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Effect of precision land leveling and Zinc bioavailability: Water use, productivity and input use efficiency in transition from flooded to aerobic rice (*Oryza sativa*)

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Abstract
The objective of this study was to establish an understanding of how aerobic rice yield and input use efficiency can be improved and how land leveling and crop establishment practices can be modified to be more efficient in water use through precision- conservation crop management techniques. To conducted a farmers participatory field experimentduring 2009 to 2011 for quantify the benefits of alternate land leveling (precision land leveling),crop establishment (aerobic rice planting) techniques alone or in combination (precision-conservation) and zinc bioavailability in terms of crop yield, water savings, and nutrient use efficiency of aerobic rice production in western Uttar Pradesh.
Zinc bioavailability is a function of both soil and plant factors that can be altered by water management, particularly in relation to conditions in the rhizosphere. Agronomic biofortification strategy appears to be essential in keeping sufficient amount of available Zn in soil solution and maintaining adequate Zn transport to the seeds during reproductive stage. Greater biofortification of the grain Zn derived from foliar applications than from soil, agronomic biofortification would be a very attractive and useful strategy in solving Zn deficiency related problems effectively. Potential agronomic management practices in aerobic rice production systems are discussed, with an emphasis on their roles in improving bioavailability of Zn. Addition of Zn fertilizers by soil or foliar application have been shown to increase Zn concentration in grain. Keeping these points in mind, this paper describes the current knowledge of precision land leveling and Zn bioavailability.

Keyword: Precision land leveling, productivity, profitibility, input use efficiency

1. Introduction

Changing global climatic patterns coupled with declining surface and ground water resources (Hira 2009) [15] have put agriculture on the back foot. The most densely populated Asian countries consume and grow staple rice mainly under submerged conditions (Kukal and Aggarwal 2003) [24] leading to its lower irrigation water productivity (WP_{IW}) (Humphreys *et al.* 2007) [17]. Since rice is one of the biggest users of world's developed fresh water resources (Tuong and Bouman 2003) [6], the agricultural scientists are facing a big challenge to improve its WP_{IW} so as to check the decline of surface and ground water resources. Precision land leveling and zinc bioavailability are being developed and evaluated for their suitability both in submerged and aerobic system of rice production (Humphreys *et al.* 2008) [18]. Precision land-leveling has been widely adopted by producers throughout the western Uttar Pradesh crop producing area because this practice provides producers more efficient methods to manage irrigation water. Precision land-leveling offers benefits other than water savings. Decreased tillage and increased harvest efficiency can be achieved because precision land leveling reduces the area consumed by levees (Naresh *et al*., 2013) [26, 27]. Furthermore, because flooding in precision-leveled fields is more uniform and more timely, improved nutrient uptake and weed management result in increased yields (Naresh *et al*., 2013) [26, 27]. Though the benefits of precision land leveling are numerous, problems often arise after land-leveling is conducted. Walker *et al*., 2003 [40] reported that extractable concentrations of P, K, and Zn, as well as total N were less in cut areas compared to fill areas across a wide range of soils cropped to rice in western U.P. In addition, rice yield in the cut areas, i.e., areas where the topsoil has been removed, was typically less than in fill areas (Walker *et al*., 2003) [40].

Precision land-leveling also increased near-surface spatial variability among soil chemical, physical, and biological properties in Arkansas Brye *et al*., 2004 [7].
Zinc deficiency is a widespread problem in plant cultivation. It is estimated that half of cereal crops worldwide are grown on Zn deficient soils (Cakmak 2008) [8]. Some cereal crops (rice, wheat, etc.) which serve as staple food, are deficient in Zn (Fageria *et al*. 2002) [10]. This trace element is essential for crop productivity and nutritional food quality. Zinc deficiency in rice decreases tillering, increases spikelet sterility and time to crop maturity. Soils do not supply sufficient Zn which result in a yield reduction and poor plant quality Plants with Zn deficiency exhibit intervenal chlorosis and necrotic spots on the leaves (Alloway 2008) [2]. Moreover, low concentrations of Zn can cause leakage of cations, *e.g.* K+ from the root system, so Zn deficiency can disturb the operating efficiency of the root system (Pinton *et al.*1993) [32]. Foliar spray could be used effectively to overcome the problem of micronutrients deficiency in sub-soil Singh *et al*., 2012 [38]. Changes in crop production technology often present opportunities to develop fertilization strategies that may reduce production costs associated with product application or materials, improve nutrient delivery to plants, or provide flexibility in the timing of crop inputs. Zinc concentration in plant tissue is determined by the bioavailability of Zn in soil and plant uptake. Balanced fertilization of a crop requires supply of major, minor and micronutrients. Plants have specific nutrient requirements which are based on crop species and cultivars under a specific set of soil conditions. So better matching of nutrient supply with crop demand is often considered a basis for improving and stabilizing yield, in irrigated as well as rain-fed systems Rehman *et al*., 2008 [34]. Micronutrients in present day agriculture play an important role to enhance the agricultural productivity. Micronutrient deficiencies are becoming serious because of escalated nutrient demand from more intensive and exploitative agriculture, coupled with use of single-nutrient fertilizers and low amounts of organic manures. Zinc (Zn) nutrition and the transition from flooded (anaerobic) rice production to irrigated dry land production (aerobic) of rice as advocated for areas where water shortages are of concern (Bouman *et al*. 2007) [6].
Zinc plays a role both in determining human health and in crop productivity in areas where aerobic rice is advocated. Biofortification of Zn in staple food crops such as rice can be achieved through use of agronomic practices, and is considered a promising and cost-effective approach to combat malnutrition (Hotz 2009) [16]. The efficacy of this approach has been supported by recent research in Bangladesh where Zn biofortification in rice substantially decreased Zn deficiency in human body by improving Zn adequacy in the dailydiet (Arsenault *et al*. 2010) [4]. Traditionally, about 75% of rice is produced under flooded (anaerobic) conditions. In many agricultural regions where fresh-water resources are scarce, the traditional lowland system with flooded fields is being replaced by an aerobic system (Fig. 1). The distinguishing feature of aerobic production systems is that crops are direct seeded in free draining, nonpuddled soils where no standing-water layer is maintained in the field, and roots grow in a mainly aerobic environment (Bouman *et al*. 2007) [6]. Cropping systems based on aerobic rice are grown commercially in Brazil (Pinheiro *et al*.2006) [33]. Aerobic rice production is also being intensively studied in India, Australia, and parts of Southeast Asia (Bouman *et al*. 2007) [6]. The new cultivation system required the development of suitable aerobic rice cultivars by crossing lowland with upland varieties. Ongoing research on production systems for aerobic rice has mainly focused on the water and nutrient use and yield potential of the aerobic rice cultivars (Matsuo *et al*. 2010; Kato *et al*. 2011) [25, 22].

Fig 1: Cultivation shift from flooded to aerobic rice production system

Zinc deficiency is frequently reported not only in traditional lowland rice (Dobermann and Fairhust 2000) [9], but also in upland or aerobic rice production, such as on calcareous soils in China (Gao *et al*. 2006) [12]. Zinc solubility and availability to plants differs between flooded soils and aerobic soils. If the conversion of flooded to aerobic rice production occurs in areas where Zn availability to the crop is likely to be at risk, there is a danger of reducing productivity not only because of less available water but also because of Zn deficiency. For example, Wang *et al*. (2002) [39] Naik *et al*. (2007) [29] reported that Zn deficiency symptoms were more pronounced in plants grown on aerobic soils as compared to anaerobic soils. An understanding of Zn behavior in soil and plants under different water regimes is therefore required to assess changes in bioavailability during and after this conversion. In this context, “bioavailability” refers to Zn availability to the crop, which is usually a small fraction of total soil Zn. Bioavailabilty of Zn may be reduced to a level where it would not become a direct production constraint to the rice crop, but the grain Zn concentration may decline, thus compromising nutritional quality. As a result, the introduction of aerobic rice on low Zn soils places the problem of Zn deficiency in rice in a new perspective (Gao *et al*. 2006, Ghulam *et al*., 2011; Wei *et al*., 2012; Phattarakul *et al*., 2012) [12, 11, 44]. Zinc bioavailability in soils is primarily regulated by adsorption - desorption reactions and solubility relations between the solution and solid phases (Fig. 2). Soil properties including the pH, redox potential, organic matter, pedogenic oxide, and soil sulfur content exert the most significant influence on the adsorption–desorption and dissolution–precipitation reactions of Zn in soils and thus regulate the amount of Zn dissolved in the soil solution (Alloway 2009) [3]. Some of these factors are expected to change after a shift to aerobic cultivation. Therefore to evaluate possible precision land leveling and mechanisms explaining the mobilization of Zn in the soil and the uptake of Zn by the plant and explore available options for crop management to improve both quantity and nutritional quality of rice produced and water use, productivity and input use efficiency.

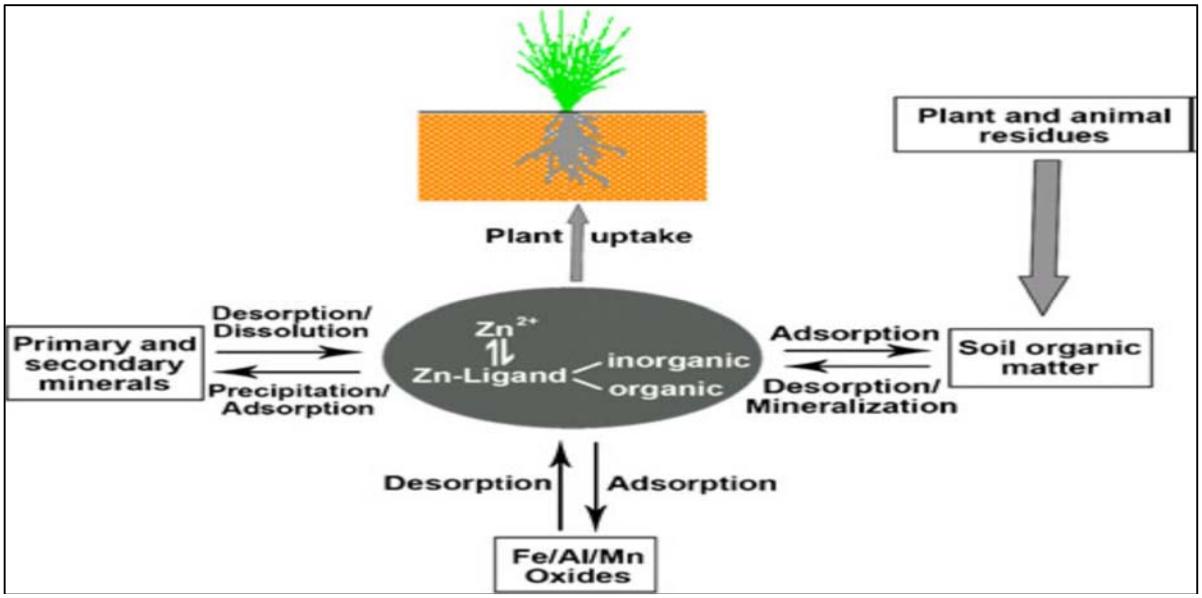

Fig 2: Soil processes affecting Zn bioavailability in soil solution

2. Materials and Methods

An experiment was conducted in District Ghaziabad in farmers participatory mode in the juridiction of Ch. Charan Singh University Meerut (U.P.), India, (28°40′07″N to 29°28′11″N, 77°28′14″E to 77°44̀18″E, 237m above mean sea level) during 2009 to 2011 and was designed as a farmer-managed with a single replicate, repeated over many farmers. The experimental design was split plot design in which farmer as a replicate commencing with kharif in 2009.The plots consisted of precision land leveling/crop establishment as main plot and fertilization as sub-plot treatments. The climate of the area is semiarid, with an average annual rainfall of 665 mm75–80% of which is received during July to September), minimum temperature of 4 ^{0}C in January, maximum temperature of 41 to 45^{0}C in June, and relative humidity of 67 to 83% throughout the year. The soils are generally sandy loam to loam in texture and low to medium in organic matter content. Soil with a bulk density of 1.47 Mg m^{-3}, pH=7.4,total N =0.84 g kg^{-1},Olsen P =21 mg kg^{-1},and K =180.5 mg kg^{-1} and had 0.54 % organic carbon. Groundwater pumping was the pre dominant method of irrigation in western UP. The treatment details is given hereunder,

2.1 Precision land leveling/crop establishment

T_1 - Precision land leveling with wide raised Beds (PL WB)
T_2 Traditional land leveling with wide raised Beds (TL WB)
T_3 - Precision land leveling with narrow raised Beds (PL NB)
T_4 Traditional land leveling with narrow raised Beds (TL NB)
T_5 - Precision land leveling unpuddled with flat Beds (PL FB)
T_6- Traditional land leveling unpuddled with flat Beds (TL FB)
T_7 -Traditional land leveling puddled with flat Beds (TL FPB)

Fertilization

F_1 - Precision land leveling with recommended dose of NPK (PL WB + RNPK)
F_2 - Precision land leveling with recommended dose of NPK +Zn (soil appli.) (PL WB + RNPK+Zn)
F_3 - Precision land leveling with recommended dose of NPK +Zn (Foliar appli.) (PL WB + RNPK+Zn)
f_4 - Traditional land leveling with recommended dose of NPK (TL WB+ RNPK)
F_5 - Traditional land leveling with recommended dose of NPK+Zn (soil appli.) (TL WB+RNPK+Zn)
F_6 - Traditional land leveling with recommended dose of NPK+Zn (Foliar appli.) (TL WB+RNPK+Zn)
F_7 - Traditional land leveling without NPK Zn (Control) (TL FB + N_0 P_0 K_0 Zn_0)

2.2 Precision Land Leveling (PL)

For laser-assisted precision land leveling, the land was first plowed at the optimum moisture level (field capacity) with a harrow/cultivator for pulverization and was leveled using a laser-equipped drag scrapper (Trimble TM, USA) with an automatic hydraulic system attached to a 50-60 HP tractor. Before running the laser leveler, the field was surveyed at 3-m distance to record the elevation and the elevation points were averaged to know the desired elevation for leveling the field. The average elevation value was entered into the digital control box for controlling the scrapper at the desired elevation point (Naresh *et al*., 2011) [26] and the tractor was run across the field till the desired elevation was achieved throughout the field. For the traditional land leveling treatment, the field was first ploughed as described above and was leveled using an iron plank attached to a tractor and was dragged across the land surface.

2.3 Traditional Land Leveling (TL)

After ploughing with a harrow/cultivator for pulverization of the field at the optimum moisture level, an iron scraper attached to the tractor was moved on the land surface on a visual elevation level. After the cuts and fills of soil, a wooden planker attached to the tractor was moved across the field to smooth the land surface.

2.4 Seeding and Seed Rate
"Sugendha -4" rice cultivar was seeded in the last week of June and a seed rate of 25 kg ha^{-1} was used in all treatments. The bed: furrow width at top was kept at 37 cm: 30 cm having two rows of transplanted rice and the depth of the furrow was kept at 15 cm for narrow beds and furrow width at top was kept at 107 cm: 30 cm having six rows of transplanted rice and the depth of the furrow was kept at 12 cm for wide beds. The plant population was maintained equal in flat as well as raised bed planting.

2.5 Fertilizer Application
Fertilizer was applied at the rate of 120-60-40 kg NPK ha^{-1}.Whole of the phosphorus, potash and 1/3rd of nitrogen was applied at sowing. Remaining nitrogen was applied in two doses at tillering and panicle initiation stage.$ZnSO_4$ (21% $ZnSO_4$) application at the rate of 25 kg ha^{-1} as basal dose, foliar application of 0.5 % Zn solution at 15, 30, 45, 60 and 75 days after transplanting.

2.6 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 x t (1)

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

where F is flow rate (l s^{-1}), t is time (s) taken during each irrigation and A is area of the plot (m^2). Rainfall data was 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 and rainfall (I+R).Water productivity (WP_I+$_R$) (kg grains m^{-3}ofwater) was computed as follows (Humphreys *et al*., 2008) [18]

WP_{I+R} =grain yield (kg ha^{-1})/[irrigation water applied (m^3)+rainfall received by the crop (m^3)]ha^{-1}.

2.7 Soil sampling and analysis
Soil samples were collected at the start of the experiment from 0 to 15-cm soil depth using an auger of 5-cm diameter. Each sample was a composite from three locations within a plot. The freshly collected soil samples were mixed thoroughly, air-dried, crushed to pass through a 2-mm sieve and stored in sealed plastic jars before analysis. Olsen P (0.5 M $NaHCO_3$ extractable) and NH_4OAc–extractable K were analyzed using the methods described by respectively. Soil organic C was analyzed by the Walkley and Black method. The samples for determination of soil physical properties (soil aggregates, mean weight diameter of aggregates) were collected at the start of the experiment and after the harvest of each crop. Soil aggregation and mean weight diameters of aggregates were analyzed using the wet-sieving method [Yoder method]. Bulk density was measured to a depth of 20-cm at intervals of 5-cm soil depth using the core-ring method and one core per stratus of each plot was collected and the samples were oven-dried for 48 h at 105 ^{0}C, weighed and bulk density calculated according to (Blake and Hartge1986) [5]. Soil moisture by gravimetric method (Jalota *et al*., 1998) [20], soil strength by cone penetrometer. The bulk density were measured at the onset of the experiment and after the 3 years of study.

2.8 Plant Analysis and Nutrient Uptake
The plants measured for growth and yield were used for analyzing the N, P and K content in grain and straw. The grain and straw samples were dried at 70 °C in a hot air oven. The dried samples were ground in a stainless steel Wiley Mill. The N content in grain and straw were determined by digesting the samples in sulfuric acid (H_2SO_4), followed by analysis of total N by Kjeldahl method using a Kjeltec autoanalyser. The P content (grain and straw) was determined by vanadomolybdo- phosphoric yellow colour method and the K content both in grain and straw was analysed in di-acid (HNO_3 and $HClO_4$) digests by Flame Photometeric method. The uptake of the nutrients was calculated by multi-plying the nutrient content (%) by respective yield (kg·ha^{-1}) and was divided by 100 to get the uptake values in kg·ha^{-1} (Wu *et al*., 2010) [43]. The uptake in grain and straw was summed to get the total uptake of nutrient·ha^{-1}.

3. Results and Discussion
3.1 Yield attributes
Yield attributes were also influenced significantly with crop establishment and zinc. Number of panicle per square meter, which contributes to the economic yield, significantly influenced with both the land leveling and nutrients. Maximum (374.0) and minimum (225.08) panicle/m^2 was recorded precision land leveling with wide raised beds planting and with the application with no application of NPK +Zn (Table 1). Number of panicle bearing tillers/m^2 was also influenced significantly with precision land leveling and the tested nutrients. Maximum (311.4) and minimum (210.28) panicle bearing tillers/m^2, was recorded precision land leveling with wide raised beds planting and with the application with no application of NPK +Zn treatments respectively (Table 1).Similar trend was also recorded in case of 1000 - grain weight and its range in between 18.52 to 24.93 g (Ali *et al.*,2012) [1]. Rice production on aerobic soils often uses conventional full tillage of aerated soil (Bouman *et al.* 2007) [6]. In contrast, resource-conserving technologies using unpuddled/ reduced tillage are normally applied in the traditional lowland rice in western Uttar Pradesh (Naresh *et al*. 2011) [26]. This difference in tillage management may have an impact on nutrient stratification in the soil profile and consequently affect bioavailability of Zn. Studies by others (Grant *et al*. 2010) [14] also confirmed the limited effect of tillage on Zn availability in soils and Zn levels in crops.

In both years precision land leveling affect the percentage of abortive kernels (AK) (Table 1). Averaged over the two-years percentage of AK ranged from 6.66% to 11.93% between precision and traditional land leveling with crop estabilishment. Minimum number of abortive kernels 6.47,6.66 and 6.86% were observed in treatments T_4 T_6 and T_7 (Traditional land leveling with various beds configuration) and maximum number of abortive kernels 11.93 % was observed in treatment T_5 with precision land leveling unpuddled with flat beds aerobic rice (Table 1).These results are in line with those of Walker *et al*., 2003 [40], who reported that kernel quality increased under precision land leveling technology. Minimum number of opaque kernels (5.59%) was observed in treatment T_1 (Precision land leveling with wide raised beds) and maximum number of opaque kernels (14.95 %) was observed in treatment T_7 (Traditional land leveling puddled with flat beds). Maximum number of normal kernels 73.82 % was observed in precision land leveling with wide raised beds crop establishment technique and minimum number of normal kernels 65.09 % in T_7 traditional land leveling puddled with flat beds crop establishment. Similar results were reported by Walker *et al*., 2003 [40] that precision land leveling crop establishment technique improved the quality of paddy.

Similarly, minimum number of abortive kernels 4.44 and 5% were observed in treatments F_2 and F_5 (Basal application at the rate of 25 kg ha^{-1} (21 % $ZnSO_4$) and maximum number of abortive kernels 8.05 % was observed in treatment F_7 with no zinc application (Table 1).These results are in line with those of Rehman *et al*., 2008 [34], who reported that kernel quality increased with the application of zinc. Opaque kernels are those that had attained full size but not translucent due to lack of carbohydrates. Opaqueness of the kernels was reduced with the application of zinc which might be due to increase in formation or decrease in utilization of carbohydrates in plant tissue. Minimum number of opaque kernels (7.78 %) was observed in treatment F_2 (Basal application at the rate of 25 kg ha^{-1} (21% $ZnSO_4$ with precision land leveling) and maximum number of opaque kernels (12.78 %) was observed in treatment F_7 (no zinc application with traditional land leveling).Foliar application of zinc at the rate of 0.5 % Zn solution showed more response to opaque kernels percentage. Maximum number of normal kernels 90.56 % was observed in basal application at the rate of 25 kg ha^{-1} (21 % $ZnSO_4$) and minimum number of normal kernels 79.16 % in F_7 with no zinc application. Foliar application of zinc treatments produced statistically similar normal kernels. Similar results were reported by Rehman *et al*., 2008; [34] That with the application of zinc quality of paddy was increased. Zn bioavailability was lower in aerobic as compared to flooded rice cultivation systems, as indicated by reduced Zn concentration in plant tissue, Zn uptake (Gao *et al*. 2006; Kabata, 2010) [12, 23]. A lower transpiration rate in aerobic than flooded fields may also decrease the mass flow of Zn from soil to plants and consequently decrease Zn uptake by plants, as well as the allocation to the grain. (Jiang *et al*. 2007) [21] versus re-allocation of previously stored Zn needs further clarification. Regardless, plant Zn uptake should be improved and possibly maintained longer to increase the nutritional quality of the grain, while adoption of aerobic growing conditions would likely lead to reduced rather than increased grain Zn concentration. Nitrogen fertilizers can also increase Zn uptake of crops by promotion of plant and root growth. Because of the relatively new concept of aerobic rice production, an appropriate N management strategy is yet to be established. While N appears to play a critical role in the uptake and accumulation of Zn in plants, the effect of N fertilization on Zn concentration in crop grain, especially under field conditions is ambiguous. Effect of N fertilizers on crop grain Zn concentration has been shown to be positive (Wissuwa *et al*.2007) [42]. Recent literature indicates that a sufficiently high rate of N application is effective in enhancing grain Zn in crops, especially on a soil naturally high in plant-available Zn or when plant Zn nutrition is sufficient through foliar Zn application (Widodo *et al*. 2010) [41].

Table 1: Effect of crop establishment and Zn application on total number of tillers,number of panicle bearing tillers,panicle length,1000-kernel weight and abortive kernels,opaque kernels and normal kernels.

Treatments / **Crop establishment**	**Total number of tillers (m^{-2})**	**Number of Panicle Bearing tillers (m^{-2})**	**Panicle Length (cm)**	**1000-kernel Weight (g)**	**Abortive Kernels (%)**	**Opaque Kernels (%)**	**Normal Kernels (%)**
T_1	374.0	311.4	25.26	24.93	9.43	5.59	73.82
T_2	327.4	300.1	24.05	24.54	7.59	13.39	70.50
T_3	294.7	287.9	23.26	24.27	11.13	6.03	73.35
T_4	288.6	271.4	22.73	23.56	6.47	14.79	67.62
T_5	357.8	303.6	24.72	24.59	11.93	5.85	73.78
T_6	309.8	291.4	23.67	24.49	6.66	13.72	67.81
T_7	369.0	307.9	25.09	24.89	6.86	14.95	65.09
C D at 5 %	**29.16**	**15.6**	**0.451**	**NS**	**2.86**	**4.35**	**3.79**
Fertilization							
F_1	236.31	246.78	26.22	18.90	6.66	10.56	82.22
F_2	252.81	246.79	26.27	20.33	4.44	7.78	90.56
F_3	258.39	249.80	26.64	21.00	7.22	9.56	85.00
F_4	235.35	227.03	24.96	18.83	6.86	11.28	80.94
F_5	237.02	226.25	25.29	19.00	5.00	8.44	86.66
F_6	254.61	230.49	25.37	20.85	7.22	9.11	83.33
F_7	225.08	210.28	24.15	18.52	8.05	12.78	79.16
C D at 5 %	24.08	21.69	1.09	NS	1.79	3.20	4.68

3.2 Water application and water productivity

The input water application includes the irrigation water applied and the rain water during the rice season of 2009 to 2011.The water application in rice system was remarkably lower with permanent wide and narrow beds compared to other practices (Table 2). The higher irrigation water application in rice under traditional leveling treatments as compared to precision leveled plots. The precision leveled plots savings in water use in raised beds with recommended dose of NPK were 11.5 % to 20.5%with recommended dose of NPK fertilizer treatment and 14.1% to 26.7 % with recommended dose of NPK+Zn fertilizer treatment as compared to traditional leveled flat beds. Water productivity under permanent beds was higher as compared to other tillage and crop establishment techniques and lowest system water productivity was recorded with traditional leveled flat beds. revealed that the saving in irrigation water with raised bed planting technique was more under traditional leveling as in this technique water moves in furrows only. Laser assisted precision land leveling can reduce evaporation and percolation losses from rice by enabling faster irrigation times and by eliminating depressions and therefore ponding of water in depressions.

3.3 Grain yields

The crop yield data from 2009-2011 (Table 2) showed that the higher grain yields of rice occurred in precision land leveling wide beds with recommended dose of NPK+Zn. Yields on raised beds consistently increased from yr.1 to yr.3 in laser leveling with recommended NPK+Zn, but the differences between laser leveling wide raised beds and flat beds were not always significant for the three rice crop cycles. Precision leveling with recommended NPK increase the yield by 8.5% to 10.9% and 10.1% to 13.1% with recommended NPK+Zn as compared to control treatment. This is an extremely important finding in relation to practical management of such systems by farmers. It showed that the raised bed planting technique is more advantageous under precisely leveled fields. Significantly higher yield of rice was recorded with precision land leveling as it takes care of maintaining near homogeneity by way of cut and fill and also tillage because flooding in precision-leveled fields is more uniform and more timely, improved nutrient uptake and weed management result in increased yields (Walker *et al*., 2003; Brye *et al*., 2004) [40, 7]. These findings are in agreement with reference (Gupta and Naresh *et al*., 2011; Jat *et al*., 2011) [26, 19] who summarized the finding of multi-location trials across IGP and reported higher yield of wheat with raised beds compared to flat sowing.

Table 2: Effect of crop establishment techniques and fertilization on water application (mm ha^{-1}), crop yield (t ha^{-1}), Water productivity and profitability of rice crop in laser-leveled and traditionally leveled plot.

Treatments	Water application & Yield						Water productivity (kg yield m^{-3} water)		
Crop establishment	2009		2010		2011				
	Water	Yield	Water	Yield	Water	Yield	2009	2010	2011
T_1	2575	5.35	2155	5.65	2395	5.25	0.208	0.262	0.219
T_2	2790	4.63	2395	4.83	2565	4.65	0.166	0.202	0.181
T_3	2615	5.25	2270	5.45	2480	5.18	0.201	0.240	0.208
T_4	2815	4.41	2465	4.61	2675	4.25	0.157	0.187	0.159
T_5	2790	4.51	2485	4.73	2885	4.50	0.162	0.190	0.156
T_6	2995	4.03	2750	4.18	3025	4.35	0.135	0.152	0.144
T_7	3075	5.73	2915	6.10	3220	5.65	0.186	0.209	0.175
C D at 5 %	186	0.38	216	0.67	78	0.53	-	-	-
F_1	2210	4.56	2255	4.65	2120	4.95	0.206	0.205	0.233
F_2	2365	4.85	2395	4.97	2285	5.35	0.205	0.208	0.234
F_3	2390	4.93	2470	5.16	2375	5.45	0.183	0.209	0.229
F_4	2450	4.60	2595	4.33	2590	4.75	0.188	0.167	0.183
F_5	2565	4.67	2615	4.85	2695	5.05	0.182	0.185	0.187
F_6	2690	4.75	2745	4.90	2790	5.15	0.176	0.178	0.185
F_7	2895	3.36	2960	3.06	2845	2.95	0.116	0.103	0.104
C D at 5 %	127	0.63	173	0.58	196	0.46	-	-	-

Nutrient Uptake

Total (grain + straw) uptake of nutrients (N, P, K) analyzed at crop maturity varied significantly due to land leveling and crop establishment techniques and zinc fertilization. Maximum uptake of total N was recorded with T_1 PLWB which was significantly higher over all other treatments (Table 3). The total P uptake by the crop though at par, under precision land leveling irrespective of the planting technique (*i.e*. PLWB, PLNB and PLFB) but significantly higher over rest of the treatments (Table 3).Similar to nitrogen, maximum uptake of total K was also recorded in PLWB which was at par to PLNB but it was significantly higher over rest of the treatments. (Table 3). The higher amount of uptake of nutrients under precision leveling and raised bed planting techniques was associated with higher bio-mass accumulation under these treatments, which led to higher amount of uptake of these nutrients. The higher nutrient uptake in precision leveling with raised beds is mainly due to less leaching loss of nutrients and availability of sufficient moisture for mineralization of native as well as applied nutrients. The higher uptake efficiency of nutrients depends on a myriod of factors including nutrient availability due to favourable soil biota under precision leveling with raised beds compared to precision leveling with flat beds. These findings are in agreement with reference (Walker *et al*., 2003; Brye *et al*., 2004; Naresh *et al*., 2013) [40, 7, 27, 28]. The lowest concentration of nitrogen was noticed in case of plots treated with 0 kg zinc. Likewise response was also obtained in case of phosphorus and potassium concentrations in both the situation i.e. flooded and aerobic conditions. similar trend were reported by (Ali *et al*., 2012; Sahaa *et al*., 2007) [1, 37].

Maximum Zinc concentration and zinc uptake was recorded with T_1 PLWB which was significantly higher over all other treatments. With an increase in Zn supply the rate of Zn uptake increased for precision land leveling and crop establishment with zinc fertilization both when calculated either as daily Zn uptake per gram of plant dry matter. Essentially, the trends were similar between soil application and foliar application, but Zn uptake rates in foliar application unpuddled (aerobic conditios) were higher than in soil application puddled (flooded condition).The maximum zinc content in grain (28.75 ppm) had obtained under precision land leveling with foliar application and the least of that equivalent to 13.65 ppm was observed at interaction of control treatment and traditional leveling (Table 3). Soil or foliar applications of Zn may also increase grain zinc content and thus contribute to grain nutritional quality for human beings. In rice, zinc application has been reported to increase grain uptake of Zn (Phattarakul *et al*., 2012) [31]. It appeared that the Zn uptake in grain varied from 275.80 to 335.60 g ha^{-1}.The highest value was obtained in the F_3 and the lowest value was found in control (Zn0). All the treatments responded better over control. In case of straw, the Zn uptake varied from 170.20 to 508.60 g ha^{-1}.

Table 3: Estimates on total N, P, K uptake and Zn concentration and accumulation in rice crop.

Treatments	Total N uptake (Kg/ha)	Total P Uptake (kg/ha)	Total K uptake (kg/ha)	Zn Concentration (ppm)		Zn uptake (g ha^{-1})	
Crop establishment				Grain	Stover	Grain	Stover
T_1	133.62	25.6	108.27	32.50	61.57	187.40	430.51
T_2	106.87	22.7	102.96	29.18	60.42	147.90	340.35
T_3	125.91	24.8	105.40	32.35	61.04	167.20	419.30
T_4	98.43	20.3	96.36	28.70	51.17	128.80	295.25
T_5	105.08	23.9	99.35	29.08	52.36	143.90	315.60
T_6	94.22	17.5	83.56	26.31	49.87	124.50	275.72
T_7	91.23	13.7	51.18	17. 35	37.46	75.47	215.30
C D at 5 %	8.02	1.81	4.63	6.40	8.26	9.01	13.78
Fertilization							
F_1	91.2	16.9	102.4	16.25	33.50	312.20	450.70
F_2	99.2	20.7	103.7	26.65	48.70	334.10	486.52
F_3	106.4	19.4	110.6	28.75	49.51	335.60	508.60
F_4	88.3	17.4	93.7	15.55	21.73	301.75	232.20
F_5	91.9	19.8	100.8	22.70	39.85	318.65	457.40
F_6	97.1	18.1	102.0	22.80	43.70	326.75	467.58
F_7	82.4	15.7	85.9	13.65	24.95	275.80	170.20
C D at 5 %	0.85	0.42	0.81	3.86	6.58	10.96	16.74

Conclusion

There are clearly many technologies with the potential to reduce the amount of irrigation water applied to rice crop. However, the responses to the technologies in terms of yield, components of the water balance and water productivity are often variable and are affected by many factors including climate, soil type and hydrological conditions, and also on the current cropping system and its management. The effects of recently, laser-assisted precision land levelling has shown promise for better crop establishment, water savings and enhanced input use efficiency. This study on the integrated effect of raised bed planting of rice on laser levelled fields increased rice yields (average of 3 yrs) by 11.49 % over flat planting on traditionally levelled fields. Whereas, the yield enhancing effects of precision land levelling alone under raised beds and flat beds were 14.8% and13.7%,respectively.The saving in irrigation water with precision conservation was21.33% compared to traditional practice (traditional levelling, flat planting),whereas precision levelling could save 6.9 % water in flat planting and 7.7 % in raised beds. The improvement in nutrient use efficiency was also significant with precision-conservation management compared to individual effects. Therefore, this study confirms that Precision- Conservation Agriculture (PCA) based crop management solutions seem to be promising options to sustain the rice systems of western Uttar Pradesh, India on a long-term basis.

The increasing shortage of irrigation water is encouraging the cultivation shift from flooded to aerobic rice production in a number of traditional rice growing areas. Plant factors such as root growth and root release of organic compounds into rhizosphere can also have major effects. The consequence of a cultivation shift for Zn bioavailability is a function of the changes of all these factors. The relative importance of each factor will differ among soils and could be carefully evaluated. Appropriate rhizosphere management has great potential to improve crop growth, as well as the micronutrient nutrition in crops, either through an increase in root exploration volume or through manipulation of the chemical conditions in the rhizosphere. Adjustment in management practices such as fertilization application, and more diversified aerobic rice based cropping systems are needed to make the cultivation shift to aerobic rice production systems a sustainable one. The effects of new management practices on bioavailability of micronutrients, as well as their concentrations in the rice grain, should be better documented. Addition of Zn fertilizers by soil or foliar application have been shown to increase Zn concentration in cereal grains. An appropriate N management strategy has yet to be established but should carefully consider the effects on soil pH in selection of source, rate, application method, and timing of fertilizers.

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