

4R nutrient stewardship based potassium fertilization for dry-direct seeded rice-wheat cropping system

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4R nutrient stewardship is the key to achieve balance fertilization and higher nutrient use efficiency in rice-wheat cropping system (RWCS). To realize the maximum benefit of every nutrient management practices the identification of 4R nutrient stewardship for each nutrient and in every crop is crucial. The adoption of identified 4R nutrient stewardship practice will improve the yield and quality of economic produce, minimize the negative impact of inorganic fertilizer and improve environmental quality, reduce the production cost and maximize net return, maintain and improve soil health, reduce the emission of greenhouse gas (GHG). Creating adequate awareness about the importance of 4R nutrient stewardship, providing on-farm training to farmers and appropriate government policy will improve the soil health and system productivity and ensure the sustainability of RWCS.

Keywords: 4R nutrient stewardship, Potassium, DSR, Wheat

THE rice-wheat cropping system (RWCS) occupies about 10 million hectares area covering Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal, Himachal Pradesh, Uttarakhand, Madhya Pradesh and Rajasthan. The intensively cultivated RWCS is fundamental for employment, income generation and livelihood security for millions in India. Presently, the RWCS of Indo-Gangetic Plains (IGP) alone contributes nearly 42% to the total food grain production in India. Nevertheless, in recent years, the RWCS, which is considered as the backbone of country food self-sufficiency and facing sustainability problem due to indiscriminate use of chemical fertilizers and pesticide. Major issues linked to the threatened sustainability are decrease in soil organic matter (SOM) due to reduced use of organic inputs and lack of appropriate rotation; negative nutrient balances leading to declining in soil fertility and development of multi-nutrient deficiencies like

potassium, sulphur, manganese, copper, and zinc; over-exploitation of groundwater leads to a rapid decline in the water table; worsening of groundwater quality, escalating salinity; increasing nitrate (NO₃) concentration in groundwater; shift in weed flora (herbicide resistance) and pest populations; in efficient management of crop residues, and ultimately decreased total factor productivity or input-use efficiency, increased cost of cultivation and reduced revenue margins.

Irrigation water use in rice

Rice occupies about 24% of gross cropped area of India and contributes about 42 and 45% of the total food grain and total cereal production, respectively. India has the largest acreage under rice (43.4 million ha) with the production of about 104.3 mt and productivity of 2404 kg ha⁻¹ milled rice. Irrigated agriculture utilizes about 90% of the freshwater and of more than 50% this freshwater is used for rice cultivation. It is estimated that by 2025, 2

million ha of Asia's irrigated dry-season (*rabi*) rice and 13 million ha of its irrigated wet-season (*kharif*) rice may experience 'physical water scarcity' and approximately 22 million ha of irrigated dry season rice in South and Southeast Asia may suffer 'economic water scarcity'. Rice has very low water-use efficiency and under irrigated conditions, it consumes 3,000 to 5,000 litres of water to produce one kg of rice. Water scarcity is becoming more and more a global concern and in India, signs of serious water scarcity are already evident in the agriculture sector. Increasing water scarcity has necessitated the development and adaption of water-saving technologies, such as alternate wetting and drying, continuous soil saturation, system of rice intensification, direct (dry) seeding and aerobic rice.

Status of potassium nutrition in RWCS

Potassium (K) is the most neglected macronutrient in RWCS. It did not receive much attention until

the 1980s, because of the general belief that Indian soils are rich in K. The scenario of crop response to fertilizer K application has been changing with time. Evidence for increasing K deficiency in Indian soil is growing rapidly. The reasons for growing deficiency of K in Indian soil are omission or sub-optimal application, imbalance use of nitrogen, phosphorus and potassium fertilizers. Crop residue removal/burning without recycling. Decreased use/addition of organic manures, intensive mono-cropping which leads to nutrient mining from the top layer of the soil. Furthermore, the demand of rice and wheat crops for nutrients, especially potassium, is very high. The ratio of nutrients applied to crops typically do not match the ratio in which they are removed from the soils, as a consequences decline in crop yields and factor productivity have been reported in RWCS of IGP, particularly in Trans- and Upper-Gangetic Plains. Surveys in the IGP revealed that farmers often apply greater than recommended rates of fertilizer N and P in RWCS, but ignore the sufficient application of other nutrients. Farmers of the IGP apply little or no K in the RWCS, and there is increasing concern that soil K reserves are being depleted to levels insufficient to sustain high yields.

Emerging problems in wheat cultivation

Growing of rice in puddled soil create hardpan and destroy soil physical property in the long run besides increasing irrigation water requirement and short window period for the sowing of wheat. The second crop of wheat grown in RWCS is showing the problem of yield stagnation/decline in recent years due to delayed sowing, imbalance fertilization, increased pressure from biotic (weed resistance) and abiotic stress (heat waves). Now it has been increasingly recognized that the growth of wheat production in India will depend on changes in other management practices, such as better tillage, time of sowing, optimum plant stand establishment, timely control of weeds, pests, more efficient use of

applied fertilizer and irrigation water. The emerging scenario in RWCS necessitates the need for adoption of the practices which maintain/improve soil health, save irrigation water and ensure food and nutritional security.

Dry direct seeding of rice

Dry direct seeding of rice (DSR) is one such technology which facilitates early sowing of wheat, save irrigation water, reduce GHG emission and improve soil health. DSR is a new technology to farmers of IGP, and technology related to nutrient, weed, and pest management are tailored to suit various agro-climatic zones are yet to reach farmers. Weeds are the major problem in DSR if it is not controlled at the early stage. The availability of new generation low dose broad-spectrum herbicides in the market may help the farmers greatly to control weeds easily at a very early stage (even before starting of competition) in DSR. Farmers are following the same nutrient management in DSR which is practised for transplanted rice. This creates the problem of low nutrient use efficiency, environmental pollution, increased incidence of pest/disease/weeds and reduced grain yield. The adoption of appropriate nutrient management will ensure multiple advantages in RWCS. Though many nutrient management technologies are developed to realize the maximum benefits from the nutrient application, farmers are not adopting it because of lack of awareness or training. 4R nutrient stewardship is one among such technology, many farmers are not aware of it.

4R Nutrient Stewardship

The 4R Nutrient Stewardship concept defines the right source, rate, time, and place for fertilizer application as those producing the economic, social and environmental outcomes desired by all stakeholders to the plant ecosystem (Fig. 1). Balanced fertilization is one of the keys to increasing nutrient use efficiency. 4R nutrient stewardship is the key to achieve balance fertilization in RWCS.

Right source: Match the fertilizer source and product to crop need and soil properties. Be aware of nutrient interactions and balance nitrogen, phosphorus, potassium and other nutrients according to soil analysis and crop needs. It recognizes synergisms/antagonisms among nutrient elements and sources, blend compatibility, associated nutritive or non-nutritive elements.

Right rate: Too much fertilizer leads to leaching and other losses to the environment and too little results in lower yields and crop quality and less residue to protect and build the soil. Realistic yield goals, soil testing,

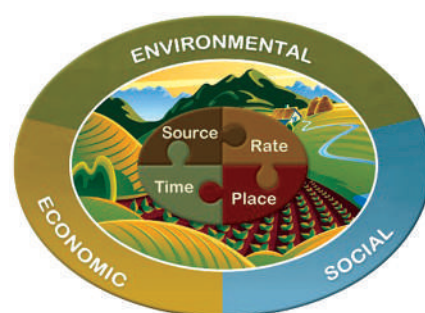


Fig. 1. 4R Nutrient stewardship

omission plots, crop nutrient budgets, tissue testing, plant analysis, applicator calibration, variable rate technology, crop scouting, record keeping and nutrient management planning are BMPs that will help determine the right rate of fertilizer to apply.

Right time: Make nutrients available when the crop needs them. Nutrients are used most efficiently when their availability is synchronized with crop demand. Application timing (pre-plant or split applications), controlled release technologies, stabilizers, inhibitors and product choice are examples of BMPs that influence the timing of nutrient availability.

Right place: Place and keep nutrients where crops can use them efficiently. The application method is critical for efficient fertilizer use. Crop, cropping system and soil properties dictate the most appropriate method of application, but incorporation is usually the best option to keep nutrients in place and increase their efficiency. Conservation tillage, buffer strips, cover crops and

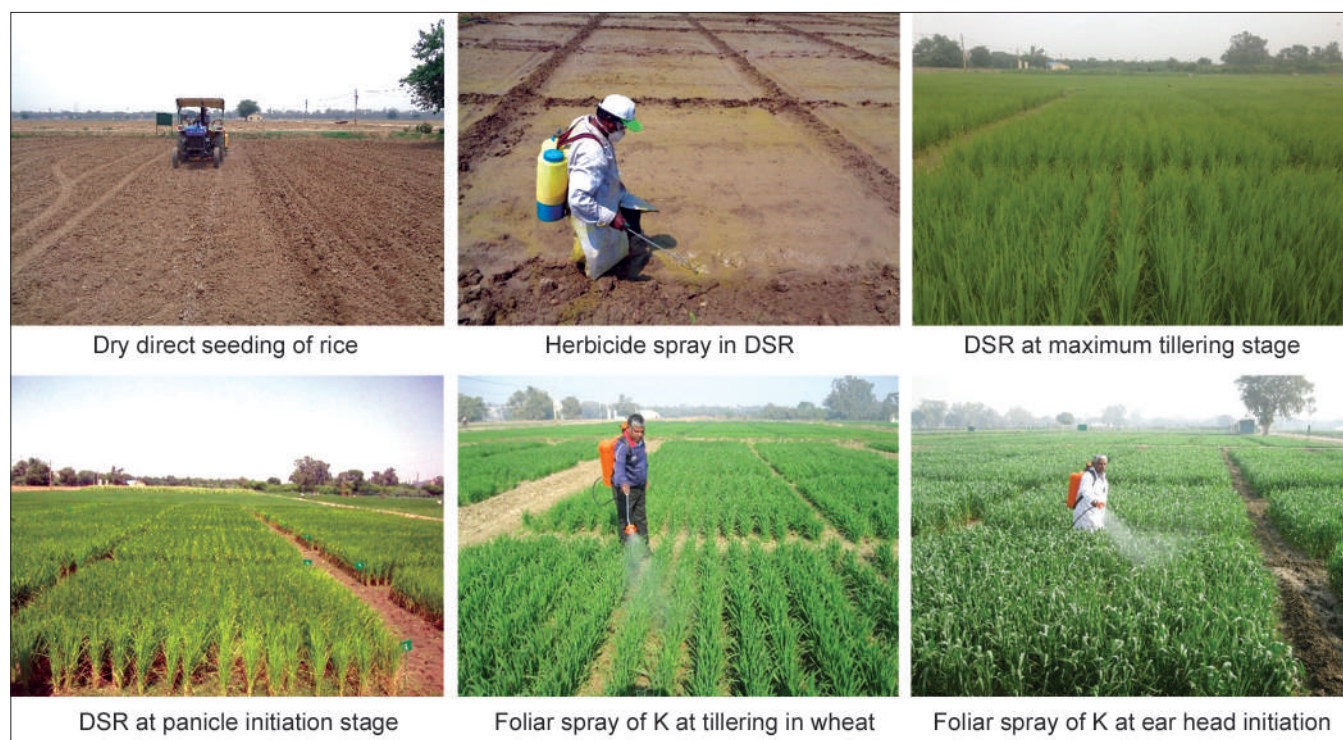


Fig. 2. Adoption of 4R nutrient stewardship in dry DSR-wheat cropping system

irrigation management are other BMPs that will help keep fertilizer nutrients where they were placed and accessible to growing crops.

Benefits of 4R nutrient stewardship

The benefits of 4R nutrient stewardship are grouped into three categories *viz.*, environmental, economic and social benefits.

Environmental benefits

- Sustain and improve soil health
- Maintain nutrient levels within the natural ecosystem
- Preserve wildlife habitat

Economic benefits

- Produce revenue to sustain farm operations
- Preserve the quality of life
- Reduce the money spent on fertilizer

Social benefits

- Produce nutritious, abundant and affordable food
- Support programs for strong and caring communities
- Help meet global food needs
- Provide ongoing employment opportunities in agriculture and related industries

4R nutrient stewardship based K application in dry DSR-wheat cropping system

Based on the result of a two-year field experiment in IARI, New Delhi, research farm it is found that the first dose of K (50% recommended dose of K=30 kg K₂O/ha) should be applied 10 days after sowing of rice. It reduces the fixation and leaching loss of applied K, especially in IGP. The demand for K in rice during germination the seedling stage is very less. However, sufficient supply of K in early-stage support healthy root

growth and resistance to various biotic and abiotic stress. While the maximum demand for K starts at tillering. During this stage, rice plant uptake maximum amount of K (even up to 10 kg/ha/day) and produce maximum dry matter. The deficiency of K at tillering stage causes a drastic reduction in tillers production. Thus, the second dose of K (15 kg K₂O/ha) should be applied at early tillering stage (i.e 35-40 days after sowing). While the last dose of K (15 kg K₂O/ha) should be applied at panicle initiation (65-70 days after sowing).

Table 1. Effect of 4R nutrient stewardship based K application on growth and yield

Treatments	Dry DSR				Wheat			
	No of tiller/m ²		Grain yield (t/ha)		No of tiller/m ²		Grain yield (t/ha)	
	2015	2016	2015	2016	2016	2017	2016	2017
No K (control)	311	314	4.01 ^D	3.94	396	401	4.29	4.28
100% basal	356	352	4.96	4.84	444	451	5.20	5.11
75% basal + 2 foliar spray	382	355	5.52 ^A	5.32 ^A	458	468	5.67	5.49
75% basal + 25% at panicle/spike initiation+ 2 foliar spray	398	381	5.54 ^A	5.36 ^A	476	480	5.69	5.55

Note: Each crop received a blanket dose of nitrogen (N) (120 kg ha⁻¹) and phosphorus (P) (60 kg P₂O₅ ha⁻¹). The recommended dose of N was applied in 3 splits by applying 1/3rd at 10 days after sowing (DAS), 1/3rd at tillering (40 DAS) and remaining 1/3rd at panicle/spike initiation stage (70 DAS). The entire recommended dose of phosphorus was applied just before sowing and incorporated into the soil while sowing by seed drill in both the crops. The N and P were applied through urea and single super phosphate (SSP) respectively.

The panicle initiation stage is found the most critical stage for K application. The deficiency of K at panicle initiation stage causes poor expression of panicle, more number of chaffy grains. The fertility percentage of rice show very high positive correlation with available potassium and panicle initiation stage. Similarly, in wheat, the recommended dose of K (60 kg K₂O/ha) should be applied in 3 splits. The optimum time of K application in wheat is 10, 40-45, and 70-80 days after sowing respectively. The 50% recommended dose of K should be applied at first split while the remaining 50% recommended dose of K should be applied at second and third split at equal proportion respectively. The effect of different source (Muriate of potash/ Potassium nitrate) of K on growth and productivity of rice and

wheat non-significant. In case of non-availability of K fertilizer during peak demand period, farmers can go for two foliar sprays of 2.5 % K at tillering and panicle/spike initiation stage respectively. The two foliar spray of K in addition to the application of 75% recommended dose of K at 10 days after sowing found to give equal benefit that of 3 split application. The synergistic interaction of K with N and P increase the recovery and use of these nutrients in RWCS thereby it reduces nutrient losses and protects the environment from the fertilizer related problems (Fig. 2).

SUMMARY

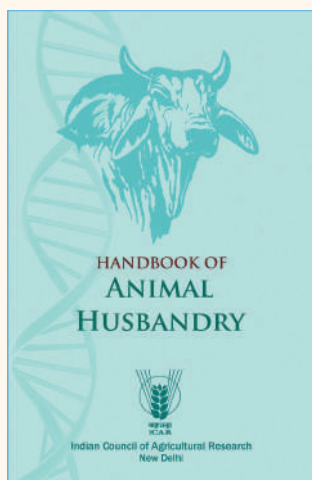
The technology which saves irrigation water and improves soil health in RWCS is need of the hour. Dry direct-seeded rice is one such technology found gaining importance

in IGP. The number of farmers adopting dry DSR cultivation is increasing over the years. However, the productivity of the system is threatened by inefficient nutrient management especially negative K balance and development of multi-nutrient deficiency. 4R nutrient stewardship based K management in dry DSR-wheat cropping system found increasing the grain yield. Similarly, 4R nutrient stewardship for nitrogen, phosphorus and micronutrient management are developed for different agro-climatic zones. Thus, educating the farmers and extension agent with 4R nutrient stewardship based nutrient management will solve the multiple problems associated with inorganic fertilizer use in RWCS.

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TECHNICAL SPECIFICATIONS

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