore, comparative evaluation of varieties suitable for early, normal and late sown conditions is warranted to identify the growth patterns, physiological traits and yield attributes that will favourably influence the grain yield and biomass in wheat under normal and late sown conditions. This review examines response of wheat varieties to integrated nutrient management practices in wheat crop sown under normal and late planting conditions.

INTRODUCTION

"Wheat(*Triticumaestivum* L.)istheworld'sprincipal and commercially important food crop. Itbelongstothegrassfamily*Poaceae*.Globalwheatconsumptionhasincreasedinthepastfour decades to around 781 million tonnes (mt)annually and accounts for approximately 25 percent of worldwide protein supply. In India (2022-23), the area under wheat production is 30.46millionhectares(mha)withtheproductionof112.18 mt. The area under wheat cultivation inHaryana(2021-22)is2364.14hawiththeproduction of12mt(India stat 2021-2022).

Wheatvarietiesdifferintheirphenology,requirementofthermalandphotoperiodunitsand growth habits which cumulatively determinethe varietal adaptation at different locations andsowing times. Therefore, comparative evaluationofvarietiessuitableforearly,normalandlatesownconditionsiswarrantedtoidentifythegr owthpatterns,physiologicaltraitsandyieldattributes that will favorably influence the grainyield and biomassin wheat under normal andlate sown conditions. The grain and straw yield inwheatisdeterminedbythegenotypeofthevarietiesandthesupplyofnutrients.Thenutrients(N,P,K andZn)canbesuppliedthrough fertilizers, organic manures, bio-fertilizers,bio-stimulantsandtheircombinedapplicationsunder integrated nutrient management. Severalworkershavereportedbeneficialeffectsofintegratednutrientmanagement(Sharma *et al*. 2020).However,the efficacy of integrated nutrient managementdepends upon the proportion

of each componentofinorganic(fertilizersformacroandmicro-nutrients) and organic sources like vermin-compostof nutrient supply and their doses as well as timeandmethodofapplication.Newrangeofbio-stimulantssuchasHairamine(proteinhydrolysate from human hair), seaweed extracts,humic acids etc. have been developed and arebeing evaluated for their efficacy and responseforyieldimprovement.However,theavailableinformationisscantyandmorestudiesarene eded.

EFFECTOFNPK

The inorganic fertilizers are applied to fulfill theplantrequirementfornitrogen,phosphorus,potassiumandothermicronutrients,butexcessive use of chemical fertilizers reduces soilfertilitybyaffectingthesoil'sphysicalandchemical properties. Therefore, it is necessary tobalance this negative effect of inorganic fertilizerswiththeuseoforganicamendmentsandbio-fertilizers.

Cui*etal*.2023conducted"afieldexperiment to study the effects of nitrogen formson N utilization, yield and quality of two wheatvarieties with different gluten characteristics. Theresultsindicatedthatcombinedapplicationofureaandnitratenitrogencouldsynergisticallyimpr ove quality and nitrogen use efficiency whilemaintainingyield,whichisimportantfortherationalapplicationofnitrogenfertilizerandachie ving stable yield, high quality and efficientproductionofwheat".

Yang *et al*. 2023 conducted a field experiment tostudytheeffectofnitrogenmanagementonwheatyield, waterand nitrogenutilizationandeconomicbenefitsunderridge-furrowcroppingsystem with supplementary irrigation. The resultsshowed that the ridge-furrow system significantlyincreased the soil moisture content and improvedthe water productivity and grain yield of wheat".

Akram *et al*. 2022 conducted "a field experiment tostudy the effect of phosphorus and sulphur onyieldandeconomicsofwheat.Theresultsshowed that the application of phosphorus at 80kg/ha+Sulphurat40kg/hawasrecordedsignificantlyhigherplantheight(96.47cm),numberoftill ers/hill(10.47),plantdryweight(18.54g/plant),grains/spike(47.36),testweight(38.59 g), grain yield (6.25 t/ha), straw yield (9.54t/ha)andharvestindex(39.6).Highergrossreturns (₹ 99,187/ha), net returns (₹ 67,049 ha^{-1})and benefit cost ratio (2.08) was also obtainedwith this combination.

Qazizadah *et al*. 2022 conducted a field experimenttostudytheeffectofnitrogenlevelsontheperformanceofwheatvarietiesundersaline water irrigation in semi-arid regions. The resultsshowedthatincrementalNlevelssignificantlyincreasedLAIandnumberofgrains/spikeupto 150kgN/habutplantheight,drymatteraccumulation, number of tillers/meter row length,number of effective tillers/meter row length andgrain yield were at par with 200 kg N/ha.

Kumar *et al*. 2022 conducteda field experiment tostudy nitrogen management in late sown wheat.The results indicated that application of 50 percentRDNatsowing+3percentureafoliarapplicationattilleringandearingrecorded41.8,52.6 and 30.6 per cent higher grain yield thanothertreatments.

Dhaker*etal*.2022concludedfrom their field experiment to study the effect ofnutrient management on growth and productivityof wheat grown under rice-wheat based croppingsystem in South-eastern Rajasthan. The resultsindicatedthattheapplicationof150percentRDF registered the maximum growth parameters*viz*., number of tillers/meter row length, CGR andplant height at different growth stages and grain,strawandbiologicalyields.Themaximumnetreturn was also obtained under the application of150 per cent RDF (₹ 106464/ha), however, 125percentRDF(₹ 103460/ha)andRDF+FYM(₹ 9907/ha) as well as RDF + Zn + S (₹ 99155/ha)werefoundatpar with150percentRDF.

Assefa *et al*. 2021 conducted field experiment tostudythe effectsof phosphorusand sulfuronyield and nutrient uptake of wheat on vertisols,North Central Ethiopia. This study revealed thatcombinationof22Pand15Skg/haproducedthehighestMMR(54.9percent).

Klikocka*etal*. 2018 conducted a field experiment to study theresponseofspringwheattoNPKandSfertilization. The experiment showedapositiveresponse of spring wheat to N and S fertilization.Thehighestgrainyieldwasfoundafterapplication of 80 kg N/ha and addition of 50 kgS/ha(5.43t/ha).Thedescribedcombinationresulted in beneficial content of P - 4.267, K –4.533, Mg – 1.567, Ca - 0.433 g/kg and uptake ofmacro-elements by grain dry mass (P-20.48, K-21.79,Mg-7.52,Ca-2.08kg/ha).

Laghari*et al*. 2016conductedafieldexperimenttostudy the effect of NPK and Boron on growth andyield of wheat variety TJ-83. The result indicatedthat maximum plant height (86.7 cm), number oftillers(418m^{-2}),spikelength(11.6cm),grains/spike(51.0),grainweight/plant(7.9g),seedindex(41.7g),biologicalyield(9131.7kg/ha),grainyield(2105kg/ha)andharvestindex(42.5percent)wereobtainedwiththeapplicationofNPK-120-60-60kg/ha+B2percentattilleringphase".

Khan*etal*.2012conducted a fieldexperiment to study the effectof different rates of NPK on the yield contributingtraitsandeconomicsofwheatinRodKohiareaofDeraIsmaildivision,Pakistan.Thedata revealed that the yield parameters increased withan increase in each fertilizer nutrient (N, P and K)duringboththeyears.Bestfertilizereconomy(maximumbenefit/ha)wasreceivedfromtheapplication of 80-40-20 kg/ha N: P: K. Greatervalues of all parameters were found during 2007-08ascomparedto2006-07,whichmaybeattributed to residual effect of NPK applicationaccompaniedbyfavorableclimaticconditionduringsecondyear of growingwheatcrop.

Malghani *et al*. 2010 conducted a field experimenttostudytheresponseofgrowthandyieldofwheat to NPK fertilizer. The result revealed thathighest grain yield of 5168 kg ha^{-1} was recordedwith the application of 175-150-125 NPK kg ha^{-1}.The increase in yield was 51.58 per cent higheras compared to control (2502 kg/ha), where nofertilizerwasused".

Warraich*etal*.2002conducted a fieldexperiment to study the effectof nitrogen on grain quality and vigour in wheat.The results proved that seeds obtained from 120kg N/ha treatment showed more vigour duringelectrical conductivity test as compared to 0, 60and 180kgN/ha.

EFFECTOFBIO-FERTILIZERS

Bio-fertilizersareconsideredasanimportantconstituent of sustainable agriculture. The cropproductivity and profitability can be enhanced byinoculatingthepulsecropswith*Rhizobium*cultureandphosphorussolubilizingbacteria(PSB). From agricultural point of view, *Rhizobium*are pivotal soil bacteria having the ability to formroot nodules and stem nodules in some cases, inlegumes to fix atmospheric nitrogen. Bio-fertilizersarecarrier-basedpreparationscontainingbeneficialmicroorganismsinaviablestateintended for seed or soil application to improvesoilfertilityandplantgrowth.Bio-fertilizersincreasethenumberandbiologicalactivityofbeneficialmicroorganismsintherhizosphere.Theyimprovesoilfertilitybyfasteningtheatmospheric nitrogen, solubilizing insoluble soilphosphates,anddischargingplantgrowthsubstancesinthesoil.Bio-fertlizersarecost-effective, eco-friendly and renewable sources ofplantnutrition.Thecropproductivityandprofitability can be improved by the inoculation ofpulse crops with phosphorus solubilizing bacteria(PSB)and*Rhizobium*(Bajracharya *et al*. 2009).

PawarandSuryawanshi2022conductedanexperiment tostudytheimpactofbio-fertilizerson paddy (*Oryza sativa* L.) cultivar Jaya. The resultssuggestthatbio-fertilizersfrommicroorganismscan replace chemical fertilizers to increase cropproduction.

Amrutha*etal*.2022conductedanexperiment to study the influence of bio-fertilizersongrowthandyieldofrice(*Oryzasativa*L.).From the data collected, it was observed that thecombined application of POP, KAU + *Azolla* +AMF had the highest number of grains/panicle(155.37), 1000-grain weight (24.16 g) and grainyield(3718.52kg/ha)whencomparedtothecontrol.

KekatpureandChaturvedi 2021conductedanexperimententitledgrowthandyield response of wheat in relation to the use ofvarieties and bio-fertilizer. On the basis of datacollected,highestplantheight(83.66cm),numberoftillerspermeterrowlength(66.47)at90 DAS while, number of spikes/plant (21.00),spike length (13.53 cm), number of grains/spike(29.40), test weight (41.36 g), grain yield (38.95q/ha),stover yield (68.21q/ha) were recordedunderthewheatvarietyGW-322sownwithbio-fertilizerof*Azotobacter*at10ml/kgseedinoculation +500 ml/acrefoliarapplication.

Achari*etal*.2021conductedanexperimenttostudytheeffectofbio-fertilizersandnitrogenlevelsongrowthandyieldofwheat(*Triticumaestivum*L.).Theresultsindicatedthattheapplication of *Azotobacter* + *Azospirillum* + 140kg/ha N was recorded significantly higher plantheight (86.07 cm), number of tillers/plant (6.34),dry weight (19.58 g/plant), number of effectivetillers/m^2(296.16),lengthofspike(11.25cm),testweight(46.93g),numberofgrains/spike (58.11), grain yield (5.63 t/ha) and straw yield(13.20t/ha),whereasharvestindex(33.1percent) was recorded maximum with *Azotobacter* +120kg/haN.

Aechra *et al*. 2020 conducted an experiment tostudytheeffectofbio-fertilizersandsplitapplication of vermi-compost on productivity andprofitability of wheat(*Triticum aestivum*L.) cropinclayloamsoils.Twoyearspooleddataindicatedthatgrowthattributes(plantheight),yield attributing traits (total tillers, effective tillersandtestweight),yieldsviz.,grain,strawandbiologicalinwheatdiffersignificantly,inbothbio-fertilizersandvermi-composttreatmentsandweremaximumwiththeB5(*Azotobacter*+PSB+ KMB + ZnSB) and V3 (50 per cent at sowing +50 per cent at tillering) as compared to control.The highest net return and B: C ratio was alsoobtainedwiththis combination.

Thejesh *et al*. 2019 conducted "a field experimententitledstudiesongrowth,yieldandeconomics of rice (*Oryza sativa* L.) *var*. Pusa Basmati-1 asinfluencedbybio-fertilizers.Theexperimentalresults revealed that the application of RDF +PSBat2kg/ha+*Azospirillum*at2kg/hahasrecordedhighestnumberofgrains/panicle(151.93) and number of panicles/hill (21.8).

Deva*et al*. 2019 conducted an experiment to study theeffectofliquidbio-fertilizersonyieldandeconomicsofrice.Theresultsindicatedthatapplication of bio-fertilizers improved yield and B:Cratioofrice.

Ali *et al*. 2019 conducted an experiment to studytheeffectofbio-fertilizersonyieldandyieldcomponentsofwheatunderIraqiconditions.Fromthisexperiment,researchersconcludedthat the application of bio-fertilizer resulted in apositive effect on nutrients balance in the soil attheendofseasonregardlessoftypeofbio-fertilizersasindicatedbytheincreaseinlevels of NH_4, NO_3, P and K".

Nagwa *et al*. 2019conducted "an experiment to study the influenceofsomebio-fertilizersonwheatplantsgrownundergradedlevelsofnitrogenfertilization.Accordingtotheobtainedresultsofthisexperiment,applicationofbacterialstrains*Azospirillum* + *Azotobacter* in present of 50 percent (nitrogen of recommended dose) could save50 per cent of the recommended dose of mineralNandcouldincreasegrowthandyieldtoanacceptable level, so it could be considered as asuitable substitute for chemical nitrogen fertilizerinorganic agriculturalsystems.

Nguyen *et al*. 2019 conducted an experiment tostudy the biostimulant effects of *rhizobacteria* onwheatgrowthandnutrientuptakedependonnitrogen application and plant

development. Theresults revealed that at 50 N, plant biomass wasmost significantly increased in roots (up to + 45percent with*Azospirillumbrasilense*65 B)atstem-elongation stage and in the ears (+19-23percent according to thestrains)at floweringstages.Therefore,combiningPGPR(Plantgrowthpromoting*rhizobacteria*)withaproper cultivated system, N rate and plant stage couldenhancetheirbiostimulanteffects.

Singh*etal*. 2015 conducted an experiment to study the effectof bio-fertilizers on growth, yield and economics ofrice(*Oryzasativa*L.).Fromthisexperiment,researchers found out that maximum grain yield(65 q/ha) was recorded with 150 kg N + 60 kgP_2O_5+40 kg K_2O with *Azotobacter* + PSB at 5kg/ha.

Karmakar *et al*. 2011 conducted a field experimenttostudytheeffectofgreenmanuringand bio-fertilizersonriceproduction.Theresultsrevealed that combined application of 50 per centofrecommendeddosethroughchemicalfertilizers and 25 per cent N through FYM alongwith in situ green manuring and blue green algaeimproved growth and yield attributing charactersresultedin an increaseinyield of rice varietyLalat(19.3percent)ascomparedtothatofrecommended fertilizer dose increase in nutrientuptake (21.4, 29.0 and 16.9 per cent of N, P andK,respectively)andimprovementofthesoilphysico-chemical properties like organic carbon(0.34-0.44percent),availableN(220.3-254.0kg/ha),P(21.2-25.8kg/ha)andKstatus(153.0-159.0 kg/ha) were also recorded. The maximumnet returns (22160 kg/ha) and B: C of 2.23 wasalsonotedunderthecombinednutrientapplication.

EFFECTOFBIO-STIMULANTS

BiostimulantHairaminereducestheneedoffertilizers and increases plant growth, developsresistance in plants against abiotic stresses. Insmall concentration, this substance is efficient infavouring good performance of the plants' vitalprocesses and allowing higher yield. In addition,bio-stimulants applied to plants enhance nutrients'efficiency,abioticstresstoleranceandplantquality traits De Vasconcelos and Chaves (2019).

Kumar *et al.* 2023 conducted afield experiment to study the genetic variabilityamong winter cereal genotypes for response toprotein hydrolysate (PH) for grain yield and itsattributes.Thisstudyconcludesthatthefoliarapplicationofproteinhydrolysateshowedsignificantresultsontheplantheight,spikelength and yield of crops. This type of proteinhydrolysate having short peptide and free aminoacidsareaccumulateddirectlybyplantsandenhancethegrowthandmaintainedplantshealth. The application can be an alternative ofchemical-basedfertilizersandreducetheenvironmentpollution.

Kumar *et al*. 2022 conducted a field experiment toevaluate the efficacy of protein hydrolysate (PlantForceAdvance)basedformulationoncottonyield.Thestudyconcludedthatthefoliarapplicati

onofproteinhydrolysatealongwithrecommended package of practices in Bt. hybridcotton have promising results on the yield andgrowthofcottonunderthefieldconditions.

Popko *et al.* 2018 conducted "an experiment tostudytheeffectofthenewplantgrowthbio-stimulants based on amino acids on yield andgrain quality of winter wheat. Field experimentsshowedthat theapplicationofproductsbasedon amino acids influenced the increase of grain yieldofwinterwheat(5.4and11percent,respectively, for the application of*AminoPrim* atadose1.0 $lha^{-1}$and *Aminohort*atdose 1.25 lha^{-1}) when compared to the control group withoutbiostimulant".

Majathoub2004conducted"anexperiment to study the effect of bio-stimulants onproduction of wheat (*Triticum aestivum* L.). Theresults showed that the plants treated with *Vigro*exhibited an increase in the total tillers (21 percent),agreaternumberoffertilefloretsperspike.Nevertheless,theeconomicyield(grainyield)ha d improvedby8.2percent.

EFFECTOFINTEGRATEDNUTRIENT MANAGEMENTONPLANTGROWTH,YIELDATTRIBUTESANDYIELDOFWHEAT

IntegratedNutrientManagementreferstotheconservationofsoilfertilityandplantnutrients upplyatanoptimumlevelforsustainingthedesiredproductivitybyutilizingallpossiblesourcesoforg anic,inorganicandbiologicalcomponentsinanintegratedmanner.Underintegratednutrientmanag ement,theharmfuleffects of inorganic fertilizers can be balancedwiththeuseof*rhizobium*culture,phosphorussolubilizingbacteria(PSB),bio-fertilizersandvermi-compost.

Jamal*etal*.2023conducted"afield experiment to study the integrated use ofphosphorusfertilizerandfarmyardmanureimproveswheatproductivitybyimprovingsoilquality and phosphorus availability in calcareoussoilundersubhumidconditions.Fromthisexperiment, it is concluded that FYM concoctionwithfertilizer-PnotonlyimprovedSOMandresidual soil, but also enhanced wheat yields withreasonable P efficiency".

Dhaliwal *et al.* 2023 conducted a field experimenttostudytheresidualeffectoforganicandinorganic fertilizers on growth, yield and nutrientuptakeinwheatunderaBasmatirice-wheatcroppingsysteminNorth-westernIndia.Theresults concluded that the integrated applicationof FYM with 75 per cent RDN could be used tosustainwheatproductivityandmaintainsoilfertility which otherwise deteriorates due to thesole application of inorganic fertilizers".

Tufa 2023conductedanexperimenttostudythevermi-compost N, P, S, Zn, B fertilizer levels onmaize(*Zeamays*L.)growth, yieldcomponentand yield at Guto Gida, Western Ethiopia. Fromthisexperiment,itisconcludedthattheintegrated applications of vermi-compost at 5 t/haandNPSZnBfertilizerat100kg/haincreased maize yield by about 10.36 per cent, with a netbenefit of 140486.00 ETB/ha and a marginal rateofreturnof797.98percent.Asaresult,vermi-

compostapplicationat5t/haratewithsynthetic NPSZnB fertilizer at 100 kg/ha is foundsuitable forthestudyarea.

Saini*etal*.2023conductedanexperimenttostudy the growth and yield attainment of wheatunderdifferentlevelsofvermi-compost,bio-fertilizers and nitrogen. The results indicatedthatsignificantlyhighergrowthandyield*viz.*,plantheight(85.1,81.6,82.5cm),numberofti llers/plant (3.72, 3.56, 3.62), dry matteraccumulation at harvest (261.0, 242.5, 249.4 gpermetrerow length), lengthofspike(10.9,10.2,10.4 cm), number of seeds/spike (40.16, 37.74,37.93),grainweight/spike(1.52,1.45,1.48g)andtestweight(38.54,37.28,37.65g)withindivi dualapplicationof4t/havermi-compost,*Azotobacter chroococcum* inoculation at 5 ml/kgseedand100percentRDN,respectively".

Messaoudi *et al*. 2023 conducted an experimentfor investigating the potassium fertilization effectonmorphologicalandagrophysiologicalindicates of Durum wheat under Mediterraneanrain-fedconditions.Basedongrainyieldandevaluatedagronomictraits,thisresearchrevealedthatanappli edpotassiumrateof100kg K_2O/ha is recommended as the most effectivedose to maximize durum wheat yield and qualityunderAlgeriansub-humidconditions.

Kantwa *et al.* conducted an experiment tostudy the effect of wheat varieties and integratednutrientmanagementpracticesonnutrientcontent, uptake and soil nutrient status. In thisstudy,theyobservedthatamongnutrientmanagementpractices,nitrogen,phosphorusand potassium content, uptake, grain and strawyieldofwheatweresignificantlyhigherunderapplication of 100 per cent RDF + *Azotobacter* +PSB.Further,resultsrevealedthatdifferentwheatvarietiesdidnotbringanysignificantvariationin availablenitrogen,phosphorus,potassium, zinc and organic carbon content insoil.Moreover,highestavailablenitrogenandphosphorusinsoilwasrecordedwiththeapplication of 100 per cent RDF + *Azotobacter* +PSB.However,significantlyhigherorganiccarbonandzinccontentinsoilwasobservedunder 50 per cent RDF + 25 per cent N throughFYM+*Azotobacter*+ PSB+$ZnSO_4$.

Patyal*etal*.2022conductedanexperimenttostudytheeffectofintegratednutrientmanageme nt(INM)ongrowthparametersand yield of wheat (*Triticum aestivum* L.). The resultsshowed that among various treatments, 100 percentRDF+25percentNthroughvermi-compost+ ZnSO4 at 25 kg ha^{-1} proved to found better withrespect to plant height (92.25 cm),drymatteraccumulation (274.65 g m^{-2}) and number of $tillersm^{-2}$(92.43m^{-2})atharveststageinrespectiveyears".

KumarandNiwas2022conductedanexperimenttostudytheeffectoforganicandinorganic fertilizers on growth and yield of wheat(*Triticum aestivum* L.). The results showed thatthehigherplantpopulation,plantheight,drymatter,numberoftillers,numberofeffectivetillers, leaf areaindex, daysto flowering,lengthof ear, number of spike, number of spikelet/year,number of grains/ear, biological yield, grain yield,straw yield, harvest index and

B: C ratio wereobservedwiththeapplicationof100percentNPK + 5 t ha^{-1}FYM + 5 t ha^{-1}vermi-compost +PSB.

Kumawat *et al*. 2021 conducted a field experimentto study about the effectof fertility levels andliquid bio-fertilizers on growth and yield of wheat.The results showed that significant increase inplant height, total tillerspermetre row length,effective tillers per metre row length, test weight,grain; straw and biological yield was observedwith the combine application of 100 per cent RDFand*Azotobacter*+PSB".

Emamu*etal*.2021conducted a field experiment entitled the effect ofintegrated application of vermi-compost and NPSfertilizer on soil physicochemical properties andyield of maize (*Zea mays* L.) crop at Toke Kutayedistrict, Western Ethiopia. From thisexperiment,itcanbeconcludedthattheapplicationofvermi-compostalongwithNPSfertilizersimproved organic matter and nutrient contents ofthesoilswhichinturnincreasedcropyields.Hence,inordertomaintainsoilfertilityandsustainmaizecropproduction,farmersofthestudyareaandsimilaragroecologiesareadvised to make integrated use of vermi-compostat 5 t/ha and NPS inorganic fertilizer at 50 kg/hatentatively.

Fazily *et al*. 2021 conducted a field experimententitled effect of integrated nutrient managementon growth, yieldattributes and yield of wheat.The highest yield attributes and yield of wheatwasproducedwiththeapplicationof100percent recommended dose of N (RDN) + 25 percent nitrogen through vermi-compost during boththeconsecutiveyears,butitdidnotdiffersignificantlywithapplicationof100percentRDN. On the basis of two years pooled data, T3produced94.96percenthighernumberof (*Triticumaestivum*L.).Theresultsoftheexperimentindicatedthatcombinedapplicationof inorganic fertilizer at higher/lower dose alongwithFYM,bio-fertilizerandsulphurgavesignificantly higher spikes per metre row length,spikelength,numberofgrainsperspikeandyield.However,thelowestyieldandyieldattributes were recorded with the RDF".

Devi *etal*. 2011conducted "a field experiment over twoyears on clay loam soil to assess the effect ofintegrated nutrient management (INM) practiceson growth and yield of wheat (*Triticum aestivum*L.). The results revealed that the application of100per cent RDF + vermi-compost at 1 t ha^{-1}+PSB and 75 per cent RDF + Vermi-compost at 1 tha^{-1}+ PSB produced higher yield attributes andgrain yield than the other treatments. The higheryield led to higher NPK uptake by wheat. Further,the available NPK content of soil also increasedin above INM treatment over control. The highestbenefit: cost ratio (2.73) was obtained from theapplicationof75percentRDF+vermi-compostat1t ha^{-1}+PSB".

Pandey *et al*. 2009 conducted "a field experimenttofindouttheeffectofintegratednutrientmanagement on productivity of late sown wheat(*Triticum aestivum* L.). The results showed thatapplication of 150 per cent RDF together with 10tonnesFYM+25kgZnSO4/haalthoughproduced maximum grain yield (3.8-3.9 t ha^{-1}).However, higher benefit: cost ratio (1.5-1.7) wasobtainedwith10tFYM/hatogetherwithRDFonly. Addition of 10 t FYM with fertilizer

levelssignificantly increased the nutrient uptake by thecrop, improved the organic carbon content, N, Pand K status and significantly reduced the bulkdensityofthesoilascomparedtochemicalfertilizer alone.

Rehman *et al.* 2008 conducted afield experiment entitled 'Organic and inorganicfertilizers increase wheat yield components andbiomassunderrainfedcondition.Fromtheresults, it is concluded that 80-60-60 kg NPK/haand 30 t FYM/ha have produced maximum wheatyieldcomponentsandbiomassunderrainfedcondition".

CONCLUSION

Inconclusion,thecollectivefindingsfromthereviewedstudiesprovidestrongevidenceinsupport of integrated nutrient management as aholistic approach for promoting productivity andsustainabilityof wheat based cropping system.By optimizing the use of organic (vermi-compost,FYM, bio-stimulants, compost *etc.*) and inorganicinputs(macro-andmicronutrientscontaining syntheticchemicalfertilizers),farmerscanimprove soil fertility, increase crop productivity,andmitigateenvironmentalimpacts,therebycontributingtothelong-termviabilityofagriculturalsystems.

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