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EFFECT OF ORGANIC MANURES ON GROWTH, YIELD AND QUALITY OF SCENTED RICE (*ORYZA SATIVA* L.): A REVIEW

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ABSTRACT
This review examines the effect of organic manures on the growth, yield, economics, soil properties and grain quality of scented rice and other rice types. Scented rice such as Vishnubhog is valued for its aroma and grain quality, but its productivity depends on a nutrient management strategy that sustains soil health without raising the cost of cultivation. The literature shows that sole organic sources (farmyard manure, compost, vermicompost, green manure, poultry manure, Azolla and biofertilizers) release nutrients slowly and often fail to match the recommended dose of fertilizer in growth and grain yield, whereas integrating roughly 25 to 50 per cent of nitrogen through organic sources with inorganic fertilizer improves tillering, dry matter accumulation, yield attributes and grain and straw yield. Organic and integrated sources also build soil organic carbon and available nitrogen, phosphorus and potassium, and several studies report favourable benefit:cost ratios. Enriched compost, green leaf manure, vermicompost and rock phosphate enriched with organic material emerged as the more promising organic options. Quality traits such as hulling, milling, head rice recovery, kernel dimensions, amylose content and aroma responded to nutrient source, nitrogen level and variety. Long-term, scented-rice-specific studies on organic combinations, their residual effects and grain quality remain limited, and these gaps should guide future research.

KEYWORDS: Scented rice, Organic manures, Integrated Nutrient Management, Grain quality, Soil Fertility etc.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of more than half of the world's population, and in Asia alone more than two billion people derive 60-70 per cent of their energy intake from rice and its derivatives (Kumari *et al.*, 2014). India has the largest area under rice, about 43.19 million ha, with an annual production of 110.15 million tonnes and a productivity of 2.55 t ha^{-1} (Anonymous, 2017).

Aromatic or scented rice holds a prime position in Indian society, not only because of its high quality but also because it is considered auspicious. The area under scented rice is increasing with the opening of the world market and rising domestic consumption owing to its premium quality (Singh and Singh, 2008). Scented rice fetches a much higher price than high-quality non-aromatic rice. Vishnubhog is one of the signature aromatic rices of Chhattisgarh; it is a non-basmati, short to medium grain traditional cultivar with intermediate amylose content and gelatinization temperature, widely grown in Chhattisgarh and Madhya Pradesh and used in everyday cooking.

Continuous use of chemical inputs affects the sustainability of soil, while consumer demand for safe, high-quality and organically produced food is increasing. Organic manures improve the physical, chemical and biological properties of soil, maintain soil health and supply almost all essential plant nutrients. Organic manures such as farmyard manure (FYM), poultry manure, vermicompost, green manure, biofertilizers and plant compost deserve priority for sustained and better organic rice production (Dahiphale *et al.*, 2003). However, FYM and most other organic sources are low in nutrient content and must be applied at high rates to meet crop demand, so they are often used along with other inputs. Green manure alone can make the soil fertile, but its combination with nitrogenous fertilizer increases rice yield, nutrient availability and nutrient uptake further because nutrients are released slowly throughout the crop growth period.

Rock phosphate is a natural and cheaper source of phosphorus, but it is poorly soluble in neutral and alkaline soils. Enriching it with compost or vermicompost is a practical approach to improve its solubilization and to add organic matter at the same time (Adhami *et al.*, 2014). Information on the conjunctive use of organic and inorganic sources specifically for scented rice is limited. This review therefore brings together research on the effect of organic manures,

alone and in combination with inorganic fertilizers, on growth, yield, economics, soil properties and grain quality of scented rice, supplemented with findings from other rice types where scented-rice information is lacking.

2. Effect of organic manures on growth parameters of scented rice:

Phosphorus sources. Kalitha and Baroova (1994) reported greater plant height, root length and tiller number with 60 than with 40 kg P_2O_5 ha^{-1} applied as single superphosphate (SSP), and Raju and Reddy (1999) found that 60 kg P ha^{-1} increased all growth parameters of rice. Saikia and Balasubramaniam (1998) observed at Coimbatore that P applied as rock phosphate + FYM + phosphobacteria recorded the highest root dry weight at all growth stages of rice (IR 50), under both wet-seeded and transplanted conditions. Suresh *et al.* (2000) reported that basal application of phosphobacteria with enriched FYM and SSP gave vigorous seedlings and higher growth and yield parameters in wet-seeded rice, and Pheav *et al.* (2003) recorded maximum shoot dry weight at panicle initiation with 16.5 kg P ha^{-1} applied in each season in Cambodia.

Nitrogen level. Gangaiah and Prasad (1999) found a marked increase in dry matter production of scented rice with each successive increment of N from 0 to 180 kg ha^{-1}, although 120 kg N + 60 kg P_2O_5 + 60 kg K_2O, 120 kg N + 60 kg P_2O_5 and 120 kg N ha^{-1} alone recorded similar dry weight. Murali and Shetty (2004) recorded significantly more tillers $hill^{-1}$ (13.71) with 150:75:75 kg NPK ha^{-1} than with 125:62.5:62.5 and 100:50:50 kg NPK ha^{-1}. Mhaskar and Thorat (2005) noticed an increase in tillers m^{-2} and functional leaves m^{-2} as N increased from 0 to 120 kg ha^{-1}, while Sultan *et al.* (2007) at Kanpur reported that 140:70:70 kg NPK ha^{-1} produced significantly taller scented rice plants (118.05 cm) at maturity than lower fertility levels. Mannan *et al.* (2010) stated that tiller number increased with nitrogen levels at 30, 45 and 60 days after transplanting (DAT) and at maturity. Prathap Reddy *et al.* (2019) emphasized that nitrogen promotes rapid plant growth through higher tillering, leaf area development, grain formation, grain filling and protein synthesis.

Organic and integrated sources. Gowda *et al.* (2001) in Karnataka reported that 10 t of fresh *Azolla* with 90 kg N ha^{-1} significantly increased plant height, tillers $hill^{-1}$, panicles m^{-2} and grain yield. Singh *et al.* (2006) observed higher dry matter production with 25% of the recommended dose of nitrogen (RDN) through press mud and 75% through inorganic fertilizer than with 100% RDN alone or its organic combinations, and Acharya and Mondal (2007) at BCKV, West Bengal, reported improved tiller production with 75% N through fertilizer and 25% N through Neematex compared with the recommended dose of fertilizer (RDF) alone.

Several studies on scented rice show that growth under completely organic nutrition lags behind that under fertilizer-based nutrition. Kumari *et al.* (2010) at Ranchi reported that RDF produced more tillers in scented rice than green manure combined with biofertilizers, FYM and vermicompost (completely organic). Srinivas *et al.* (2010) noticed higher dry matter accumulation at all growth stages with 100% NPK along with Zn, S and FYM than with other organic combinations and organic treatments alone. Bhowmick *et al.* (2011) recorded a significant improvement in plant height at all growth stages with 50% RDF + 50% FYM compared with 100% RDF alone and sole FYM. Alekh *et al.* (2017) at Faizabad found the maximum tillers m^{-2} at all stages with 50% of the recommended NPK through fertilizers + 50% of the recommended N through FYM + 5 kg Zn ha^{-1}, which was at par with 100% NPK + Zn through chemical fertilizers and with 100% nutrients through FYM + Zn.

Teli *et al.* (2018) reported significantly higher growth parameters in the scented variety Pusa Sugandh-3 with RDF (60:40:20 kg N:P_2O_5:K_2O ha^{-1}) + 5 t FYM + 2.5 t vermicompost ha^{-1}, with tillers m^{-2} (450) at 60 DAT higher than in Mushkabudji, although the plants of Pusa Sugandh-3 were shorter. Manivannan and Sriramachandrasekharan (2018) revealed that organics, mineral N or both significantly improved growth and yield characters over control, and that growth and yield were higher with 100% mineral N than with 100% N from an organic source alone. Moe *et al.* (2019) found that integrating 50% of the recommended N through poultry manure enhanced growth parameters and yield, and that combined organic and inorganic fertilizers increased tiller number, panicle number, spikelet number, dry matter production and panicle length. Xuan *et al.* (2020) likewise reported that combined application of animal manure and inorganic fertilizer enhanced tiller number, panicle length and yield attributes and improved the physicochemical properties of rice grain compared with the recommended chemical dose, and they called for research on new application methods and appropriate amounts based on crop type, soil and region.

3. Effect of organic manures on yield parameters of scented rice:

Green manures. Bhuiyan *et al.* (1988) reported that green manure at 7.6 t ha^{-1} produced a grain yield almost similar to that of the recommended fertilizers. Singh *et al.* (1991) summarized that the yield response of rice to green manuring in India ranged from 0.70 to 3.10 t ha^{-1} in high yielding varieties and was particularly high in coarse-textured soils; rice yield increases of 78 per cent in less fertile soils (against 21.6 per cent in highly fertile soils) in China, 30-128 per cent in the Philippines and more than 100 per cent in Sri Lanka were also reported. Saravana Pandian and Perumal (1994) observed that FYM at 12.5 t ha^{-1} or dhaincha green manure at 12.5 t ha^{-1} increased yield and yield attributes when combined with nitrogen up to 100 kg ha^{-1}. Dwivedi and Thakur (2000) reported that dhaincha or biogas slurry at 10 t ha^{-1} with 100:60:40 kg NPK ha^{-1} significantly increased rice yield, dhaincha being superior to biogas slurry, while incorporation of rice straw at 5 t ha^{-1} gave no yield advantage. Premi (2003) at Palampur found that in-situ incorporation of sunhemp or dhaincha with 50% of the recommended N improved grain yield compared with RDF

alone and 25% RDF with green manure. In basmati rice-wheat, Bhoite (2005) recorded higher panicle length (27.2 cm) with 50% RDF + 50% N through green manure than with RDF alone or with FYM, and Choudhary *et al.* (2011) reported that 75% RDN + 25% N through dhaincha gave higher panicle length than the same combination with FYM. Mahajan *et al.* (2012) found that in organically grown basmati rice, green leaf manure (5 t ha^{-1}) + vermicompost (2.5 t ha^{-1}), green leaf manure (10 t ha^{-1}) and neem cake (2.5 t ha^{-1}) gave 20.2, 16.7 and 15.2 per cent higher grain yield than the recommended level of N.

FYM, poultry manure, vermicompost and other organics. Chithra and Janaki (1999) reported a beneficial effect of 12.5 t FYM ha^{-1}, with grain and straw yield increasing significantly when it was combined with 50 kg N ha^{-1}; yield also improved with composted coir pith, press mud or green leaf manure along with 50 kg N ha^{-1}. Pandey *et al.* (1999) found that 10 t FYM ha^{-1}, 80 kg N ha^{-1} or 5 t FYM + 40 kg N ha^{-1} were equally effective as 120 kg N ha^{-1} in terms of grain yield of scented rice. Channabasavanna *et al.* (2000) reported that poultry manure at 2 t ha^{-1} gave significantly higher grain yield than FYM, with increases of 6.4 and 20.5 per cent over FYM and no organic manure, respectively. Murali and Setty (2001) noted that vermicompost at 5 t ha^{-1} gave a significantly higher yield (4.89 t ha^{-1}) than no vermicompost (4.07 t ha^{-1}), because of more panicles $hill^{-1}$ and filled grains $panicle^{-1}$. Samal (2001) found that *Azolla* (10 t ha^{-1}) with 60 kg N ha^{-1} increased panicles m^{-2} through more productive tillers and thus grain yield. Balasubramaniyan (2004) obtained 3.9 t ha^{-1} with a completely organic combination of green manure, neem cake and *Azospirillum*. Urkurkar *et al.* (2010) in Chhattisgarh obtained a rice yield of 3.66 t ha^{-1} when 100% N was supplied through cow dung manure, neem cake and composted crop residues, which was very near to that obtained with 100% N through chemical fertilizers. Bahadur *et al.* (2013) noticed that 100% RDF with FYM and biofertilizers recorded a higher straw yield than RDF alone and other organic combinations. Shaikh *et al.* (2017) recorded the highest grain (51.00 q ha^{-1}) and straw yield (62.71 q ha^{-1}) with a combination of FYM, vermicompost, gliricidia leaves and neem cake, and Ramesh (2018) reported the highest grain yield (5.81 t ha^{-1}) of the variety ADT 43 with 50% N through urea + 50% N through press mud vermicompost. Syed *et al.* (2019) at Killikulam observed a higher grain yield (7160 kg ha^{-1}) with 75% of N through inorganic sources and 25% through poultry manure.

Scented and basmati rice. Gautam *et al.* (2005) reported that each successive increase in the level of nitrogen significantly enhanced the grain yield of aromatic rice. Saha *et al.* (2007) observed that 75% RDF with a pelleted organic manure recorded a higher grain yield of scented rice than 100% RDF alone and its organic combinations. Davari and Sharma (2010) found that FYM + wheat residues + biofertilizers and vermicompost + wheat residues + biofertilizers increased grain yield of basmati rice by 51-58 per cent over control and 18-22 per cent over FYM or vermicompost alone. Kumari *et al.* (2010) recorded a higher grain yield of scented rice (4 t ha^{-1}) with 100% RDF than with the complete organic treatment of green manure, FYM and biofertilizers. Naidu *et al.* (2013) reported a 15.3 per cent yield increase in the variety Swarna with 100:50:50 over 60:30:30 kg NPK ha^{-1}, and Rao *et al.* (2013) found that, among organic manures tested on scented varieties in Andhra Pradesh, 60 kg N ha^{-1} + poultry manure gave the best result (4405 kg ha^{-1}). Bora *et al.* (2014) tested FYM, green manure, vermicompost, enriched compost and biofertilizer treatments on the scented variety Ketekijoha and found that enriched compost at 2.5 t ha^{-1} recorded the highest grain yield (2.45 t ha^{-1}).

Rock phosphate and enriched sources. Many studies have compared rock phosphate (PR) with water-soluble phosphorus fertilizers. Balasubramaniyan (1989) found that PR increased panicle number m^{-2} and that 50% P as PR + pyrites in a 1:5 ratio with 50% P as SSP gave the highest yield. Siddaramappa *et al.* (1991) in acid soil of Karnataka recorded the highest grain yield (5.64 t ha^{-1}) with Udaipur rock phosphate at 60 kg ha^{-1}, followed by 5.49 t ha^{-1} with superphosphate, against 2.86 t ha^{-1} in the control. Krishnappa *et al.* (1991) reported that PR alone or with SP gave higher total productivity than SP alone, and Mitra *et al.* (1992) found that PR significantly increased rice yield in lateritic and red soils, a 1:1 PR + SSP mixture performing as well as SSP. Partohardjono and Adiningsih (1991) concluded that reactive PR gave similar or even larger yields than TSP in several crops, including upland rice, and Fageria *et al.* (1991) noted that in later years of a rice-common bean rotation the efficiency of phosphate rocks equalled that of TSP. Bado and Hien (1998) reported that BPR increased the yield of upland rice more efficiently than TSP in the second year, and Mongia *et al.* (1998) showed that lime and rock phosphate increased the grain and straw yield of rice. Ortega and Rojas (1999) found that SSP, TSP or PR increased grain yield and decreased floret sterility, and Rajendran (1999) obtained 5.48-5.73 t ha^{-1} with different sources of 60 kg P_2O_5 ha^{-1}, against 4.34 t ha^{-1} without P, the highest yield being with rock phosphate. Rosamalin *et al.* (1999) noted that TSP gave higher grain yield than PR when lime was applied, whereas PR gave significantly higher yield without liming. Sahu *et al.* (1999) reported in a rice-groundnut rotation that rice grain yield was highest with 80 kg P_2O_5 ha^{-1} as SSP or as raw rock phosphate + SSP, while groundnut yield was highest with 80 kg raw rock phosphate. Rodriguez *et al.* (2002) reported that partial acidulation of rock phosphate made it highly effective, and Kumar *et al.* (2002) found that Mussoorie rock phosphate could be effectively used in a rice-black gram sequence. Subodth *et al.* (2003) observed that a PR + SP mixture (1:3) was the most efficient in a dhaincha-rice sequence, and Rahman (2005) recorded significantly higher rice yield with a higher rate of PR (210 kg P ha^{-1}).

4. Effect of organic manures on economics of scented rice:

Sadler and Stewart (1984) cited that tropical acid soils are very low in native phosphorus and that locally available phosphate rock is a potentially economically attractive source. Seyoum and McIntire (1987) concluded that direct application of ground rock phosphate to crops on acid soil is a simple, low-cost method of substituting refined phosphates, especially when PR is locally available. Hellums *et al.* (1992) showed that in every trial PRs were as economically effective as TSP, and Prakash *et al.* (1994) reported higher total net returns and benefit : cost (B:C) ratio with rock phosphate along with lime in coastal soils of Karnataka. Policegoudar *et al.* (1994) observed the highest B:C ratio in rice when P was applied as rock phosphate alone, Goswami *et al.* (1996) obtained the highest net returns with Mussoorie rock phosphate at 90 kg P_2O_5 ha^{-1} in a rice-wheat system, and Goswami and Baroova (1998) reported that the highest net return was recorded with Mussoorie rock phosphate at 90 kg ha^{-1}. Duraisamy (1997) found that SSP + phosphobacteria with the full recommended P increased net return and B:C ratio in a groundnut-rice sequence. Tomita *et al.* (2001) and Islam (2005) likewise reported higher profit and net benefit with rock phosphate.

Studies on integrated nutrient management also point to favourable economics. Dass *et al.* (2009) stated that Gliricidia at 2.5 t ha^{-1} + biofertilizers + 50% RDF was the most productive and remunerative practice for upland rice in the Eastern Ghats of Orissa. Choudhary *et al.* (2011) noticed an increased B:C ratio with RDF alone and with 75% RDF + dhaincha green manure, owing to the lower cost of green manuring and higher yield. Murthy *et al.* (2012) reported that gross and net returns and the B:C ratio increased progressively with nitrogen up to 120 kg N ha^{-1}. Baishya *et al.* (2015) recorded the highest B:C ratio (2.76) and net returns (Rs 47,616 ha^{-1}) with 5 t Sesbania green manure + 75 kg N + 16.5 kg P + 31.3 kg K ha^{-1}. Tiwari *et al.* (2017) found that 50% RDF + 50% FYM gave a significantly higher grain yield (5459 kg ha^{-1}) and straw yield (7042 kg ha^{-1}) along with the highest net return and B:C ratio. Ramteke *et al.* (2018) showed that vermicompost at 5 t ha^{-1} with FYM at 5 t ha^{-1}, PSB and *Azospirillum* increased tillers, panicle length, test weight and grain yield of scented rice in Chhattisgarh, with gross returns of Rs 58,500 ha^{-1} and net returns of Rs 32,250 ha^{-1}, showing better opportunities for organic agriculture in rice. Yadav *et al.* (2019) concluded in a review that FYM, vermicompost, biofertilizers, blue-green algae and other organics with 100% RDF gave good growth, yield attributes, economic returns and grain quality, and Shenoy and Siddaraju (2020) concluded that integrated nitrogen management with organic sources such as vermicompost and poultry manure along with inorganic fertilizers is beneficial for yield, nutrient uptake and soil properties, 50 per cent from organic and 50 per cent from inorganic sources being the best combination reported by many workers.

5. Effect of organic manures on soil properties under scented rice:

Phosphorus sources and biofertilizers. Rautaray *et al.* (1995) reported that a product prepared from Purulia rock phosphate and Na_2CO_3 heated at 900 °C was comparable to superphosphate in P availability, straw and grain yield and P uptake of rice in coastal soils of Orissa. Prakash and Badrinath (1995) found that P and lime increased the soil availability of N and P and exchangeable Ca in lateritic soils of coastal Karnataka. Paulraj and Velayutham (1995) reported that phosphobacteria did not exert a striking influence on the availability of P from Mussoorie rock phosphate, while Datta and Banik (1997) found that the bio-inoculant *Bacillus firmus* gave higher rice yield, P uptake, P use efficiency and P recovery than SSP and partially acidulated rock phosphate. Ortega and Rojas (1999) found that P availability in soil increased with SSP, TSP or rock phosphate, and Sankhajit *et al.* (2000) reported that rock phosphate at 100-150 kg P ha^{-1} and superphosphate at 60 kg P ha^{-1} gave the highest N, P and K contents in rice plants at the vegetative stage, with non-significant differences in crop yield. Jayaramasoundari (2001) recorded an increase in soil available P when the entire P was applied basally through Mussoorie rock phosphate, and Roul *et al.* (2003) found that 75 or 100% of the recommended P blended with cow dung + PSB was best in terms of bacterial population, soil P availability and yield of a rice-mustard system.

Azolla and green manures. Singh and Mandal (1997) reported that *Azolla* with mineral N increased N, P and K uptake in both wet and dry seasons and increased the post-harvest available soil N, P and K. Jayanthi *et al.* (1998) observed that *Azolla* at 10 t ha^{-1} with 40 kg N ha^{-1} gave the highest beneficial effect on rice N uptake and soil available N, and Tamizh Vendan *et al.* (1999) found that dual cropping of *Azolla* enhanced soil available N at 35 and 65 DAT. Samal (2001) noted that consecutive application of *Azolla* for two years improved soil fertility and organic matter status, and Sundaravarathan and Kannaiyan (2001) reported higher NH_4^+-N accumulation after incorporation of *Azolla microphylla* with prilled urea. Singaravel *et al.* (2003) found that 100% NPK or 75% NP + *Azospirillum* and phosphobacterium with *Sesbania aculeata* at 6.25 t ha^{-1} enhanced nutrient availability, growth and yield of rice.

Organic manures and integrated nutrient management. Bandyopadhyay and Puste (2002) reported that 3 t FYM ha^{-1} or 3.65 t rice straw ha^{-1} with 25% of the recommended dose improved the available NPK of soil over sole fertilizer treatments in red and laterite soils of West Bengal. Bhoite (2005) found that the N, P and K status of soil improved with 150 kg N ha^{-1} compared with RDF alone, 180 kg N ha^{-1} and their organic combinations. Saha *et al.* (2007) noticed the highest total soil N, P and K with 75% RDF and a pelleted organic manure. Sikdar *et al.* (2008) reported that soil pH, organic matter, available phosphorus and potassium increased with increasing levels of nitrogen, and Singh *et al.* (2010) found that graded levels of nitrogen to basmati rice significantly increased soil organic carbon and P up to 60 kg N ha^{-1}. Srinivas *et al.* (2010) reported higher available N, P and K after harvest with RDF + zinc than with RDF

alone and 50% RDF with organic manures, while Kumari *et al.* (2010) recorded higher plant N content with green manure (5 t ha^{-1}) + biofertilizers (BGA, *Azolla*), P with karanj cake (2.5 t ha^{-1}) and K with green manure + paddy straw (10 t ha^{-1}). Jakasaniya *et al.* (2019) reported that 100% N through castor cake gave significantly higher available soil potassium after harvest, and Shenoy and Siddaraju (2020), reviewing the integrated use of cow dung, compost and vermicompost with inorganic fertilizers, concluded that 50% N from inorganic and 50% from organic sources is the best combination for rice yield and soil properties.

6. Effect of organic manures on quality parameters of scented rice:

Grain quality of scented rice, including kernel size, hulling, milling and head rice recovery percentages, elongation ratio, amylose content and aroma, is determined by variety and is further modified by nutrient management. Sharma *et al.* (2012) reported that among basmati cultivars and six N and P levels, Pusa Basmati-1121 gave the highest grain yield (4870 kg ha^{-1}), kernel length and length : breadth ratio, and that although yield attributes, yield and returns were maximum at 90:45 kg N:P ha^{-1}, quality parameters were not affected. Bora *et al.* (2014) found that enriched compost at 2.5 t ha^{-1} gave the maximum grain yield together with better grain length (8.38 mm), breadth (2.62 mm), protein content (9.63%) and aroma (3.52 ppm) in the scented variety Ketekijoha.

Nitrogen levels. Tayefe *et al.* (2014) reported that biomass, grain yield, tillers m^{-2} and panicles m^{-2} reached their maximum with 90 kg N ha^{-1}, that all quality characters except gelatinization temperature differed significantly among N levels, and that amylose content was highest in the check. Dakshina Murthy *et al.* (2015) found that hulling percentage improved up to 125% of the recommended N and then declined slightly, while milling percentage and head rice recovery increased up to a 50 per cent increase in N. Mishra *et al.* (2015) observed that the highest N level (225 kg ha^{-1}) recorded the maximum yield, protein content, hulling percentage, kernel length and kernel length after cooking. Swaroopa and Lakshmi (2015) recorded the highest protein content (9.1%), hulling (87.5%), milling (80.7%) and head rice recovery (71.0%) with 150% RDN against 8.2%, 81.4%, 75.6% and 63.3% with 75% RDN. Kumar and Kureel (2017) reported that 120 kg N ha^{-1} gave the highest grain yield, hulling percentage, kernel length and breadth in Pusa Basmati-1, and that P at 40 kg ha^{-1} gave the maximum yield and hulling percentage.

Nutrient sources and varieties. Zaidi *et al.* (2016) reported that organic sources in general were superior to fertilizers in improving grain and quality attributes, recording hulling of 78.6%, milling of 67.79%, kernel length of 6.74 mm, kernel breadth of 1.84 mm, amylose content of 26% and gel consistency of 61.6 mm; among varieties, the improved basmati Vasumathi recorded the highest hulling (79.5%) and milling (68.6%), followed by Kalanamak. Sahu *et al.* (2015) in Chhattisgarh found that, among the scented varieties Dubraj, Badshahbhog and CR Sugandha Dhan 907, the last recorded the greatest paddy, brown rice and kernel dimensions and elongation ratio, whereas hulling (76.67%), milling (70.16%) and head rice recovery (57.22%) were highest in Badshahbhog. Kumar *et al.* (2017) observed that the variety PAC-837 gave maximum grain and straw yield and the highest protein and amylose content, while the length : breadth ratio before and after cooking was maximum in PR-115 and DRRH-3, respectively; yield, quality and the B:C ratio varied with the level of fertility.

CONCLUSION

The literature reviewed shows that organic manures are an essential component of nutrient management for scented rice, but their best use is in combination rather than alone. Sole organic sources such as FYM, compost, green manure and vermicompost improve soil organic carbon, available nutrients and soil biological activity, yet they frequently give lower tillering, dry matter and grain yield than recommended fertilizer doses in the short term because of their low and slow nutrient supply. Integrating about 25 to 50 per cent of the recommended nitrogen through organic sources (green leaf manure, vermicompost, poultry manure, enriched compost or FYM) with inorganic fertilizers generally sustained or increased growth, yield attributes and yield, improved soil fertility and gave good economic returns. Enriched compost, green leaf manure, vermicompost and enrichment of rock phosphate with organic materials were the more promising organic options. Grain quality traits are influenced mainly by variety and nitrogen supply, with organic sources having a favourable or neutral effect on most quality parameters.

Nevertheless, the information on conjunctive use of organic manures and inorganic fertilizers specifically for scented rice is limited and often drawn from basmati or non-aromatic rice. Suitability of organic sources also depends on local availability, soil type and environment. Future research should therefore (i) include multi-season and long-term trials with scented varieties under different agro-climatic conditions, (ii) study the residual effect of applied organic manures and inorganic inputs over more than one cropping system, (iii) identify the cheapest and most efficient organic source that can be combined with inorganic fertilizers to improve yield and maintain soil health, (iv) examine the effect on aroma and cooking quality in more detail and (v) integrate livestock and crop production so that farmers can sustain the supply of organic manures.

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