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Short Communication

Rice-Wheat Cropping Sequence *Viz*-A-*Viz* Natural Resources of Punjab, India

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Rice-Wheat Cropping System (RWCS) is the world's largest agricultural production system occupying 24 Million hectares (M ha) throughout India and China alone [1]. The Indo-Gangetic Plains (IGP) region of India has RWCS spread over a vast area spanning from Punjab in the Northwest to West Bengal in the East [2]. Around 12.3 M ha area in India, 0.5 M ha in Nepal, 2.2 M ha in Pakistan and 0.8 M ha in Bangladesh is under RWCS and around 85% of this area falls in IGP [3]. This cropping system produces more than 45% of the region's food grains and provides staple grains for nearly 42% of the total population (1.3 billion) in South Asia [2]. The productivity and sustainability of rice-based systems are threatened because of the inefficient use of inputs, increasing scarcity of resources especially water and labor, the emerging energy crisis and rising fuel prices. The global water scarcity analysis has shown that up to two-third of the world population will be affected by water scarcity over the next several decades [4].

The small states of Punjab and Haryana often referred to as the 'Food Bowl' of the country, produce 50% of the national rice production [5]. Rice in these states is normally flood irrigated during most part of the season with water pumped out from the below-ground aquifers leading to a steady decline in the water table in the region since 1970s [6]. The fall in water table particularly in central Punjab, has been reported to increase from 0.2 m year-1 during 1973-2001 to about 1.0 m year-1 during 2000-2006. Majority of the blocks in Punjab are being overexploited for pumping out ground water [6]. The lowering of the ground water table in the state has been resulting in an increase in the energy requirement, tube well infrastructure cost and deteriorating groundwater quality [6]. Moreover, repeated puddling of coarse and medium textured soils in the state has led to the sub-surface compaction in these soils [7], which has been proving detrimental for the upland crops like wheat [8]. The high bulk density layer at 15-20 cm depth formed due to repeated puddling restricts the root growth of wheat in addition to creating aeration stress [8]. Thus, puddle transplanted system of rice is water-, capital- and energy-intensive and leads to the structural deterioration of the soil.

Another major issue related to RWCS is effective management of rice crop residue, which due to high silica content is not fed to the animals and is normally burnt by the farmers. Burning of rice residues is the predominant method of rice residue disposal especially in the areas under combine-harvesting system. Disposal of crop residues by burning is not a viable option due to losses of soil organic matter, nutrients, C- emissions, intense air pollution and reduced soil microbial activity [9]. As per the estimates, 113.6 Mt of rice and wheat residues containing 1.90 Mt nutrients are produced every year in IGP of India [10]. In Punjab, about 12 Mt of rice straw is burnt annually causing 0.7 Mt of N loss apart from emission of 70% CO_2, 7% CO, 0.66% CH_4 and 2.09% of N_2O [3]. The intensive tillage for wheat seedbed preparation breaks down the aggregates to expose soil organic carbon leading to its loss into the atmosphere [11].

In order to take care of the above-said issues of declining ground water and soil health and residue management in RWCS in the region, various Resource Conservation Technologies (RCTs) *viz.* laser land leveling, Alternate Wetting and Drying (AWD), irrigation system in rice on fixed day interval or Soil Matric Potential (SMP) based scheduling, mechanical transplanting, zero-tilled wheat and transplanted rice, direct seeded rice, rice and wheat on raised beds, mulching etc. are being advocated for increasing the productivity, sustainability and profitability of this system by reducing the structural degradation of soil, air pollution and increasing water-, labor- and nutrient-use efficiencies.

Zero Tillage (ZT) improves the soil physical environment [12,13] because of residue retention in the fields resulting in increased infiltration rate, water retention, hydraulic conductivity, lower soil compaction [12,14] etc while conventional tillage breaks down the macro-aggregates into micro-aggregates, which adversely affect the soil properties [15]. The contradictory results related to zero tillage effects on soil and crops are reported in the literature [16,17]. It is mainly due to the site-specific conditions including soil type, climatic conditions and cultural practices especially for herbicide use [18]. Moreover, there is need to delineate the residual effects of these proposed resource conservation technology *viz.* laser land leveling [19], Alternate Wetting and Drying (AWD), irrigation system in rice on fixed day interval or Soil Matric Potential (SMP) based scheduling, mechanical transplanting [20], zero-tilled wheat and transplanted rice, direct seeded rice [1], rice and wheat on raised beds, mulching [21] etc. on proceeding or succeeding crops in the rice-wheat cropping sequence as a whole including intervening periods [1,22-25].

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