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Comparative Study Of Post-Harvest Soil Health of the Paddy Cultivated Through Chemical Fertilizer and the Biofertilizers

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ABSTRACT: Rice productivity in the tropics largely depends on fertilizers as soils are commonly low in nitrogen and phosphorus. Some farmers in this region cultivate rice using the hand-broadcast method, which has resulted in a low yield. Therefore, this on-farm experiment was conducted to compare the performance and yield of broadcasted and transplanted rice production systems under different fertilizer combinations. The experimental was set up in a split plot design with six combination treatments and seven replications. The main plots were planting methods comprised of transplanting and broadcasting. The subplots were a combination of NPK fertilizer, urea, and biofertilizer (BF) with and without compost, while the control treatment was NPK fertilizer and urea. The BF contained nitrogen fixer bacteria and phosphate solubilizer microbes. The results showed that fertilizer combination increased shoot height, root length, shoot and root dry weight (RDW), root-to-shoot ratio (R/S), tiller number, 1,000-grain weight, and yield but did not affect clump number. In addition, the planting method affected the parameters except for R/S and 1,000-grain weight. The yield of transplanted rice grown with NPK fertilizer and urea was 17.5% higher than that of the broadcasting method. Incorporation of chemical fertilizer combined with compost and BF resulted in a comparable yield; transplanted rice yield was only 2.18% more than broadcasted. This showed that diverse fertilizer application is needed to minimize the yield gap between broadcasted and transplanted rice

KEYWORDS-rice, chemical, fertilizer, biofertilizer, effect, growth

I.INTRODUCTION

Substituting chemical fertilizers with manure is an important method for efficient nutrient management in rice cropping systems of China. Labile nitrogen (N) is the most active component of the soil N pool and plays an essential role in soil fertility. However, the effects of manure substitution on soil labile N in rice cropping systems and their relationships with soil properties, fertilization practices, and climatic conditions remain unclear and should be systematically quantified. Here, we investigated rice grain yield and four types of soil labile N that have been widely reported, including available nitrogen (AN), ammonium nitrogen (NH+4-N), nitrate nitrogen (NO-3-N), and microbial biomass nitrogen (MBN). We reviewed 187 published articles and performed a meta-analysis to quantify the effects of manure substitution on yield and soil labile N. The results showed that manure substitution increased AN, MBN, NH+4-N, and NO-3-N by 11.3%, 38.5%, 5.9%, and 8.1%, respectively. Partial substitution significantly increased the yield by 1.4%–5.9%, but full substitution significantly decreased the yield by 2.9%. The positive effects of manure substitution on yield and AN were stronger with long-term fertilization. The differences in responses varied across specific manure types, N application rates, soil properties, and climatic factors. In conclusion, manure substitution can increase soil labile N and is regarded as an efficient strategy for improving soil N fertility and a recommended measure for applying both chemical and organic fertilizers in rice systems. This study provides evidence of the effects of manure substitution on yield enhancement by increasing soil labile N.[1,2,3]

Chemical fertilizers depended rice cultivation is destroying soil health and it can be a threat for future rice production in many countries. An integrated nutrient management practices by incorporating chemical, organic/biofertilizer nutrient sources will be the best strategies for restoring soil health and carbon storage in soils. Green manuring crops like Sesbania can improve soil fertility and increase rice yield, and can be a potential input in organic farming. Biofertilizers with N2-fixing bacteria and PSB can supplement N and increase P fertilizer use efficiency, respectively having higher crop productivity. Hence, future rice production strategy should be combined use of chemical, organic and biofertilizer, rather than sole chemical fertilizers.

Chemical fertilizers are being used in higher amounts in order to increase the crop yield. However, chemical fertilizers above threshold level pollute the water bodies, besides getting stored in crop plants. This has made the environmentalists to switch over to organic farming. Organic farming is the production of unpolluted crops through the use of biofertilizers and biopesticides which provide optimum nutrients availability to plants, keeping pathogens and pests in control.

Nitrogen fixing free living bacteria: e.g., Azotobacter, Clostridium, Bacillus polymyxa, Beijerinckia
Nitrogen fixing free living Cyanobacteria: e.g., Nostoc, Anabaena, Aulosira, Totypothrix

Partial association of nitrogen fixing bacteria: e.g., Azospirillum
Symbiotic nitrogen fixing bacteria: e.g., Actinomycete, Rhizobium, Ardisia
Symbiotic nitrogen fixing cyanobacteria: e.g., Blue-green algae
Microphos biofertilizers: e.g., Aspergillus species, Pseudomonas striata
Plant growth promoting rhizobacteria: e.g., Pseudomonas fluorescens
Mycorrhiza: Ectomycorrhiza, Endomycorrhiza

Recommended use of biofertilizers for different crops, which include Rhizobium (pulses, chickpea, groundnut, soybean, beans, lentil, lucern, berseem, greengram, blackgram, cowpea, and pigeonpea), Azotobacter (cereals, wheat, oat, barley, mustard, seasum, linseeds, sunflower, castor, and millets), and Azospirillum (rice, maize, and sorghum) by either seed or soil treatment.[7,8,9]

Microbial biofertilizers increase rice plant growth:

PGPR	Plant	Attribute	References
Bacillus megaterium, B. subtilis, B. subtilis subsp. subtilis, and Pseudomonas sp.	Arachis hypogaea	Biocontrol and plant- growth promotion: Inhibit Aspergillus niger growth that causes root rot diseases, produces auxin (indole-3-acetic acid, IAA), and increases nitrogen fixing activities in plant.	Yuttavanichakul et al. (2012)
Bacillus cereus (Sneb 560), B. subtilis (Sneb 815), Pseudomonas putida (Sneb 821), P. fluorescens (Sneb 825), and Serratia proteamaculans (Sneb 851)	Solanum lycopersicum	Biocontrol: Incorporating these five bacterial isolated in S. lycopersicum, promotes the plant biomass and inhibits root-knot nematode Meloidogyne incognita.	Zhao et al. (2018)
Bacillus subtilis LHS11 and FX2	Brassica napus	Biocontrol and plant-growth promotion: Antagonistic activity against Sclerotinia sclerotiorum (Lib.) de Bary and showed phosphate solubilization, nitrogen fixation, and IAA production activities.	Sun et al. (2017)
Bacillus velezensis strains 5YN8 and DSN012	Piper nigrum	Biocontrol: Control the gray mold disease caused by necrotrophic pathogen Botrytis cinerea.	Jiang et al. (2018)
B. subtilis, Bacillus pumilus, Burkholderia cepacia, P. putida, Bacillus amyloliquefaciens, Bacillus atrophaeus, Bacillus	Solanum tuberosum	Biocontrol: Inhibit the dry rot disease of S. tuberosum caused by Fusarium sambucinum, Fusarium	Recep et al. (2009)

PGPR	Plant	Attribute	References
macerans, and Flavobacter balastinium		oxysporum, and Fusarium culmorum under storage condition.	
Sphingomonas sp. LK11	S. lycopersicum	Plant growth promotion: Production of gibberellins and IAA.	Khan et al. (2014)
B. amyloliquefaciens	Capsicum annum	Biocontrol and plant growth-promotion: Induces resistance against anthracnose disease (Colletotrichum truncatum) and enhances germination of seed along with vegetative growth.	Gowtham et al. (2018)
B. amyloliquefaciens strain CEIZ-11	S. lycopersicum	Biocontrol: Control damping-off disease caused by Pythium aphanidermatum.	Zouari et al. (2016)
Pseudomonas aeruginosa	Launaea nudicaulis	Biocontrol: Activity against Macrophomina phaseolina, Fusarium solani, and F. oxysporum, inhibits the maximum infection of M. phaseolina on mungbean roots.	Mansoor et al. (2007)
P. aeruginosa	Triticum aestivum	Bioremediation and plant growth-promotion: Causes oxidative stress tolerance under Zn stress and enhances nutrient availability, antioxidant defense system and reduction in Zn uptake for wheat plant growth promotion.	Islam et al. (2014)
Enterobacter aerogenes strain K6	Oryza sativa	Heavy metal tolerance and plant growth-promotion: Provide resistance against Cd2+, Pb2+, and As3+, and PGP traits like also associated with IAA) production, nitrogen fixation, phosphate solubilization, and 1-aminocyclopropane-1-carboxylate (ACC) deaminase activity for plant-growth promotion.	Pramanik et al. (2018)
Enterobacter cloacae strain (HSNJ4)	B. napus	Stress tolerance and plant-growth promotion: Balances the relative content of IAA and ethylene to enhance the salt tolerance. In addition, proline content and antioxidant enzyme activity	Li et al. (2017)

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PGPR	Plant	Attribute	References
		were also enhanced.	
Pseudomonas koreensis	Helianthus annuus	Stress tolerance: Provides tolerance to plant in drought conditions.	Macleod et al. (2015)
Pseudomonas sp.	Eleusine coracana	Stress tolerance: Provides tolerance against oxidative stress inducing by drought condition and induces plant fitness.	Chandra et al. (2018)
P. aeruginosa BHU B13-398 and B. subtilis BHU M	Vigna radiata	Plant-growth promotion and biocontrol: Exhibits PGP traits for plant-growth promotion such as phosphate solubilization, ammonia, siderophore, and hydrogen cyanide (HCN) production along with resistance against root rot pathogen Rhizoctonia solani.	Kumari et al. (2018)
B. cereus and B. safensis	Lens culinaris	Plant-growth promotion and biocontrol: PGP traits showed were production of siderophores, indole acetic acid, and phosphate solubilization along with biocontrol activity against Alternaria sp.	Roy et al. (2018)
Bacillus sp. strain WU-5, WU-9, and WU-1	P. nigrum	Stress tolerance and plant-growth promotion: Provides salinity tolerance via increasing the proline content and antioxidant enzyme activity and induces plant growth such as phosphate solubilization, ACC deaminase, ammonia, and siderophore production.	Wang et al. (2018)
B. amyloliquefaciens isolate WE15 and B. firmus isolate WD19	Brassica oleracea var. alboglabra	Phytoremediation and plant-growth promotion: phytoremediation of soil mediated iron ion contamination and induces plant fitness via phosphate solubilization, auxin phytohormone, and siderophore production.	Sarawaneeyaruk et al. (2018)
Streptomyces sp. PM1 and PM5	S. lycopersicum	Biocontrol: Showed resistance against Pectobacterium carotovorum subsp. Brasiliensis causing soft rot disease.	Dias et al. (2017)

PGPR	Plant	Attribute	References
Bacillus aryabhattai	O. sativa	Heavy metal tolerance and plant growth promotion: Arsenic tolerant along with PGP traits such as ACC deaminase activity, IAA production, nitrogen fixation, and siderophore production.	Ghosh et al. (2018)

II.DISCUSSION

Chemical fertilizers have been widely used to achieve maximum productivity in conventional agricultural systems. The continuous and excessive utilization of chemical fertilizers plays a major role, directly and/or indirectly, in changing environmental conditions. To overcome this problem and achieve food security for the rising population, a new sustainable approach is needed for agriculture (Glick, 2018). Sustainable agriculture is advanced where the maximum output is gained at the minimal cost. Beneficial microbes have been successfully used in sustainable agriculture to enhance production[4,5,6]

Chemical fertilizers are more resistant to the environment, reduce soil fertility, and actually cause a lot of degradation of soil and land (Liu et al., 2009). The use of chemical fertilizers reduces soil microorganisms and causes groundwater pollution. Nitrogen fertilizers break down in the soil and converts into nitrates that are soluble in water and easily pass through the soil and they can remain in that position for decades, and this accumulation causes problems. This accumulation of chemicals leads to surface and groundwater pollution (Uthirapandi et al., 2018).

Nano-fertilizers are finding new solutions to the problems caused by the use of chemical fertilizers. The application of nano-fertilizers has benefits such as the gradual and controlled release of minerals, higher adsorption owing to a free passage from small pores and by molecular transporters as well as root secretions, effective delivery of nutrients to sink within the plants by passing through plasmodesmata, use in smaller amounts, reduction of environmental pollution, higher solubility, and diffusion. Smart nano-fertilizers such as polymer-coated fertilizers avoid premature contact with soil and water owing to thin coating encapsulation of nanoparticles such as leading to a negligible loss of nutrients. On the other hand, these become available as soon as plants are in a position to internalize the released nutrients (Iqbal, 2019).

The utilization of organic fertilizers and other organic materials in conjunction with nano-fertilizers results in more efficient nutrient efficiency and better soil health. Nano-biofertilizer can provide many benefits to plants, for example, slow releasement, increased yield stability, low dose use, improving crop performance characteristics. The future of nano-based agriculture is very bright and may create an eco-friendly approach and an economic approach for sustainable agricultural development (Fig. 3) (DeRosa et al., 2010; Iqbal, 2019; Mahmood et al., 2017; Singh et al., 2017; Solanki et al., 2015).

The large surface coating of nanoparticles on biofertilizers is an important factor that effectively improves the nutrient distribution (Golbashy et al., 2017). The nanoencapsulation approach could be used as a dynamic mechanism to elongate the structural protection of being delivered biofertilizer, enhance its chemical shelf life and dispersion in fertilizer formulation, allowing a controlled release (Vejan et al., 2016). Besides improving nutrient release characteristics, the technology also betters the field performance and conclusively reduces the economic expenditure (through cost reduction as well as reduced application extents). Improvement of inorganic nutrient utilization (the N, P, and K hypothesis), the activity of associated soil systems, bettered crop product quality along with an improved disease resistance are some key advantages of the nano-biofertilizer technology (Thirugnanasambandan, 2019; Bernela et al., 2020).[10,11]

It could be noted that these positive properties of fertilizers did not be obtained without cost. Some of the limiting factors of these fertilizers that complicate their availability for the host plant are vulnerability to nanoscale tissue preservation, poor stability in the soil and various activities under environmental fluctuations (temperature, pH sensitivity, Radiation exposure), lack of beneficial bacterial strains, susceptibility to drying, and the need for significant-high doses of biofertilizer for rice cultivation (Mishra et al., 2017; Bernela et al., 2020).

III.RESULTS

Chemical fertilizers are synthesized industrially out of known amounts of elements like nitrogen, phosphorus, and potassium which can cause air, water, and soil pollution if overused or abused (Youssef and Eissa, 2014). Increased use of chemical fertilizers and pesticides accelerates the acidification of soil thus contaminating the groundwater and the environment overall. It also hampers the plant roots making it susceptible to various pathogens. Sincere efforts are needed for ecologically sustainable options in crop production which can be met by using organic products instead of synthetic chemicals (Raja, 2013).

Organic farming has emerged as an important priority area globally in view of the growing demand for safe and healthy food and long term sustainability and concerns on environmental pollution associated with the indiscriminate use of agrochemicals. Organic farming not only ensures food safety but also improves the biodiversity of soil (Megali et al., 2014).[12,13,14]

Biofertilizers are an important component of organic farming, which contains live microorganisms in carrier-based formulations that can be applied directly in the soil, seed, or seedling stage. On application, it improves the nutrient status of the plant by efficient nitrogen fixation or phosphate solubilization or by increasing the number of microorganisms that assist in the availability of nutrients which are easily assimilated by the plants. Biological control of various phytopathogens is also another facet of using biofertilizers in agriculture.
Growth, yield, and quality parameters of certain plants significantly increased with biofertilizers containing bacterial nitrogen fixers, phosphate- and potassium-solubilizing bacteria, and microbial strains of some bacteria (Khosro and Yousef, 2012).

These biofertilizers on establishment in the soil form an important component of the plant often referred to as the plant second genome, contributing significantly to nutrient cycling in soil and evading pathogen attack (Zhang et al., 2019; Berendsen et al., 2012). Biofertilizers form a better alternative to synthetic fertilizers as it improves the soil fertility and crop productivity without causing any detrimental effects on the environment in an eco-friendly and cost-effective manner (Khosro and Yousef, 2012).

In nature, there are a number of useful soil microorganisms which can help plants to absorb nutrients. Their utility can be enhanced with human intervention by selecting efficient organisms, culturing them, and adding them to soils directly or through seeds in rice cultivation.

Chemical fertilizers, such as urea, diammonium phosphate (DAP), and single superphosphate (SSP), are used to maintain the shortage of nitrogen, phosphorus, and potassium in the soil. However, most of these fertilizers are lost as they flow or evaporate. It has been determined in studies that 40%–70% of the nitrogen, 80%–90% of the phosphorus, and 50%–70% of the potassium of the fertilizers applied are lost in this way in the environment and consequently cannot be absorbed by the applied plant. In addition, it has been reported to cause financial losses as well as environmental pollution (Trenkel, 1997; Ombodi and Saigusa, 2000; Duhan et al., 2017).
Nanomaterials have an important place in fertilizer applications in agriculture and feed the plant slowly in a controlled manner (Sohrab et al., 2016). In recent years, the use of slow-release fertilizers has become one of the important innovative technologies in which fertilizers are entrapped with nanoparticles to save fertilizer consumption and to minimize environmental pollution. Nanofertilizers have a positive effect on plants and environment by reducing environmental risk factors arising from soil pollution caused by chemical fertilizers (Naderi et al., 2011). One of the biggest advantages is that it is used less than other fertilizers (Selivanov and Zorin, 2001; Reynolds, 2002; Raikova et al., 2006; Batsmanova et al., 2013; Subramanian et al., 2015). Besides their large surface areas, in many studies on nanofertilizers, it has been demonstrated that plants have smaller sizes than their leaf and root pore sizes, and they increase the efficiency of use by making the intake of nutrients easier (Singh et al., 2017). With nanoparticle applications in the soil, a suitable and sufficient microelement content can be found, thus increasing the resistance of plants against pathogens.

The small size of nanofertilizers allows the plant to easily benefit from minerals by allowing the mineral to pass through stomata easily. Thus, maximum efficiency can be obtained from the applied fertilizers. Nanofertilizers have many advantages over conventional fertilizers (Liu and Lal, 2016; Singh et al., 2017; Daghan, 2017, Ahmad et al., 2019). Some of these advantages are as follows: the fact that the highest yield can be obtained at the lowest cost by using a very little amount of fertilizers, increasing the efficiency of using the current nutrients in the plant, increasing the efficiency of fertilizer use, avoiding the continuous use of fertilizers, and minimizing the possible negative effects on the environment by reducing the losses of nutrients useful for plants and soil. It can be listed as reducing the risk of possible toxicity and increasing soil fertility and product quality. Nanofertilizers increase product yield and nutritional value by allowing the plant to grow and develop healthily throughout the growing period. Thus, nanofertilizers are important for the healthy plant to gain more resistance against diseases and adverse environmental conditions. In most of the field applications, chitosan, nitrogen, phosphorus, titanium, and zinc nanoparticles are used as fertilizers.

Silver nanoparticles provide an improved uptake of nutrients from the soil than the bulk one due to having many unique properties and being a nutrient for the plants. It has been reported that silver nanoparticles could be used to enhance seed germination potential and can be used to enhance the nutrient uptake in the plants (Duhan et al., 2017; Anand and Bhagat, 2019). Therefore, it can be applied as nanofertilizers in crop protection of paddy.[15,16,17]

Chemical fertilizer application plays a vital role in enhancing rice (Oryza sativa L.) grain yield, which has been considered as an effective channel to address the food safety issue due to an increasing population. In recent years, the input of chemical fertilizer is rising rapidly and N and P have been overused in rice production, leading to not only environmental pollution but also an increase in production cost (Asman et al., 1998). However, the use efficiency of fertilizer is relatively low in China (Jin, 2012). It was estimated that the recovery efficiencies of N, P and K were only 24.8%, 10%, and 25.4% in rice paddy, respectively (Jin and Yan, 2005). It has been reported that the N use efficiency in China is only 30%-35%, most of which is lost through volatilization, leaching and land surface erosion (Zhu and Li, 2003). As a result, a series of problems on lower use efficiencies of fertilizer and pollution because of the excessive application of fertilizer have now posed a challenge for agricultural workers. Promoting fertilizer use efficiency and reducing its input have an important implication for the boost of economic and ecological benefits (Xing et al., 2015). Focusing on the hot issue, a numerous researches about the effects of controlled- release fertilizer and the combined application of inorganic and organic fertilizers on physicochemical traits of soil and grain yield in rice have been conducted (Li et al., 2013; Peng et al., 2013; Miao et al., 2016; Huang et al., 2017; Moe et al., 2017). Wang et al. (2012) found that a 4-yr application of pig-manure compost to crop fields demonstrated an enhancement in organic-C and N concentrations in soil. Moe et al. (2017) reported that the combined application of inorganic fertilizer and organic manures was instrumental in decreasing the use of chemical fertilizer and improving N uptake in rice, resulting in better environment. Xing et al. (2015) and Miao et al. (2016) observed that an application of controlled-release fertilizer accompanied by tiller urea could increase the creation of photosynthetic matter, N use efficiency and grain yield in rice. All these literatures suggest that optimizing N fertilization application strategy through the use of chemical fertilizer in conjunction with organic fertilizer and controlled-release fertilizer appears to be feasible for reducing chemical fertilizer application rate and improving soil fertility and rice grain yield. Nevertheless, information regarding the effect of combined application of chemical fertilizer with organic fertilizer and the effect of controlled- release fertilizer on rice grain quality is still limited now.

With the increment of consumption level in China, the consumer's requirement for rice grain quality is becoming more and more rigid. Much attention has been paid to enhancing grain quality in rice production (Cai et al., 2011; Liu et al., 2014; 2015). In general, rice grain quality was determined by many factors, such as cultivation condition, fertilizer application method and water management (Lu et al., 2007; Zhang et al., 2008; Liu et al., 2014). It has been established that fertilizer application is a key factor responsible for rice grain quality (Dou et al., 2017). The aim of the study was to assess the effects of different types of fertilizers treatments on rice grain quality.

Previous research indicated that the combined application of organic and inorganic fertilizers could promote nutrient synchrony and use efficiency of N and lower nutrient losses by converting inorganic N into organic forms (Kramer et al., 2002). Meng et al. (2009) reported that substitution of 10%-20% inorganic N with organic

N evidently enhanced N utilization efficiency and grain yield in rice. Tang et al. (2015) found that the application of 50% chemical fertilizer in conjunction with 50% organic fertilizer was capable of increasing the weight of the grain located in the upper and middle parts of a panicle and the seed-setting rate of the secondary branches in the middle and bottom parts of a panicle. In addition, the significant increment in rice grain yield due to the application of bio-organic fertilizer was reported by Zhang et al. (2014). All these literatures suggest the positive effects of organic and bio-organic fertilizers on rice production. In the current study, we found that, compared to CF, BOF+CF dramatically enhanced rice eating quality and OF+CF markedly increased rice nutritional quality (especially brown rice nutrition quality). The result was primarily in accordance with that reported by Wang et al. (2004), who observed an improvement in rice eating and nutritional qualities because of the combined application of organic and chemical fertilizers under rice-duck mutualism condition. Interestingly, we observed that BOF+CF generated more influences on amino-acids contents in milled rice than those in brown rice, conversely, OF+CF showed more influences on amino-acids in brown rice than those in milled rice. Rice eating quality under NF treatment was significantly higher than that under BOF+CF and OF+CF treatments, which was closely linked to the marked reduction in protein content of milled rice under NF. That is because protein could influence starch gelatinization through the agency of a network linked by disulfide bonds, thereby leading to poor rice eating quality[18,19,20]

IV.CONCLUSION

Rice eating quality under no fertilizer application (NF) was better than under combined application of organic fertilizer and conventional fertilizer (OF+CF), combined application of bio-organic fertilizer and conventional fertilizer (BOF+CF), controlled-release fertilizer (CRF) and conventional fertilizer (CF), but rice processing and nutrition qualities under NF were poorer than those under other treatments. In contrast with CF, BOF+CF treatment evidently enhanced rice eating quality but reduced nutritional quality. The OF+CF treatment markedly increased rice nutritional quality and did not show significant influence on rice eating quality as compared to CF. The CRF treatment also evidently improved rice eating quality while it decreased brown rice yield and milled rice yield when compared with CF.[21]

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