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Conservation agriculture practices in intensive cropping systems and its effect on crop productivity and soil health under North-Western Himalaya

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Abstract
A two years study (2012-2014) on conservation agriculture was conducted at the research farm, FSR, Centre, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main Campus, Chatha, Jammu, India. The experiment was laid out in split- plot design with two crop establishment methods (Minimum / Zero tillage and conventional tillage) and three cropping systems (Rice-Wheat, Rice-Marigold-French bean and Maize + soybean -Wheat) and two fertilizer rates (Rec. Dose of Fertilizer and 75% RDF + 25%N through FYM) with and without mulching in sub-plots under clay loam soil having alkaline in reaction (pH-8.1), medium in soil organic carbon(0.55%) available P(19.20Kgha^{-1}& K(122.0Kgha^{-1}) and low in available N(221.12 Kgha^{-1}) with three replication. Among system based performance, Rice (*Oryza sativa*)-Marigold (*Tagetes erecta*)-Frenchbean (*Phaselous vulgaris*) recorded higher rice equivalent yield (REY) of (22.4 t/ha^{-1} and 19.48t/ha^{-1} in 1st and 2nd year of study). The maximum net return of Rs. 240372 ha^{-1} and Rs. 239015 ha^{-1} was recorded under Rice- Marigold- French bean cropping system with B:C ratio of 2.18 and 2.03 in 1st and 2nd year of study. Soil organic carbon content showed 6-9%& 9-11% enhancement over initial value in integrated nutrient management treatment where 75% RDF + 25% N through FYM was applied and in mulched treatment during first and second year respectively. Application of 75% RDF + 25% N through FYM and mulching with paddy straw @ 5t/ha also contributed a positive improvement in soil bulk density. The available NPK was slightly build up (4-12%, 14-30%, 10-14%) in all the treatments except rice –wheat cropping system (varied -1.36 to 22% N, 0.52 to 1.4%% and 1.64 to 4.9% K, respectively). However, NPK uptake (132.85, 45.47, 183.78 kgha^{-1}) was recorded maximum in Rice-Marigold – French bean cropping system due to 300% cropping intensity of the system during both the years. With regards to microbial population, the maximum population of bacteria, fungi and actinomycetes was recorded in minimum tillage over conventional tillage. However maximum population of bacteria (17.56 x 10^6 CFU/g soil), fungi (22.72 x 10^3 CFU/g soil) and Actinomycetes (21.25 x 10^4 CFU/g) was recorded in second year of study. However, among the different cropping systems maize + soybean – wheat recorded more number of bacteria and fungi in first year and second year, while actinomycetes was recorded maximum in Rice-marigold-French bean, respectively. Moreover mulched and INM treatment plots also recorded higher microbial count during both the years.Based on the two years of investigation it can be concluded that application of paddy straw as mulch @ 5 ton ha^{-1} during Rabi season with INM under conventional method of sowing to Rice-Marigold-French bean yielded maximum REY of 21.09 t/ha^{-1}with net returns (Rs 239693ha^{-1}) and B:C ratio of 2.10.

Keywords: resource conservation, conservation agriculture, minimum tillage, mulching, direct seeded rice, cropping system, rice equivalent yield, microbial population

Introduction
With technological innovations in agriculture during mid sixties, the era of green revolution helped the country to march ahead from begging bowl to achieve the self sufficiency in food production. Continuous and indiscriminate use of technologies even after attaining the purpose threatened our land water and environment in many ways like land degradation, decline in soil fertility, desertification, ground water depletion, water contamination, accumulation of green house gases in atmosphere which are responsible for climate change. Indian food grain production and its sustainability are in ambiguity due to climate variability and natural resource base degradation. The total food grain production of India during 2013-14 was 260 m tonnes (Anonymous, 2014) [1] whereas the total food grain production of Jammu &Kashmir (latitude of 32^0-40 ' N and longitude of 74^0-58 ' E with an altitude of 332 m above mean sea level) was 15619 thousand quintals 2012-13 (Digest of statistics, 2012-13).

The present population of India is 1.25 billion and is estimated to become 1.4 billion by 2025 and 1.7 billion by 2050 AD, needing annually about 380 mt and 480mt food grains, respectively (Yadav and Singh, 2000) [24]. Keeping natural resource base sustainable, more emphasis is needed on resource conservation practices to meet the future food grain requirements of ever-growing population to ensure food security of the country. Conservation agriculture is the need of the hour and are include the part of practices in agriculture which helps in conserving the land, water and environment while achieving desirable sustainable yield levels. Conversation agriculture is currently practiced on 154.8 million hectare worldwide in more than 50 countries and the area is expanding rapidly (FAO, 2014) [10]. In the developing world, conservation agriculture has been most successful in South American countries of Brazil and Argentina. In these countries 45-60 per cent of all agriculture land is said to be managed by conservation agriculture system (Derpsch, 2001) [7]. In India, significant efforts to develop and spread the resource conservation technologies are underway through the combined efforts of several state and national institutions and CG centres, particularly rice-wheat consortium of Indo-Gangetic plains. According to available estimates, the resource conservation technologies are practiced in more than 3 mha under the rice-wheat based system in Indo-Gangetic plains in India (Sharma and Singh, 2014) [17]. Zero tillage is one of the most important components of conservation agriculture which disrupts interdependent cycles of water, carbon and nitrogen and is defined as "any tillage system that reduces soil loss or water related to conventional tillage,where as minimum soil disturbance refers to low disturbance, no tillage and direct seeding. The disturbed area for seeding must be less than 15 cm wide or less than 25% of the cropped area (whichever is lower). There should be no periodic tillage that disturbs a greater area than the aforementioned limits. Mulching or maintenance of organic soil cover is another resource conservation practice which is categorized as 30-60%, 60-90%and >90% ground cover, measured immediately after the direct seeding/ planting operation. Mulching maintains soil cover, conserve soil moisture, control soil temperature, suppress weed and increase in population of micro flora thereby augment the crop yield (Banik and Sharma, 2008) [4]. Also mulching has favorable effect on soil physico-chemical and biological properties (Singh *et al*., 2005) [19]. Another important practice is crop rotation/association which involves at least three different crops.

However, modern agricultural production technology aims at maximization of productivity per unit area per unit time with intensive use of synthetic fertilizers, pesticides, fossil fuel based energy which are leading to degradation of natural resource i.e. Soil, water, environment and biodiversity. Keeping this in view, the present investigation was undertaken to study the "Conservation agriculture practices in intensive cropping systems and its effect on crop productivity and soil health under north-western Himalayan conditions"

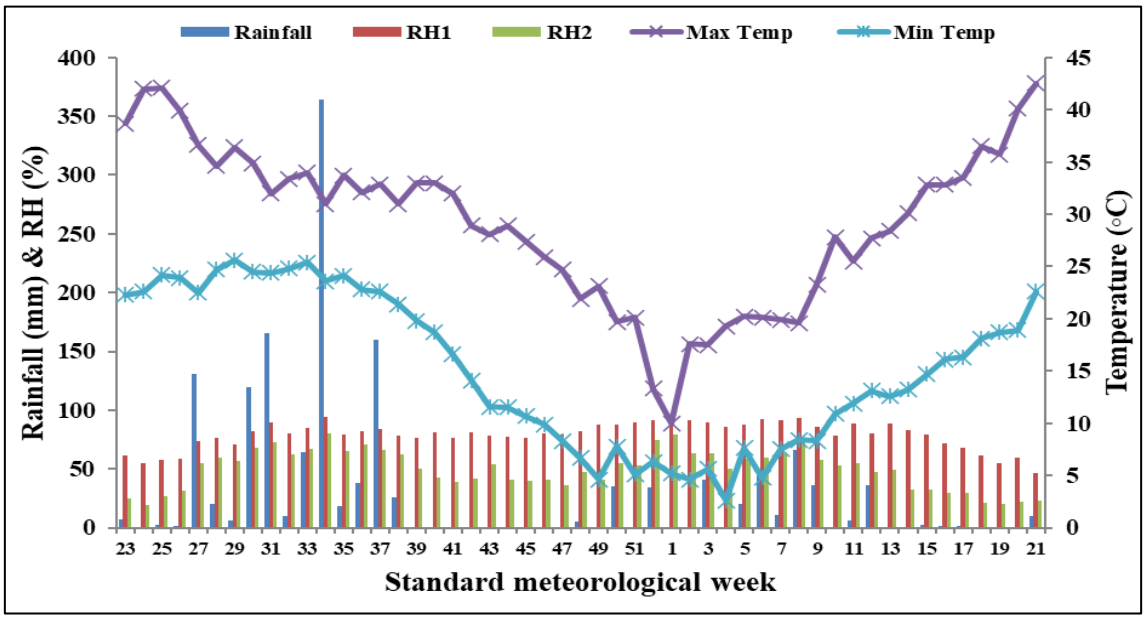
Materials and Methods

Site description

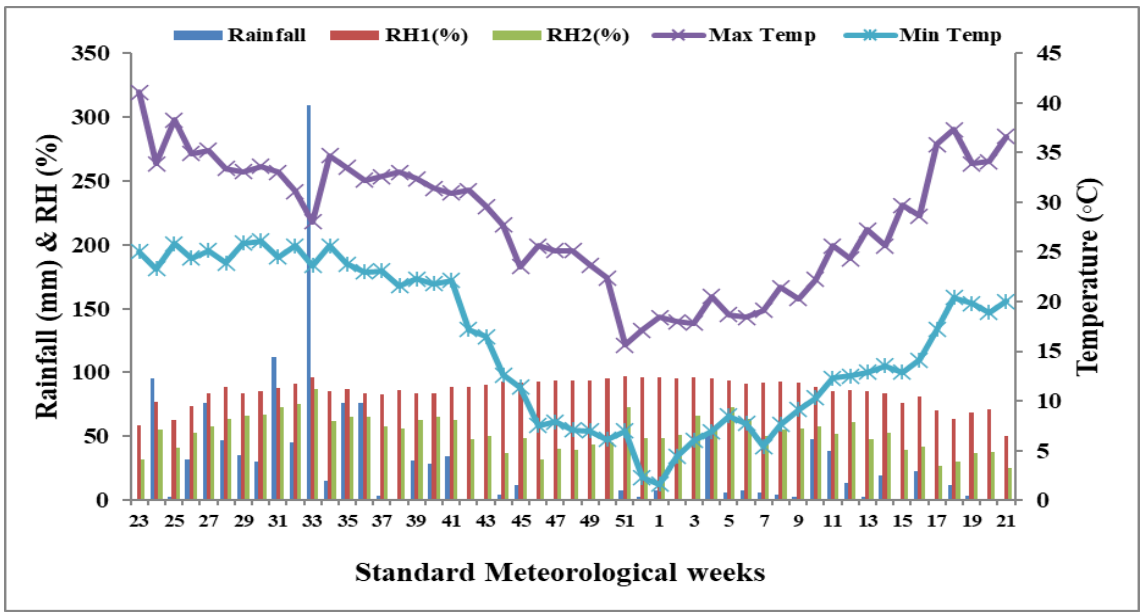
A two years study (2012-2014) on conservation agriculture was conducted at the research farm, FSR, Centre, Sher-e-Kashmir University of Agricultural Sciences and Tchnology of Jammu, Main Campus, Chatha (32^0-40*'* N, 74^0-58*'* E and 332m msl), Jammu and Kashmir, India. The study area represents tubal irrigation and input intensive region of sub-tropical zone (NARP Zone) of India. The soil of the experimental field was very deep (>20m), with high water table (1.5 m from top) clay loam with one% slope and classified as typic ustocrept. The top soil layer (0-15 cm) at the start of the experiment was non saline (EC 0.17 dsm^{-1}) with pH 8.10 and contained 5.50 gkg^{-1}Walkley Black Carbon, 8.53 $mgkg^{-1}$available nitrogen (Subbiah and Asija, 1956) [21], 0.5 mg kg^{-1} $NaHCO_3$- Exchangeable P (Olsen *et al*, 1954) [15] and 54.22 mg kg^{-1} $1NH_4OAc$ – Extractable K using flame photometer (Jackson, 1973) [11].

Weather information

The climate of Jammu is Sub-tropical (Low altitude sub tropical zone of Jammu) with hot and humid rainy season, hot dry summer and warm autumn and cool winter. The maximum temperature during summer rises to about 42 ºC and minimum temperature during winter fall to 3 ºC average rain fall of the study area is 1150 mm, major portion which is received during the months of July to September. The meteorological data with respect to rainfall, temperature and relative humidity were recorded at meteorological observatory located very close to the experimental area which reveals that the experimental site was mainly sub-tropical in nature endowed with hot and dry early summers followed by hot and humid monsoon seasons and cold and dry winters. The mean annual rainfall of the location varies from 1050-1115 mm of which about 70 per cent rainfall is received from June to September, whereas the remaining 30 per cent of rainfall is received in few scanty showers of cyclonic winter rains from December to March. Amongst the months, July and August during summer and December and January in winter experience the highest rainfall. The meteorological data for the crop growing periods from2012-13 to 2013-14 have been presented graphically in Fig 1.



2012-13



2013-14

Fig 1: Weekly weather parameters prevailing during the crop season

Rice and Maize + soyabean season

During the crop growth period of rice and maize + soybean, about 1125.7 mm of rainfall was received during the first year of cropping whereas 1067.7 mm of rainfall was received during the succeeding rice crop growth period of rice 2013.The total rainfall in the crop growing recorded during the first year of cropping remained substantially higher as compared to second year. The first year of cropping of 2012 and 2013 experienced 33.21 and 26.35 per cent higher rainfall over their respective normal rainfall of about 845.0 mm usually received at the location. The mean weekly rainfall ranged from 0.0 to 363.8 mm during the first year of 2012 and the corresponding value during 2013 was 0.0 to 309.4 mm. The temperature of the Jammu region often rises as high as 43 ^{0}C in the month of May-June. Mean weekly maximum temperature during *kharif* season (June-Oct.) period ranged between 28.7 ^{0}C to 42.1 ^{0}C and mean weekly minimum temperature ranged from 22.5 ^{0}C to 10.7 ^{0}C during 2012. However during 2013 mean weekly maximum and minimum temperature recorded values were 30.9 ^{0}C to 41.1 ^{0}C and 17.2 ^{0}C to 26.1 ^{0}C, respectively during 2013. Data with respect to relative humidity recorded during the *kharif* season of 2012 reveal that morning mean maximum and mean minimum relative humidity varied from 55 per cent to 94 per cent and 19 per cent to 80 per cent, respectively in the evening. Whereas, the corresponding values were between and 63 to 96 per cent and 41 to 87 per cent, respectively during 2013.

Wheat, marigold and French bean season

During the *rabi* season (Nov. to May) about 338.8 mm of total rainfall was received during the first year of cropping, whereas 257.8 mm of rainfall was received during the succeeding year of crop growth period i.e. 2013-14.The total rainfall in wheat, marigold and French bean crop growing period remained considerably higher as compared to that received during 2013-14.The mean weekly rainfall ranged

from 0.0 to 65.8 mm, respectively during 2012-13 and 0.0 to 52.0 mm, respectively during 2013-14. Mean weekly maximum temperature ranged from 10.0 ºC to 40.1 ºC in 20th standard meteorological week and mean weekly minimum temperature ranged from 2.6 ºC in 4th standard meteorological week to 18.9 ºC in 20th standard meteorological week during 2012-13. Likewise, mean weekly maximum temperature ranged from 15.6 ºC in 51st standard meteorological week to 37.3 ºC in 18th standard meteorological week and mean weekly minimum temperature ranged from 1.6 ºC in 1st standard meteorological week to 20.4 ºC in 18th standard meteorological week during 2013-14. Mean weekly maximum and minimum relative humidity ranged from 55 to 94 per cent and 20 to 79 per cent during 2012-13 and 64 to 97 per cent and 27 to 73 per cent, respectively during 2013-14.

Experimental details

The experiment was laid out in split-plot design with two crop establishment methods (Minimum/Zero tillage and conventional tillage) and three cropping systems (Rice-Wheat, Rice-Marigold-French bean and Maize + soybean-Wheat) in main plot (21m x 5m= 105m^2) and two fertilizer rates (Rec. Dose of Fertilizer and 75% RDF + 25%N through FYM) with and without mulching in sub-plots making 24 treatment combinations with three replications. The sub plot size was 60m²(12m x 5m). Treatments were assigned to the same experimental plots in the both years of study. Treatment details are summarized as under:-

Treatment details

A. Main Plot (Crop establishment method x Cropping System)

I Crop establishment methods

T1 = Minimum Tillage
T2 = Conventional Tillage

II Cropping System

CS1 = Predominant Cropping System (Rice-Wheat)
CS2 = Rice-Marigold-Frenchbean
CS3 = Maize+Soybean – Wheat

B. Sub Plot (Mulch x Fertilizer)

I Mulch

M1 = No Mulch
M2 = Mulch

II Fertilizer rates

F1 = Recommended Dose of Fertilizer
F2 = 75% RDF + 25% N through Organic Manure

Crop management

Fertilizer management

The schedule of fertilizer application varied with crop requirement in system and fertizer rate treatments is summarized in Table-1

Table 1: The schedule of fertilizer application varied with crop requirement in system and fertizer rate treatments is summarized

S. No	Crops	Fertilizer Applied (Kg^{-1})			FYM	Mode of application
		N	P	K		
1	Rice	50	30	20		Broadcasting
2	Wheat	100	50	25		Broadcasting
3	Marigild	120	100	100		Band placement
4	Maize	90	60	30		Band placement
5	Frenchbean	50	100	50		Broadcasting

Seedling and Seeding rate

Rice

Wet bed rice nursery (cv. IET-1410) for conventional method(manual dry seeding method) with 25 kg seed was grown on an nursery area 300m^2. 28 days old rice seedlings were transplanted at 20 x 10cm spacing with one seedling per hill. Where as the plots under direct seeded rice (DSR) was sown with commercially sold tillage seed drill having inclined plate seed metering system at 20 cm row spacing using a seed rate of 25 kg ha^{-1}. The sowing of DSR and raising of rice nursery for conventional method was done on the same day in 2nd week of june in each year.

Wheat

During *rabi* season, the wheat variety *PBW 557* was sown in the month of November using seed drill @ 100 kg seed/ha for crop established under conventional practice where as under minimum tillage, zero till drill was used with same seed rate.

Maize+Soyabean

Hybrid maize crop (variety- double Monsanto) was also raised during *kharif* season i.e. third week of June during both the years. The field was prepared with tiller followed by rotavator under conventional method of sowing and seeds were directly sown with line marker under both the methods of sowing (minimum/zero tillage and conventional tillage) using seed rate of 20kg/ha having spacing of 60 x 20 cm. whereas, Soybean crop was taken as inter crop, an additive series (1:1) with a seed rate of 20kg/ha.

Marigold

Marigold (*PusaNarangi*) crop was raised in nursery in September @ 1 kg seed/ha and later transplanted in the month of October at the experimental site at distance of 50X40cm.

Frenchbean

French bean (cv. contender) was sown in the month of march in both the years with seed rate of 80kg/ha at spacing of 60X10 cm was sown manually with line marker under minimum tillage practice and conventional method of sowing.

Weed Management

Rice

The weeds (Broad leaves, sedges and grasses) under minimum tillage treatments of dry drictseeded rice were controlled with the application of pendimethaline @ 1000 g (ai) ha^{-1} as preemergence followed by bispyribac applied @ 250 g (ai) ha^{-1} as post emergence at 25 DAS using flatfannozeel Knapsac sprayer. In conventional method (Mannual transplanting) one manual weeding was done at 30DAT

Wheat
Application of Clodinofoppropogyl @ 60 g (ai)ha^{-1}as post emergence at 30 DAS using flatfannozeel Knapsac sprayer.
Maize+Soyabean.
Weeding was done manually with the help of *khurpi* at 20 and 40 DAS and earthing was done manually at knee high stage 25 DAS.

Marigold and Frenchbean
For effective weed control, mechanical weeding with *khurpi* was done at 20 DAT.

Irrigation and water management.
All the crops in a system i.e rice-wheat, maize+soyabean-wheat and rice-marigold-frenchbean were grown under assured irrigation condition. In general, irrigation was applied as per the critical growth stages of the crops so that the crops did not suffer due to moisture stress and thus had no mazor effect on yields retention/incorporation of residues lowered the irrigation water requirement arranging from 3-6 ha cm in rice and 1-3 ha cm in wheat, maize, soyabean, frenchbean and marigold under different treatment. However the crop wise irrigation practice followed is summarized as under.

Rice
In conventional method (manual transplanting) plots kept flodded (6 cm of standing water) for 1st two weeks followed by five irrigations (6 cm depth) at the appearance of hair like cracks on the soil surface till maturity. Alternate wetting and drying system DSR received pre sowing irrigation and subsequent seven irrigatins were applied at the appearance of hair like cracks after seedling emergence till maturity.
Wheat.
Wheat crop received one pre sowing irrigation and three post emergence irrigations (5 cm each) at critical stages of water stress viz CRI (25 DAS), tillering (45 DAS), panicle initiation (70 DAS).

Maize + Soyabean
Maize crop received one pre sowing irrigation and two post emergence irrigations (5 cm each) at critical stages of water stress viz Knee high and taselling

Marigold
Marigold crop received one pre sowing irrigation and three post emergence irrigations (5 cm each) at critical stages of water stress viz Young seedling, branching and flowering.

Freenchbean
Frenchbean crop received one pre sowing irrigation and three post emergence irrigations (5 cm each) at critical stages of water stress viz Young seedling, flowering pod formation.
Before starting the experiment a composite soil sample (0-15 cm) was collected from the experimental site. At the end of cropping cycle, post harvest soil sample (0-15 cm) were collected and analyzed for physico-chemical properties as per standard procedure. For biological properties soil samples were collected at the end of each cropping cycle. Microbial count was recorded as per standard plate count technique (Wollum, 1982) by employing different media's for bacteria, fungi and actinomycetes. Soilsamples for determination of bulk density of undisturbed soil was taken before and after each crop cycle by using core sampler having 4.5 cm internal diameter. Collected soil samples were oven dried and bulk density was expressed as Mg m^{-3}**.** For N, P and K uptake uniform representative samples were randomly selected from each plot, dried, processed and analyzed to determine the N, P and K content in plant samples (grains and straw) of rice at harvest. Uptake (grain and straw) was calculated by multiplying their respective contents with plant dry matter (grain and straw). Statistical analysis of all the data was done as per the methodology of Gomez and Gomez (1984). The rice equivalent yield was calculated by using the following formula:

$$REY = \frac{\Sigma. Yi \times Pi}{P(p)}$$

Where REY denotes rice equivalent yield
Yi = yield of different crops
Pi = price of respective crops
P (p) = price of paddy
&
Apparent nutrient use productivity was calculated by using the following formula:

$$ANUP = \frac{EY}{\text{Total nutrient used}}$$

Result and Discussion
Yield and productivity in terms of REY (kg/ha)
The grain yield of different crops in a system observed during *kharif* 2012-*rabi* 2013-14 was expressed in Rice Equivalent yield (REY). Grain yield of different crops in a system is quantifiable and important parameter which is dependent upon various parameters involved in crop production. The expression of grain yield in a cropping system is expressed in rice equivalent yields (REY) which is the measure to quantify the yields obtained from different crops in a crop cycle.
Under crop establishment methods, conventional tillage recorded significantly higher rice equivalent yield than (14.3 and 12.9t/ha) the minimum tillage (12.8 and 11.5t/ha) which works out to be 12.04 per cent and 17.5 per cent higher during 2012-13 and 2013-14, respectively. Economic yields under minimum tillage were lower which may be due to poor crop establishment, higher microbial resistance to soil and crop weed competition (Brar *et al*., 2011) [6]. Under various cropping system treatments, rice-marigold-frenchbean produced significantly higher REY (22.3 and 19.8t/ha) followed by maize + soybean-wheat (10.18 and 7.39t/ha) over existing rice-wheat cropping system(8.33 and 7.50t/ha) during 2012-13 and 2013-14 respectively (Table-2). Kachroo *et al.* (2012) [12] reported similar findings. Shivay *et al.* (2001) [18] reported that involving legume as intercrop in maize crop increased the maize equivalent yield. Rice equivalent yield (REY), during both the years, under cover with rice mulch (more than 66% land cover) during *rabi* season produced significantly higher values of REY(14.0 and 12.6t/ha) and no mulch treatment(13.23 and 11.84t/ha). Dessai *et al.* (2014) [8] reported that significantly higher paddy equivalent yield was recorded in mulching over no mulch. However, between the fertilizer application of 75% recommended dose of fertilizer coupled with 25% N through FYM to each crop in a cycle during both the years of experimentation resulted significantly higher REY (13.85 and 12.48t/ha).

Soil properties

In general, organic carbon and pH under different treatments was found non-significant which ranged from 0.55%-0.60% and 8.07%-8.24% during 2012-13 and 0.58%-0.63% and 8.22%-8.38% during 2013-14 (Table 3). Under different treatments bulk density was also found to be non-significant but numerically higher value (1.40 g/cm^3) was observed under minimum tillage, subjected to some amount of soil compactation as compared to conventional tillage practices, when soil is loosened which increased soil aeration and hence decreased bulk density (1.37).Under crop establishment method available nitrogen, phosphorus and potassium (NPK) was found to be non-significant during both the years of experimentation. However, under cropping system treatments. Maize +Soybean cropping system recorded significantly higher available nitrogen (239 and 248 kg/ha) during 2013 &14 crop cycle followed by rice-marigold-frenchbean cropping system (230&233 kg/ha). However rice-marigold-french bean cropping system recoded significantly higher P&K (22.40&140 kg/ha) over the existing rice-wheat cropping system (19.10 &128 kg/ha) during 2012-13 crop cycle followed by maize+soybean-wheat cropping system (25.06 & 135 kg/ha) in 2013-14 crop cycle. Similarly, in 2013-14 crop cycle higher P&K (25.10&136 kg/ha) was observed in rice-marigold-french bean cropping system over the existing rice-wheat system followed by maize + soybean-wheat cropping system (22.84 & 133 kg/ha) which was owing to more removal of nutrients by cereal-cereal rotation (Kachroo *et al*. 2014 and Thakur *et al*. 2009) [13, 52]. Mulching with rice straw @ 5t/ha to Rabi crops recorded significantly higher available NPK over no mulching treatments during both the years of experimentation which might be due to positive effect of mulching that increased the organic matter in the soil decomposition.

Soil microbial count (Bacteria, Fungi and Actinomycetes) was found significantly higher under minimum tillage as compared to conventional tillage (Table 4) that might be due to higher organic matter and favorable temperature and continuous carbon supply from crop residue, serves as an energy source for microorganisms. Bazaya *et al*. (2009) [5] reported that bigger colonies of bacteria, fungi and azotobacter were found with zero tillage. Soil carbon/organic matter known as 'black gold' affects the physical, chemical and biological processes within the soil system (Reicosky and Saxton, 2007) [16]. Under cropping system treatments, maize+soybean-wheat cropping system recorded significantly higher population of bacteria and fungi followed by rice-marigold-frenchbean cropping system over existing rice-wheat system which might be due to intercropping of soybean (legume crop) with maize. Similar results were reported by Walia *et al*. (2011) [23]. Application of 75% RDF + 25% N through FYM recorded significantly higher microbial population over 100% RDF that might be due to continuous supply of soil carbon, serves as an energy source for microorganisms. Microbial population was found to be increased in wheat due to application of different sources of organic nutrients in combination to control, which accordingly resulted in a notable enhancement in dehydrogenase enzyme activities (Singh *et al.* 2011) [20]. Application of inorganic fertilizer integrated with FYM and biofertilizers produced favorable influences on soil bacteria and indirect effects on higher yield and nutrient uptake of rice and wheat (Bahadur *et al.* 2013) [3].

System nutrient uptake (Kg/ha) and apparent nutrient productivity (Kg/ha/Kg) and Total nutrient uptake (N, P& K) in a system was recorded significantly higher under conventional tillage during both years of cropping. Arshad *et al*. (1995) [2] reported that increased availability of nitrate nitrogen under conventional tillage resulted in better growth and development and ultimately higher grain yield. Higher temperature in top soil (conventional sown plots) promoted metabolic processes (Lavahun *et al*., 1996) [14] which increased N, P, and K absorption and ultimately resulted in more uptakes. Application of rice straw @ 5 t/ha to *rabi* crops recorded significantly higher total N, P, K uptake over 100% RDF.

Under crop establishment methods, conventional tillage recorded significantly higher apparent nutrient productivity (33 and 34 kg/ha) than minimum tillage (30 kg/ha) during both the years of study. Among various cropping systems, rice-marigold-frenchbean cropping system recorded significantly higher apparent nutrient productivity (36 kg/ha) over existing rice-wheat cropping system (30 kg/ha). Mulching with rice straw @ 5 t/ha to *rabi* crops recorded significantly higher apparent nutrient productivity (33 kg/ha) over no mulched treatments (31 kg/ha) during the both years of cropping. Application of 75% RDF + 25% N through FYM recorded significantly higher apparent nutrient productivity (32 kg/ha) as compare to 100% RDF (31 kg/ha).

System economics (Rs. /ha)

conventional tillage recorded higher cost of cultivation during both the years of experimentation which works out to be 10.61 per cent and 10.67 per cent (Table-5). Similarly under different cropping system treatments, rice-marigold-frenchbean recorded higher cost of cultivation (Rs 111107/ha and Rs 118224/ha) than maize+soybean-wheat (Rs 67809/ha and Rs 76244/ha) and rice-wheat (Rs 61758/ha and Rs 67131/ha) in 1st and 2nd year, respectively. Cost of cultivation during both the years of experimentation under cover with rice straw (< 66% land cover) recorded higher (Rs 83654/ha and Rs 90706/ha) than under no mulch (Rs 76794/ha and Rs 83706/ha) which indicated 8.93 per cent higher cost of cultivation during *kharif* 2012 crop cycle and 8.36% during *kharif* 2013 crop cycle.However, between the fertilizer doses, application of 75% recommended dose of fertilizer coupled with 25% N through FYM to each crop in a crop cycle of both the years of experimentation recorded higher cost of cultivation (Rs 87629/ha and Rs 94441/ha) over 100% recommended dose of fertilizer application (Rs 72820/ha during *kharif* 2012 crop cycle and Rs 79970/ha during *kharif* 2013 crop cycle).

Moreover, Conventional tillage recorded higher gross and net returns than minimum tillage which works out to be 12 per cent and 12.89 per cent during *kharif* 2012 crop cycle and 11.52 per cent and 12.08 per cent during *Kharif* 2013 crop cycle.Similarly, among various cropping systems, rice-marigold-frenchbean recorded higher gross and net returns (Rs 351840 and Rs 240372/ha) than maize+soybean-wheat (Rs 160441/ha and Rs 92631/ha) and rice-wheat (Rs 131338/ha and Rs 69580/ha) in 1st year of the study and (Rs 357257/ha and Rs 239150/ha) than maize+soybean-wheat (Rs.169005/ha and Rs. 92761/ha) and rice-wheat (Rs 135184/ha and Rs 68022/ha) in the 2nd year of study. The per cent increase was in order of 167.8 per cent and 245.46 per cent in rice-marigold-frenchbean and 22.15 per cent and 33.12 per cent in maize+soybean-wheat over existing rice wheat cropping system during 1st year of the experimentation and

during 2nd year of experimentation the per cent increase was of the order of (164.2 per cent and 251 per cent) in rice-marigold-frenchbean and (25 per cent and 36.36 per cent) maize+soybean-wheat over the existing rice-wheat cropping system.Gross and net returns during both the years of experimentation under cover with rice mulch (< 66% land cover) recorded higher values (Rs 220593/ha and Rs 136938/ha) as compared with no mulch (Rs 208486/ha and Rs 131691/ha) during *kharif* 2012 crop cycle which indicated 5.80 per cent and 3.98 per cent higher gross and net returns and (Rs 227685/ha and Rs 136978/ha) under mulched treatments over no mulch (Rs 213259/ha and Rs 129553/ha) which indicated 6.76 per cent and 5.73 per cent higher gross and net returns during *kharif* 2013 crop cycle However, between fertilizer application of 75% recommended dose of fertilizer computed with 25% through FYM, the crops in a crop cycle of both the years of experimentation resulted higher gross returns (Rs 218217/ha and Rs 224658/ha respectively) over 100% RDF (Rs 210863/ha and Rs 216286/ha) during both the years of experimentation. Whereas net returns (Rs 138042/ha and Rs 136315/ha) were recorded higher with application of 100% RDF as compared to 75% RDF + 25% through FYM (Rs 130587/ha and Rs 130216/ha) during both the years of experimentation.

No much difference was observed in B:C ratio in conventional tillage (1.58) and minimum tillage (1.57) during *kharif* 2012 crop cycle and the trend was reversed during *kharif* 2013 crop cycle i.e. B:C ratio under minimum tillage (1.44) was observed higher than conventional tillage (1.43). Among various cropping system treatments, rice-marigold-frenchbean recorded the higher B:C ratio (2.18 and 2.03) than maize+soybean-wheat (1.40 and 1.40) and rice-wheat (1.15 and 1.03) during 1st and 2nd year of experimentation respectively. However, B: C ratio during both the years of experimentation under cover with rice straw (< 66% land cover) observed lower B: C ratio (1.54 and 1.42) as compared to no mulch (1.61 and 1.45) whereas between fertilizer application 75% RDF + 25% through FYM the crop in a crop cycle of both the years registered low B:C ratio (1.38 and 1.28) over the 100% RDF (1.77 during 2012-13 and 1.59 during 2013-14).

Table 2: Productivity &Economics as affected by crop establishment methods, cropping systems, mulching and fertilizer rates

Treatment	REY			Gross returns (Rs ha^{-1})			Cost of cultivation (Rs ha^{-1})			Net returns (Rs ha^{-1})			B:C Ratio		
	2012-13	2013-14	Mean	2012-13	2013-14	Mean	2012-13	2013-14	Mean	2012-13	2013-14	Mean	2012-13	2013-14	Mean
Crop Establishment Methods															
Minimum Tillage	12848	11581		202363	208464		76181	82789		126181	25674		1.57	1.44	
Conventional Tillage	14395	12916		226716	232480		84268	91622		142447	140858		1.58	1.43	
SEM ±	37.3	61.9		588	1115.1					588	1115.1				
LSD (P=0.05)	113.3	188		1784	3382					1784	3382				
Cropping System															
Rice-Wheat	8339	7509		131338	135184		61758	67132		69580	68022		1.15	1.03	
Rice-Marigold-Frenchbean	22339	19848		351840	357257		111107	118224		240372	239150		2.18	2.03	
Maize+soybean-Wheat	10187	7389		160441	169005		67809	76244		92631	92761		1.40	1.24	
SEM ±	45.7	75.9		720	1365.2					720	1365.2				
LSD (P=0.05)	138.7	230		2185	4142					2185	4142				
Mulching															
No Mulch	13237	11848		208486	213259		76794	83706		131691	129553		1.61	1.45	
Mulch with rice straw	14006	12649		220593	227685		83654	90706		136938	136978		1.54	1.42	
SEM ±	37.5	33.1		591	595.8					591	595.8				
LSD (P=0.05)	106.8	94		1681	1694					1681	1694				
Fertilizer Rates															
100% RDF	13388	12016		210863	216286		72820	79970		138042	136315		1.77	1.59	
75%RDF+25% N through FYM	13855	12481		218217	224658		87629	94441		130587	130216		1.38	1.28	
SEM ±	37.5	33.1		591	595.8					591	595.8				
LSD (P=0.05)	106.8	94		1681	1694					1681	1694				

Table 3: Soil fertility status and bulk density as affected by crop establishment methods cropping system mulching and fertilizer rates

Treatment	pH		O C (g/kg)		Bulk density (g/cm^3)		Av.N (kg ha^{-1})		Av.P (kg ha^{-1})		Av.K (kg ha^{-1})	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Crop Establishment Methods												
Minimum Tillage	8.16	8.26	0.58	6.0	1.40	1.42	240	232	21.03	22.36	139	135
Conventional Tillage	8.14	8.34	0.57	5.9	1.37	1.39	224	224	21.62	21.35	134	131
SEM ±												
LSD (P=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Cropping System												
Rice-Wheat	8.12	8.25	0.55	5.8	1.37	1.37	226	218	19.10	19.4	128	120
Rice-Marigold-Frenchbean	8.15	8.32	0.59	6.0	1.34	1.34	230	233	22.40	25.10	140	136
Maize+Soybean-Wheat	8.17	8.33	0.57	5.9	1.36	1.36	239	248	22.06	22.84	135	133
SEM ±							4.0	2.8	0.7	0.4	1.9	2.8
LSD (P=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	12.2	8.4	2.0	1.1	5.9	8.6
Mulching												
No Mulch	8.16	8.32	0.55	5.8	1.37	1.36	226	231	20.41	21.28	129	126
Mulch with rice straw (>60% area)	8.15	8.28	0.60	6.1	1.35	1.35	238	245	21.24	22.42	144	140
SEM ±							3.8	3.5	0.4	0.5	2.8	2.3
LSD (P=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	10.9	10	1.0	1.3	8.0	6.6
Fertilizer Rates												

100% RDF	8.24	8.38	0.56	5.8	1.37	1.36	237	244	21.53	22.36	140	136
75%RDF+25% N through FYM	8.07	8.22	0.59	6.63	1.35	1.35	227	232	20.83	21.34	133	130
LSD (P=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Initial			0.55				221.12		19.20		122.02	

Table 4: Microbial count of crop establishment methods, cropping systems, mulching and fertilizer rates

Treatment	Bacteria (x 10^6 CFU/g)		Fungi (x 10^3 CFU/g)0^3)		Actinomycytes (x 10^4 CFU/g)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Crop Establishment Methods						
Minimum Tillage	14.0	17.56	20.17	22.72	18.97	21.25
Conventional Tillage	11.7	16.39	17.17	18.42	16.89	18.94
SEM ±	0.4	0.3	0.7	0.6	0.5	0.5
LSD (P=0.05)	1.2	0.9	2.2	1.9	1.5	1.5
Cropping System						
Rice-Wheat	10.92	15.79	16.83	19.81	17.0	18.79
Rice-Marigold-Frenchbean	12.67	17.00	19.42	21.13	18.67	21.13
Maize+soybean-Wheat	14.17	18.13	19.75	20.75	18.13	20.38
SEM ±	0.5	0.4	0.9	0.8	0.6	0.6
LSD (P=0.05)	1.5	1.1	2.7	2.30	1.9	1.8
Mulching						
No Mulch	12.0	16.50	18.14	20.03	17.64	19.75
Mulch with rice straw	13.0	17.44	19.19	21.11	18.12	20.44
SEM ±	0.4	0.5	0.5	0.6	0.5	0.4
LSD (P=0.05)	1.2	1.3	1.5	1.6	1.4	1.3
Fertilizer Rates						
100% RDF	11.91	15.61	16.89	18.75	16.67	19
75%RDF+25% N through FYM	13.22	18.33	20.44	22.39	19.19	22.79
SEM ±	0.4	0.5	0.5	0.6	0.5	0.4
LSD (P=0.05)	1.2	1.3	1.5	1.6	1.4	1.3

Table 5: Total system nutrient uptake and apparent nutrient productivity as affected by crop establishment methods, cropping systems, mulching and fertilizer rates

Treatment	Nitrogen (kgha^{-1})		Phosphorus (kgha^{-1})		Potassium (kgha^{-1})		Apparent Nutrient Productivity (kgha^{-1} kg^{-1})	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Crop Establishment Methods								
Minimum Tillage	136	129	40	37	185	171	30	30
Conventional Tillage	155	147	46	42	210	196	33	34
SEM ±	1.2	0.9	1.0	0.8	1.4	1.1	0.10	0.10
LSD (P=0.05)	3.7	2.9	2.9	2.5	4.1	3.3	0.31	0.32
Cropping System								
Rice-Wheat	128	118	30	27	149	136	30	30
Rice-Marigold-Frenchbean	169	166	51	48	253	246	36	36
Maize+soybean-Wheat	139	129	48	43	190	169	29	29
SEM ±	1.5	1.2	1.2	1.0	1.2	1.4	0.13	0.13
LSD (P=0.05)	4.5	3.5	3.6	3.1	5.1	4.1	0.38	0.39
Mulching								
No Mulch	139	131	41	37	189	175	31	31
Mulch with rice straw	152	144	45	42	206	192	33	33
SEM ±	1.3	1.2	1.5	1.2	1.3	0.9	0.11	0.11
LSD (P=0.05)	3.7	3.5	4.2	3.4	3.6	2.5	0.31	0.30
Fertilizer Rates								
100% RDF	145	138	44	41	197	185	31	31
75%RDF+25% N through FYM	146	137	42	38	198	183	32	32
SEM ±	1.3	1.2	1.5	1.2	1.3	0.9	0.11	0.11
LSD (P=0.05)	3.7	3.5	4.2	3.4	3.6	2.5	0.31	0.30

Conclusion

Overall, from the study, it can be concluded that application of mulching with rice straw @ 5ton/ha to *rabi* crops in conjugation with 75% RDF + 25% N through FYM to rice-marigold-frenchbean cropping system recorded significantly higher REY with higher gross returns, net returns and B:C ratio.

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