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Crop diversification - a way for sustainable agriculture and ecological balance in post-green revolution era

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Abstract. *In intensively cultivated high productive cereal-based systems the associated post-green revolution problems were identified as- reduction in profitability, decline in factor productivity, over-mining of nutrients, lowering of groundwater tables and build-up of pests including insects, diseases and weeds. These factors are threatening the agricultural sustainability and ecological balance. However, research findings indicate that with the choice of suitable alternative crops and cropping systems, the adverse effect of green revolution technologies may be mitigated. These will help in conserving the soil environment by minimizing nitrate leaching, arsenic and other heavy metal pollution. Along with the suitable crops and cropping systems, adoption of the system based nutrient management, integrated pest management and resource conservation technologies such as, zero tillage, furrow-irrigated raised bed, raised bed – sunken bed and ridge or bed planting are some of the new technologies deserve immediate attention. The immediate focused areas are system-based integrated resource management, development of site-specific precision input management, organic farming systems and development of sustainable production models using computer software.*

Keywords: Cropping system, green revolution, integrated resource management

1. Introduction

The Indian Agriculture can be broadly grouped into 3 periods viz. pre-green revolution, green revolution and post green revolution. In the pre-green revolution era the gap in the food grain requirement had to bridge through imports. Research and development initiative to attain self-reliance was therefore considered most essential. High-yielding varieties of wheat and rice were introduced and adopted to boost the production. The positive results ushered in “Green Revolution”. Thus an era of food grain imports was ended and the stigma of ‘begging bowl’ status was permanently shed off.

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Still Indian economy largely depends on agriculture and allied sector. As a concomitant of growth, the share of agriculture and allied sector in India's gross domestic product (GDP) declined to 13.9% in 2013–14 from 14.6% in 2009–10 (Government of India 2014). 30 important cropping systems have been identified in India (Yadav et al.1998). Out of these systems, rice + wheat is the highest contributor and together shares 65% of the national food grain production (Gangwar and Prasad 2005). Until now, foodgrain based cropping systems, viz. rice–wheat (10.5 m ha), rice–rice (5.9 m ha) and coarse grain-based systems (10.8 m ha) are the chief contributors to the national food basket in India (Gangwar and Prasad 2005). Thus, most of the high productive systems are cereal-based, having high resource demand and continuously practiced over the decades in major parts of the country. Now it has been understood that the green revolution, that helped us to make an increase in our production, is not totally green for environmental sustainability and long run crop productivity. Thus it has resulted in several problems like, imbalanced production, decline in factor productivity, reduction in profitability, lowering of groundwater table and build-up of pests, including weeds, diseases and insects. These problems are causing concern for sustainability.

2. Materials and Methods

There is no doubt that green revolution increased the productivity and overall production, but it has shown some deleterious effect on environmental sustainability and long run productivity. In post green revolution era several problems like soil degradation, imbalanced production, lowering of ground water table and build up chemical hazards by inviting new pests, weeds, diseases and insects are the major challenges for agriculture. The present article reviews the works done in recent years on important aspects of cropping systems with major focus being on second generation problems and their management. Methodology adopted in crop diversification, considered a way for sustainable agriculture and ecological balance in post green revolution era. Several cropping systems and their management practices have been taken for mitigation of problems. The major cropping systems reviewed are: Rice-Wheat, Rice-Potato-Wheat, Rice-Potato-Groundnut, Rice-Legumes, Rice-Potato-Jute, Rice-Wheat-Groundnut and Rice-Potato-Groundnut.

Methodology includes the discussion of works conducted by several researchers during post green revolution era on second generation problems like, over-mining of soil nutrients, decline in factor productivity and soil health, imbalanced production, lowering of water table and water quality, environmental degradation and build up pest and diseases, mainly during the period of 1990 to 2016.

3. Results and Discussion

3.1 Consequences of green revolution

Imbalanced production

The technologies which brought the green revolution demands intensive energy, fossil fuel based artificial fertilizers, diesel fuel or electricity to run irrigation pumps. The resource-poor farmers could not afford to go in for such costly inputs, with the result poor became poorer and rich became richer. Only prosperous and large farmers, who controlled more land and had the financial resources, who adopt these new technologies. This is explained by the fact that resourceful farmers, who accounted for less than 15% of the total area under food grains in India, contributed as much as 56% of the increase in food grain production by green revolution. Crop-wise disparities between food grains and non-food grains are another aspect of disparities. The increase realized in food grain production was mainly due to increase in the production of cereal grains, especially of wheat and rice. As a result, the production of other food crops, like pulses and oilseeds are not adequate (Yadav et al 2009).

Over mining of soil nutrients

Among the several indicators of soil degradation, over-mining of nutrients is considered to be the major concern under irrigated intensive cropping system. This happens due to nutrient removal by crops from soil far exceeded replenishment through fertilizer and manures, causing negative balance in soil (Hegde and Dwivedi 1992). In most of the fertile irrigated soils due to continuous practice of cereal-cereal system multiple nutrient deficiencies have cropped up. The findings of long-term experiments on cereal-cereal system across India clearly show a decline trend in organic carbon, nitrogen phosphorus and potassium in soil. Depletion of soil potassium seemed to be general cause of reduction in yield of rice-wheat system in 23 rice-wheat long term experiments in Indo-Gangetic plains (Ladha et al 2003). Shukla et al (2004) reported a negative balance of primary nutrients in rice-wheat system even with recommended NPK doses, whereas N and P balance was positive in rice-wheat-greengram system, but K balance remained negative. Thus, it can be concluded that K is most removable nutrients and needs adequate supplementation through K fertilization (Sharma and Sharma 2002). Apart from these primary nutrients condition of secondary and micronutrients are equally poor. In Indo-Gangetic plains, the rice-wheat system, giving an average yield of 3.92 tonnes/ha rice and 3.95 tonnes/ha wheat, removes about 331, 2.88, 3.84, 6.72, 9.19 and 0.76 thousands tones of S, Zn, Fe, Mn, Cu and B respectively. Except Zn, which is added about 77.2 thousands tonnes yearly, the addition of other secondary and micronutrients are almost nil (Shukla et al 2004).

Decline in factor productivity and soil health

In the last two decades, agricultural soils of India have been intensively used for conventional crop production, especially for cereal production and started showing fatigue. That is, they are no longer able to maintain the yield level. Many producers have adopted organic amendments for sustainable crop production, but most of them use inorganic fertilizer in abundance. Excessive and continuous use of inorganic fertilizers is deteriorating crop productivity and soil health (Dawe et al 2003). Due to imbalance in fertilizer use, widespread deficiencies of secondary and micro-nutrients have been manifested which leads to declining trends in nutrient response.

Lowering of water-table and water quality

In Punjab, Hariyana and Western Uttar Pradesh, indiscriminate installation of shallow pumping sets, to meet the irrigation demand of intensively cropping involving rice, wheat and sugarcane, has caused a serious overdraft of ground water. This has eventually results lowering of ground water table (Hira and Khera 2000). Lowering of water table not only increased the cost of irrigation but also different types of the water quality problem emerged viz. due to excessive pumping in coastal areas leads to ingress seawater into the ground aquifer and arsenic contamination in pumped water in lower Gangetic plain (Shankar et al 2014).

Environmental degradation

Agriculture contributes to over 20% of global anthropogenic greenhouse gas emissions (OECD 2001) and this is considered as the source for number of some environmental pollution. It is responsible for about 80-90% NH_3, which causes acidification and eutrophication, when deposited to soils and water. The pollution of groundwater due to leaching of nitrates is relatively a new concern in India. Because, it was believed that comparatively low rates of N-fertilizer use prevalent in the country, nitrate leaching is not likely to pose a serious threat in most of the farming situations. Studies with ^{15}N-labelled urea on sandy loam soils of Delhi revealed that wheat utilized only as much as 48% of applied N and rest of the applied N is the potential for leaching beyond the root zone (Sachdeva et al. 1977). Summer grown flooded rice contributes to significant N losses via nitrate leaching and de-nitrification (Aulakh et al 2001).

Build up of pest and diseases

The threat for the buildup of pest and diseases has been cropped up due to intensification of cropping system with high input use. Due to continuous cropping of rice, the incidence of sheath blith (*Rhizoctonia solani* Kuhn) has been increased. In wheat, increased incidence of *Alternaria* and *Helminthosporium* leaf blight has been reported under continuous cropping of rice-wheat (Hobbs et al 1991). *Phalaris minor* Ritz severity is the major concern for sustain the rice-wheat system.

3.2 Cropping system management for an ever-green revolution

The ever green revolution refers to an improvement in crop and animal productivity in perpetuity. The adverse effect of green revolution technologies are the driving force to find out alternative crops and cropping system with advanced management. In rice-rice system, different new and efficient alternative cropping systems viz. rice-greengram, rice-sunflower, rice-okra, rice-potato-sesame , rice-mustard-okra etc. has been found superior to the existing system (Ray et al 2016, Biswas et al 2006, Samui et al 2004). In rice-wheat system, maize, sorghum, groundnut, vegetables etc. can be as an alternative of rice, whereas the crops like, potato, lentil, sunflower, mustard, pea etc. can substitute wheat crop. Inclusion of grain legumes in cereal-based cropping system had considered beneficial in terms of yield and fertilizer saving (Singh and Varma 1999).

Recycling of crop residues may be a potential source to sustain the soil health. Residue incarnations of either rice or wheat increases the yield and nutrient uptake and also improve physico-chemical properties of soil, ultimately improves soil environment. The soil organic carbon, available nitrogen, phosphorus and potassium content of soil increases through rice-berseem rotation as compared to rice-wheat (Dwivedi and Singh 1995).

Inclusion of certain crops in sequence and inter cropping reduces some obnoxious weeds to a considerable degree, thereby reducing the need of herbicides. For example, Johnson grass (*Sorghusm halepanse* L.) become a predominant weed in continuous maize-based systems but can be controlled by rotating with cotton (Hosmani and Maiti 1993). Inter cropping system has also been found to suppress weeds through formation of canopies due to competitive planting pattern and thus provide an opportunity to utilize cropping system as a tool of weed management with non-chemical means.

Nitrate leaching is inevitable under most of the agricultural production system. Improve management practices leading to arrest nitrate leaching can reduce potential contamination ground water. Choice of crops and cropping systems minimize nitrate leaching besides improving efficiency of nitrogenous fertilizer. Split application of N-fertilizer to well developed root system checks the losses of nitrogen through leaching or other means.

4. Conclusion and Future research thrust

- Raising of crops having morphologically and physiologically different habits in intensive cropping systems results complementary effect on themselves and succeeding associations. This concept is more appropriate under water shortage condition.
- No fixed system is expected to sustain in future. Therefore, diverse systems dynamic in nature and capable of absorbing the effect of change may be desirable.
- Development of an integrated nutrient management system to supply secondary and micronutrients particularly S, Fe, Cu and Zn to correct their hidden hunger.
- Development of sustainable models using computer software needs to be attempted to cope with change in the existing systems.
- System-based integrated resource management approach needs to be focused for long-term sustainability.
- Development of appropriate decision support systems for diversification options and resource use of optimization under variable scenarios.

References

[1] Aulakh S, Khera T S, Doran J W and Bronson K F. 2001. Dcnitrification, N,O and CO, fluxes in rice-wheat cropping system as affected by crop residues, fertilser-N and legume green manure. *Biol. Fert. Soils* **34** : 375-8

[2] Biswas B, Ghos DC, Dasgupta MK, Trivedi N, Timsina J and Dobermann A. 2006. Integrated assessment of cropping systems in the Eastern Indo-Gangetic plain. 2006. *Field Crop Research* **99**: 35-47.

[3] Dawe D, Doberman A, Ladha JK, Yadav RL, Lin B, Gupta RK, Lal P, Panaullah G, Sariam O, Singh Y, Swarup A and Zhen QX. 2003. Do organic amendments improve yield trends and profitability in intensive rice systems? *Field Crop Research* **83**: 191-213.

[4] Dwivedi B S, Shukla A K, Singh V K and Yadav R L. 2003. Improving nitrogen and phosphorus use efficiencies through inclusion of forage cowpea in the rice-wheat systems in the Indo-Gangetic Plains of India. *Field Crops Research* **84**: 399-418.

[5] Gangwar B and Prasad K. 2005. Cropping system management for mitigation of second-generation problems in agriculture. *Indian Journal ofAgricultura1 Sciences* **75**(2): *65-78.*

[6] Government of India. 2014. Agriculture and food management. *Survey of India 2013-14*, pp 137-159. Government of India, New Delhi.

[7] Hegde D M and Dwivedi B S. 1992. Nutrient management in rice wheat cropping system in India. *Fertiliser News* **37** : 27-41.

[8] Hira GS and Khera KL. 2000. *Water resource management in Punjab under rice-wheatproduction system.* Research Bulletin No 212000 Punjab Agricultural University, Ludhiana, Punjab,India, pp 84.

[9] Hobbs P R, Hattel G P, Singh R P, Singh Y, Harrington L W and Fusisaka S. 1991. Rice-Wheat Cropping Systems in Terai Areas of Nainital, Rampur and Pilibhit Districts in Uttar Pradesh: Sustainability of Rice-wheat System in South Asia. Diagnostic Surveys of Farmers Practices and Problems and Need for Further Research. CIMMYT-Indian Council of Agricultural Research-Iniemational Rice Research Institute.

[10] Hosmani M M and Maiti S S. 1993. Non-chemical means of weed management in crop production. *(in) Proceedings of International Sytnposium oti Integrated Weed Management for Sustainable Agriculture*, held during 18-20 November 1993 at the Chaudhary Charan Singh Waryana Agricultural University, organized by Indian Society of Weed Science, pp 299-305.

[11] Ladha J K, Dawas D, Pathak **H,** Padre A T, Yadav RL and Singh, B. 2003. How extensive are yield declines in long-term rice-wheat experiments in Asia. *Field Crops Research* **81** : 159-80.

[12] OECD. 2001. *Envirartrnental Indicators for Agriculture: Methods arid Results,* vol3. Organization of Economic Co-operation and Development, Paris.

[13] Ray M, Roy DC and Zaman A. 2016. Evaluation of rice (*Oryza sativa*)-based cropping systems for increasing productivity, resource-use efficiency and energy productivity in coastal West Bengal. *Indian Journal of Agronomy.* **61** (2): 131-137.

[14] Sachdeva M S, Ojha A M and Subbiah B V. 1977. Possibilities of improving the efficiency of nitrogenous fertilisers. *(in) Soil Organic Matter Studies,* pp 371-82. International Atomic Energy Agency, Vienna.

[15] Samui RC, Kundu AL, Majumder D, Mani PK and Sahu PK. 2004. . Diversification of rice (*Oryza sativa*)-based cropping system in new alluvial zone of West Bengal. *Indian Journal of Agronomy.* **49** (2): 71-73.

[16] Shankar S, Shanker U and Shikha. 2014. Arsenic Contamination of Groundwater: A Review of Sources, Prevalence, Health Risks, and Strategies for Mitigation. *The Scientific World Journal*. http://dx.doi.org/10.1155/2014/304524.

[17] Sharma S K and Sharma S N. 2002. Balance sheet of nitrogen, phosphorus and potassium under different rice-based cropping systems. *Indian Journal ofAgrononzy* **47** : 6-1 1.

[18] Shukla A K, Sharma S K, Singh V K and Upadhyay N C. 2004. Rice-wheat system: Fertilizer management constraints and their remedial measures. (in) Souvenir- of Natio~zal S)onposium on Second Generation Problenz in Agriculture and its Re~tredies,held at Modipuram, Uttar Pradesh, India, during 26-27 November 2004, pp 121-39.

[19] Singh N B and Verma K K. 1999. Impact of selected rabi crops on productivity and nitrogen economy in rice-based cropping systems. Oyza *35* : 89-91.

[20] Yadav RL, Yadav DV and Shukla SK. 2009. Bio-intensive Agronomy: A paradigm shift in agronomic research. *Indian Journal of Agronomy*. **54**(2): 105-112.

[21] Yadav RL, Prasad K, Gangwar KS and Dwivedi BS. 1998. Cropping system and resource use efficiency. *Indian Journal of Agricultural Sciences* **68** (8): 548-558.