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Experiences with Rice Grown on Permanent Raised Beds: Effect of Crop Establishment Techniques on Water Use, Productivity, Profitability and Soil Physical Properties

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Abstract: In recent years, conventional rice production technologies have been leading to deterioration of soil health and declining farm profitability due to high inputs of water and labor. Conservation agriculture (CA) based resource-conserving technologies i.e. zero-tillage (ZT), raised-bed planting and direct-seeded rice (DSR) have shown promise as alternatives to conventional production technologies to overcome these problems. Present study was undertaken during 2009–2012 to establish an understanding of how permanent raised bed cropping system could be practiced to save water at the field application level to improve water productivity and also have the capability to enhance productivity, profitability and soil physical quality. The results showed that among different crop establishment techniques, conventional-tilled puddle transplanted rice (CT-TPR) required 14%−25% more water than other techniques. Compared with the CT-TPR system, zero till direct-seeded rice (ZT-DSR) consumed 6%–10% less water with almost equal system productivity and demonstrated higher water productivity. Wide raised beds saved about 15%–24% water and grain yield decrease of about 8%. Direct-seeded rice after ZT or reduced tillage or on unpuddled soil provided more net income than CT-TPR. The CT-TPR system had higher bulk density and penetration resistance due to compaction caused by the repeated wet tillage in rice. The steady-state infiltration rate and soil aggregation (> 0.25 mm) were higher under permanent beds and ZT and lower in the CT-TPR system. Under CT-TPR, soil aggregation was static across seasons, whereas it improved under no-till and permanent beds. Similarly, mean weight diameter of aggregates was higher under ZT and permanent beds and increased over time. The study reveals that to sustain the rice productivity, CA-based planting techniques can be more viable options. However, the long-term effects of these alternative technologies need to be studied under varying agro-ecologies in western Uttar Pradesh, India.
Key words: permanent raised bed; water productivity; profitability; yield; water saving; crop establishment technique

In most of South Asia, the common practice of establishing rice in the rice-wheat systems is through puddling followed by transplanting. Puddling reduces percolation losses and helps maintain ponded water, which is beneficial for controlling weeds. But puddling is costly, cumbersome and time consuming, and it degrades soil structure for the succeeding wheat crop in rotation. The significantly higher value of soil bulk density after rice harvest under zero tillage plots in the surface soil layer may be due to non-disturbance of the soil matrix, which resulted in less total porosity compared to tilled plots (Bhattacharyya et al, 2008). The disadvantages associated with puddled transplanted rice include the development of a hardpan at a depth of 15–30 cm, and the increased bulk density and soil compaction impair root growth of wheat due to the hardpan (Martinez et al, 2008). The higher bulk density under zero or reduced tillage might be due to more compactness of the soil, while the soil became

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more porous with the increased intensity of tillage in conventional practice (Ram et al, 2006). Surface irrigation is an ancient and widely used technique for irrigation in the Indo-Gangetic Plains of South Asia. Surface irrigation contributes to low application efficiency, which depends upon many factors, including infiltration soil characteristics, field undulation, intake discharge and run-off. Development of suitable crop-specific layouts can improve the application efficiency of available irrigation water resources. Different techniques have been developed for efficient utilization of irrigation water and for reducing water loss in the field. Alternate wetting and drying results in large irrigation water savings (15%–50%) in comparison with continuously flooded rice. The irrigation water savings are much larger on permeable soils where watertables are deep (Humphreys et al, 2008) than on soils of low permeability where watertables are shallow.

Raised beds are formed by moving soil from the furrows to the area of the bed, thus raising its surface level. The furrows serve as irrigation channels, drains and traffic lanes. Generally, two to six rows is planted on the top of each bed for rice crop (Naresh et al, 2011). In permanent raised bed technique, the bed-furrow system once developed is not destroyed seasons after seasons. The beds are only renovated and not misplaced. The renovation operation consists of only using a bed renovator. The bed renovator consists of two or three furrowers depending on the size of the raised beds for cleaning the furrows and two horizontal blades that cuts the bed at the base of crop root zone without disturbing the top of the bed. As experience has been gained with bed planting and appropriate implements have been developed, farmers who grow crops on beds can now simply reshape the beds before planting the next crop and retain all or part of the crop residues on the surface, a practice referred to as ‘Permanent Raised Bed Planting’.

Raised bed dimensions and configurations vary with soil type and available machinery. The ability of the soil to ‘sub’ (i.e. allow the lateral movement of irrigation water into the centre of the bed) is a key determinant of bed dimensions. For sandy loam soils that sub easily, growers use bed widths at 1.37 m centres for all crop types like rice, wheat. Soils do not sub as well, narrower beds at 0.67 m centres are frequently used. Bed height may also vary with soil conditions and field slope. Higher beds are frequently used on soils that sub well and have flatter grades and longer run lengths, while beds of a lower height are used on steeper graded fields. The flat top of the bed varies from 0.37 to 1.07 m in width. Furrow irrigation used with raised beds requires growers to adopt a whole-farm planning approach to deal with drainage water and the integration of on farm drains and drainage water recycling systems, to increase both water use efficiency and drainage water quality control (Beecher et al, 2005). This paper presents a result of the on-farm experiment and observation from bed/flat sown rice techniques currently practiced in the western Uttar Pradesh, India.

MATERIALS AND METHODS

An experiment was conducted at crop research centre of SardarVallabhbhai Patel University of Agriculture & Technology, Meerut (Uttar Pradesh), India, during 2009–2012 at 29°01′ N, 77°45′ E, and 237 m above mean sea level. The experiment was laid out in a randomized block design with three replications. Description of different technologies is presented in (Table 1). The size of each plot was 15 m × 9 m. The climate of the area is semiarid, with an average annual rainfall of 765 mm (75%–80% of which is received during July to September), the minimum temperature of 4 °C in January, the maximum temperature of 41–45 °C in June and relative humidity of 67%–83% throughout the year. In general, the soils of the experimental sites were sandy loam in texture with medium fertility status. The particle size distribution of 0–20 cm soil layer is 64.2% sand, 18.5% silt and 17.3% clay. The soil samples were taken at 0–15 cm soil layer from top of the beds in permanent beds and within the row in flats. The bulk density was 1.40 mg/m^3, weighted mean diameter of soil aggregates was 0.58 mm, and infiltration rate was 23 mm/h.

Water application and measurements

Irrigation water was applied using polyvinyl chloride pipes of 15-cm diameter and the amount of water applied to each plot was measured using a water meter (Dasmesh Co., India). The quantity of water applied and the depth of irrigation were computed using the following equations:

Quantity of water applied (L) = $F \times t$ (1)

Depth of water applied (mm) = $L / A / 1000$ (2)

Where F is flow rate (L/s), t is time (s) taken during each irrigation and A is the area of the plot (m^2). Rainfall data were recorded using a rain gauge installed within the meteorological station. The total amount of water (input water) applied was computed as the sum of water received through irrigation (I) and