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Raised bed planting through broad bed furrow

Smita N. Solanki , S.H. Thakare and R.T. Ramteke

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See end of the Paper for authors' affiliation

Correspondence to :

Smita N. Solanki
Department of Farm Power and Machinery, College of Agricultural Engineering and Technology, Dr. P.D.K.V., **Akola (M.S.) India**
Email : smitansolanki@yahoo.com

ABSTRACT : In recent years, it is imperative to improve sowing techniques through preferred seedbed preparation and early crop growth. Sowing techniques and type of seeding machines play an important role in seed placement and seedling emergence which ultimately affect crop growth and grain yield. The selection of suitable planting methods is dependent upon the time of planting, irrigation methods, amount of residue in the field and type of planting machines. The present work deals with the review of research work done by using broad bed furrow (BBF) worldwide to study the effect of raised bed planting on soil health, yield, water saving, fertility of soil etc. From the study it is revealed that raised bed (RB) farming systems combine most of the elements of conservation agriculture and have produced encouraging production results under various environmental conditions. RBs offer the opportunity of reducing field compaction and restoring physically degraded soil structure, as well as, the potential to reduce irrigation water and increase crop yield while reducing the risk of water logging. Different raised planting configurations are used throughout the world depending on soil type, available machinery, farmer preference and expertise. In general, increasing the width of the bed reduces total water used and increases land use efficiency and yield by reducing the uncropped furrow area.

KEY WORDS : Broad bed furrow, Permanent raised beds, Crop growth, Seedbed, Yield

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Sustainable development in agriculture can be archived through farm mechanization. It is the application of engineering technology in agricultural operations to do a job in a better way to improve productivity. This includes development, application and management of all mechanical aids for field production, water control, material handling, storing and processing. Mechanization of different farm operations can increase the agricultural productivity by more work in less time, efficient use of inputs, by producing quality product, improving the safety of the farmers, reducing the loss of produce and drudgery of farmers and thus, improving comforts of farmers. It also reduces drudgery in farm operations.

Change from growing crops on the traditional flat bed to the raised bed offers more effective control of irrigation water and drainage, reduced weed infestation and lodging, improved nutrient use efficiency, reduced tillage, water saving, and higher yields with decreased operational cost (Aquino, 1998; Connor *et al*., 2003; Fahong *et al*., 2005; Hobbs and Gupta, 2003 and Sayre and Moreno Ramos, 1997) and to improve soil organic matter and physical characteristics owing to surface retention of residues.

Raised bed farming is a system where the crop zone and the traffic lanes (wheel tracks or furrows) are distinctly and permanently separated. Soil is moved from the traffic lanes (or furrows) and added to the crop zone, slightly raising the surface level of the crop zone. Raised bed technology is an adaptation of the traditional hill and furrow row cropping design.

Advantages of raised beds :

– Improved surface and internal drainage of the soil, because the entire soil surface is not flooded.

– Improved soil structure of the crop zone, because most machinery wheel compaction is confined to the furrows. Crop growth is improved, as soil conditions are maintained within favourable limits.

– Reduced tillage requirements, because the crop zone is not compacted by wheeled traffic. The use of the furrows for traffic is more likely to allow cultural operations to be undertaken at the optimum time, unlike border check and contour layouts, where delays are experienced, and where the soil is looser and potentially more boggy.

– Increased range of crops and pastures that can be grown in rotation. The grower can easily change crop sequences to benefit from favourable market prices.

– Improved financial returns.

Numerous researchers throughout the world have conducted various experiments by using BBF and few of which are reviewed as under.

Work done in India:

Over the past decade there has been increasing interest in the development, evaluation and adoption of raised bed planting technology for a wide range of crops in north-western (NW) India. This interest has arisen from initial success with planting wheat on raised beds, from associated opportunities for intercropping and crop diversification (including financial benefit for farmers), and from the large irrigation water savings being achieved on beds. Serious concern about the sustainability and productivity of the dominant rice–wheat cropping system is also driving the search for crops with a lower water use requirement than rice Ram *et al.* (2005).

Results to date suggest that raised beds have the potential to enable diversification and increase the productivity of cropping systems in NW India through growing a much wider range of crops in the monsoon season and increasing yields of water logging sensitive crops by irrigation. These results also suggest significantly reduced irrigation water requirements for crops on beds, saving costs and energy, although whether this is a real water saving is yet to be determined. Permanent beds offer the additional possibility of direct drilling, with advantages of rapid turnaround between crops, reduced tillage and energy costs, reduced greenhouse gas pollution from burning diesel, and improved soil structure due to controlled traffic and reduced disruption of bio pores and oxidation of soil organic matter.

The raised beds are widely used in agriculture in developed countries and have proven to be an excellent option for wheat. Permanent raised beds may also offer benefits for rice–wheat (RW) systems in South Asia, in terms of both production and the possibility that furrow-irrigation may be more efficient than flood irrigation. The performance of a RW system on permanent raised beds (37 cm wide, 15 cm high, furrow width 30 cm) was compared with conventional cultivation on the flat on sandy loam and loam soils in replicated experiments in central Punjab, India by Singh *et al.* (2009). Further it is concluded that productivity of RW on permanent raised beds with transplanted rice declined as the beds aged, and averaged 77–79 per cent of the productivity of the best systems mainly due to declining yield of transplanted rice on permanent bed (TRB) relative to Puddle transplanted rice (PTR). Averaged over the first 3 years, productivity of permanent beds with direct-seeded rice (DSRB) was even lower (only 62–68% of the best systems) due to much lower yields of DSRB. Permanent bed RW systems seem to have limited potential under the prevailing soil and climatic conditions of Punjab, India, with current varieties and management.

Singh *et al.* (2010) reported that permanent raised bed (PRB) system of planting, as widely used particularly for wheat in different countries, has seldom been studied in the pigeonpea–wheat system. We, therefore, conducted a field experiment at Modipuram (29840N, 778460E, 237 m asl), India, for 3 consecutive years (2001–02 to 2003–04) to evaluate the PRB *vis-a-vis* the conventional flat bed (FB) system of planting at varying fertilizer NP rates in the pigeonpea–wheat system, in terms of changes in soil organic carbon, nutrient and water use efficiencies, annual productivity and economic returns.

The findings of our study revealed the superiority of PRB over FB in all respects including net economic returns. Greater irrigation water use efficiency and relatively smaller specific energy requirement under PRB make the practice further attractive, particularly in view of dwindling ground and surface water resources due to over-exploitation in the high productivity transects of IGP. Future research should focus on selection of appropriate wheat cultivars suitable for PRB and fertilizer management especially N scheduling and application methods.

Khambalkar *et al.* (2010) carried out an experiment on mechanical sowing of safflower on broad bed furrow (BBF) to find out overall benefit over traditional method of sowing in *Rabi* season (winter) of 2009 in Maharashtra. The average soil moisture in BBF method and traditional method was observed 29.99 per cent and 27.36 per cent, respectively. The sowing was carried out in pair rows by introducing BBF between them. Row to row spacing between crop rows on broad bed was kept 30 cm with 60 cm of bed width. The plant to plant spacing (20 cm) was kept same as in traditional method of sowing safflower crop. The average depth of placement of seed in BBF method was observed to be 4.44 cm and in traditional method it ranges from 2 to 2.5 cm. The sowing of safflower on BBF resulted in conservation of moisture in soil which was observed to be 9.61 per cent more as compared to traditional method of sowing.

The field performance of BBF method shows effective conservation of soil moisture than in traditional method. It resulted in higher yield of safflower crop in *Rabi* season. The cost of operation of BBF method was less as compared to traditional method of sowing of safflower crop. From the result of study it is concluded that sowing of safflower crop using the BBF method is feasible to enhance the crop yield with saving in cost of operation.

Singh *et al.* (2011) developed a tractor-drawn broad bed furrow (BBF) seed drill machine for soybean [*Glycine max* (L.) Merrill]. It effectively operates in Vertisols and associated soils and is attachable to the tractor for facilitating formation of broad bed along with furrows on both the sides of the beds of desired width and depths and subsequent sowing in one go. Plant population mortality in soybean with tractor-drawn BBF seed drill for Vertisols was reduced in the range of 14–19 per cent as compared to flat bed under the vagaries of monsoon which subsequently resulted in yield enhancement to the extent of 18.65 per cent. Study also indicated that tractor-operated BBF seed drill specifically fabricated for individual tractor performed better in Vertisols and under prevailing field draft conditions.

The feasibility study of developed tractor operated broad bed-furrow (BBF) planter was carried out by Khambalkar *et al.* (2014) ; Waghmare and Talokar (2013) and Talokar *et al.* (2017) in Maharashtra, India by using Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola developed BBF for sowing of winter crops in dryland. The planter was tested in laboratory and in field as per Regional Network for Agricultural Machinery (RNAM) test code for JAKI 9218, AKS-207 and AFLR variety of chickpea, safflower and onion, respectively. The planter was used for preparing broad bed and furrows and simultaneously sowing seed on beds. The field efficiency of planter was 72 per cent, 74 per cent and 71 per cent at working width of 1.40, 1.70 and 1.40 m and at speed of 3.38, 3.20 and 4.03 km/h for chickpea, safflower and onion, respectively.

The study revealed that planter can be used for preparing the broad beds and simultaneously sowing the seeds on the beds at required row and plant spacing. The moisture conservation on broad beds was higher than traditional method of sowing.

The performance evaluation of planter concluded that BBF planter was suitable for the selected crops namely sunflower, soybean and chickpea. The performance of the planter for plant to plant distance, plant population, seed rate per hectare and visible damage was satisfactory and it could be used for the field trials.

The sowing of seed on broad bed improves root rot

Table 1 : Results of demonstration of broad bed furrow planter for groundnut crop

Parameters	Farmer practice (Tractor drawn seed drill)	Improved practice (PKV BBF planter method)	Increase /remark
Yield (qt/ha)	39.00	49.4645	Increase by 26.8 %
Net return (Rs.)	138612.5	175317	ANR Rs. 36704.5 per hectare
Seed rate (kg/ha)	150	112.5	Saving of seed 37.5 kg per hectare
Cost of operation (Rs./ha)	1250/-	1750/-	Higher than farmer practice
Intercultural operation labour saving (man days/ha)	0	02	Labour saving of 02 man day/ha
Field efficiency	72.75	68.58	Need to increase

and provides favourable root growth condition (Talokar *et al.*, 2017). The application of technology developed by Dr. PDKV for sowing of seed with BBF planter shows increase in yield by 26.66 per cent, seed saving of 37.5 kg/ha and increase in ANR of rupees 36705 per hectare of groundnut crop in comparison with local practice (Table 1).

The use of PDKV BBF planter cum inter row cultivator for groundnut crop sowing is recommended for farmers as it shows increased production and seed saving when compared to local practice.

Naresh *et al.* (2011) conducted a farmers participatory field experiment during 2009-2011 in the jurisdiction of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, U.P. Multi crop planter with inclined plate seed metering device machine were given to the farmers and crops were sown on permanent raised beds in maize-wheat cropping system. The data collected from the farmers participatory field experiment showed that there was about 20.4 per cent (295.8 mm/ha for wide beds that is, 107 cm furrow centre gap) water saving and about 16.5 per cent (310.3 mm/ha for narrow beds that is, 37 cm furrow centre gap) with grain yield increase of about 13.5 per cent (5.13 and 4.44 t/ha) for wheat crop and 11.8 per cent (4.33 and 3.82 t/ha) for maize crop with precision land levelling raised bed planting compared to traditional land levelling with flat beds planting. The agronomic efficiency (AE) of N (23.4 and 30.4 kg grain/kg N for maize and wheat) and uptake of N, P and K (103.85, 25.6 and 110.7 kg/ha for maize and 112.95, 19.49 and 112.96 kg/ha for wheat) were significantly improved under precision land levelling with raised bed planting technique compared to other practices.

Broad bed and furrow (BBF) farming is a novel concept for conservation of rain water in of dry land areas. Hence, a comparative analysis of the BBF method of cultivation *vis-a-vis* traditional method of flat-bed sowing was has been made during *Rabi* 2014-15 with the main objectives to study the yield and economics of safflower and to assess the moisture conservation efficiency of the system (Sudhakar *et al.*, 2017). The field experiment was conducted on a medium black soil at Agricultural Research Station, Tandur, Telangana state during *Rabi* 2014-15. The performance of Safflower was studied under 2 treatments (T_1- BBF method of cultivation and T_2 - Traditional method of flat-bed sowing). Safflower hybrid DSH-185 was sown in an area of 0.2 ha each under BBF and traditional system.

The study revealed that broad bed and furrow method of sowing thus, offers a better opportunity to maximize the yield and economics of safflower. BBF method shows effective conservation of soil moisture than in traditional method which was reflected in improved seed yields of safflower in *Rabi* season under receding soil moisture conditions. Maximum attainable available soil moisture at different crop growth stages is possible with BBF method of sowing.

A field study was carried out by Verma *et al.* (2017) during *Kharif* 2014-15, 2015-16 and 2016-17 on thirty seven farmers field of Mohbhatta village of Simga block of the district Balodabazar-Bhatapara of Chhattisgarh state with size of trial is one acre each farmers to determine the impact of sowing techniques on yield of soybean under farmers' conditions. Six-row broad bed furrow machine was used to plant soybean having top bed width of 2.35 cm. Result showed that growth character (plant height, number of branches per plant and number of root nodules per plant) and yield contributing character *viz.*, number of pods per plant, seed yield weight per plant, seed index, seed yield, straw yield and harvest index (%) were found higher in broad bed furrow compared to the normal flat bed sowing which subsequently resulted in yield enhancement to the extent of 28.38 per cent for soybean crop. The average yield in broad bed furrow method recorded 15.20 q ha^{-1}. The B:C ratio was observed 2.05 due to drainage of excessive rain water from the fields and stronger plant anchorage on the beds. Similarly, 40 to 50 per cent saving in irrigation water was recorded with broad bed furrow method of soybean in comparison with flood irrigation of controlled plots. Results indicated that broad bed furrow technology has a lot of potential to increase water productivity of soybean.

Work done abroad :

Field study was carried out by Ahmad and Mahmood (2005) to determine the impact of sowing techniques on yield and lodging of wheat under farmers' conditions. For this purpose, four-row wheat bed planting machine developed at the Water Management Research Centre, University of Agriculture, Faisalabad, was used to plant wheat on 90 cm bed-furrow system. Results indicated minimum impact of lodging in raised bed planting (20.5%)

as compared to wheat sown by flat method (34.6%). In addition, raised bed planting registered 11.2 per cent increase in grain yield over that of flat-sowing methods. Reduced lodging in raised beds was due to drainage of excessive rain water from the fields and stronger plant anchorage on the beds. Similarly, 40 to 50 per cent saving in irrigation water was recorded with bed planting of wheat in comparison with flood irrigation of controlled plots. Results indicated that raised bed planting technology has a lot of potential to increase water productivity of wheat.

Fig. 1 : Four-row wheat bed planting machine

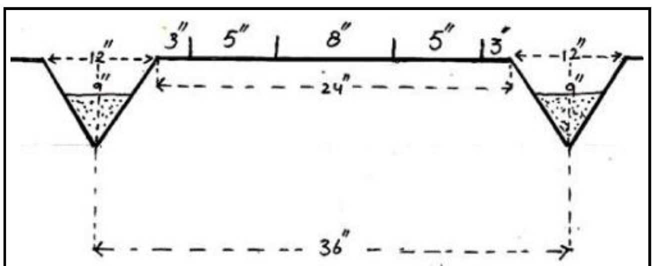

Fig. 2 : Schematic diagram of wheat bed planter

Hassan *et al.* (2005) conducted a study for 4 consecutive years (2000–04) in farmers' fields near Mardan to compare soil and water productivity in permanent raised beds versus the traditional basin system under maize–wheat double cropping. The results indicated that for the maize crop there were increases of 30 per cent, 32 per cent and 65 per cent in grain yield, water saving and water productivity, respectively, under permanent raised beds compared to basins. Similarly, permanent raised beds demonstrated 13 per cent, 36 per cent and 50 per cent higher grain yield, water saving and water productivity, respectively, for the wheat crop. Weed infestation was also 24 per cent and 31 per cent lower for maize and wheat crops, respectively, under permanent raised beds, which maintained lower soil bulk density and high infiltration rates. Partial budgeting showed that raised beds generated 54 per cent and 35 per cent increased net benefit for maize and wheat, respectively.

Meisner *et al.* (2005) With the growing use of bed-sown wheat in the Indo-Gangetic Plains of South Asia, the use of permanent raised beds (PRB) within the rice–wheat system has become a researchable question for growers and scientists alike. Permanent bed use in the rice–wheat system in Bangladesh and Pakistan is limited to a few hectares for demonstration and on-station or on-farm research. However, initial findings indicate potentially sustain- able increases in both productivity and profitability when the use of residue mulching on permanent beds is included. There are still major hurdles to overcome before the practice can become wide spread, including:

– Selection of rice germplasm that performs well under aerobic conditions such as PRB

– Perfection of machinery design and manufacture that can deliver seed and fertilizer precisely, reliably and affordably using the 2-wheel tractors plentiful in Bangladesh or 4-wheel tractors in Pakistan

– Involvement of all stakeholders, *i.e.* growers, agronomists, machinery manufacturers, agricultural engineers and equipment operators, to further extend and expand the use of PRB in Bangladesh while continuing to monitor and collect data on how its use can be maintained within the Bangladesh and Pakistan contexts.

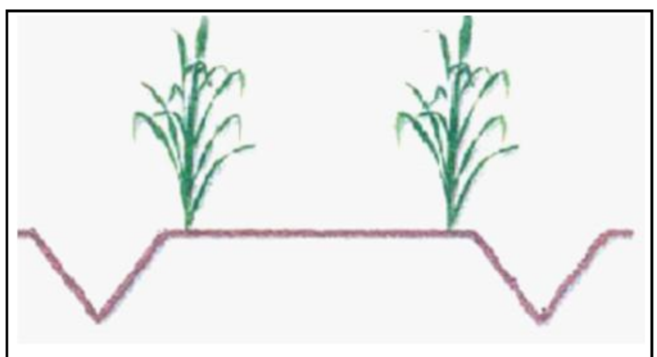

Fig. 3 : Usual bed size developed by bed

Fig. 4 : Bed planter based on toolbar formers in Bangladesh

Fig. 5 : Bed former based on POTS with the Chinese hand tractor with square and cone shapers

When some of these major constraints can be overcome through participatory research with growers, agriculture manufacturers, scientists and machinery operators/service providers, the potential of this system in productivity, sustainability and profitability can continue to be developed.

The Hexi Corridor is a moderate altitude (1000–2300 m), low rainfall, irrigated region in Gansu province of northwestern China. It is representative of irrigation areas in western China and thus is an important window to regional development. Water scarcity is the major issue facing the irrigated cropping system, causing many environmental problems and resulting in a poor output to input benefit ratio. To resolve this issue it is necessary to establish new cropping systems with increased water use efficiency, thereby reducing groundwater degradation and negative environmental impacts.The raised bed cropping system is one advance which may help achieve this goal. Preliminary research on raised beds, including factors such as planting density, fertilizer application rate, bed width, water allocations per irrigation, number of allocations and suitable varieties, suggest that a 25–30 per cent saving in water is possible without yield loss for spring wheat. The yield on raised beds increased by 34–46 per cent over that on flats under irrigation amounts of 2100–2850 m^3/ha, but when the irrigation amount exceeded 3600 m^3/ha the yield difference was not significant. For equal yields beds saved 750 m^3/ha of water compared to flats. (Zhongming *et al.*, 2005).

Overseas experience has shown that the use of raised beds with furrow irrigation not only saves water, but is also convenient for water management. Therefore, in order to increase water use efficiency, we started a research and demonstration programme of raised bed planting for wheat, with support from CIMMYT, in 1998. Experimental results in northern China indicating reduced irrigation water use, higher yields and greater water use efficiency were most promising, and are reported here. Increased yield with wheat on raised beds may be due to less dynamic fluctuations in soil water, and reduced disease and lodging. Fahong *et al.* (2005) developed a bed-planter pulled by a small 4-wheel tractor, suitable for the very small scale of Chinese farms (0.3–0.5 ha per family). Raised bed planting for wheat has not only been extended widely in Shandong province, but has also been introduced to Henan, Hebei, Shanxi and Ningxia provinces, reaching a total of 40,000 ha.

Fig. 6 : Left–the planter for raised bed planting; right - making bed, applying fertilizer and sowing wheat at same time

In northern Australia permanent raised beds (PRB) were first used as a means by which soybeans could be grown in the field using saturated soil culture (SSC), the concepts of PRB and SSC were extended from soybeans to rice in the Burdekin River Irrigation Area (BRIA) of North Queensland, the studies undertaken in the BRIA suggest that the development of a rice-based cropping system, in which rice and field crops are double cropped in rotation, is feasible and may provide additional synergistic and logistic benefits over those found in the traditional rice–fallow system. These benefits include improved water, nitrogen and phosphorus economies; energy savings; greater timeliness of operations; and reductions in soil compaction. Further, in practical terms, such a system is only feasible if based on PRB (Borrell and Garside, 2005). It is suggested that it has substantial potential as a preferred system in high rainfall and/or irrigated areas in the tropics and thus would appear ideally suited for much of the rice-growing land in South East Asia.

The need to increase the water productivity of irrigated winter and summer crops in the irrigated areas of southern New South Wales (NSW), Australia, has seen the development and adoption of raised bed cropping systems, an approach which better addresses root zone limitations caused by both seasonal and irrigation water logging and soil compaction. Raised bed farming systems have become part of the irrigated agricultural scene in the Murrumbidgee and Murray valleys over the past 25 years. The adoption of these systems continues to expand as growers seek to increase water use efficiency and cropping flexibility. Permanent raised beds are the recommended irrigation design to achieve high yields in many irrigated crops on heavy clay soils, including maize, soybean, faba bean, canola and winter cereals (Beecher *et al.*, 2005). The study revealed that permanent raised bed technology is an effective and profi table form of farming that prevents winter waterlogging in rainfed cropping areas. Its application to waterlogged and saline land seems to offer a reasonable prospect of success.

Fig. 7 : Rotary hoes can be used after listing, to form beds

Fig. 8 : Level and smooth seeding surface being created on raised beds by use of a rotary hoe and rotary harrows

Two experiments investigating PRB systems used for wheat-maize rotations were conducted by Ghani *et al.* (2010) over a ten year period on a silt clay loam in Pakistan. The use of PRBs generally resulted in higher yield, lower water application and higher Gross Production Water use indices (IGP) compared to traditional flat basin systems. The study revealed that permanent raised beds have been shown to produce higher yields, require less water and have higher gross production water use indices than traditional flat basin systems in north-west Pakistan. The volume of irrigation water applied was found to be a function of the bed width with wider beds typically having smaller water application volumes. However, the yield achieved on the beds was less affected by bed width. Anecdotal evidence suggested that wider beds experienced difficulty with lateral water movement from the furrows but wider beds also typically had a larger infield cropped area due to fewer furrows. Investigations of soil structural properties in the beds indicated that matching the machinery track width to the furrow spacing and using horizontal blades for renovating beds without soil inversion resulted in lower soil bulk densities and higher hydraulic conductivities within the root zone.

Benefits and risks associated with PRBs :

– Permanent raised bed (PRB) configurations and renovation methods vary throughout the world depending on soil type, cropping pattern, farmer preferences, available machinery and local expertise. An increase in the bed width generally increases land use efficiency due to a smaller cropped land loss due to furrows. However, PRB configuration and seasonal pre-sowing renovation need careful selection due to their influence on crop production.

– Depending on the purpose and context of use of PRBs and also risks and disbenefits following inferences are drawn:

– In cases where PRB systems are primarily used to manage waterlogging, results consistently indicate higher yields, particularly in wet years. On the basis of soil water and soil physical data provided by Hamilton *et al*. (2005) it is possible to conclude that these beneûts are directly related to the beds.

– Yield increases are also reported for PRB systems targeting the issue of water savings in irrigated land

– Many of the papers presented here indicate that PRB systems deliver higher returns. There is some evidence that this is probably because PRB systems reduce input costs for labour, machinery, energy and seeds (Beecher *et al.*, 2005; Hulugalle and Daniells, 2005; Kukal *et al.,* 2005 and Sayre and Moreno Ramos 1997), rather than generating increased yields (Hassan *et al.*, 2005 and Meisner *et al.*, 2005).

– Even if irrigation water savings were realised at the farm-scale through use of PRBs, it remains uncertain to what degree these savings may aggregate upto scheme or basin level water savings.

– Several farm operational beneûts have also been identified. A benefit observed in most systems is that of increased timeliness of planting and general improved accessibility for weeding and fertilizer top dressing, especially during wet periods using the fur- rows as trafic lanes.

– PRB systems generally also provide benefits in terms of soil health. However, the rate at which these benefits accrue depends heavily on the amounts of residues retained (Meisner *et al.*, 2005; Sayre and Moreno Ramos, 1997).

– New cropping systems and methods of residue management should be researched, and suitable small farm machinery should be developed for zero-till and relay planting methods, and residue and weed management.

Authors' affiliations:

S.H. Thakare, Department of Farm Power and Machinery, College of Agricultural Engineering and Technology, Dr. P.D.K.V., **Akola (M.S.) India**

R.T. Ramteke, Department of Electrical and Other Energy Sources, College of Agricultural Engineering and Technology, V.N.M.K.V., **Parbhani (M.S.) India**

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