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Smart Nutrition Management of Rice Crop under Climate Change Environment

Rai Mukkram Ali Tahir, Noor-us-Sabah, Muhammad Afzal, Ghulam Sarwar and Ijaz Rasool Noorka

Abstract

Soil fertility and plant nutrition remained main pillars of agricultural sciences in twentieth century. However, due to recent interest in achievement of sustainability and restricted natural resources, importance of soil fertility and plant nutrition is expected to be increased many folds in twenty-first century. Therefore, increasing rice crop yield under such scenario will require judicious and efficient use of mineral sources of nutrient with combination of natural resources, recycling of bioavailable nutrients, and genetic modification of crops for efficient nutrient utilization. There is an increasing pressure on agricultural land to produce sufficient amount of food needed to feed the growing global population. The pressure is associated with changing weather patterns related to fluctuations in rainfall and temperature, supply of fertilizers inflating price associated with energy demand, which is very closely linked with weather patterns and reducing soil fertility. Increasing rice yield under these constraints will require a rational use of chemical fertilizers with increase the use of natural resources of nutrition, recycling of plant available nutrients, and an exploitation of the genetic potential of crop species to make efficient use of nutrients a key feature to establish smart plant nutrition management in the recent global climate change scenario.

Keywords: rice, mineral nutrition, aerobic, flooded soil, climate change

1. Introduction

Rice is the world dominant food crop, that is, widely adapted to a variety of climatic zones (temperate, tropical, sub-tropical and semiarid) in all continents [1]. Since differences exist in growth conditions and yields of upland and low land rice resultantly their nutritional requirements are also different [2]. In case of low land rice due to conducive environmental and growth conditions, crop yield positively respond to application of fertilizers. On the other hand, for upland rice, inadequacy of water especially at the stage of flowering resulted in significant yield reductions and crop yield response to application of fertilizers is not evident in the world dominant food crop widely distributed throughout the tropical, subtropical, semiarid and temperate zones of all continents [3]. This crop is dominant due to two major factors as more breeding work done for it and secondly grown mostly on better irrigated land. Based on land and water management, rice culture is

categorized as upland and low land crop. Upland rice refers to rice grown on both flat and sloping field that are prepared and seeded under dryland conditions and depend on rainfall for moisture. This is also termed as dryland, rainfed and aerobic rice. Low land rice is grown on flat land with controlled irrigation, it is also known as flooded, irrigated and water logged soil. About 76% of the world rice production comes from irrigated area [3, 4].

Nutrient requirements for upland and lowland rice are different due to differences in yield levels and growing conditions. In low land rice, environmental conditions are most stable and favorable for plant growth and high fertilizer application can ensure high yields. But in case of upland rice, inadequate water particularly around flowering mostly reduced yield significantly and at the end there is little or no differences in yield between well fertilized and unfertilized crops [3, 5].

Soil fertility is the major constraint in upland rice production, as rice grown in naturally drained soil without surface water accumulation. Soil acidity, low cation exchange capacity, and high P fixation capacity are the major soil chemical properties affecting upland rice production [3]. In the era of climate change, the carbon dioxide content increased in the atmosphere this impact lead to less nutritious rice a serious issue for human kind due to huge consumption of rice as food, so it's a dire need of time to recommend a precise amount of mineral nutrient in growth environment for healthy growth of rice in this climate change situation. The basic premise of this chapter was to highlight the smart mineral nutrition management approach for the growth of rice under aerobic and flooded soil condition.

2. Nutrient stress

Nutrient stresses refer to deficiencies of essential plant nutrients as well as toxicities. Nutrient deficiencies are more common than toxicities in many arable lands around the world as mentioned in **Table 1** [4].

In the 1980s and 1990s evidence accumulated that nutrient depletion is problem in many tropical soils. If nutrient stress is not alleviated, crop yields are decreased and soils cannot support adequate plant growth. Under this situation, soil degradation starts. If the land continues to be used for crop production, crop yields become so low that farmers have to abandon the degraded areas. Approximately 1/4th of the earth's soils are considered to produce some kind of mineral stress in crops [3, 4, 6].

2.1 Nutrient stresses alleviation system

For the assessment of efficient working of nutrient management practices on sustainable basis, soil testing need to be done frequently. Soil testing is one of the keys to success of cost-effective, environmentally benign and effective sustainable farming program [4]. Soils on which rice grows varied in texture, climate, pH, salt content, organic matter content and nutrient availability [7]. Fertilizer recommendation for a given crop should be based on series of research trials, the results should then fit on response functions and then profitability should be calculated by using economic variables and equations in order to calculate optimum doses of fertilizers. Following outcomes are achieved by adopting adequate soil fertility in terms of prevention of land degradation.

- i. Adequate fertility gives the crop a better vigor at early stages and good canopy cover which protect the soil from erosion.

Element	Deficiency (D)/toxicity (T)	Critical level	Plant part	Growth stage
N	D	2.5%	Leaf blade	Tillering
P	D	0.1%	Straw	Maturity
	T	1.0%	Straw	Maturity
K	D	1.0%	Straw	Maturity
	D	1.0%	Leaf blade	Tillering
Ca	D	0.15%	Straw	Maturity
Mg	D	0.10%	Straw	Maturity
S	D	0.10%	Straw	Maturity
Fe	D	70 ppm	Leaf blade	Tillering
	T	300 ppm	Leaf blade	Tillering
Zn	D	20 ppm	Shoot	Tillering
	T	1500 ppm	Straw	Maturity
Mn	D	20 ppm	Shoot	Tillering
	T	2500 ppm	Shoot	Tillering
B	D	3.4 ppm	Straw	Maturity
	T	100 ppm	Straw	Maturity
Cu	D	6 ppm	Straw	Maturity
	T	30 ppm	Straw	Maturity
Al	T	30 ppm	Shoot	Tillering

Table 1.
Deficiency and toxicity of essential plant nutrients along with critical level content at different growth stages of rice plant.

- ii. After crop harvesting provision of more crop remains on soil surface provide the soil protection against wind and water erosion and buildup of soil organic matter status thereby, increasing soil potential for crop raising on long term basis.
- iii. An improvement efficient utilization of nutrients by crops results due to adequate fertility, which gives both economic and environmental benefits. Balanced NPK fertilization results in enhancement of nitrogen utilization efficiency. Thereby, mitigating nitrogen losses due to leaching and safe guard the ground waters from nitrate pollution.
- iv. Adequate soil fertility results in water conservation by increasing crop water use efficiency.
- v. Adequate soil fertility maximize the outcomes from crop due to positive interaction with other production inputs like tillage practices, pest control management, selection of crop variety etc.

Under the scenario of global climate change, placement of fertilizer is also integral component of efficient crop management in addition to adequate rate of fertilizer. Placement of fertilizers has role in nutrient utilization and ultimately on crop yield. Placement of nutrients (N, P and K) in the form of band is preferred over broad casting due to many reasons, for example,

- In case of band placement fertilizer is placed in the vicinity of roots thus making the nutrients readily available to plants.
- As compared to broadcasting less quantity of fertilizer is used in band placement.
- Due to placement of nutrients at right place there is no weed emergence therefore lowering the cost of weedicide or weeds eradication.
- Crop nutrient use efficiency is improved in case of band placement.
- Nutrient losses resulting from erosion, immobilization and leaching of N is significantly reduced by adopting band placement technique.

Implementation of this system to any cropping system results in optimization of nutrient management and reduction of soil degradation. In addition improvement in soil nutritional deficiencies and reduction in land degradation also be achieved by the exploitation of genetic variability of plants in terms of nutrient absorption and utilization. Efforts are being made around the globe to make use of genetic resources in order to genetically modify the crop cultivars to produce such cultivars that are more efficient and productive under stressed environments [3–6, 8, 9].

3. Rational nutrient management approaches for rice growth under climate change environment

3.1 Integrated plant nutrient management approach

Integrated plant nutrient management system (IPNS) is a holistic approach to integrate the one of all natural man made sources of plant nutrient to maintain and sustain soil fertility to enhance rice crop productivity in an efficient, environmentally safe, ecologically compatible, socially acceptable and economically viable way. It use both organic and in organic plant nutrients to attain higher crop productivity and prevent soil degradation.

IPNS system keep a balance between nutrients removed by the crop and nutrient added to soil. The smart nutrient management program taking into account the availability of nutrients in all types of soil, crop requirement and other factors, such as, removal of nutrients from the soil by the crop, economics of fertilizer profitability, farmers ability to invest, soil moisture regime, physical and microbiological condition of the soil, available soil nutrient status, nutrient recycling and cropping sequence, limiting loss to the environment [10, 11] (**Figure 1**).

3.2 Four R nutrient management approach in rice crop production

Soil is marvelous, complex substances. Thousands of soil types exist in the world having arisen from different parent material under diverse ecological conditions. Some are fertile, tillable and wonderfully suited for agriculture other may need a great deal of husbandry to become useful. Sustainable agriculture or regenerative farming all aim to produce food and fiber on a sustainable basis and to repair the damage caused by destructive procedure [3, 4] (**Figure 2**).

4R nutrient stewardship is based on the principle that fertilizer should be applied meeting the following requirements:

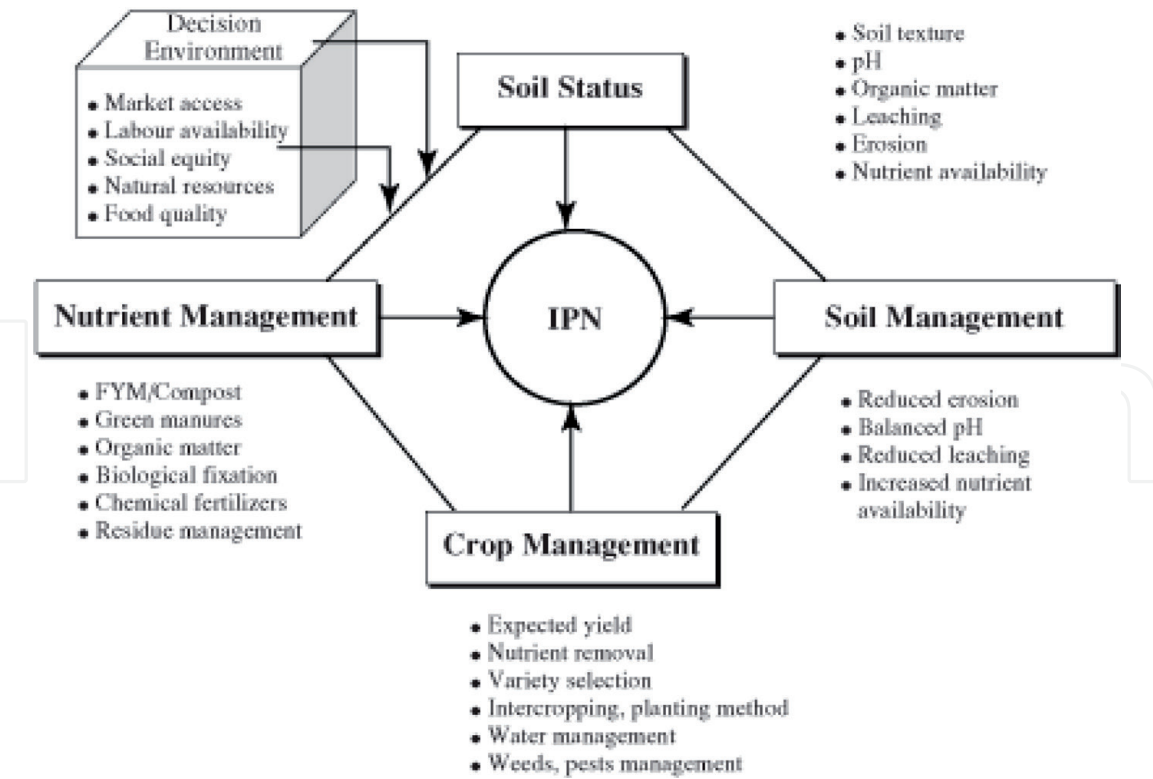


Figure 1.
Integrated plant nutrient management system in industrial agriculture.

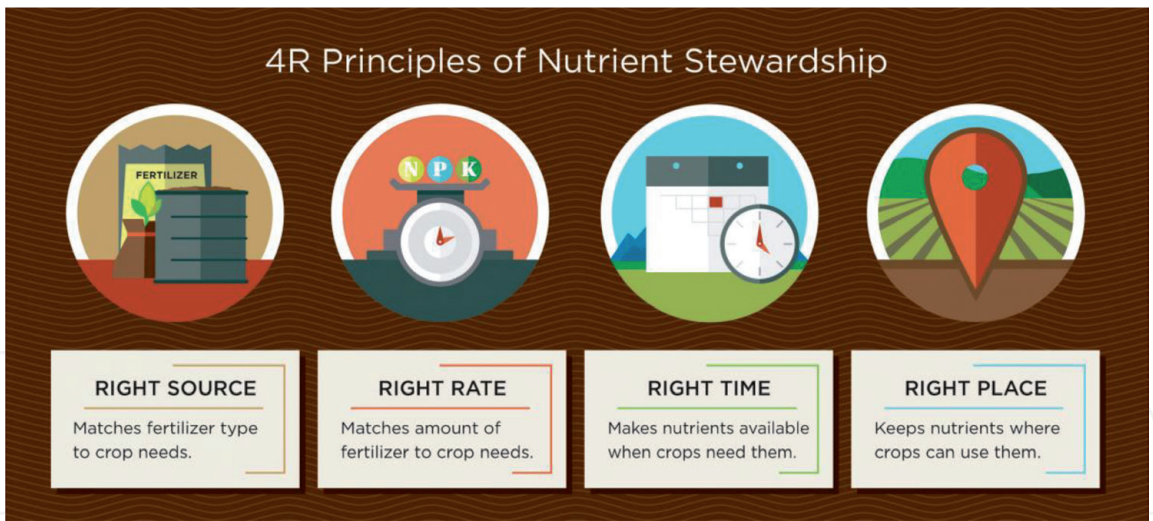


Figure 2.
Four-R nutrient stewardship model for best management practices (BMP).

- i. Right type or source
- ii. Right rate or dose
- iii. Right place and
- iv. Right time

Adaptation of this model helps the growers to achieve sustainability. Although the recommendations are specific with respect to site but scientific principles are universal.

4. Smart mineral nutrition management of essential plant nutrients in the scenario of global climate change

4.1 Smart nitrogen fertilizer management

Management of no other fertilizer nutrient presents a great challenge to the rice. The N fertilizer rate required to achieve optimum yield in rice can be influenced significantly by the preceding crop. The nitrogen fertilizer rate required to produce the best grain and milling yield of rice is dependent on rice genotypes, stand density, previous crops, straw management, soil texture, permeability, N fertilizer methods, water management, soil reaction, tillage and N fertilizer source. In rice plant nitrogen fertilizer loss mainly by nitrification and denitrification, and diffusion (Figure 3) [8, 9].

Rice grain yield mainly affected by the number of tillers, which, in turn, is influenced by the N fertilizer rates. The application of N for rice highly depends on soil separates content. In sandy soil with low CEC fertilizer is subjected to considerable leaching losses, higher N rate or multiple N applications may be considered to overcome losses. The clay soils generally need 40–60 kg N/ha more N fertilizer than those rice grown on silt loams to achieve similar grain yield. The use of climate smart nitrogen fertilizer like: neem coated, sulfur coated, polyamine coated that may improve yield of rice under tough soil and climate condition [12].

4.2 Smart phosphorous nutrition management

Adequate P nutrition of rice is essential because it is needed for energy storage and transfer within plant body. In rice P ensured early maturity, straw strength, and crop quality and disease resistance. Phosphorus exists in soil in two basic pools, organic and inorganic. The organic P (Po) is the part of soil organic matter and soil biomass. The dynamic nature of soil organic matter mineralization and immobilization processes dictate that some of Po contributes to plant available P. Actually inorganic P (Pi) regulates P nutrition for rice plant uptake [13]. Pi in soils has been characterized by five forms: (1) calcium phosphate (Ca-P), (2) iron phosphate (Fe-P), (3) aluminum phosphate (Al-P), (4) occluded P (O-P), (5) soluble orthophosphate (Sl-P) last once more readily utilized by plant body within a wide range of

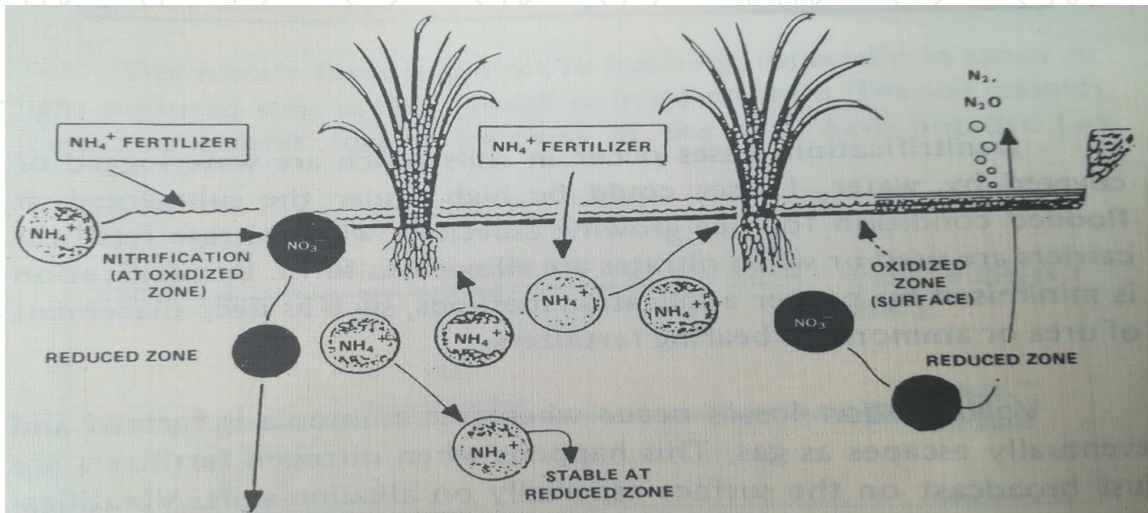


Figure 3. Nitrogen chemicals forms, transformations, and behavior in the flooded soil environment in which rice is grown. Nitrogen sources are in blocks, nitrogen chemical form are in circles and the mechanisms responsible for the various nitrogen transformations or behavior are located on the arrowed lines [8, 9, 13].

soil reaction. The availability of other forms in different soil system depends upon sorption, desorption and diffusion by maintain equilibrium between labile and solution P levels. P deficiency mostly shown as bronzed leaf very similar symptoms appeared when rice grown on Zinc deficiency soil. In general, P fertilizer rates of 30, 20 and 10 kg P/ha are recommended for rice when the soil test are very low, low and medium in P respectively. In industrial agriculture, the foliar P application may also be recommended at the stage of grain filling [11].

4.3 Smart potassium fertilizer management

Potassium is taken up by rice as K^+ ion. Potassium exists in the soil as four basic forms (1) solution, (2) exchangeable, (3) nonexchangeable, (4) mineral; these four forms of K are all in a state of dynamic equilibrium. Potassium deficiency has not been a common problem in rice but P deficiency enhances the occurrences of disease like, kernel smut, stem, and sheath rot'. In the field condition K status change easily from K-deficient to K-sufficient by interactions of K pools. In general recommendation the foliar application of potassium nitrate produced better results against disease in rice plant [10, 11, 14] (Figure 4).

4.4 Smart micronutrients management in rice growth

The metal micronutrients reported to affect the growth of rice under climate change environments are zinc, iron and manganese. Several mechanism in which aerobic and flooded environment influence the availability of trace element by (1) increased solubility of compounds via the dilution effect of excess water, (2) pH changes associated with oxidation-reduction reactions, which can cause nutrients to be transformed to soluble and insoluble forms, (3) increased availability due to mobility of nutrients in the saturated soil. Nutrient plant uptake also affected by temperature change [4]. The use of chelated for micronutrients proved successful to improve yield of rice under the condition of global climate condition. Iron and Mn in the soil conceptually exist in four basic forms: solution Fe and Mn, adsorbed Fe and exchangeable Mn, organic complexed Fe and Mn, and Fe and Mn in primary and secondary minerals. All of these forms of Fe and Mn are in equilibrium with solution Fe and Mn, and the organic complexed forms facilitate their transport in the soil solution and uptake by rice. Unlike Zn, these two metal micronutrients can be reduced in flooded soil and become much more soluble and plant available [5, 15, 16] (Figure 5).

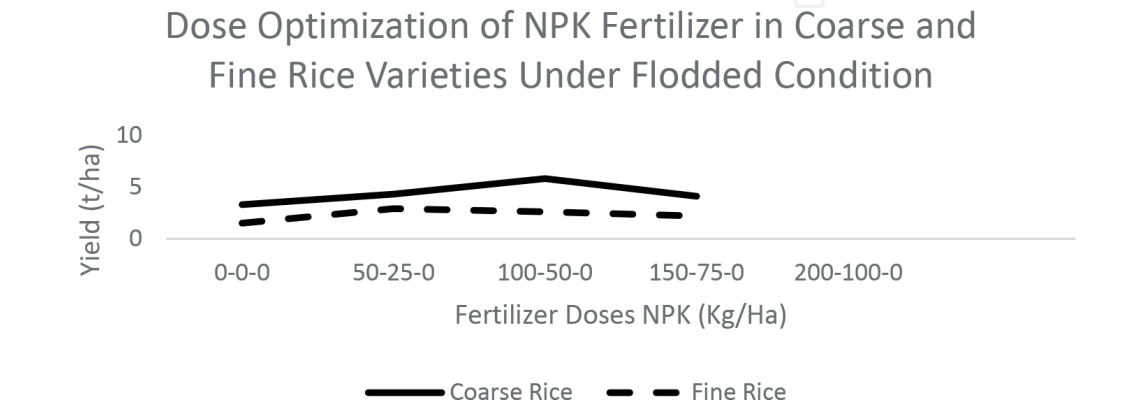
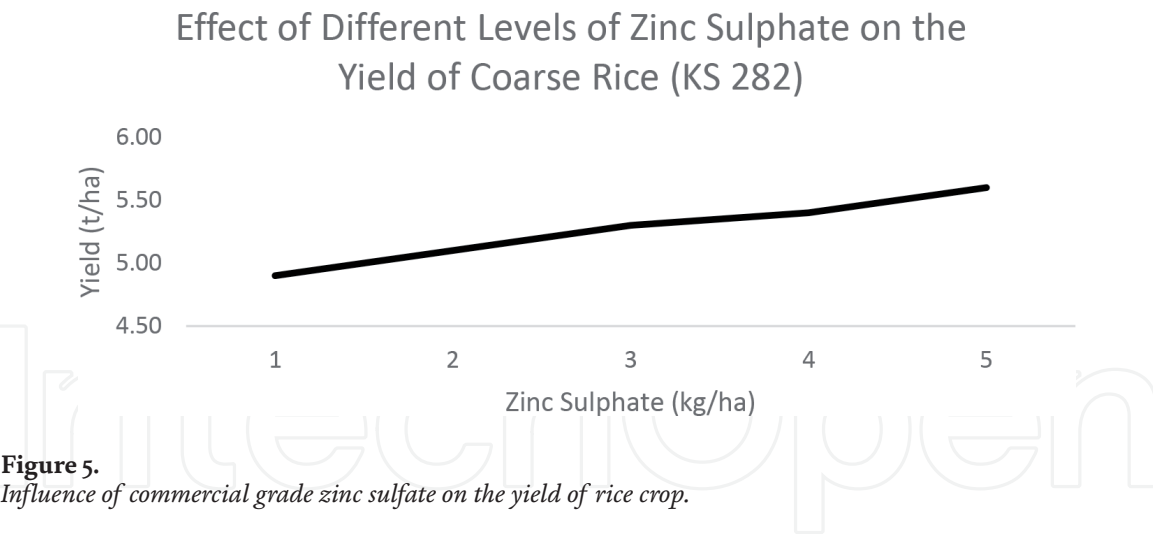


Figure 4. Dose optimization of NPK fertilizer among two fine and coarse contrasting rice varieties for better yield management.



4.5 Beneficial plant nutrient management and rice growth

Silicon is the second most abundant mineral in the earth’s crust but is not considered an essential element for many plant species. Silica is considered a beneficial element for rice growth, because it has not been shown that rice fails to complete its life cycle in the absence of Si. Plant species are categorized as either Si-accumulators or non-accumulators. Rice is considered as Si-accumulator specie. Application of Si amendments have been shown to be beneficial to rice growth, yield, and pest reaction in some areas of the United States. Research in Pakistan has demonstrated that Si containing soil amendments have produced significant yield increase on mineral soils. 2 kg silicon/hectare is required for better yield of rice [10, 11].

5. Conclusion

The change in greenhouse gasses concentration leading to global climate change is evident at present. In this global climate change we can now address plant ability to efficiently use the nutrients available to it whether from chemical fertilizers, manures or what is naturally available in the soil and water by inventing a simple hypothetical perfect food plant which contains high nutritional value of food that we eat.

The aim of this contribution is firstly to print out of some if presently available plant nutrition ways to rice crop and secondly to demonstrate the impact of global climate change on the rice crop growth. We should that efficient use of fertilizer material have to potential combat agent the climate change situation. This enables us to construct a new approach of plant nutrition new concept and methods are desperately needed to achieve the goal of sustainable agriculture growth of rice under alarming global climate change situation. Low productivity in rice crop is mainly caused by native low soil fertility and water stress. The low soil fertility is associated with low organic matter and clay content in soil, which also produce low recovery efficiency of chemical fertilizer.

The field of investigation revealed a linear relationship between paddy yield and fertilizer application rate between N and Zn. Frequent split fertilizer application of slow release fertilizer improved fertilizer recovery efficiency that a key to feature in rice productivity in this climate change scenario.

The integrated use of natural and chemical fertilizer improved the fertilizer holding capacity that critical factor to enhance rice productivity under all type of rice culture. Application of poultry litter, either fresh or composted, has been shown to be the most effective means of quickly restoring rice productivity to soils that have been altered by precision grading. Graded soils have lower organic matter

and thus lower amounts of potentially mineralization of native soils N than do typical undisturbed soils. Consequently, N fertilizer rates for rice should be adjusted only when extremely high rates of litter are applied immediately prior to planting.

Global climate change is a major concern in the twenty-first century that may lead to depletion of the soil organic matter that will decrease the efficient uptake of mineral nutrient in rice crop. The smart nutrient management program taking into account the availability of nutrients in all types of soil, crop requirement and other factors, such as, removal of nutrients from the soil by the crop, economics of fertilizer profitability, farmers ability to invest, soil moisture regime, physical and microbiological condition of the soil, available soil nutrient status, nutrient recycling and cropping sequence, limiting loss to the environment. Achieving balance between the nutrient requirements of plant and the nutrient recovered in soils is essential for maintaining high yields and soil fertility to sustain agriculture production over the long term. Smart nutrient management program has considerable potential to enhance growth of rice in developing countries in the next decade.

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Conflict of interest

There is no conflict of interest.

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