

## Improving chickpea productivity in rice-fallow of Indo-Gangetic Plain with soil moisture conservation and cultivar selection

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### ABSTRACT

Rice fallows offer an extensive scope for cropping intensification in the country. Presently, the grain legumes or pulses are recommended for sustainable intensification of rice-fallows. An experiment was carried out (2011-2013) to evaluate the effect of preceding rice cultivars and soil moisture conservation practices on chickpea productivity in rice-fallow condition. The treatments comprised of two levels of rice cultivars [Pant Dhan 12, local tall cultivar), three levels of residue management treatments (residue removal, rice straw mulching, and retention of (~20 cm) rice stubbles), and two levels of chickpea cultivars (JAKI 92-18, DCP 92-3), fitted in split-split plot design with three replications. Rapid depletion soil moisture was observed in the surface soil (0-15 cm) after rice harvest. Rice straw mulching increased the chickpea grain yield by 6-14% ( $p < 0.05$ ) over residue removal, whereas the effect of stranding stubble was marginal. The increased chickpea yield with straw mulching was primarily attributed to the higher soil moisture, favorable soil temperature, and reduced crop-weed competition. The early harvesting of rice variety Pant Dhan 12 had advanced the chickpea crop establishment (15-18 days) over the late local rice cultivar that facilitated efficient use of the residual soil moisture, leading to the higher chickpea yield by 11-16% ( $p < 0.05$ ). Higher relative water content was observed in chickpea following rice variety Pant Dhan 12 and straw mulching. Increased chickpea yield was primarily attributed to an increase in shoot and root biomass, nodulation, and number of pods plant<sup>-1</sup>. The performance of early and high biomass chickpea variety JAKI 92-18 was superior over DCP 92-3 under rice-fallow condition. Thus, the early maturing rice cultivar followed by early and high biomass producing chickpea cultivar with rice straw mulching in chickpea could improve the chickpea its system productivity, and thereby improve the farmers' income in rice-fallows.

**Key words:** Chickpea, Economics, Energy budgeting, Relative water content, Rice straw mulching, Rice fallow

Now days, rice-fallow areas are targeted for cropping intensification in south Asia (Kumar et al. 2019a). In India, approximately 30% of rice growing areas (11.7 m ha) remains fallow during the post-rainy seasons (DAC 2011; Hazra and Bohra 2020). Hence, there is an extensive scope to include a winter crop in rice-fallows through right selection

of crop/cultivar and soil moisture conservation practices (Ghosh et al. 2014; Kumar et al. 2016a). However, inclusion of winter crop in rice-fallows is largely challenged by several biotic and abiotic factors (Kumar et al. 2016b). Non-availability of irrigation sources, fast depletion of soil residual moisture, uncertainty in rainfall, and soil related constraints are major stumbling blocks including a post-rainy season crop in the rice-fallows (NAAS 2013).

Pulses or grain legumes, with their unique characteristics such as low-input requirement, deep roots and higher soil moisture extraction potential, ability to establish with surface seeding, could be the key crops for cropping intensification in rice-fallows (Ali et al. 2014; Kumar et al. 2018). Nevertheless, the productivity potential of post-rainy crops in rice-fallows is essentially depends on residual soil moisture availability and water use efficiency of the crop, and tolerance to biotic stresses (Ghosh et al. 2016). So, conservation of the residual soil moisture likely to improve the productivity of winter crop in rice-fallows (Kar et al. 2004). Zero-tillage with crop residue retention increases the soil moisture storage and increase the winter crop productivity (Kumar et al. 2019b; Nandan et al. 2019). In rice-fallow areas, farmers mostly grow the long duration rice cultivars that delay the sowing of winter crop/s; thus, the crop often expose to the terminal moisture stress. Therefore, advancing the sowing of winter crop taking early maturing rice cultivars could be a strategic intervention in rice-fallow areas. Further, early biomass accumulating cultivars of legume may have an advantage over low biomass cultivar.

Therefore, an experiment was designed and executed during the year 2011-2013 to evaluate the effect of crop residue management as soil moisture conservation practices and cultivar combination of component crops on soil moisture storage and performance of chickpea crop in rice-fallows. Comparative assessment of two maturity group rice cultivars (early and late cultivars) and two chickpea cultivars (high and medium biomass) was made to characterize appropriate cultivar combination option for rice-fallow conditions. Hence, the information of the study will be useful in promoting pulses in rice-fallows.

## MATERIALS AND METHODS

**Site characteristics:** A Field experiment was conducted at main experimental farm of ICAR-Indian Institute of Pulse Research (ICAR-IIPR), Kanpur, India during 2011-2013. The climate of experimental site is tropical sub-humid; receives 722 mm rainfall annually, and the mean annual maximum and minimum temperature is 33.0°C and 20.0°C, respectively. The weather variables during the cropping seasons are presented in Figure 1. The soil of experimental farm is sandy-loam in texture and belongs to the taxonomical class *Typic Ustochrept (Inceptisol)* (Table 1), bulk density 1.39 g cc<sup>-1</sup>, soil pH 8.2.

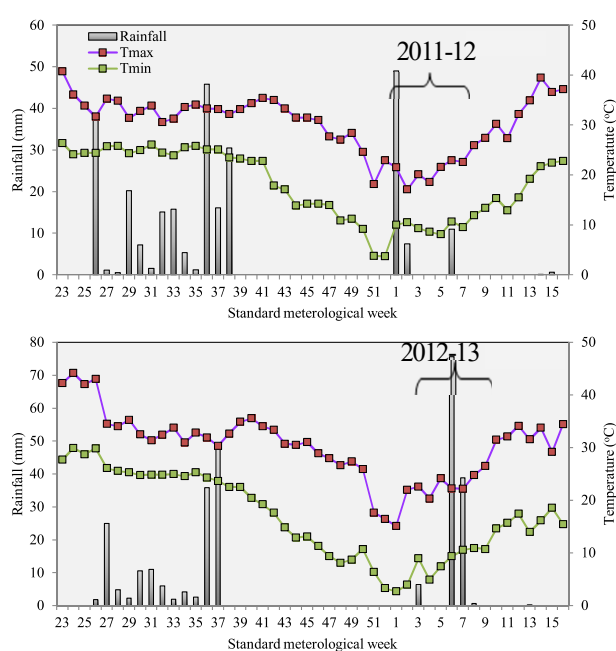


Fig 1. Weekly rainfall (mm), minimum and maximum ambient temperature (°C) during the rice-chickpea cropping season of 2011-12 and 2012-13.



(a)



(b)

Fig 2. Field view chickpea crop with mulching (a) and standing rice stubble retention (b)

**Treatment details:** Treatments comprised of three main factors (rice cultivars, rice residue management, and chickpea cultivars) fitted in split-split plot design (2×3×2) with three replications. Main plots consisted of two rice cultivars [long duration local rice cultivar and early maturing Pant Dhan-12 (PD 12)], three residue management practices as sub-plot treatment *viz.*, residue removal, rice straw mulch and standing rice stubbles (~ 20 cm) and two chickpea cultivars as sub-sub plot treatment *viz.* JAKI 92-18 (early high biomass producing cultivar) and DCP 92-3 (medium biomass producing cultivar). The dimension of the each sub-sub plot was 7 m × 10 m (70 m<sup>2</sup>). In residue removal and mulch treatment, the rice crop was harvested at ~ 5 cm above ground as commonly practiced by farmers. For standing stubbles treatment, rice crop was harvested at ~ 20 cm above ground. Under rice mulch treatment, the total rice straw was uniformly spread over soil after sowing of the winter crop (Fig 2).

**Crop management:** For rice crop, the field was prepared by two passes of harrow followed by one wet-tillage (puddling with rotavator). Both the rice cultivars were sown the same time, and 21-25 days rice seedlings were transplanted in the main field. Two seedlings per hill were transplanted following a planting geometry of 20 cm × 20 cm. The recommended fertilizer rate (120:60:40 kg N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O ha<sup>-1</sup>) were applied to rice crop. Rice cultivar PD 12 was harvested during 3<sup>rd</sup> week of October. Subsequently, chickpea after PD-12 was sown during third week of October. Local rice was harvested during 8-12 November and chickpea after local rice was sown during second to third week of November. Chickpea was sown by manual Zero-till Seed Drill developed by ICAR-IIPR. Chickpea was grown completely on residual soil moisture and no supplemental irrigation was given. At pod development stage of chickpea, foliar spray of 2% urea solution was applied using Knapsack sprayer.

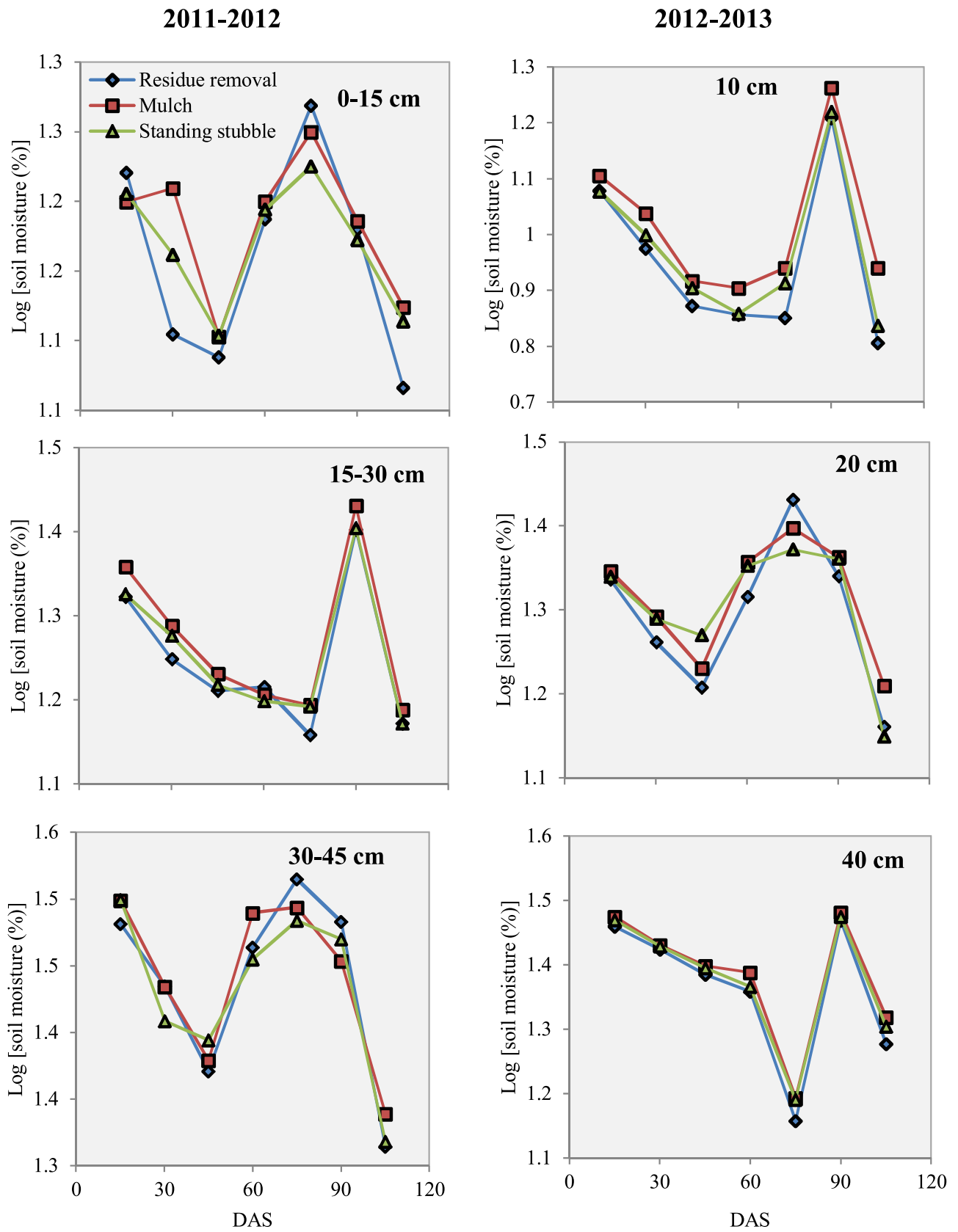


Fig. 3: Soil moisture [log (% v/v)] dynamics under different residue management practices during chickpea growing seasons (2011-2012 and 2012-13)

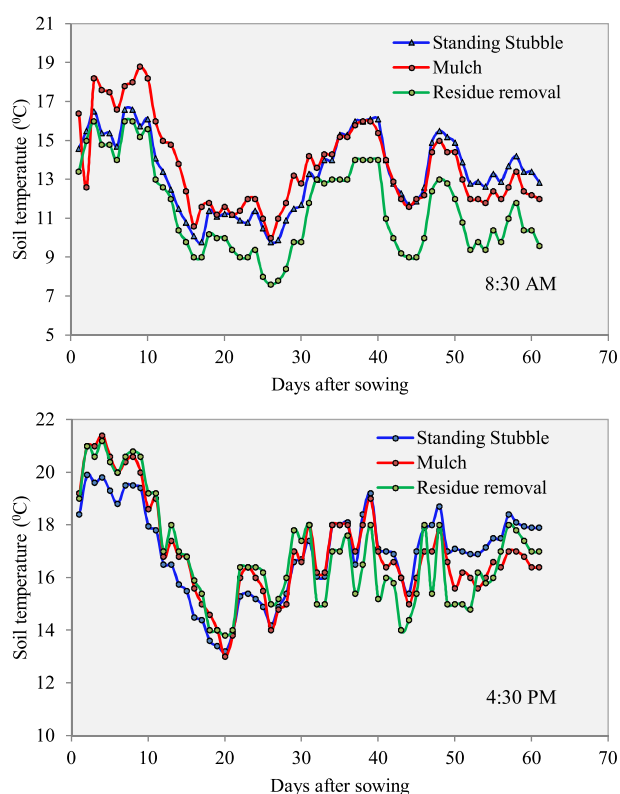


Fig 4. Soil temperature ( $^{\circ}\text{C}$ ) in morning (8:30 am) and evening (4:30 pm) as influenced by different residue management practices during chickpea growing season.

**Table 1.** Physico-chemical properties of surface soil (0-20 cm) at the initiation of the experiment a

Parameter	Value
Soil texture	Sandy-loam
Bulk density ( $\text{Mg}/\text{m}^3$ )	1.39
pH (1:2.5 soil: water)	8.22
EC (dS/m)	0.25
Soil organic C (g/kg)	2.90
Available-N (kg/ha)	243.0
Olsen-P (kg/ha)	17.5
Available-K (kg/ha)	199.1

**Determination of soil moisture:** In the year 2011-2012, the soil moisture was determined by gravimetric method. Soil samples from different soil depth (0-15, 15-30, 30-45, and 45-60 cm) were collected in aluminium moisture boxes from each plot at fifteen days interval. The soil samples were dried in oven at  $105^{\circ}\text{C}$  for 72 h. Based on soil fresh and oven dry weights, moisture content was calculated and expressed in percentage (eq. 1).

$$\text{Soil moisture content (\%)} = \frac{\text{Soil fresh weight} - \text{Soil dry weight}}{\text{Soil dry weight}} \times 100 \quad \text{- eq. 1}$$

During the second year of study (2012-2013), soil moisture was recorded using the TDR soil moisture meter (model Delta-T Devices Ltd; Cambridge, UK). In PR2 probe, soil moisture sensor was fitted at 10, 20, 30, 40, 60 and 100

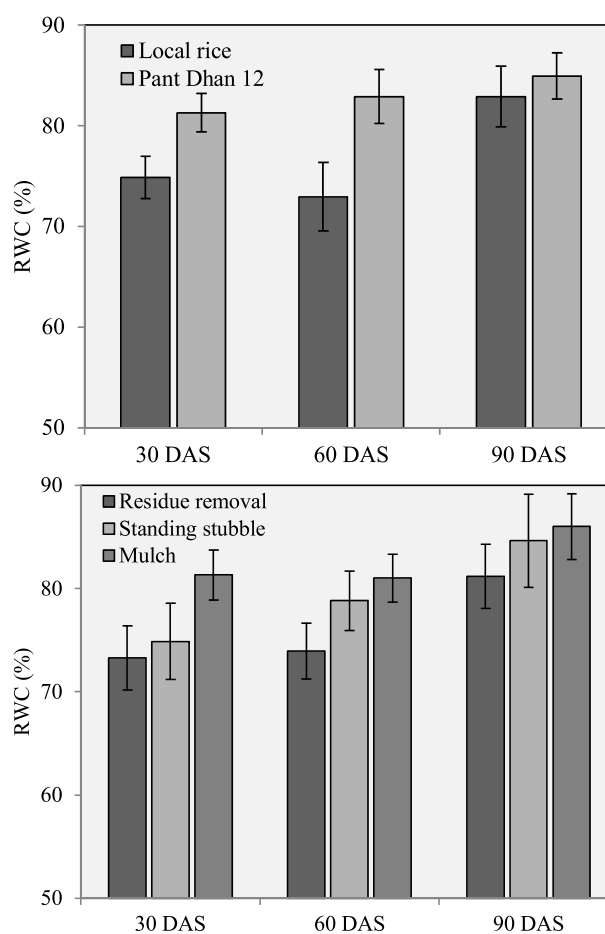


Fig 5. Effect of preceding rice cultivar and residue management on relative water content (RWC) of chickpea.

cm to estimate soil moisture at corresponding depth simultaneously. Soil thermometers were installed to measure the soil temperature of 0-30 cm under different residue management treatments. In a day, the soil temperature data were recorded twice at morning (8:30 am) and evening (4:30 pm) time.

**Relative water content (RWC):** Five fully developed leaves from top of the chickpea plant were collected at 12:00 h for measuring the RWC. The RWC was calculated taking the fresh, turgid, and oven dry weights of leaves according to the method given by Jiang and Huang (2001) as follows:

$$\text{RWC (\%)} = \frac{\text{Fresh weight of leaves} - \text{Oven dry weight of leaves}}{\text{Fully turgid weight of leaves} - \text{Oven dry weight of leaves}} \times 100 \quad \text{- eq. 2}$$

**Economics and energy budgeting:** The economics of the variable production systems was computed on the basis of prevailing market price of inputs and outputs in Indian rupees (INR). The total cost of cultivation of component crops was calculated on the basis of different operations performed and input used for raising the crop including the cost of tillage, sowing, labours, fertilizers, seeds, crop

**Table 2. Effect of preceding rice cultivar, residue management, and chickpea cultivar on crop growth and yield attributes of chickpea in rice-fallow (pooled data)**

Treatment	pH	NL	NDW			AGDW			RDW			DMA	PPP	TGW
			30DAS	60 DAS	90 DAS	30DAS	60 DAS	90 DAS	30DAS	60 DAS	90 DAS			
<i>Rice cultivar</i>														
Local rice	39.8	79.4	0.17	0.34	0.61	0.52	1.46	2.09	0.15	0.31	0.36	21.6	43.3	168
Pant Dhan 12	45.2	102.2	0.20	0.38	0.69	0.84	2.61	3.36	0.19	0.36	0.47	29.4	45.2	170
LSD (p = 0.05)	3.3	13.1	0.03	ns	0.07	0.18	0.43	0.41	ns	0.04	0.06	3.7	1.9	ns
<i>Residue management</i>														
Residue removal	41.2	85.8	0.17	0.33	0.56	0.59	1.85	2.53	0.15	0.26	0.37	22.3	41.4	192
Mulch	45.3	98.6	0.19	0.38	0.70	0.77	2.33	2.93	0.20	0.43	0.46	28.3	48.9	193
Standing stubble	41.5	87.8	0.19	0.37	0.68	0.67	1.93	2.72	0.17	0.35	0.43	26.0	42.5	193
LSD (p = 0.05)	3.6	6.3	ns	0.04	0.07	0.10	0.24	0.26	0.05	0.11	0.07	3.2	2.3	3.5
<i>Chickpea cultivar</i>														
Jaki 92-18	42.5	94.4	0.22	0.43	0.73	0.71	2.22	2.89	0.20	0.38	0.45	27.1	42.5	192.9
DCP 92-3	42.0	87.3	0.15	0.29	0.55	0.64	1.85	2.58	0.17	0.29	0.39	23.9	47.0	145.0
LSD (p = 0.05)	ns	6.2	0.04	0.09	0.08	ns	0.34	0.21	ns	0.08	0.06	2.1	3.5	12.6

pH-plant height (cm); NL-number of leaves; NDW-nodule dry weight (g plant<sup>-1</sup>); AGDW-aboveground dry weight (g plant<sup>-1</sup>); RDW- root dry weight (g plant<sup>-1</sup>); DMA-above ground dry matter accumulation (unit); PPP-number of pod per pant; TWG-thousand grain weight † DAS

**Table 3. Grain yield of rice, chickpea and system productivity (rice equivalent yield) as influenced by cultivars and residue management practices**

Treatment	2011-2012			2012-2013		
	Rice	Chickpea	REY	Rice	Chickpea	REY
<i>Rice cultivar</i>						
Local rice	47.0	20.2	92.6	43.1	13.7	73.9
Pant Dhan 12	49.4	22.4	99.8	44.7	15.9	80.4
LSD (p = 0.05)	2.0	1.1	3.4	1.1	1.1	4.1
<i>Residue management</i>						
Residue removal	47.8	20.0	92.7	43.9	14.3	76.2
Mulch	48.6	22.7	99.6	44.3	15.1	78.4
Standing stubble (30 cm)	48.2	21.3	96.1	43.4	14.8	76.8
LSD (p = 0.05)	NS	1.5	4.7	NS	0.7	2.1
<i>Chickpea cultivar</i>						
Jaki 92-18	47.9	22.1	97.5	44.2	12.2	71.7
DCP 92-3	48.5	20.5	94.7	43.7	17.3	82.7
LSD (p = 0.05)	NS	1.4	2.3	NS	1.8	4.3

RCY: Rice Equivalent Yield

**Table 4. Total weed counts and weed biomass in chickpea crop at 40 DAS as influenced by different treatments (pooled data)**

Treatment	Weeds Number (Numbers m <sup>-2</sup> )	Weed dry weight (g m <sup>-2</sup> )
<i>Rice cultivar</i>		
Local rice	281	52.9
Pant Dhan 12	234	37.4
LSD (p = 0.05)	31	9.2
<i>Residue management</i>		
Residue removal	492	106.6
Mulch	532	75.9
Standing stubble (30 cm)	522	88.5
LSD (p = 0.05)	19	7.9
<i>Chickpea cultivar</i>		
Jaki 92-18	549	81.4
DCP 92-3	481	99.3
LSD (p = 0.05)	33	11.3

**Table 5. Economics and energy productivity as influences by different crop management practices (calculated on mean values)**

Treatment	Net Return (INR)		B: C ratio		Energy productivity		Energy use efficiency
	2011-12	2012-13	2011-12	2012-13	Rice	Chickpea	
<i>Rice cultivar</i>							
Local rice	76552	50215	2.42	1.93	0.255	0.182	8.22
Pant Dhan 12	86927	59342	2.61	2.10	0.287	0.195	8.84
<i>Residue management</i>							
No-residue	76148	49431	2.41	1.92	0.251	0.179	8.34
Mulch	88335	59616	2.64	2.10	0.292	0.196	8.70
Stubble	80165	55399	2.48	2.03	0.271	0.185	8.49
<i>Chickpea cultivar</i>							
Jaki 92-18	83601	47129	2.55	1.87	0.264	0.187	8.54
DCP 92-3	79488	62515	2.47	2.16	0.278	0.188	8.48

residues etc (Nandan *et al.* 2018). The net return was calculated as:

Net return (INR) = Gross return - Cost of cultivation - eq.3

Energy budgeting was calculated considering the energy input through fertilizers, seeds, plant protection chemicals, fuels, human labor and machinery power and whereas output consists of both main and by-products of the crops. Inputs and outputs were converted from physical to energy unit measures through published conversion coefficients (Singh *et al.* 2008).

**Statistical analysis:** The significant of treatment effect was determined using F-test. Analysis of variance was performed using online statistical program OPSTAT. Comparisons of treatment mean values were performed using least significant difference (LSD,  $p = 0.05$ ).

## RESULTS AND DISCUSSION

**Soil moisture and temperature dynamics:** The residual soil moisture is the most important factor that strongly influences the performance of winter crop in rainfed agro-ecosystems. During both the years, soil moisture content after rice harvest was fairly good (16-20%), which was  $\sim 3/4$  of the field capacity ( $23.4 \pm 0.2\%$ ). The soil moisture depleted sharply at initial growth period of chickpea (Fig 3). In the surface soil (0-15 cm), 33-50% depletion in soil moisture was observed within 45 days to sowing. However, the deeper soil depths had sufficiently higher soil moisture content. Notably, the chickpea sowing after medium duration cv. PD 12 was advanced the chickpea sowing by 15-18 days as compared to local rice cultivar. The early sowing of chickpea following cv. PD 12 had 10-13% higher soil moisture in the surface soil during the initial growth stages. Rice straw mulching conserved the higher soil moisture over residue removal; while, moisture conservation potential of standing rice stubble in this study was comparatively marginal. Indeed, the re-growth of standing rice stubbles led to significant amount of moisture loss and thus, the advantage of residue retention for moisture conservation was not likely to be observed in this study. Generally, the shading effect and restricted air movement near soil surface

due to standing stubbles helps in protecting the soil moisture loss (Kumar *et al.* 2006; Patil *et al.* 2013), which was not evident in this study.

Up to 60 days after sowing (DAS) of chickpea, the soil moisture content was found in the treatment order of mulching > standing stubble > residue removal. At the time of chickpea harvest, straw mulching treatment had maintained the higher soil moisture over residue removal and stubble retention treatments, confirmed the potential of mulching for soil moisture conservation. The rainfall event during the study period was unexpectedly differed from the normal. During 2011-2012, a higher amount of rainfall received during January (49 mm in the 1<sup>st</sup> week and 7.4 mm in the 2<sup>nd</sup> week). Similarly, during 2012-2013, 6.4 mm rainfall was received during the 3<sup>rd</sup> week of January and rainfall was received during the month of February also (115 mm during 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> meteorological week) (Fig 1). Therefore, we failed to get the terminal soil moisture stress at later stages of chickpea. Despite this, if we extrapolate the initial soil moisture trend (up to 60 DAS), surely the crop might have faced severe soil moisture stress at later stages with normal rainfall events. Interestingly, it was observed that the soil temperature during the initial crop growth stages is substantially improved with straw mulching and standing stubble over residue removal (Figure 4), indicating that the mulching or residue retention could modify the soil micro-environment by modifying the soil temperate regime and growth of winter crops in rice-fallows.

**Relative water content (RWC):** Relative water content was estimated as an indicator of plant moisture status with response to variable soil moisture content (Kalariya *et al.* 2015). The RWC data was recorded at three crop stages viz. 30, 60 and 90 DAS of chickpea, which coincides with the critical crop growth stages viz., branching, flowering and pod development stages, respectively. The data demonstrated that chickpea after PD 12 had relatively higher RWC over the chickpea plant sown after local rice cultivar (Fig 5). Likewise, higher RWC values were registered in the straw mulch treatment and least was measured in residue removal treatment. Plant water content has direct relation with soil moisture (Kumari and Sairam 2013). The higher

RWC in chickpea with mulch was primarily attributed to the higher soil moisture content in mulch treatment. The findings are also in consistence with Rahimia et al. (2010).

**Chickpea crop growth and yield attributes:** Early sowing of chickpea after cv. PD 12 resulted in higher shoot dry weight (61-79%), leaf numbers (24-40%) and root dry weight (13-31%) and pod plant<sup>-1</sup> (Table 2). The higher nodule number and nodule biomass were also recorded in the chickpea crop following cultivar PD 12 over local rice cultivar. Improvement in chickpea growth attributes possibly has a direct relation with soil moisture and plant water balance under early planting of chickpea after cultivar PD 12 and the results are in accordance with the findings of Singh et al. (2002).

Irrespective of the cultivar effect, the higher above ground biomass of chickpea was recorded in straw mulch plots, which was 31%, 22% and 16% higher over residue removal at 30, 60, and 90 DAS, respectively. Straw mulching and rice stubble treatments increased the chickpea nodulation over residue removal. The increased nodulation might be associated to better root development and higher soil moisture over residue removal. Besides this, the straw mulching resulted in the higher number of pods plant<sup>-1</sup>, which was 18% higher over residue removal. Thus, the results demonstrate that the straw mulching is much effective in conserving the soil moisture over standing stubble treatment. In rice fallow condition, the performance of chickpea cultivar JAKI 92-18 was superior over cultivar DCP 92-3 during 2011-2012. The higher shoot (9-11%) and root weight (15-31%), was observed in cultivar JAKI 92-18 over cultivar DCP 92-3. Likewise, the nodule number and biomass was also recorded higher ( $p < 0.05$ ) in cultivar JAKI 92-18 over cultivar DCP 92-3.

**Grain yields, production economics and energy productivity:** Early crop establishment of chickpea after rice cultivar PD 12 increased the chickpea grain yield by 11-16% as compared to chickpea after local rice cultivar (Table 3). The increased yield of chickpea was attributed to the higher soil moisture and thus the crop might have effectively utilized the carry over soil moisture leading to higher initial biomass accumulation and yield at the end. Results revealed that only mulching treatment increased the chickpea grain yield ( $p < 0.05$ ). However, the effect of standing rice stubble on chickpea grain yield was non-significant when compared with residue removal. Our results demonstrated that the combined effect of the higher soil moisture, favourable soil temperature, and reduced crop-weed competition (Table 4) in the straw mulching treatment effectively translated to higher grain yield in chickpea. The higher productivity of cultivar JAKI 92-18 was associated with early biomass accumulation. In contrast, during the 2<sup>nd</sup> year of experiment, the performance of cultivar JAKI 92-18 was far lower compared to DCP 92-3. In second year (2012-2013), the abnormal rainfall events strongly influenced the productivity

of cultivar JAKI 92-18 as the rainfall coincided with flowering time of cultivar JAKI 92-18.

Results further demonstrated that rice straw mulching and early maturing rice cultivar followed by high biomass chickpea cultivar could upscale the profit margin in rice-fallow condition. The data on net return and benefit cost ratio was found much higher for these treatments (Table 5). The higher energy use efficiency was observed with residue retention (straw mulch in particular) and growing of early rice cultivar PD 12 over local rice cultivar. Thus, the study recommended that the combination of early duration rice cultivar followed by early high biomass chickpea cultivar with rice straw mulching could improve chickpea productivity and farmers profitability in rice-fallows. There is need to assess more combinations of rice and chickpea cultivars to optimize the system productivity and to upscale the performance of chickpea in rice-fallows.

#### ACKNOWLEDGEMENT

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