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Site-specific Nutrient Management for Enhancing Crop Productivity

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ABSTRACT

Nutrient management plays a crucial role in achieving self-sufficiency in food grain production. High price index of chemical fertilizers coupled with mount pollution problem gave rise to interest in precision nutrient management tools. Site specific nutrient management (SSNM) increases and maintains the yield by optimizing the balance between supply and demand of nutrients. Nutrient application as per SSNM concept resulted in significantly higher grain yields of maize, rice, wheat and other important crop over recommended dose of fertilizers (RDF) and farmer's fertilizers practices. The SSNM is real time feeding of crops with nutrients while recognizing the inherent spatial variability which enhances crop productivity, nutrient use efficiency (NUE) and avoids nutrient wastage. For effective SSNM, utilization of different sensing devices of soil and plant nutrient status,

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decision support systems, GIS, remote sensing, simulation models and nenoparticles play an important role. Traditional techniques *like* balanced fertilization, use of nitrification inhibitors and slow-release nitrogenous fertilizers (SRNF) are also used to attain higher productivity and reduce environmental pollution. This paper deals with the SSNM approaches which are able to enhance crop productivity, NUE and sustainability.

Keywords: Crop productivity; site-specific nutrient management; green seeker; SPAD; N-management.

1. INTRODUCTION

Fertilizer consumption in India has witnessed a phenomenal increase over the past four decades. India has attained self-sufficiency in food grain production, primarily due to increase in fertilizer use. India rank 2nd in the world terms of fertilizer consumption next to China. All India consumption of total fertilizer nutrients (N+P+K) increased by 5.9% from a total of 25.58 MMT during 2014-15 to 27.2 MMT during 2018-19. N consumption at 17.63 MMT recorded growth of 3.8% & P_2O_5 at 6.91 MMT showed an increase of 15.9% during 2014-15 to 2018-19 & K_2O consumption at 2.69 MMT fell by 7.9% during this period. Per hectare use of total nutrients increased from 131.6 kg in 2014-15 to 138.9 kg in 2018-19 [1]. Most of the fertilizers are used in the rice crop followed by wheat, pulses and oilseeds (Fig. 1) [1]. The important reasons for low and declining crop responses to fertilizer nutrients include continuous nutrient mining from the soil due to imbalanced nutrient use (6.1:2.5:1 NPK) leading to serious soil degradation qualitatively [2].This resulted in wastage of fertilizers and low NUE.

Increasing productivity and production are essential to meet the food requirement of the burgeoning population [3]. This is achieved through its unique balance of nutrients and clay minerals, which also increases microbial activity and builds long term soil fertility [4]. The voice come from the farmers field beside research conducted in many Asian countries, including North-west India, has depicted the limitations of the conventional approach of fixed-product, fixed-rate, fixed-time and fixed-place fertilizer recommendations, the concept of SSNM of nutrients means right-product, right-rate, right-time and right-place was developed [5,6]. Site-specific nutrient management is an approach of feeding crops with nutrients when needed. It provides principles and tools for supplying nutrients to crops when needed to achieve high production while optimizing the use of nutrients from indigenous sources. This concept can be applied to any field and any crop.

1.1 Why Nutrient Management is Important?

High price index of chemical fertilizers coupled with escalating pollution problems gave rise to interest in precision nutrient management tools. In this context SSNM based on crop nutrient demand & variability in indigenous nutrient supplying capacity of the soil serves as an ideal tool. SSNM provides guidelines, tools and strategies that allow farmers to determine when and how much nutrients they should apply to their crop fields under actual growing conditions in a specific season and location.

1.2 Site-Specific Nutrient Management

SSNM has been proposed as an approach to tailor fertilizer application to match the field-specific needs of crops and to improve the productivity and profitability. This could be done by utilizing available information on indigenous nutrient supplying capacity, nutrient contributions from organic manures, irrigation water, rainfall and crop residue pools and finally crop nutrient demand for targeted yield of crops/cropping systems. Site-specific nutrient management is a component of precision agriculture and can be used for any crop or field. It combines plant nutrient requirements at each growth stage and the soil ability to supply those nutrients and apply that information to areas within a field that requires different management practices. SSNM provides guidance relevant to the context of farmer's fields. SSNM maintains or enhances crop yields, while providing savings for farmers through more efficient fertilizer use [2].

1. It aims to apply nutrients at optimal rates and times to achieve high yield and high efficiency of nutrient use by the crop.
2. It feeds the crop with nutrients as and when needed.

1.2.1 Key messages of SSNM

1. Site-Specific Nutrient Management (SSNM) optimizes the supply of soil nutrients over space and time to match crop requirements.

2. SSNM increases crop productivity and improves efficiency of fertilizer use [7].
3. SSNM mitigates greenhouse gases emission from agriculture by minimizing fertilizer overuse. Greenhouse gas emission can be reduced, in some cases up to 50% [8].

1.2.2 Key principles of SSNM

Site-Specific Nutrient Management (SSNM) aims to optimize the supply of soil nutrients over time and space to match the requirements of crops through four key principles. The principles, called the “4 Rs”, date back to at least 1988 and are attributed to the International Plant Nutrition Institute [9]. They are: Right product, Right rate, Right time and Right place.

Right product, match the fertilizer product or nutrient source to crop needs and soil type to ensure balanced supply of nutrients. Right rate, match the quantity of fertilizer applied to crop needs, taking into account the current supply of nutrients in the soil. Too much fertilizer leads to environmental losses, including runoff, leaching and gaseous emissions, as well as wasting money and little fertilizer exhausts soils, leading to soil degradation. Right time, ensure nutrients are available when crops need them by assessing crop nutrient dynamics. Right place, placing and keeping nutrients at the optimal distance from the crop and soil depth so that crops can use them is the key to minimizing nutrient losses [10].

1.2.3 Benefits of SSNM

After the introduction of SSNM, farmers observed benefits associated with grain yield & quality, pest & disease incidence, reduction GHG emission and cash returns (Table 1).

1.3 SSNM Approaches

The relatively new approach of SSNM is mainly based on the indigenous nutrient supply from the soil and nutrient demand of the crop for achieving targeted yield (Fig. 2) [11].

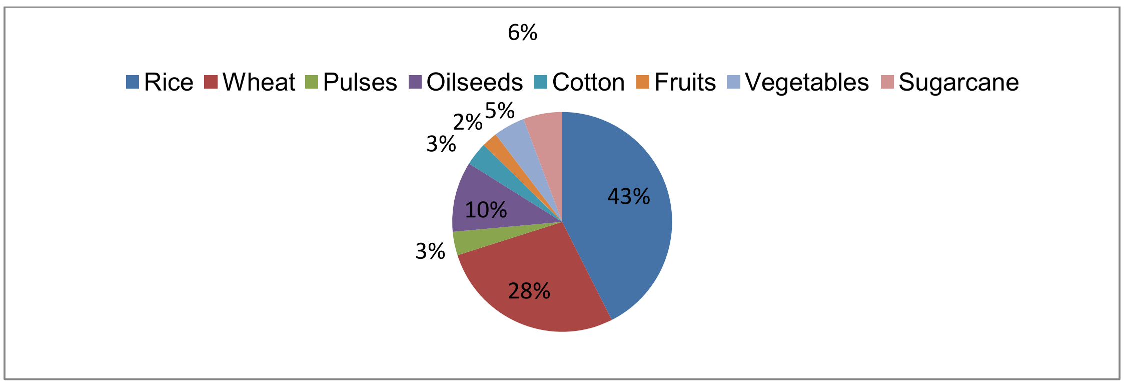

Fig. 1. Crop wise consumption of chemical fertilizers in India

Table 1. Major benefit of SSNM

SSNM Benefits	Description
Higher profits	SSNM can increase and maintain yields by optimizing the balance between supply and demand of nutrients and providing more balanced plant nutrition.
Improves disease resistance	The more balanced NPK nutrition that comes with SSNM may lead to improved resistance to plant diseases.
Reduces nitrous oxide emissions	SSNM reduces N_2O emissions by reducing total N application or timing applications to crop needs, thus avoiding N losses to volatilization, leaching and runoff.
Economic benefit	For SSNM to increase farmers’ profits, SSNM must deliver either a) savings from reduced fertilizer use without a reduction in yields, or b) yield increases that are valued higher than the costs of acquiring and using SSNM technology [10].

Step 1. Establish a grain yield target

- Select a yield attainable in a typical season with farmer's crop management and improved nutrient management.
- It is location and season specific (depending on climate, cultivar and crop management).

Step 2. Effectively use existing nutrients

- Estimate the supply of existing (indigenous) nutrients from sources other than fertilizers.
- Use nutrient omission plot technique, fertilizer use history, soil type and residue and crop management to estimate indigenous nutrient supply.

Step 3. Apply fertilizer to fill the deficit between crop needs and indigenous supply

- Distribute the required fertilizer N in several applications during the growing season to best feed the crop needs for supplemental N.
- Apply sufficient P and K to overcome deficiencies and maintain soil fertility.

1.4 SSNM Can be

1. Prescriptive
2. Corrective

1. **Prescriptive N management:** Relies on information generated before the planting of a crop.
2. **Corrective N management:** Relies on information generated after the planting of a crop or in the standing crop. *E.g.* Use of Leaf Color Chart (LCC) and Chlorophyll Meter (SPAD), Remote Sensing & GIS, Green Seeker, Decision support systems and Nanoparticles.

Nutrient application as per site-specific nutrient management (SSNM) concept resulted in significantly higher grain yields of maize, rice, wheat and rabi jowar over recommended dose of fertilizers (RDF) and farmer's fertilizers practices [12]. Fertilizer application based on SSNM techniques are more flexible and meet the crop demand and a saving of up to 20–30% fertilizer application [13]. Wang et al. [14] found significant increases in NUE through the SSNM treatment. Gill et al. [15] reported that maximum N, P and K accumulation by crop was registered in SSNM, followed by improved state recommendations (ISR), and it was lowest in the farmers' fertilization practice (FFP). NPK use efficiency addition of micronutrients was much higher in SSNM compared with FFP. Khurana et al. [16] also observed significant increases in NUE through the SSNM treatment compared with the FFP.

1.4.1 SPAD meter

Soil plant analytical device (SPAD) meter which was originally developed in Japan for nitrogen management in rice (Oryza sativa) is now commonly used for rapid and non-destructive estimation of foliar chlorophyll concentration. SPAD meter/Chlorophyll meters are reliable alternatives to traditional tissue analysis as plant N nutritional diagnostic tools. Most widely used chlorophyll meter is the hand-held Minolta and SPAD-502 [17]. It uses two LEDs (light emitting diodes) which emit red light with a peak wavelength of 650 nm and an infrared radiation with a peak wavelength of 940 nm [18]. The SPAD meter readings are doesn't have unit and need to be calibrated with chlorophyll or N content and leaf greenness. In the field trials, use of 35 critical SPAD reading resulted in similar yields with less N fertilizer applied (higher agronomic efficiency) compared to fixed split timing schemes or recommended splits [19]. In South India too, SPAD value of 35 was found to be the appropriate threshold value for guiding need-based N management in transplanted rice. Hussain et al. [20] found that the critical SPAD value of 37.5 appropriate for guiding the need based N top dressing in rice in Pakistan. Chlorophyll meter-based N management saved 12.5–25% on the existing fertilizer N recommendation [21].

1.4.2 Leaf Color Chart (LCC)

Leaf color chart (LCC) is a high quality plastic strip with different shades of green color ranging from light yellowish green to dark green. First LCC was developed in Japan. An improved version of six-panel LCC (IRRI-LCC, six-panel) was developed through collaboration of the International Rice Research Institute (IRRI) with agricultural research systems of several countries in Asia [11]. Chinese researchers at Zheijiang Agricultural University developed a LCC (ZAU-LCC) with scale of eight green color shades (3, 4, 5, 5.5, 6, 6.5, 7 and 8) and it was calibrated for Indica, Japonica and Hybrid rice [22]. The leaf color chart is an innovative cost-effective tool for real-time or crop-need based N management in Rice, Maize and Wheat. LCC is a visual and subjective indicator of plant nitrogen deficiency and is an inexpensive, easy to use and simple alternative to chlorophyll meter/SPAD meter. In this, scheduling of nitrogen fertilizer is done by comparing the leaf color with panel color. Thus, it is an eco-friendly tool in the hands of farmers.

The LCC shade 4 on the six-panel IRRI-LCC has been found to be the threshold score for transplanted coarse grain rice varieties prevalent in the Indo-Gangetic plains [20,21]. The critical six-panel IRRI-LCC score was found to be 3.5 in the lower Gangetic plain in Bangladesh. 2 and 3.5 is reported as critical LCC value (IRRI-LCC, four-panel) for aromatic and transplanted semi-dwarf indica or transplanted hybrid rice, respectively.

Nitrogen Use Efficiency (NUE) was markedly higher in the LCC treatment with or without basal N application than recommended N or Farmer's Practice in all the years. Mean recovery efficiency of N under LCC was 42.1, 45.4 & 52.7% compared with 30.9, 29.1 & 39.8% obtained in recommended farmers practice in 2000, 2001 & 2002 [23]. Bhat et al. [24] reported that the highest net return in treatment LCC≤ 5 @ 30 kg ha^{-1} (Table 2). It was due to the steady supply of Nitrogen which synchronized with the peak period of N requirement that had produced higher yield.

1.4.3 Remote sensing and GIS

An improvement in the NUE can be achieved by using modern tools like remote sensing and GIS (geographical information system). The reflectance of near infrared radiation (NIR; 800–1000 nm) can be measured using remote sensing tools. This reflectance is correlated with plant N status, as shown by the greenness of the leaves [8]. Normalized difference vegetative index (NDVI) based on the in-season sensor reading can predict biomass, plant N concentration and plant N uptake [25]. The NDVI calculates as: $(F_{NIR} – F_{Red})/(F_{NIR} + F_{Red})$, where F_{NIR} and F_{Red} are spectral reflectance in near-infrared and red (visible) regions, respectively. The NDVI increases with increasing leaf greenness and green leaf area, and can be used as a guide for in-season N applications. Extensive research work through on-farm trials in the Indo-Gangetic Plains (IGP) has clearly demonstrated that these modern tools are effective for site-specific input management [8].

1.4.4 Green seeker

Chlorophyll meter and LCC do not take into account the photosynthetic rates or biomass production and the expected yields for working out fertilizer N requirements. Green seeker optical sensors measure spectral response from plant canopies to detect the N stress [26]. The use of green seeker, which is also a hand-held instrument for measuring the NDVI at various critical growth stages, generates data for crop conditions [25,27]. These NDVI data from a standard plot, which has been sufficiently fertilized with N, can be compared with a reference plot for which the N requirement is to be determined. The use of green seeker helps in applying adequate N at specific crop growth stages in various management zones. Experiment clearly showed that optical sensor-guided fertilizer N applications resulted in high yield levels and high N use efficiency [28].

1.4.5 Decision support systems

Decision support systems have taken various forms and differ in their level of sophistication [29]. Decision support systems are sophisticated tools, often being driven by computer-simulation models, but usually deal with a single element such as N. The CROPGRO-legume model can simulate N fixation in legumes and its relationship with N uptake by plants [30]. Nutrient Expert® (NE) is an easy-to-use, interactive, and computer-based decision support tool that can rapidly provide nutrient recommendations for an individual farmer field in the presence or absence of soil testing data [2]. Crop Manager is also a computer- and mobile phone-based application that provides small-scale rice, rice-wheat, and maize farmers with site- and season-specific recommendations for fertilizer application. The tool allows farmers to adjust nutrient application to crop needs based on soil characteristics, water management and crop variety on their farm. Recommendations are based on user-input information about farm location and management, which can be collected by extension workers, crop advisors and service providers. The software is freely downloadable at http://cropmanager.irri.org/home [10].

1.4.6 Nanoparticles

The discovery of nanomaterials and nanodevices in agriculture is novel for nutrient management. Generally, nanoparticles are materials that have dimensions of 1-100 nm. The novel properties of nanomaterials such as high surface area, high surface energy and quantum confinement thus improve the dissolving properties of bioactive components in the cellular matrix. Nanotechnology and nanomaterials have revolutionized the industrial, agricultural and food industries with new tools that are used for the molecular treatment of diseases and rapid disease detection and thus enhancing the ability of the absorbed nutrients and the productivity of plants [31]. Many studies have reported that the application of nanomaterials reflects positive effect in terms of crop productivity [32]. Moreover, the application of nanomaterials increased the growth rate and seed germination by 33% and 20%, respectively, as compared to that of regular P fertilizer [33]. However, the efficiency of plants is low because of the loss of 50–70% of the nitrogen supplied in the conventional fertilizers. The soybean seeds were treated with micronutrient nanomaterial *like;* Cu, Co and Fe, the chlorophyll index and number of nodules was increased by 7–15% and 20–49%, respectively and the soybean crop yield was increased up to 16% as compared to the control sample [34].

1.4.7 Balanced fertilization

It has been observed that unbalanced NPK ratios diminish the plant use of applied N and decrease the NUE. Attention to NPK is desirable because 89% of Indian soils are low to medium in available N, 80% are low to medium in available P and 50% are low to medium in available K [35]. Therefore, it is essential to apply NPK and other secondary and micronutrients in adequate and balanced amounts. The efficient use of any nutrient depends on the balanced supply of other nutrients, *i.e.* all nutrients should be available in the right amount and at the right time.

Nitrification/urease inhibitors, controlled or slow-release nitrogenous fertilizers (SRNFs), laser land leveling and integrated nitrogen management (INIM) are also a key component for SSNM mechanism, which reduced the leaching loss of nitrate-N and denitrification loss of ammonical-N, resulted improving nutrient efficiency and minimize environmental pollution [36]. Bana et al. [37] clearly showed that Zn-coated urea act as a slow released fertilizer,

Table 1. Average grain yield of different field crops as influenced by site-specific nutrient management (pooled)

Crop	Average yield target (t/ha)	Average grain yield (t/ha)			CD@ 5%
		SSNM	RDF	FFP	
Maize	7	7.02	5.98	5.44	0.48
Rice	9	8.34	7.47	6.74	0.63
Wheat	3.75	3.79	3.22	2.85	0.28
Rabi jowar	2.75	2.56	2.09	1.89	0.18
Sunflower	2.75	2.44	2.01	1.8	0.15
Chickpea	2.75	2.39	1.99	1.89	0.1
Cotton*	2.75	2.55	2.21	2.01	0.17
Chilli**	2.25	2.18	1.94	1.76	0.16

**seed cotton yield, **dry chilli yield*
Source: [12]

Table 2. Relative economics of different treatment combinations of LCC (mean of 2012 & 2013)

Treatments (N/ha)	Cost of cultivation (□)	Total returns (□) Grain+straw)	Net returns (□)	B:C ratio
Jhelum				
Control	35980	75830.35	39870.85	0.77
Recommended N	37415	123491.00	80519.34	1.78
LCC≤3@20Kg	36937	117052.70	75949.84	1.66
LCC≤3@30Kg	37056	121133.40	80764.34	1.75
LCC≤4@20Kg	37175	129796.80	88754.08	1.94
LCC≤4@30Kg	37415	134200.80	91885.92	2.02
LCC≤5@20Kg	37415	140160.60	99175.77	2.16
LCC≤5@30Kg	37773	145075.60	103425.80	2.24

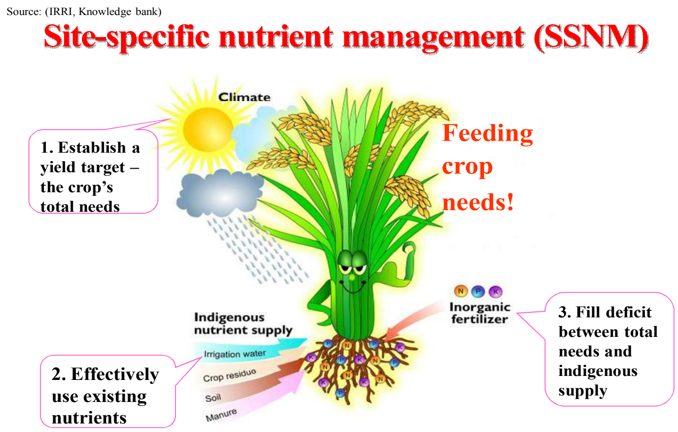

Fig. 2. The three basic steps of SSNM approach

therefore significantly highest N, P, K and Zn uptake by grain and straw was recorded with the application of 4% Zn through $ZnSO_4.7H_2O$ coated urea + 0.2% Zn foliar spray ($ZnSO_4.7H_2O$) + recommended P_2O_5 and K_2O. In the same experiment with same treatment also found to improved yield attributes and yield of rice with coated fertilizer besides proving itself economically viable [3].

2. CONCLUSION

Site-Specific Nutrient Management is successful in their role of enhancing crop production and input use efficiency while minimizing the cost of production. To maintain and even increase the efficiency of applied nutrient, more precise and diverse management strategies are needed. Optimizing the amount, time and method of fertilizer application with suitable source are all helpful in achieving the goal of enhancing crop productivity and sustainability.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Anonymous. Statistical database. FAI; 2019. Available:https://www.faidelhi.org/general/con-npk.pdf.
2. Dass A, Suri VK, Choudhary AK. Site-specific nutrient management approaches for enhanced nutrient-use efficiency in agricultural crops. Journal of Crop Science and Technology. 2014;3(3):1-6.
3. Bana RC, Gupta AK, Puniya R, Singh P. Effect of zinc ferti-fortification on yield and economics of basmati rice (*O sativa* L.) under subtropical region of Jammu. Green Farming. 2020a;11(1):52-55.
4. Ranva S, Singh YV, Jain N, Bana RC, Bana RS Bajya DR. Effect of natural safe rock minerals on growth, yield and quality of rice (*Oryza sativa*) in rice-wheat cropping system. Indian Journal of Agricultural Sciences. 2019;89(9):1529-35.
5. Dobermann A, White PF. Strategies for nutrient management in irrigated and rainfed lowland rice systems. Nutr Cycling Agroecosyst. 1999;53:1-18.
6. Pathak H, Singh Y, Singh B. Site-specific nutrient management for improving the productivity of rice–wheat cropping system. In: Singh Y *et al.,* editors. Nutrient management for sustainable rice–wheat cropping system. New Delhi (India): National Agricultural Technology Project, Indian Council for Agricultural Research and Ludhiana (India): Punjab Agricultural University. 2003;79–98.
7. Rao KV. Research themes site specific integrated nutrient management for sustainable rice production and growth. Rajendranagar, Hyderabad, India: Rice

Knowledge Management Portal (RKMP), Directorate of Rice Research; 2014.
8. Gill MS, Pal SS, Ahlawat IPS. Approaches for sustainability of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system in Indo-Gangetic plains of India- a review. Indian Journal of Agronomy. 2008;53(2):81-96.
9. Bruulselma TW, Fixen PE, Sulewski GD, editors. 4R Plant Nutrition Manual: A manual for improving the management of plant nutrition. International Plant Nutrition Institute (IPNI), Norcross, GA, USA; 2012.
10. Richards MB, Butterbach-Bahl K, Jat ML, Lipinski B, Ortiz-Monasterio I, Sapkota T. Site-Specific Nutrient Management: Implementation guidance for policymakers and investors. PRACTICE BRIEF Climate-smart agriculture; 2015. Available:https://core.ac.uk/download/pdf/132679166.pdf.
11. IRRI. Knowledge bank; 2020. Available:http://www.knowledgebank.irri.org/ericeproduction/IV.4_SSNM.htm.
12. Biradar DP, Aladakatti YR, Basavannepa MA. Management performance in a rice-wheat cropping system. Better Crops. 2012;92(4):26-28.
13. Hach CV, Tan PS. Study on site-specific nutrient management for high-yielding rice in the Mekong delta. Omonrice. 2007;15:144-152.
14. Wang G, Dobermann A, Witt C, Sun Q, Fu R. Performance of site-specific nutrient management for irrigated rice in Southeast China. Agron J. 2001;93:869-878.
15. Gill MS, Shukla AK, Singh MP, Tomar OK, Raj Kumar, Majumdar K, Tiwari KN. Evaluation of nutrient management options for yield, economics, and nutrient use efficiency. Better Crops. 2009;3:12-15.
16. Khurana HS, Phillips SB, Singh B, Dobermann A, Sidhu AS, Singh S, Peng S. Performance of site-specific nutrient management for irrigated, transplanted rice in northwest India. Agron J. 2007;99:1436-1447.
17. Singh V, Singh B, Singh Y, Thind HS, Gupta RK. Need based nitrogen management using the chlorophyll meter and leaf color chart in rice and wheat in South Asia: a review. Nutr. Cycl. Agroecosyst. 2010;88:361-380.
18. Hussain F, Bronson KF, Singh Y, Singh B, Peng S. Use of chlorophyll meter sufficiency indices for nitrogen management of irrigated rice in Asia. Agron J. 2000;92:875-879.
19. Peng S, Garcia FV, Laza RC, Sanico AL, Visperas RM, Cassman KG. Increased N-use efficiency using a chlorophyll meter on high- yielding irrigated rice. Field Crops Research. 1996;47:243-252.
20. Hussain F, Zia MS, Akhtar ME,Yasin M. Nitrogen management and use efficiency with chlorophyll meter and leaf color chart. Pak. J. Soil Sci. 2003; 22:1-10.
21. Singh B, Singh Y, Ladha JK, Bronson KF, Balasubramanian V, Singh J, Khind CS. Chlorophyll meter- and leaf color chart -based nitrogen management for rice and wheat in northwestern India. Agron J. 2002;94:821-829.
22. Yang WH, Peng S, Huang J, Sanico AL, Buresh RJ, Witt C. Using leaf color charts to estimate leaf nitrogen status of rice. Agron J. 2003;95:212-217.
23. Singh V, Singh Y, Singh B, Singh B, Gupta RK, Singh J, Ladha JK, Balasubramanian V. Performance of site specific nitrogen management for irrigated transplanted rice in northwestern India. Arch Agron Soil Sci. 2007;53:567-579.
24. Bhat AT, Kotru R, Ahmed L, Ganai MA. Management of N through Leaf color chart (LCC) in Rice under irrigated conditions of Kashmir. Applied Biological Research. 2015;17(1):24-30.
25. Gupta R. Crop canopy sensors for efficient nitrogen management in the Indo-Gangetic plains. Progress Report (1-11-2004 to 31-10-2006). Mexico: The Rice-Wheat Consortium, New Delhi International Maize and Wheat Improvement Center (CIMMYT); 2006. Available:http://www.nue.okstate.edu/GreenSeeker/GS%20-Full%20TechReport-%20%20Dec%2014-06. Pdf.
26. Raun WR, Solie JB, Johnson GV, Stone ML, Lukina EV, Thomason WE, Schepers JS. In: Season prediction on potential grain yield in winter wheat using canopy reflectance. Agron. J. 2001;93:131-8.
27. Singh I, Srivastava AK, Chandna P, Gupta RK. Crop sensors for efficient nitrogen management in sugarcane: potential and constraints. Sugar Tech. 2006;8(4):299-302. doi: 10.1007/BF02943572.
28. Singh B, Sharma RK, Kaur J, Jat ML, Martin KL, Singh Y. Assessment of the nitrogen management strategy using an optical sensor for irrigated wheat. Agron. Sustainable Dev. 2011;31:589-603.

29. Kitchen NR, Goulding KWT. On-farm technologies and practices to improve nitrogen use efficiency. In: Follett RF, Hatfield JL, editors. Nitrogen in the environment: sources, problems, and management. Amsterdam (The Netherlands): Elsevier. 2001;335-369.
30. Boote KJ, Hoogenboom G, Jones JW, Ingram KT. Modeling nitrogen fixation and its relationship to nitrogen uptake in the CROPGRO model. In: Liwang MA, Ahuja LR, Bruulsema T, editors. Quantifying and understanding plant nitrogen uptake for systems modeling. Boca Raton (FL): CRC Press. 2009;13-46.
31. Bao V-VQ, Vuong LD, Luan LV. Biomimetic synthesis of silver nanoparticles for preparing preservative solutions for mandarins (*Citrus Deliciosa Tenore*). Nano LIFE. 2018;8(01):1850003.
32. Panpatte DG, Jhala YK, Shelat HN, Vyas RV. Nanoparticles- the next generation technology for sustainable agriculture. In: Singh DP, Singh HB, Prabha R (eds) Microbial inoculants in sustainable agricultural productivity volume 2: functional applications. Springer, New Delhi. 2016;289-300:2016.
33. Singh A, Singh N, Hussain I, Singh H, Singh SJIJPSI. Plant-nanoparticle interaction: an approach to improve agricultural practices and plant productivity. Int J Pharm Sci Invent. 2015;4(8):25-40.
34. Ngo QB, Dao TH, Nguyen HC, Tran XT, Van Nguyen T, Khuu TD et al. Effects of nano crystalline powders (Fe, Co and Cu) on the germination, growth, crop yield and product quality of soybean. Adv Nat Sci Nanosci Nanotechnol. 2014;5(1): 015016.
35. Motsara MR. Available nitrogen, phosphorus and potassium status of Indian soils as depicted by soil fertility maps. Fertil Newsl. 2002;47(8):15-21.
36. Singh B, Singh V, Singh Y, Gupta RK. Nitrogen management in rice for high fertilizer use efficiency. Indian Farming. 2009;11-14.
37. Bana RC, Gupta AK, Bazaya BR Singh, P. Influence of ZN-fertilization on nutrient uptake and soil nutrient dynamics in basmati rice (*O. sativa* L.). International Journal of Chemical Studies. 2020b;8(1):279-282.

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