Tactical water management in field crops: the key to resource conservation

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Water is a critical input for productivity enhancement especially of field crops. Its judicious and optimum use is needed utmost for realizing higher resource use efficiency and plugging gaps in production. Resource conservation technologies or key technological interventions, which could alter or rectify the usage pattern or strategies in freshwater utilization in agriculture, are the need of the hour. Tactical or strategic approach in water management could help in conserving and making more-efficient use of scarce water resources through integrated management combined with selected external inputs/technologies. In this context, the scientific interventions on water management involving precision levelling of land, no tillage or reduced tillage systems, furrow irrigated raised bed planting or broad bed furrow systems, management of soil cover and crop diversification and other inclusive technological practices could enforce appropriate water management schedules.

Keywords: Field crops, pulses, resource conservation, sustainable development goals, tactical water management, technological interventions.

IT is true that without water security there is no food security. Water insecurity is becoming a global challenge. The crisis is building up for decades due to ever-growing population, intensification and/or diversification of agriculture through an unsustainable use of ground water, and diversion of our fresh water resources for agriculture. As of now there are 34 countries having per capita fresh water levels below the so-called water poverty line, which is quantified as 1000 m^3 per year[1]. Therefore, there is a need to produce more from less (of water) because of the underlying facts and related problems worldwide in the context of our own survival[2,3] and that of future generations.

Studies suggested that per capita availability of water, the precious non-renewable resource, is declining at a rapid rate[1] and developing countries have to sustain with only 20% of this resource. The demand for food is increasing at a rapid rate. Since it is set to double by 2050, to nourish the global population, the water needed for it will double as water productivity (WP) gains are minimal. In addition, rapid urbanization in developing countries is throwing up new and harsh challenges. As a result, conflicts between rural and urban regions on the sharing of water and its allocation are increasing nationally and globally[3]. Moreover, rainfall variability and non-productive water management is estimated to cost 1/3rd of the growth potential in farming at the level of nations. It warrants managing water resources judiciously and tactically for effectively utilizing the allocated water for food or farm production especially in populous countries like India. This calls for an appropriate blending of technological considerations related to water consisting of its judicious and appropriate conservation, management and planning, allocation and policy support.

Agriculture in India is in post-green revolution era where major R&D demands an efficient and sustained resource conservation and utilization. The need of the hour is to shrink production costs, raise profitability and (re)make farming more competitive to meet emerging challenges of widespread resource degradation. In this endeavour, to evolve and spread resource inventories (conservation technologies like reduced and zero tillage systems, retention of crop residues and practising optimum crop/cropping systems), rapid strides have been made on improved planting systems and better management of crop wastes. It enhances conservation of primarily two precious inputs, viz. water and nutrients[4–6]. With optimum management of resources, conservation agriculture (CA) – the key input being water – is needed for up-scaling and out-scaling farm productivity. Therefore, CA with its ancestry in universal principles of providing minimum soil disturbance/traffic, permanent soil cover and crop rotations/farming systems is now regarded as the express way to sustainable agriculture and for realizing sustainable development goals (SDG)[2,7].

Plugging in crop production gaps

There is an urgent need to produce more food per drop of water worldwide as conservation and management of

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water and other natural resources play a key role in food production systems (FPS). Here comes the role of technological innovations that is employed (tactically) to fit in FPS, resulting in accelerated yet sustained productivities over space and time. With the advent of new crop production and resource conservation technologies (RCTs), this could be doable with higher margins. Moreover, improved agro-technologies combined with water or resource conservation (RC) principles through reduced tillage, minimum traffic load, and more soil cover on surface lead to conservation agriculture. Therefore, tactical water management is the key to RC mediated with RCTs.

The key challenge to RC for enhancing resource use efficiency (RUE) now-a-days is to adopt practices that will address the dual concerns of maintaining/up-scaling the integrity of natural resources and enhanced productivity, while the former like that of water takes a lead as it constitutes the very basis for sustainability in the long run[8,9]. It needs to bring together all stakeholders to share experiences/information and to promote interaction for future R&D efforts[7]. Thus, the key technological interventions include the tactically essential components of RC or CA. Thus, the key points in tactical management of water incorporate precise and scientific management and scheduling of available precious water. It includes water harvesting, determining priority areas and crops requiring life-saving/supplemental irrigation in critical stage(s), meeting precision fertigation needs with micro-irrigation (precision techniques involving laser leveller, drip, sprinkler and other atomized application, etc.), and following improved land configurations cum agro-technologies (ridge/raised bed and other integrated technological practices, ITPs). This also amalgamates with use of crop cafeteria/cropping system intensification (water requirement based), residues/mulching for water conservation during crop's life cycle and consideration towards crop/species/genotype based specificity for water need with higher water use efficiency (WUE) and productivity (WP) following application of varied management options. This will in turn help in plugging shortfalls in crop production especially in the field crops.

Technological intervention for water management

There is a need for evaluating existing technologies on water management for developing the efficient tactics or practices labelled as appropriate technology interventions for their sustainable farm level impact in India. These include precision land levelling, no-till or reduced tillage systems, furrow irrigated raised bed (FIRB) planting or broad bed furrow (BBF) planting systems, management of soil cover and crop diversification, etc. which have proven their tremendous potential for efficient water use (and WUE) for sustainable farming systems[1,10–12]. Roughness of the soil surface has a definite influence on crop stand, agriculture operations, drudgery involved, aeration, energy use, and grain yield mainly through adverse nutrient–water interactions. In India, the general practices of land levelling used by farmers is either through use of (draft animals and small tractor drawn) plankers or by (4-wheel tractors drawn) iron scrappers/levelling boards (as an usual practice in Indo-Gangatic Plains of India). These are not perfect as they involve low yield at the cost of more water consumption[13] and less input use efficiencies (IUE). Here for achieving a better crop stand, laser land levelling is handy especially in intensively cultivated irrigated agriculture while saving precious irrigation water (reinforcing RC in water and improving IUEs) and boosting crop productivity in India (more so in regions where land consolidation is in vogue). These novel technological interventions are discussed in the following sections.

In addition to conserving both soil and water, for example, seedling planted by zero-till drill performed better on a well levelled field (or a laser leveller plots) due to better seed placement (at a certain soil depth in the vicinity of adequate moisture), germination and uniform distribution of irrigation water and plant nutrients[6], compared to unlevelled or fairly levelled field. Zero tillage also allows timely planting of wheat by enabling uniform drilling of seed, saving of water (following less tillage), improving fertilizer use efficiency and increasing yield up to 20% (ref. 14). Recent trial on zero till seed drill highlights the importance of use of machinery for higher farm income and input use efficiency[2]. Similarly, the importance of no-till system in India is quite apparent in terms of emission of greenhouse gases (GHGs) and carbon sequestration[15]. It is computed that for each litre of diesel fuel consumed, 2.6 kg of CO_2 is released to the atmosphere. Assuming that 150 litres of fuel per annum per tractor per hectare is used for irrigation purposes in conventional system, it would amount to nearly 400 kg CO_2 being emitted per annum per hectare. Therefore, no-till system has proved to be a significant step in tactical water conservation and its management in agriculture, as has been amply demonstrated from many field trials and crops[16,17]. No tillage and no-till sowing (also a cost cutting option) is being accepted in the farming community as it has assisted in desired growth in farm income through saving on irrigation water, fuel, labour, production cost, energy, etc., along with its positive effects on soil health and environmental quality benefits[16,17].

Another tactical approach, where the crop is sown on ridges or beds about 15–20 cm height from the soil surface, is called FIRB planting systems. The raised beds are 40–70 cm wide. Some broad beds are 1 m wide depending on the crops, as the major concern here is enhancing the productivity per unit space and saving precious irrigation water. A similar situation is also experienced in wheat growing areas of NW Mexico. Potential advantages in terms of agronomic benefits of these raised beds or FIRBs of convenient sizes/widths include both biophysical means through reduction in farm expenditure, completion of sowing on time, improved soil structure as a result of reduced compaction through controlled trafficking, and less water logging (better surface drainage) and timelier machinery operations. There are several reports of successful endeavours through reduced irrigation with respect to its quantity or time or both, with similar or higher yields of wheat on beds as compared to conventional tilled wheat. A typical irrigation savings ranging from 18% to 30–50% has been observed from farmer participatory trials and researcher plots across the Indo-Gangetic Plains (IGP)[18–20]. Trials by farmers and researchers in IGPs in India show irrigation water savings of 12–60% for direct seeded (on raised beds, direct seeded raised bed, DSRB) and transplanted (seedlings on raised beds, transplanted raised bed, TRB) rice on beds, with similar or lower yields for TRB compared to puddled flooded transplanted rice (PTR)[21]. Reduced tillage and direct seeding with permanent beds decrease costs of labour, diesel, and machinery and thus offset the costs of initial bed formation and its maintenance. Moreover, raised bed planting out-yields flat planting by 18.8% and increases WUE in chickpea[2,10,11] tremendously. Similarly, ridge planting has similar beneficial effects over flat plating[2,12]. Micro-irrigation through sprinkler irrigation also proved better than surface irrigation, in terms of both seed yield and WUE in chickpea[14,22].

Under sustainable practices (conservation agriculture), soil cover is maintained by retaining crop residues or maintaining these as a protective soil cover by stubble cutting at a specific height (20–30 cm) or keeping crop residues or mulches on soil surface[2]. On the contrary, drop in soil organic carbon (SOC and soil organic matter, SOM) as a result of limited/no return of organic biomass is universally considered as one of the key factors for ecosystem degradation and un-sustainability of the cropping systems[23]. Inappropriate crop residue management (by burning or destruction/removal) due to inadequate *in situ* recycling[24] leads to loss of substantial amount of soil nutrients, viz. N, P, K and S. Moreover, it also contributes to global NO_2 and CO_2 budget[25] and destruction of beneficial micro-flora of the soil, although there is substantial amount (80.12 million tonnes per annum) of crop biomass or residues available[26] for recycling especially in rice–wheat system of IGP region. Similarly, growing a cover crop or simply crop diversification/sequence or cafeteria approach under ITP improves the stability of water utility system and agro-ecosystem biodiversity. An inter-cropping of legume in cereals grown with wider row spacing has shown reduction in nitrate leaching[27]. This is possible again due to integration of diverse factors with soil moisture availability. Therefore, adopted RC system should amalgamate and reciprocate tactical water management approach for sustainable farming (and farm income). This should be the thrust area of future farming[13] for both under tropical and subtropical condition where oxidation of SOC causes adequate loss/depletion of both soil nutrients/carbon resulting in deteriorating soil fertility (and crop productivity) status.

Notwithstanding the proven importance of these systems, precision water supply does have a role in strategic water management under field condition (both under normal/undulated land configurations). Precision technologies involving drip-irrigation techniques are used for efficient management of both nutrient and water very precisely near the rhizosphere of crop plant with established advantages like enhanced conveyance and WUE through direct supply of water (could also use saline water up to 8–10 m mhos/cm of electrical conductivity) to the root zone of plants. In this era of life-saving/supplementary irrigation (mostly adopted in water deficit areas under rainfed/dryland agro-ecosystems), there is a larger need to apply both fertilizers and water through trickle drip especially at critical stages to improve productivity of crop, water and nutrient[8] (Table 1). A single irrigation (20 mm in 5 splits) through drip-fertigation with half of N and K fertilizers at branching of a long duration pigeonpea, produced significantly higher (20%) grain yields and economic return over rainfed crop[1,2,4]. Similarly, an experiment carried out at ICAR-Indian Institute of Pulses Research, Kanpur during 2010–2014 also revealed the compatibility of drip-fertigation with that of intercropping in a wide spaced pulse crop – a long duration pigeonpea. Results also revealed that drip-fertigation in pigeonpea + urdbean produced significantly higher total pigeonpea grain yields (14%) compared to the sole crop. Similar higher values of WUE and WP with low water use were evident in case of above intercropping over the sole crop (Figures 1 and 2). Actual pigeonpea-based system yield (3322 kg/ha) and monetary net return were also higher with urdbean/jowar based intercropping system with trickle drip-fertigation once or twice during the entire crop growth of long duration pigeonpea (depending on rainfall). Therefore, single or a couple of life-saving irrigation(s) at the most critical stages (in the absence of rainfall events) was crucial for both productivity and profitability of most pulse crops[1,2]. The study also confirmed that differential irrigation schedules based on the ratio of irrigation water to cumulative

Table 1. Water productivity ($g\ m^{-3}$) of rice and wheat – a comparison among different countries[2,29]

Country	Rice	Wheat
China	1321	690
USA	1275	849
Australia	1022	1588
India	2850	1654
World	2291	1334

pan evaporation (IW/CPE based with varied irrigations frequencies of 1–4 numbers) could not influence pigeonpea productivity under the existing agro-climatic conditions in IGP (Figure 3). These micro-irrigation strategies, thus, could serve as a sort of control (in the context of irrigation) mechanism for life-saving irrigation in terms of realization of crops' potential yield[12,28] in time to come (Table 2). Moreover, as majority of our crops and their water use are dependent on rainfall, water conservation and utilization[22] requiring scientific management of water, the most precious resource. Its infield utilization plays a key role for both scaling and stability in crop productivity (strategic technology under ITP).

In the case of chickpea, the major pulse crop of India with almost 50% contribution in terms of production, irrigation at both pre-plant and pre-podding stages raised the grain yield to the tune of 77% over no irrigation[14]. Although under rainfed conditions, external use of anti-transpirant significantly enhanced seed yield (33%) over control, no such improvement was recorded under irrigated condition[14]. Other water-saving technologies, viz. precision irrigation through micro-irrigation (trickle drip, sprinklers and other devices used for controlled irrigation), rainwater harvesting, weather-based irrigation controllers are really a boon for sustained production of field crops. Therefore, minimizing losses due to evaporation, runoff or subsurface drainage should be given major emphasis to secure optimal irrigation and water use efficiency resulting in maximizing production. Since altering existing irrigation systems could be a costly (and unviable) proposition, conservation efforts more often concentrate on maximizing the efficiency of the existing (irrigation) system. These include several measures such as chiselling compacted soils, making furrow dikes to prevent runoff, and using rainfall and soil moisture sensors to optimize irrigation schedules. In addition, infiltration basins, also known as recharge pits, capture rainwater and recharge ground water supplies. Therefore, use of these management practices in an integrated manner (ITPs) reduces both water and soil erosion caused by storm water runoff. Further, it improves water quality in nearby surface water.

Conservation of natural resources includes conservation and management of water (as the key input for raising crops many a time without cultivating the soil) while retaining crop residues on the soil surface. Thus, altering land configuration like, technology-backed land preparation through precision land levelling, and bed and furrow configuration for planting crops could improve water management further[23,29]. Therefore, appropriate and strategic management of water (and associated soils) permits

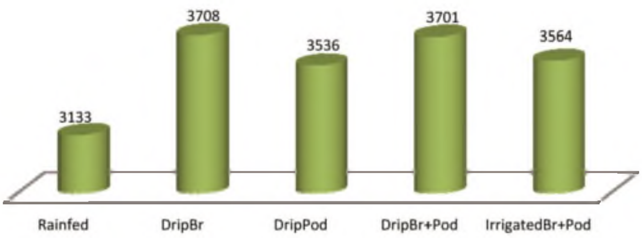

Figure 1. Productivity potential (seed yield, kg/ha) of pigeonpea through microirrigation (drip-fertigation)[4]. Drip^{Br}-drip irrigation (DI) at branching, Drip^{Pod}-DI at pod development, Drip^{Br+Pod}-DI at branching + pod development, Irrigated^{Br+Pod}-furrow irrigation at branching + pod development (ICAR-IIPR, Kanpur 2012–13).

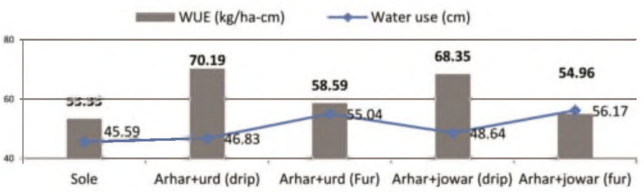

Figure 2. Water use and its efficiency as influenced by drip-fertigation on pigeonpea based cropping system (ICAR-IIPR, Kanpur 2013–14).

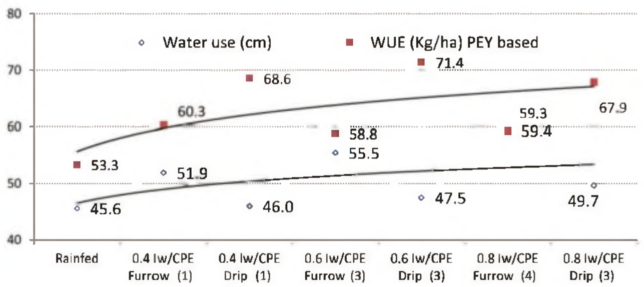

Figure 3. Logarithmic trend of water use and its efficiency in pigeonpea based system under irrigation frequency (ICAR-IIPR, Kanpur 2013–14) IW/CPE: ratio of irrigation water and cumulative PAN evaporation, PEY: pigeonpea equivalent yield, Drip/furrow with number in parentheses indicates irrigations applied.

Table 2. Potential and attainable yields (kg/ha) of some of rainfed crops[30]

Crop	Potential yields attainable	Actual yields	Difference	Quotient
Sorghum	4560	902	3658	5.0
Maize	3870	2062	1808	1.9
Pearl millet	2870	906	1964	3.2
Groundnut	2590	1171	1419	2.2
Soybean	2850	1089	1761	2.6

Table 3. Water requirements of major food crops[6,14]

Crops	Duration (days)	Water requirements (cm)
Rice	100	95–100
Ragi	105	45–50
Pulses	70	20–25
Pulses (long duration)	150–250	30–50
Maize	100	40–45
Cotton	165	60–75
Groundnut	105	60–65
Sugarcane	300	225–250

RC for higher farm production without markedly altering or disturbing the soil, while protecting it from the processes that contribute to soil degradation (mostly by its physical processes such as erosion, compaction and aggregate breakdown etc). As reflected from developments worldwide, attempts to promote RC globally are underway as it emerges as a major way for transition to the sustainable intensification in the crop production systems. Application of RC also conserves, improves and makes more efficient use of natural resources in the course of its integrated management in combination with desired external inputs[5,28].

Are pulses the candidate crops for tactical water management?

Yes. These belong to short, medium as well as long duration groups matching as sandwich crop(s) through their introduction in cereal/oilseed-based cropping diversity. Being grown mostly under rainfed conditions (>85%) and requiring less water (Table 3), these upland crops could be a boon to both the soil and environment. With one or two life-saving supplementary irrigations in the time of need (in absence of rainfall events, if required, during critical stages), these crops practically perform even better compared to solely rainfed crops. Being suitable for diverse conditions, these could fit in cropping/farming systems adopted by marginal and smallholder farmers for satisfying the local/native requirements. These also have proven capability to grow on mountain slopes to reduce soil erosion. Protein (an important constituent of food) in their seeds (21%) compares well with other food crops. These also have diversity in food supplementation through dhal (dry, dehulled, split seed used for cooking), vegetables (green seeds), animal feed (crushed dry seeds), fodder (green/dry leaves), fuel wood and wood to make huts, baskets, etc. (from its stalks) and insect culture (the lac-producing insect). Therefore, there is scope for large improvements in pulses yield grown even under rainfed/dryland conditions (known to be water deficit condition). The potential attainable yields and the actual yields accrued for some of the dryland crops are presented in Table 2. Thus, with advanced level of management and moderate input levels, grain yields can be improved substantially (two to five times the current levels). Specialized dry land management practices, such as water harvesting and reduction of soil moisture loss, can also lead to increase in yields[30] or substantial economic benefits. It is quite pertinent to mention here that due to consistent efforts by both centre and states, the country has produced 23.13 million tonnes of pulses (from 29.46 million ha with a productivity of 779 kg/ha) in 2016–17 right from 13.30 million tonnes (from 22.25 million hectare area with the productivity of 598 kg/ha) in 1993–94. Again, it is estimated that the country will produce 25.23 million tonnes of pulses during 2017–18 (at a yield level of 811 kg/ha). Strategically, these pulse crops really have the potential to be promoted at all the stakeholders' level, and the time is not far from achieving self-sufficiency in pulses (targeting at 32 million tonnes by 2030).

Tactical water management – case studies

Concerted efforts put in over the past decade and beyond by the rice–wheat consortium (RWC) for IGP, a consultative group initiative and the national research system of Bangladesh, India, Nepal and Pakistan have conclusively proved wider adoption of RCTs for conservation and management of water, mainly for sowing wheat. According to a recent assessment made in more than 5 million ha area, it was ascertained that wheat was sown using a no-till seed drill in the region for conserving soil moisture. Experiences from Punjab, Sindh and Baluchistan provinces of Pakistan confirmed that with zero-tillage technology, farmers were able to save at least one or two irrigation costs in addition to normal land preparation costs by about Rs 2500/ha and reduce diesel consumption by 50–60 l/ha (ref. 5). In addition, rainfed semi-arid and arid regions are often characterized by more variable and unpredictable rainfall, structurally unstable soils and low overall productivity. Here, there is a need to identify locations where reduced tillage can be combined with availability of even moderate amount of residues to enhance soil quality and conservation/use of rainwater.

However, approach towards water supply, conservation and its management under irrigated ecosystems is different as these regions are facing increasing production costs, declining resource quality, declining water table, stagnating productivity and increasing environmental pollution (more evident in NW India where green revolution started). Similarly, developing and promoting strategies to overcome the constraints responsible for continued low cropping system productivity in the eastern region (covering eastern UP, Bihar and West Bengal) have been a major concern. This is mainly attributed to unhealthy water management practices adopted as evident from many field experiments. Therefore, laser land levelling, zero-till planting of wheat and raised bed planting are few other technologies being increasingly adopted by farmers of the region for efficient use of stored ground water.

Although water management does not lead in RC from a short term perspective, yet from a long-term perspective, no tillage and crop residues/cover (accompanied with it) will definitely improve RUE that becomes evident only slowly, and benefits come about only with time and not early in the years/season. Evaluating the impact of appropriate water management practices therefore, must have a long-term perspective. A typical example of such effect noticed on a large scale includes direct seeding of rice or transplanting rice under unpuddled condition. This aerobic rice culture is becoming popular and spreading in IGP, which has substantial potential for minimizing soil health hazards, the cost of production and the negative impacts on crops. As a result, significant reduction in GHG emission through lower CH_4 emission from paddy fields was also observed due to adoption of water (the major resource) conservation technologies (through growing aerobic rice) especially in rice–wheat production system[16,31–33].

Comparing the various types of irrigation

There is always scope for scaling WUE and WP following appropriate irrigation method(s) for a given crop and ecosystem. Water use by micro-irrigation (drip or sprinkler) system is always less (30–50%) compared to flood or other surface irrigation methods. Moreover, application of water through subsurface drip is so far the most efficient one practised in many field crops. New molecules (certain gel or chemicals) or nanoparticles used with several motives (known for herbicidal, fertilization or pesticidal properties or enhancing adsorption or absorption efficiency) are known to be the future technologies or efforts as far as higher factor productivity and input use efficiency are concerned. In most cases, it is observed that these are efficient technologies because they result in increasing the efficiency in input (water) application (Figures 2 and 3). Combined with fertilizers or other micro-molecules, these enhance application efficiency[2]. However, applications of these improved technologies alone do not raise substantial productivity (Figures 4 and 5). For example, drip-irrigation results in significant increase in WUE compared to furrow irrigation (Figure 1). However, drip-fertigation results in increase in yield (Figures 2 and 3) because addition of fertilizer molecule supplements nutrition both in crop and soil. It results in optimum crop performance through its accelerated growth and development. Moreover, many other intricate issues also decide the efficiency of certain methodology for irrigation. Surface/normal flood irrigation on a laser levelled plot has much higher efficiency and crop performance (both in terms of WUE and yield) compared to unlevelled or undulated land. Therefore, every system has its pros and cons, and needs appropriate application strategy. Besides cost effectiveness, the optimum technology is that which increases both conveyance/application efficiency and output efficiency. If it amalgamates other processes or application in an integrated manner, is an added advantage in terms of cost saving and higher outputs[2,4].

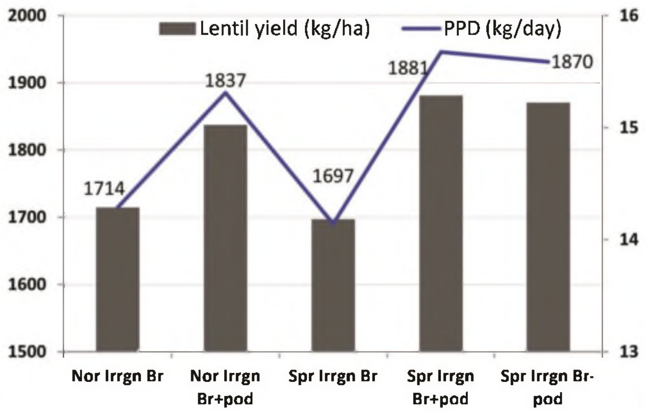

Figure 4. Effect of irrigation methods (nor-flood and Spr-sprinkler) on lentil grain yield and productivity per day (kg/ha), Br, pod and Br-pod are branching, pod development and branch to pod development respectively (ICAR-IIPR, Kanpur 2016–17).

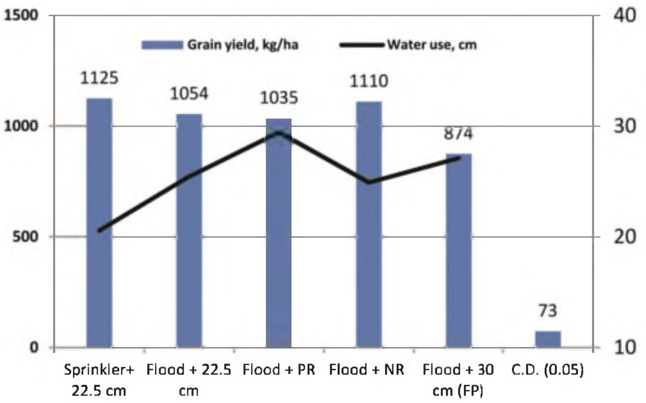

Figure 5. Effect of irrigation methods on mungbean grain yield and water use (PR, paired row planting; NR, normal row of 22.5 cm spacing; FP, farmers' practice) (ICAR-IIPR, Kanpur 2016–17).

Constraints in management of water

Managing water for RC is a complex process, as it requires an understanding of the system as a whole. Surface maintained crop residues or residue retention[24] act as mulch against absorption of heat that reduces losses in soil water through evaporation and thus maintains a moderate soil temperature regime. However, at the same time, these could offer an easily decomposable source of carbon (organic matter) for harbouring undesirable pest populations or might alter the ecology of the system in some other way[9]. Therefore, adaptive strategies for CA systems are highly site-specific, and learning across the sites are immensely helpful in understanding the effectiveness of certain technologies or practices in a set of situations. This learning process will greatly accelerate building a knowledge base for resource management on sustainable basis, as managing water for RC is the main objective of such scientific interventions. Thus, the sole aim of tactical management of water for conserving natural resources is to bring all the stakeholders to have the information/experience backups for mediating in all endeavours towards sustainable development goals

(SDG). This is needed for realizing production sustainability through conservation agriculture[7] although it has inherent constraints (as under) which calls for accelerated efforts in developing, standardizing and popularizing different management tactics.

- RC or CA poses a challenge for both the farmers and scientific community to conquer the past mindset and explore opportunities for improving our natural resources.
- Since tactical water management for RC determines the whole system performance, it requires a better understanding of basic processes and component interactions.
- Appropriate water management many a time does necessarily require use of some machinery aimed at diverse RC strategies through a range of crop and cropping systems, permanent bed and furrow planting systems, harvesting operations to deal with crop residues, etc.
- CA is now regarded as a route to sustainable agriculture. Tactical water management under CA uses precision agricultural principles. Thus, it should be invariably highly productive and remunerative.
- Managing CA system is highly knowledge-intensive and invariably requires skills/expertise which are many a time inadequate in major field crops.
- These deficiencies will call for greater capacity building to address problems in terms of a systems perspective. Moreover, researchers should be able to work in close partnership with the clientele (the farmers and other stakeholders)[17]. This partnership should also strengthen knowledge and information sharing mechanisms.
- Water and nutrient uptake and mineral cycling are dependent on tillage, i.e. soil traffic and other factors that ultimately influence the depth of root penetration and distribution of root system and in turn the productivity (biomass/grain yield). Therefore, these should be taken on a holistic approach.
- Building a research-based systems perspective has been fundamental in generating and promoting water management-based RCTs. These also include system interactions and consequently develop management strategies. This is a slow process and may require considerable time.

Therefore, resource conservation has emerged as a way for transition to sustainable intensification of crop production systems. This is established over the past 2–3 decades both within and outside the country. Since CA permits management of soils and water for agricultural production without excessively disturbing the soil, it should invariably protect itself from processes like, erosion, compaction, aggregate breakdown, etc. that contribute to degradation/de-conservation. Therefore, tactical water management has assumed significance now than ever before in view of the widespread natural resource degradation leading to higher production costs, untenable resource use, environmental problems, and health of agro-ecosystems. Attempts are underway to promote these globally. It was reflected from developments worldwide wherein scientists, private sector stakeholders, decision makers and above all farmers joined together and interacted to share information and experiences for future research and development. Water is likely to be deficient in many nations needing appropriate policy decisions for its ultimate conservation and distribution both at micro-(farm, village or village cluster) and macro-level (watershed, district/zone or even for the state/country). So, appropriate and strategic planning based on land parameters, agro-climate and ecosystem services including future demand for water is the key in achieving the SDGs related to water. Since better management of water and other inputs is possible through effective and appropriate conservation tactics and technologies, efficient water use is the key to sustainability and tactical management of it is the key to resource conservation.

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