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Organic nutrient management in aromatic rice-rice sequence: A critical review

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Abstract
Rice is the most important cereal crop and staple food consumed by more than half of the world's human population. Based on the presence of aroma, rice is categorized as the aromatic and non-aromatic rice. Aromatic rice is an important food grain crop and preferred by majority of human population. Most of the aromatic rice (short and long grain cultivars) varieties are low yielding, exhibiting inferior agronomic performance, highly sensitive to the environmental condition. Among several management practices, nutrient management is of utmost importance for its role not only in growth and development of the crop but also the maintenance of soil health and quality of the produce. At present, the farmers cultivate such premium aromatic rice following chemical-based agricultural practices which has increased productivity with inferior grain quality, degraded soil health and increased environmental pollution. Thus, it has been realized that organic nutrient management in aromatic rice is to be given paramount importance so as to attain sustainability in production and high economic return with better quality of produce. Different sources of organic manures seemed to have differential effects not only on the soil health but also on the quality of aromatic rice. Most of the cases poultry manure is considered to be one of the best organic sources when it is used after one season. Besides, other organic sources like FYM and concentrated manure are also better in sustaining crop productivity, maintaining soil health and reducing environmental pollution as compared to that with chemical farming.

Keywords: aromatic rice, organic manures, grain quality, nutrient uptake, soil microbial biomass, economics

Introduction
In the era of exploitative agriculture crops are usually grown with hazardous chemicals on and in the soil which leave residue on our food and pollute water sources. Conversely, organic farming is dedicated for promoting healthy land and a toxic free environment. Its underlying principle is to produce food of exceptional quality and quantity by using farming methods that co-exist with the environment around it.

To consider the soil as living system; to make it possible high quality compost (1-3 t/ac) should be used each or in alternate years to enhance the microbial population of soil. A healthy and diverse web of life in the soil will conserve and recycle nutrients from organic residues, release nutrients in the root zone of growing crops, reduce leaching losses, slowly unlock nutrients from insoluble soil minerals, stabilize soil pH so the much less liming is needed. "Feed the soil to feed the plant" is another basic principle of organic farming for managing the soil fertility. To increase soil organic matter, supplement with a series of approved biologically active and nutritionally rich organic manures like green manures, crop residues and composts to the cultivated field need to be emphasized.

The important benefits of organic manures such as accelerating plant growth, increasing production and quality agricultural produce and maintenance of soil health have already been realized by farmers. In the present juncture with the burgeoning population it is always apprehended that the continuously increasing food demand of India cannot be satisfied with the practice of organic farming. However, some intellectuals are in opinion that organic produce are having better export opportunity and fetch high premium price to enhance the farm profitability in one hand and restoration of soil health on the other.

Aromatic rice is an important food grain crop and preferred by majority of human population. At present, the farmers cultivate such premium aromatic rice following chemical-based agricultural practices which has increased productivity with inferior grain quality, degraded

soil health and increased environmental pollution. Thus, it has been realized that organic nutrient management in aromatic rice is to be given paramount importance so as to attain sustainability in production and high economic return with better quality of produce. The effects of organic manures like Farm yard manure (FYM), Poultry Manure (PM), Concentrated Manure and liquid manure on biometric characteristics, grain yield and quality and soil health after harvest of aromatic rice were critically reviewed. The up-to-date and pertinent literature available on topic **"**Organic nutrient management in aromatic rice-rice sequence**"** has been presented under the following heads.

Effect of organic nutrients on growth of aromatic rice

Application of lime with FYM and urea before planting resulted enhanced initial growth and dry matter production through stimulated mineralization of nitrogen from FYM and soil (Khan *et al.,* 1986) [29]. Increasing levels of nitrogen through FYM produced significantly higher numbers of leaves per hill than without FYM (Mondal *et al.,* 1990) [36]. FYM application @ 10 t/ha significantly increased the growth components, viz, number of leaves and tiller per hill (Rajput and Warsi, 1992). Singh *et al.,* (1996) [48, 64] recorded that application of FYM @ 20 t/ha significantly increased the plant height, LAI and tiller per hill. Babu *et al.,* (2001) [5] reported that application of FYM 12.5 t/ha along with 100% recommended dose of fertilizer recorded the highest plant height (118.0 cm), number of tillers/hill (12.60), leaf area index (6.73) and dry matter production (17.69 t/ha) at harvest stage which was significantly superior than other combination. Yadav *et al.,* (2013) [75] studied on the growth of low land rice during both *kharif* and *rabi* season at ICAR Research Station, Tripura and stated that not only the maximum values of growth parameters i.e plant height, tillers/hill and total dry matter accumulation/hill were obtained with 50% recommended N fertilizer dose along with organic source as FYM@ 11.2 t/ha but also 50% inorganic source can be saved with the use of organic sources.

Mohanty *et al.,* (2013) [35] conducted an experiment at OUAT, BBSR on sandy loam soil and reported that application of 1/3 rd recommended dose of N each through chemical fertilizer, FYM and Azolla registered the highest plant height and leaf area index in rice as compared to other treatment combinations. Dada *et al.,* (2014) [17] conducted a long term experiment at Nigeria in nutrient deficient soil with different type of compost and noticed that cattle dung maize stover compost enhanced the growth of plant and dry matter content in 3 different types of upland rice cultivars. Sudhankar *et al.,* (2018) reported significant effect of pre-rice incorporation of FYM @10 t/ha on growth parameters of rice like plant height, dry matter accumulation, leaf area index along with yield attributes in comparison to no manuring treatment.

Banerjee *et al.,* (2013) [9], conducted an experiment in sandy loam soil in BCKV, West Bengal, and reported greater tiller production with the application of FYM@ 50% RDN in combination with 50% mustard cake or vermicompost over sole FYM plots (FYM @ 100% RDN) in Gobindabhog scented rice. Goutami *et al.,* (2018) [22] conducted a long term fertilizer experiment at Bapatla and observed higher dry matter accumulation with the application of 100% NPK in combination with ZnSo4 and FYM@ 5t/ha under rice cropping system.

Saranraj and Imayavaramban 2015 from Annamalainagar observed that foliar application of vermiwash @5% at tillering and flowering stage significantly increased the growth parameters like Plant height (100 and 102cm), number of tillers/ hill (13.50 and 13.56), dry matter production (11715 and 11986kg/ha) during *rabi* and *kharif* season, respectively.

Application of poultry manure (0 to 6 t/ha) in combination with 0, 25, 50 and 100 % recommended dose of fertilizer increased the plant height of paddy both at maximum tillering stage and at harvest on sandy loam soils of Bapatla (Latha and Rao, 2001) [70]. Jha *et al.,* (2004) [27] conducted an experiment on sandy loam soils at Raipur and reported significant increase in the plant height at 50 DAT due to application of inorganic fertilizer of 30 kg N /ha along with 2 t/ha of poultry manure. Budhar *et al.,* (1991) [14] reported that more number of tillers per hill with the application of poultry manure @ 5 t/ha as compared to FYM application @ 5 t/ha during *Kharif* season of 1987 in clay loam soil of Coimbatore.

Application of RDF (120-60-40 kg N, P2O5, K2O) + poultry manure@ 20 t/ ha resulted significant increase in dry matter production of rice up to harvest in silty loam soils at Research Farm, Shalimar (Altaf Hussain *et al.,* 2012) [2]. Hassanuz zaman *et al.* (2010) [24] from Dhaka, Bangladesh observed that all the growth parameters in rice except plant height, total tiller per hill and biological yield were significantly superior to the combined application of poultry manure @4 t/ha +50% ($N_{40}P_6K_{36}S_{10}$).

Sarkar *et al.,* (2015) conducted a field trial in the Sher-e Bangla Agricultural University Farm, Dhaka and confirmed that the combination of organic (5t/ha PM) and inorganic fertilizers (100% RDF) significantly increased most of the growth parameter like plant height, number, length and diameter of leaves and total tiller/plant than sole use of inorganic fertilizer or organic manure. When same PM@ 5 t/ha was applied in combination with urea super granules 2.7 g resulted highest plant height number of tillers/hill and total dry matter production in aromatic Boro rice (Biswas *et al.,* 2016) [12] from Bangladesh.

Moe *et al.* (2019) [34] from Japan recorded maximum dry matter production in Indica rice with the combined application of organic with inorganic i.e 50% chemical fertilizer (CF_{50}) plus PM with 50% EMN (estimated mineralizable N) based on their N content in both the years of study. They concluded that organic fertilizers with total N less than 4% were only effective at improving growth and yield in the second year after being continuously applied for 2 years.

Usman *et al.,* (2003) [73] conducted a field experiment at PG Agriculture Research Station, Faisalabad, Pakistan and noticed that the application of NPK @ 50-37.5-30 kg/ha along with poultry manure @20 t/ha recorded significantly the maximum LAI (2.98), plant height at maturity.

Hossaen *et al.,* (2011) [25] from Dhaka observed the maximum plant height and total tillers per hill in Boro rice with poultry manure @ 2.4 t/ha plus 70% RDF ($N_{100}P_{15}K_{45}S_{20}$). Nila *et al.,* (2018) [40] conducted an experiment at Bangladesh and revealed that application of 75% RDF with poultry manure @2.5 t/ha produced the tallest plant (72-79cm), highest no. of tillers/hill (15.13) and LAI (2.78) over sole application of PM 5 t/ha in aromatic Boro rice.

Effect of organic nutrients on yield attributing characters of aromatic rice

Usman *et al.,* 2003 [73] observed maximum number of ear bearing tillers, grains per panicle and 1000 grain weight in scented rice where FYM was applied @ 20 t/ha in combination $N_{50}P_{37.5}K_{30}$ kg/ha.

Yield attributing characters are directly correlated with economic yield of plant. Panicle length, spikelet per panicle,

fertile grains per panicle and grain weight of BRRI dhan 40 was higher in plots supplied with poultry manure @ 4 t/ha plus $N_{40}P_6K_{36}S_{10}$ (50% NPK) which was also better than inorganic fertilizer and other organic manures alone. Hossaen *et al.,* (2011) [25] recorded the maximum number of tillers per hill (13.52), panicle length (24.59 cm), total grain per plant (97.45) and 1000 seed weight (21.80 g) from 2.4 t/ha poultry manure plus 70% N $N_{100}P_{15}K_{45}5_{20,}$ whereas, yield attributing characters given highest result when applied poultry manure @ 5 t/ha along with 100% recommended dose of fertilizer. Quick release of N from poultry manure compared to other organic sources can be attributed for the superior performance resulted with application of 60 kg N/ha through PM in sandy clay laom soil during *rabi* season from Seethampeta (Rao *et al.,* 2013) [50].

Arif *et al.,* 2014 [4] recorded the highest value of yield attributing characters from the plot receiving poultry manure @10 t/ha in combination with 50% RDF ($N_{150}P_{90}K_{60}$) in Basmati rice in Pakistan. Paul *et al*., (2019) [44] also experienced similar result in aromatic Boro rice through the application of 2.5 t /ha PM along with 25% less than inorganic fertilizer. Similarly, the advantageous effect of poultry manure in producing higher yield attributing characters in scented rice cv. Geetanjali is also reported by Nayak, 2020 [39] from two years of study at OUAT, Bhubaneswar.

Effect of organic nutrients on yield of aromatic rice

The farmyard manure is traditionally an important source of nutrient supplement for rice in India and is recognized as a substitute of inorganic fertilizer (Sharma and Mitra, 1991). Magnitude of response of rice to FYM depends on the type of FYM and its characteristics and moisture status during the crop growth (Gaur, 1982). Similar observation was also reported by Anon (1988) [3] and Gaur (1990) [20]

Verma (1991) [74] reported that FYM application increased the rice yield significantly. Application of 50-60 kg N per hectare through FYM increased the rice yield by 64 percent over control (Rajput and Warsi, 1992) [48], whereas, incorporation of FYM 5 t/ha into the rice field significantly influenced the yield of rice over control (Thakur and Kanwar, 1994) [71]. Amending the soil using FYM @ 12 t/ha alone without any chemical fertiliser increased the yield of rice by 22% (Singh *et al.,* 1998) [62]. The quantum of 62 kg N/ha supplied through 10 tonnes of FYM recorded grain yield (3.70 t/ha) similar to that of 80 or 120 kg N/ha (3.86 t/ha) in scented rice (Pandey *et al.,* 1999) [43]. Application of 20t FYM/ha produced as high yield of rice (5504 q/ha) as that application of $N_{60}P_{50}K_{30}$ (Singh *et al.,* 2001b). Whereas, lower yield of rice (23.6 q/ha) under absolute application of farmyard manure because of poor nutrient availability owing to immobilization of soil nitrogen (Sumathy *et al.,* 1999) [67].

Quyen *et al.,* (2002) [46] from Indian Agricultural Research Institute, New Delhi in his comparative study of organic and inorganic farming on basmati rice in a sandy clay loam soil reported that 4.20 t/ha grain yield was obtained through the application of FYM @ 10 t/ha alone which was similar to 50% RFD (60:30:20) as inorganic. Kumari *et al.,* 2013 [30] reported that application of FYM @ 10 t/ha produced maximum grain yield (3.28t/ha) as compared to rest of the organic treatments in Scented rice (Basmati) from Jharkhand. Sudhakar *et al.,* 2018 [66] claimed that superiority in grain yield due to continuous use of FYM @ 10t/ha produce 10.4% in the first year and 21.1% in the second year over no manuring treatment from Hyderabad. Rao *et al.,* 2013 [50] from Sethampeta, A.P observed that application of 60 kg N/ha through poultry manure registered highest yield over FYM@ 60 kg N/ha in scented rice varieties.

Sangeetha *et al.* 2013 [54] from Coimbatore studied that enriched poultry manure compost on equal N basis @ 2.3t/ha registered highest yield in scented rice over control and inorganic fertilizer in 2years of study. Bora *et al.,* 2014 [13] reported that scented rice yield (Ketakijoha) recorded highest grain yield 2.45 t/ha due to the application of enriched compost @ 2.5t/ha in comparison to the application of FYM alone from Jorhat during *kharif.*

From a 5 years study in Hyderabad Surekha *et al.,* 2013 [69] reported that in wet season grain yield under 100% inorganic was almost 15-20% higher during first two years whereas, during later three years grain yield improved with organic (4.8-5.2 t/ha) but in dry season superiority of organic was observed after fourth years in scented rice. Haque *et al.,* 2018 [23] reported from Bangladesh that residual effect of treatments of poultry manures bioslury, poultry manure, cow dung bioslury and cow dung registered 11.7, 8.9, 5.4 and 3.1 % increase in total system productivity over sole chemical fertilizer (N_{46}, P_{20}, K_{50}, and S_{18}) in a wheat-rice cropping system.

When FYM 80 kg N/ha was applied in combination with other organics produced 10% lower yield in basmati rice than inorganic in rice –wheat cropping system reported by Sharma *et al.* 2007 from IARI, New Delhi. But Sigh *et al.,* 2007 reported in IARI research farm that the scented rice (Pusa basmati) grain yield increased by 114 to 116.8% over absolute control when FYM applied with other organic sources in combination which was also at par with the yield recorded under inorganic in rice-wheat–green gram cropping system. Ganajaxi and Math 2008 [19] from Dharwad reported scented rice yield produced organically were insignificant among organic treatments where as it was superior to rice produced with no organic manure during wet season in low land situation. Ram *et al.,* 2011 [49] from New Delhi reported that in *rabi* season the cumulative effects of FYM in combination with organics was more effective than its direct and residual effects for increasing productivity in rice –wheat cropping system in a sandy clay loam soil. Sigh (2011) from Patna claimed that application of FYM in combination with other organic nutrients produced significantly higher yield in Scented rice (Sugandha dhan) than alone application of FYM in rice. Application of FYM in combination with other organic manures resulted at par yield of the scented rice varities (Type-3 and Taraori) with the inorganic rice yield reported by Bisarya *et al.,* (2018) [11] from Uttarakhand. Devi *et al.,* 2019 [18] noticed that the yield of black aromatic rice recorded at par grain yield with conventional method (60:40:30kg/ha) in the first season whereas, higher grain yield in the second season produced through application of 50% FYM with 50% loktak phumdi compost from Manipur. Similarly, Ojobor, 2017 [41] from Nigeria also recorded highest maize yield with application of compost @10t/ha (rice husk amended with poultry manure at ratio 1:1 by weight) in both early and late season.

Choudhary and Suri 2009 [16] from Palampur reported that sole application of FYM @10t/ha produced higher grain yield than the FYM applied in combination with green manure in situ or mushroom spent compost but registered highest yield when FYM applied in combination with inorganic fertilizer. Yadav *et al.,* 2013 [75] noticed that substitution of 50% RDN through FYM @ 11.2 t/ha produced higher yield over control in both *kharif* and *rabi* season from Tripura district in low

land rice. Mohanty *et al.*, 2013 [35] reported that wet season rice productivity was highest (4.88 t/ha) with the 1/3rd combination of organic with inorganic fertilizer which was at par with the 50% combination of organic with inorganic fertilizer from Bhubaneswar. Goutami *et al.*, 2018 [22] from his long term soil fertility experiment from Bapatala reported that FYM @ 5t/ha in combination with chemical fertilizer produced highest yield which was superior to rest of the organic or inorganic sources of nutrients. Sankar *et al.*, 2014 from Bangladesh concluded that combined application of 75% RDF and 50% cowdung registered higher yield and yield attributes in aromatic fine rice cv. BRRI dhan 34.

Rao *et al.*, 2013 [50] from Sethampeta, A.P reported that application of 60 kg N/ha through poultry manure registered higher yield over FYM@ 60 kg N/ha in scented rice varieties. Usman *et al.*, 2003 [73] from Faisalabad, Pakistan observed that application of poultry manure @ 20 t/ha with chemical fertilizer @50-37.5-30kg/ha recorded highest yield (3.82 t/ha) over sole application of chemical fertilizer or poultry manure in scented rice (Basmati-2000) during Kharif. Sujatha *et al.*, 2014 from Bapatala registered at par yield (5665 kg /ha) of rice produced through the application of poultry manure 50% RDN as basal + 50% at 10 days before PI stage with 100% RDN(120:60:40) through chemical fertilizer. Sarkar *et al.*, 2015 from Bangladesh observed that combined use of PM@5 t/ha with 100% RDF produced highest grain yield over sole application of PM at the same dose in rice (BRRI dhan 33).

Ali *et al.*, 2009 [1] from Bangladesh registered that integrated use of poultry manure @ 3 t/ha along with 70% NPKS once in a year can reduce the use of 30% NPKS fertilizer in both Boro rice(N_{100} P_{15} K_{45} S_{10} kg/ha) and Aman rice (N_{40} P_{45} K_{60} S_{20} kg/ha) productivity. Hasanuzzaman *et al.*, (2010) [24]-46 from Bangladesh supported the findings of Ali et al. 2001 observed that application of poultry manure @4 t/ha along with 50% NPKS (N_{40} P_6 K_{36} S_{10}) produced the highest yield similar to yield of 100% NPK and saved the use of 50% NPK. Hossaen *et al.*, 2011 [25] reported from Bangladesh that similar results with Ali *et al.*, 2009 [1] and registered highest yield produced through combined application of PM @ 2.4 t/ha with 70% (N_{100} P_{15} K_{45} S_{20}) in Boro rice which save 30% use of chemical fertilizer. Arif *et al.*, 2012 from Pakistan reported that grain yield was realised from the integrated use of PM@10 t/ha with 50% RDF (150:90:60) over 100% RDF which can reduce the use of 50% RDF chemical fertilizer in Basmati rice during *kharif* season. Roy et al., 2017 from Bangladesh studied the effect of integrated fertilizer in aromatic Boro rice (BRRI dhan 50). They observed that the application of 75% of recommended dose of fertilizer plus poultry manure @2.5 t/ha recorded highest yield (6.40 t/ha). *Poul et al.*, 2019 from Bangladesh observed highest grain yield with combined application of PM@2.5 t/ha with 75% RDF (Urea, TSP, MOP, Gypsum, $ZnSO_4$ @ 250, 120, 120, 100, 10kg/ha respectively) in aromatic Boro rice (BRRI dhan 50).

Kabir *et al.*, 2009 [28] from Bangladesh observed that similar yield was obtained in Aman rice with the application of PM @ 2.5 t/ha in combination with full dose of Urea super granule (USG: 1.8g) or with full dose of prilled urea (PU) when compared with the yield obtained from full dose of USD (1.8g) and other inorganic fertilizers. Biswas *et al.*, 2016 [12] from Bangladesh suggested that combined application of PM@5 t/ha with urea super granule 2.2g and prilled urea (115kg N/ha) produced significantly highest yield in scented rice (BRRI dhan 50). Islan *et al.*, 2017from Bangladesh noticed that integrated use of PM@3.5 t/ha along with 1.8g Urea Super Granule and other inorganic recorded higher yield in BRRI dhan 34 over sole application of PM and also from control. Moe *et al.*, 2019 [34] from Japan revealed that application of poultry manure as estimated mineralizable nitrogen based N content recorded 8.69% and 9.70% higher grain yield from the plot supplied with $CF_{50}PM_{50}$ over CF_{100}.

Polthanee *et al.*, 2011 [45] from Thailand reported that the rice straw incorporated in the soil combined with the application of cattle manure produced maximum grain yield (3820kg/ha) which was at par with that of rice straw incorporated into soil combined with cattle manure and bio-extracted fertilizer (3797kg/ha). It was also recorded that 18.77% higher yield over the incorporation of rice straw alone.

Padmanabhan *et al.*, 2014 [42] from Bengaluru conducted an experiment during wet season of 2012-13 at Zonal Agricultural Research Station, the result indicated that application of 50%RDN through goat manure + 50% N through bio-digested liquid manure increased grain yield (5.11t/ha) and straw yield (6.10t/ha) in transplanted rice which was evidenced by increase in soil microflora. In the same experiment they also observed that with the application of 50% RDN through glyricidia + 50% through bio-digested liquid manure the microbial population was enhanced as bacteria, fungi and actinomycetes (51.22cfuX10^6/g of soil, 62.45cfuX10^3/g of soil and 38.98 cfuX10^3/ g of soil).

Nayak, 2020 [39] from a two year experiment conducted at OUAT, Bhubaneswar, reported that among the organic nutrient management practices highest yield in aromatic rice was obtained when the crop was fertilized with poultry manure to supply 100%RDN along with top dressing twice with liquid manure at 25DAT and 50DAT which was at par with the yield obtained from poultry manure alone or concentrated manure +Top dressing with liquid manure at 25DAT and 50DAT. The same treatment registered almost 15.11 and 17% higher yield over farm yard manure +Top dressing with liquid manure twice at 25DAT and 50DAT during both *kharif* and r*abi* season, respectively.

Effect of inorganic nutrients on yield of rice

Kumari *et al.* (2010) [31] conducted a field trial at Ranchi during *Kharif* season for 2 years in scented rice Basmati and reported that almost 20% increase in grain yield with recommended dose of fertilizer compared to the best organic source combination i.e. green manure @ 5 t/ha + FYM @ 10 t/ha (3.3 t/ha). Sujatha *et al.*, (2014) observed that application of chemical fertilizer (100% RDF) produced maximum crop yield (5856 kg/ha) which was at par with the combined application of 50% PM and 50% RDN as basal, but significantly superior to sole application of organic manures (Poultry manure/ FYM). Application of 150% RDN increased the grain yield to an extent of 11.8% in the first year and 8.7% in the second year over 100% RDN (Sudhakar *et al.*, 2018) [66]. Nayak, 2020 [39] also reported that when the aromatic rice was grown with 100% recommended dose of chemical fertilizer produced the maximum grain yield in aromatic rice in both the seasons during the period of study and it on par with the yield obtained from Geetanjali rice crop when supplemented with organic sources like Poultry Manure or Concentrated Manure either in isolation (100%RDN) or in combination with liquid manure twice at 25 and 50 days after transplanting (DAT).

Effect of organic nutrients on aroma and grain quality

Quyen *et al.*, (2007) reported that rice quality parameters i.e. milling percentage, kernel length (KL), Kernel breadth (KB),

L: B ratio before cooking of rice were not affected by different sources of nutrients, but the head rice recovery, KL, KB and L:B ratio after cooking resulted an increasing trend with the application of organic sources compared to control (un-manured) in scented rice (Pusa basmati) in *kharif* season at New Delhi.

Ganajaxi and Math (2018) [19] from Dharwad studied the effect of organic manure on aroma of basmati rice in silty clay loam soil during wet season and reported that aroma of Basmati rice was superior to the plot that received poultry manure @ 2 t/ha which was also equivalent to control plot (No organic manure). They also concluded that by reducing the inorganic fertilizer level aroma was improved.

Ravi *et al.,* (2012) [51] from Chennai conducted a field experiment with organic rice (Salem samba) and observed that organically grown plants improved in their nutrients contents, milling characteristics, physico-chemical qualities and cooking quality compared to conventionally grown rice varieties. Bagchi *et al.,* (2016) [7] conducted an experiment in rice to assess the quality in both wet and dry season and concluded that the rice produced through organic production system (OPS) based on Nitrogen & phosphorous resulted low in protein and phytate and higher in anti-oxidative capacity and it's responsible phytochemicals, physico-chemical characteristics, but hulling, milling, HRR and other working qualities were at par with the quality of rice grown with standard cultivation method (SCM). Biswas *et al.,* (2016) [12] stated that the maximum grain protein content was (7.49%) noticed with combined application of manures (PM 5 t/ha) as compared to sole application of inorganic fertilizer in aromatic Boro rice (BRRI dhan).

Nayak and Reddy (2005) [38] from NRRI, Cuttack conducted a field experiment with 28 scented rice and non- scented rice for their quality characters on both *rabi* and *kharif* season. They confirmed that higher hulling and milling percentage occurred in *rabi* season due to higher binding of glucose molecules and more sunshine hour during grain filling, at the same time due to compactness at starch in endosperm head rice recovery was also more in *rabi* season whereas, other characters were better in *kharif* season than *rabi*.

Nutrient content (N,P,K, Fe, Mn, Zn, Cu), protein and amylase content was higher in Basmati rice when it was supplied with FYM along with other organic manures (Green manure and Bio-fertilizer) in rice-wheat cropping system in 2 years of study (Ram *et al.,* 2011) [49].

Sangeetha *et al.,* (2013) [54] from Coimbatore reported that the physical and cooking qualities of Basmati rice grown with organic (enriched poultry manure) were comparatively inferior than the rice grown with inorganic fertilizer, but aroma was better in rice- blackgram cropping sequence.

Surekha *et al.,* (2013) [69] from Hyderabad reported that there was no significant effect on physical grain quality parameters viz. milling percentage, Hulling percentage, HRR, L/B ratio and cooking quality parameters like amylase content and elongation ratio in scented rice Vasumati by different nutrient sources even after 5 years of study, however in the fifth year there was improvement in HRR by 9.5% and ER by 4% and moderate improvement in nutritional quality parameters like protein, phosphorous and potassium with organic over inorganics. Bora *et al.,* (2014) [13] from Jorhat evaluated the scented variety Ketekijoha in *kharif* and observed that some grain quality improved with organic nutrition as compared to control, but no significant difference were observed in quality parameter like KL, KB, L/B, protein content and aroma.

After ten years of long term experimentation on organic nutrient management in scented rice variety Geetanjali revealed that there was no significant difference in physico-chemical and cooking properties of grain except Amylose content and gel consistency. However antioxidant capacity, y-oryzonal and total phenolic content were higher with combined application of FYM and GM, but flavonoids, soluble protein and crude oil content were maximum under only Green manure treated crops. Bagchi *et al.,* (2015) [6]

Paul *et al.,* (2019) [44] from Bangladesh concluded that protein content in aromatic boro rice (BRRI dhan 50) was highest when grown with 2.5 t poultry manure along with 75% RDF (urea, TSP, MUP, Gypsum, $ZnSO_4$ @250,120,120,100,10 kg/ha).

Effect of organic nutrients on nutrient uptake of aromatic rice

Choudhury *et al.* (2009) [37] concluded that application of FYM @ 10t/ha alone realised significantly higher nutrient uptake in wheat crop and succeeding rice crop over FYM application in combination with other organic sources in Western Himalayas. Similar result was also experienced by Kumari *et al.,* (2010) [31] in scented rice from Jhansi. Whereas, fertilizer level up to N_{60} P_{30} K_{30} + 6 t FYM/ha significantly increased the N, P and K uptake by crop as compared with other level of fertilizers applied through inorganic source or in combination with FYM (Choubey *et al.,* 1997) [15]. The N concentration in rice plant at 30 and 90 DAT and at harvest was significantly higher in case of preconditioned urea than that of prilled urea. The pre conditioned urea with FYM + soil (1:3:1) built up higher N status in soil than prilled urea (Lokpale *et al,,* 1999). The N uptake by rice nourished with 60 kg N/ha as urea blended with FYM (1:3:1) was noted to be similar to prilled urea application in three splits (Upadhyaya *et al.,* 2000).

Mohanty *et al.,* (2013) [35] from OUAT confirmed that the maximum nitrogen, phosphorous and potassium uptake were with use of 1/3 rd N each as chemical fertilizer, FYM and azolla. This result was also supported by Dada *et al.,* (2014) [17] from Nigeria. He confirmed that cattle dung maize stover enhanced the nutrient uptake by plants in a nutrient depleted soil in tropical rain forest Derived Savannah Transition Zone.

Ram *et al.,* (2011) [49] revealed that higher nutrients uptake was recorded when FYM @ 10 t/ha applied in combination with other organic sources in comparison to alone in Basmati rice on sandy loam soil under rice –wheat cropping system.

Rao *et al.,* (2013) [50] conducted an experiment in high altitude areas of AP on scented varieties of rice and revealed that application of 60 kg N/ha through PM resulted significantly higher root volume, root biomass and the maximum uptake of N and K by the crop over farm yard manure.

Saranraj and Imayavaramban 2015 from Annamalainagar from 2 years experiments noticed that foliar application of vermiwash @5%at tillering and flowering stage significantly recorded higher nutrient uptake i.e. nitrogen uptake 126.6 and 127.5, phosphorus uptake of 23.9 and 24.6, Potassium of 284.2 and 298.4 kg /ha during *rabi* and *kharif* seasons, respectively.

Ray *et al.,* (2018) conducted a pot culture experiment in net houses where rice plants were grown with application of organic manures like cow dung manure, poultry manure and rice husk. They concluded that the accumulation of phosphorous and potassium was followed the order that treated with poultry manure > cow dung manure > Rice husk

> control in sandy clay loam soil with alternate wetting and drying condition.

From a two years field experiment conducted at OUAT, Bhubaneswar, Nayak, 2020 [39] reported that, maximum amount of nutrients depleted by the scented rice Geetanjali when grown with 100% RDF alone which was closely followed by the removal when the rice crop was supplemented with poultry manure alone or in combination with liquid manure at 25 and 50 DAT in both *kharif* and *rabi* seasons during the period of study.

Effect of Organic nutrients on microbial biomass and enzymatic activity in soil

Brajendra *et al.* (2016) conducted an experiment for 2 years at IIRR, Hyderabad to compare the performance of field fertilized poultry manure application on some microbiological properties of soil. He revealed that mineral enriched treated soil recorded improved soil microbial biomass compared to RDF and also highest values of soil dehydrogenase activities were recorded, but alkaline phosphate skewed from the mineral enriched compost. Simultaneously he recorded the lowest value of dehydrogenase in soils received RDF.

Application of organic amendments increased soil microbial population of actinomycetes, bacteria, fungi and BCG which further influenced the soil dehydrogenase activity and phosphate enzyme activities and recorded the maximum value over control and RDF in basmati rice-wheat-green gram cropping system at IARI, New Delhi (Brajendra *et al*., 2016).

Basha *et al.*, (2017) [10] from Dharwad reported that integrated application of Farmyard manure(1/3) + vermicompost (1/3) + green leaf manure (1/3) equivalent to RDN(100kg/ha) with recommended FYM(5t/ha)+ microbial consortium (Azospirillum+ PSB) with soil application of bio digester @ 2500 l/ ha at 30, 60, 90 DAS recorded significantly higher nitrogen fixers (42.7 and 39.8 x 10^3cfu/g soil), PSB(44.2 and 41.8 x 10^4cfu/g soil), Azospirillum population (3.95 and 0.08 x 10^6 cfu/g soil), dehydrogenase (15.7and 41.3g TPF/g /soil/day) and phosphatase (29.9 and 28.7 g pNP/g/soil/ha) at flowering and harvest, respectively in aerobic rice in clay soil. However, they also reported that soil application of bio digester, the liquid organic manure @2500l/ha at 30, 60, 90 DAS recorded significantly higher nitrogen fixers (34.4 and 31.6 x 10^3cfu/g soil), PSB (31.0 and 28.3 x 10^4cfu/g soil), Azospirillum population (1.90 and 0.31 x 10^6 cfu/g soil) at flowering and harvest, respectively in aerobic rice in clay soil.

Siddharam *et al.*, 2017 from Bengaluru reported that there was enhancement of population of bacteria (24.2cfu x 10^5/g of soil), fungi (16.4cfu x10^3/g of soil) and actinomycetes (11.2 cfu x 10^4/ g of soil) after harvest of aerobic rice was registered with FYM 12.5t+ Biodigester liquid manure 150kgN/ha as compared to recommended practice. Padmanabhan *et al.*, 2014 [42] from Bengaluru conducted an experiment during wet season of 2012-13 at Zonal Agricultural Research Station, the result indicated that application of 50% RDN through glyricidia + 50% through bio-digested liquid manure the microbial population was enhanced as bacteria, fungi and actinomycetes (51.22cfu x 10^6/g of soil, 62.45cfu x 10^3/g of soil and 38.98 cfu x 10^3/ g of soil).

Naher *et al.*, (2020) [37] conducted an experiment on effect of long term nutrient management in rice –rice fallow rotation at Bangladesh research farm. They reported that high bacterial population in treatment imposed with PM@ 3 t/ha along with chemical fertilizer from last 10 years, whereas lowest bacterial population was found in control treatment where no nutrient was added for last 31 years. Similarly Surekha *et al.*, (2013) [69] reported biological indicators (Soil respiration and enzyme activities glucoside, phosphate and dehydrogenase) were significantly improved in organic compared to inorganic in his 5 years experiment at Hyderabad.

Maximum bacterial population (6.76 x 10^6cfug^{-1} and 6.82 x 10^6cfug^{-1}), fungi population (4.65 x 10^2 cfug^{-1}and 4.90 x 10^2 cfug^{-1}), actinomycetes population (5.76 x 10^3 cfug^{-1},5.82 x 10^3 cfu g^{-1}) in were reported from soil fertilized with 100% RDF in *kharif* and *rabi* season, respectively which was also at par with the population reported from the soil supplied with poultry manure alone or in combination with top dressing of liquid manure twice at 25 and 50 DAT during the period of study in Geetanjali rice (Nayak. 2020) [39].

Effect of organic nutrient management on economics of aromatic rice

Sharma *et al.*, (2008) [59] reported 27% higher net returns of rice-wheat cropping system under organic farming assuming 50% higher premium prices for organic produce as compared to inorganic produce. Farmers can use the combination of organic manures and inorganic fertilizer to uplift the yield as well as profit. It confirmed by Hasunuzzaman *et al.*, (2010) [24] who reported that highest profit with B: C ratio of 1.75 was obtained from combination of PM @ 4 t/ha + 50% inorganic fertilizer N_{40}, P_6, K_{36}, S_{10} over control but almost similar to 100% of recommended dose of fertilizer (1.07). When FYM was applied in combination with Azotobacter to Sugandha rice variety generated a higher net profit of Rs. 2,98,628 with B:C ratio 3.42 which was at par with the profit realised through FYM alone (Rs. 2,77,298 with B:C ratio 3.25) in rice-tomato-bottle gourd cropping system reported by Singh *et al.*, 2011.

Mohanty *et al.*, (2013) [35] reported that the maximum net return of Rs.1,8,777/ha in the treatment receiving 1/3N each as chemical fertilizer, FYM and Azolla to rice crop which was significantly superior to 100% inorganic fertilizer alone in OUAT, Bhubaneswar.

Poultry manure bioslury based IPNS (Integrated plant nutrition system) treatment had the highest monetary advantage of 1165 US $/ha as compared to the sole chemical fertilizer treatment receiving plot as reported by Haque *et al.*, (2018) [23] from Bangladesh in wheat-rice cropping system on a sandy clay loam soil. Higher net return and gross return was realised in the treatment receiving 60kg N/ha through poultry manure than over FYM and sheep manure treated plots in scented rice in Andhra (Rao *et al.*, 2013) [50].

Banarjee *et al.*, (2013) from West Bengal conducted an experiment on scented rice Gobindbhog and reported that combined use of FYM (50% RDN as basal), mustard cake (50% RDN at 21 DAT) fetched highest return (19,261 and 19,071/ha) and higher benefit cost ratio (1.90 and 1.84) during 1st year and 2nd year of investigation. Similarly Kumari *et al.*, (2010) [31] experienced that green manure plus FYM fetched higher net return of Rs.35, 975/ha and B:C ratio (2.61) when compared with rest of the organic manures in scented rice Fozo Raveli.

Surekha *et al.* (2013) [69] reported from long term experiment that cost of production was high with organics in all 5 years of study. Though gross returns, net returns and benefit cost ratio were higher in inorganic in the initial four year (with 1.37 and 1.09 B:C ratio in inorganic and organic system, respectively) organic system proved its superiority in the fifth year by fetching higher returns (with 1.75 and 1.99 B:C ratio in inorganic and organic system respectively). The production cost can be reduced in due course by proper utilization of on-

farm residues and waste materials. Bora *et al.,* (2014) [13] also reported higher profit in organic farming of scented rice.
Rahman *et al.,* (2019) from Bangladesh after 2 years of field trial on Aman and Boro rice, reported that gross and net return was increased and this was due to the application of poultry manure either with IPNS (integrated plant nutrient system) based dose 50% STB (soil text based) dose chemical fertilizer than sole application of STB based chemical fertilizer.

Effect of organic nutrient management on residual status of soil

Mineralization of FYM and other manures takes very longer time and it was experimentally observed that a part of nutrients released after mineralization by these manures becomes available to standing crop and most of the parts remain in soil and this residual nutrient become available to succeeding crops, respectively.
Application of FYM/compost to rice at 10-15 t/ha produced a moderate to high response and saved up to 40 kg N/ ha and had a residual effect (Gaur, 1984) [21]. Similarly, Meelu and Morris (1984) [33] observed that application of FYM resulted considerable direct and residual effect and saved much nitrogen for succeeding crop. Whereas organic manures considerably improve the fertility status of soils measured by percentage carbon and available N after crop harvest (Sharma and Mitra, 1991).
In a study on the effect of different level of nitrogen and organic manures on yield of rice and its residual effect, Rajput and Warsi (1992) [48] reported that application of FYM at the rate of 10 t/ha saved 50 kg N /ha. Lakpale *et al.,* (1999) [32] reported that application of urea preconditioned with FYM and soil (1:3:1) built up higher N status of soil. Upadhyaya *et al*.(2000) also reported that urea blended with FYM and soil (1:3:1) on application to rice released N for longer period and also enhanced.
Quyen *et al.* (2002) [46] ensure that FYM applied with green manure significantly increased available N, P and K content of the soil over the control and this increase was equal to that with 50% RFD, whereas, FYM significantly improved P and K status in soil. Similar result was reported by Sharma *et al.* (2008) [59] from IARI, New Delhi in Basmati rice cropping system.
Ali *et al*. (2009) [1] stated that integrated use of manures (3 t/ha poultry manure) in a year with 70% NPKS saved the use of 30% NPKS as fertilizers. They also revealed that there was improvement in soil health by increasing organic matter thereby the available P and S contents in the soil. But Choudhary and Suri (2009) [16] stated that application of both organic and inorganic, improved the soil organic carbon, total N and available NPK content over initial status in Basmati rice-wheat cropping system due to slow release of nutrient year after year might have also resulted in built up of these nutrients in soil.
Continuous application of the organic sources to rice for three years significantly improved the SOC, available N,P & K status of soil at the end of the scented rice –tomato-bottle gourd cropping system at Patna (Sigh, 2011). Ojobor (2017) [41] reported significant improvement in soil pH, EC, total N, available P and with application of 50% rice husk plus 50% poultry manure, but organic carbon was maximum when 60% rice husk plus 40% poultry manure was applied to maize in soil of Abaraka, Nigeria.
Siddharam *et al.,* 2017 from Bengaluru concluded from a 2 years experiment that the residual fertility status of soil improved with higher available N (356.2kg/ha), P_2O_5 (69.5kg/ha) and K_2O (208.0kg/ha) after the harvest of aerobic rice was noticed by the application of FYM 12.5t/ha+ biodigester liquid manure 75kgN/ha as compared to recommended practice.
Sigh *et al.* (2007) reported that the soil organic C and available P content were increased due to organic amendments along with FYM over control as well as chemical fertilizer after the harvest of scented rice-wheat – green gram cropping system from IARI research farm.
Surekha *et al.,* (2013) [69] observed that significant improvement in soil physical properties (Bulk density and penetration resistance), soil fertility (Organic C and available N, P and K) and biological properties (soil respiration and enzymes activities) with organics compared to inorganic fertilizers. They also recorded that increase in SOC 59-65%, N 3-10%, P 10-27% and K 8-25% with organics, respectively over five years of study in black clayey vertisols at DRR, Hyderabad. Among different organic manure treatments application of 100% RDN through FYM recorded highest NPK in soil after harvest which was at par with 50% RDN as basal plus 50% at 10 days before PI stage through FYM over application of 100% RDN through poultry manure.
Irrespective of rate of poultry manure, the percentage of OC and nitrogen were increased significantly in plots compared to control `plot, whereas, positive nutrient balance at P and S was observed in the combined use of PM and chemical fertilizer treated plots but N and K remained in negative balance which was reported by Rahman *et al.* (2018) [23] in wet land Boro rice in Gazipur, Bangladesh.
Maintenance of higher soil organic carbon (0.63%), and available nutrients like N (296.87kg/ha), P (62.94kg/ha), K (189.23kg/ha) after completion of two year experiment was reported when the crop Geetanjali was grown with 100% RDN through poultry manure along with top dressing with liquid manure twice at 25 and 50 DAT (Nayak, 2020) [39].

Conclusion

Aromatic rice grown organically with application of different sources of organic manures not only sustains productivity for a longer period of time but also maintains soil health. Sometimes intensively managed organic cultivation, accumulate higher soil organic matter (SOM) through heavy annual application of organic manure from off-farm sources. However, these farms often have excessive soil P, K and soluble N posing a risk of water pollution and soil cation imbalance. If soil tests show ample soil organic matter and very high P and K levels, it is time to cut back the off farm organic inputs, and use cover crops to replenish organic matter and N without adding P and K. This will also save money, labour and resources.

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