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CONSERVATION AGRICULTURE EFFECTS ON SELECTED SOIL QUALITY PARAMETERS UNDER CEREAL-CEREAL-LEGUME AND CEREAL-LEGUME-LEGUME CROPPING SYSTEM IN FAR WESTERN NEPAL

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ABSTRACT

Conservation agriculture (CA) practices improve soil quality and recuperate degraded soils. This experiment was carried out at the research field of Regional Agricultural Research Station, Bhagetada, Dipayal, Doti, Nepal for two consecutive years 2014/15 to 2015/16 to determine the effect of maize based conservation agriculture system on soil quality parameters namely bulk density and soil organic carbon. This study examined the effects of the two cultural practices (conservation agriculture and conventional agriculture), two cropping systems (cereal-cereal-legume and cereal-legume-legume) and two varieties of maize [(*Zea mays* L.) (Rajkumar and Arun2)], two varieties of wheat [(*Triticum aestivum* L.) (Dhaulagiri and WK 1204)], two varieties of lentil [(*Lens culinaris* Medik.) (Shimal and Khajura1)] and two varieties of mungbean [(*Vigna radiata* L. Wilczek) (Pratikshya and Kalyan)] in the varietal sequence of Rajkumar-Dhaulagiri and Shimal-Pratikshya, Rajkumar-WK 1204 and Khajura1-Pratikshya, Arun2-Dhaulagiri and Shimal-Kalyan and Arun2-WK 1204 and Khajura1-Kalyan. The treatments were laid out in split-split plot design with four replications. Results indicated that the bulk density of maize-wheat-mungbean cropping system was lower (1.65 g/cm^{-3}) than that of maize-lentil-mungbean cropping system (1.66 g/cm^{-3}). The bulk density of CA practices was found higher (1.67 g/cm^{-3}) than that of conventional agricultural practices (1.65 g/cm^{-3}). The ratio of soil organic carbon (SOC) increment under cereal-legume-legume cropping system and conservation agricultural practices was 1.5% (1.38) and 11.6% (1.44) higher than cereal-cereal-legume cropping system (1.38) and conventional agricultural practices (1.29), respectively. Similarly, the ratio of SOC increment obtained from the interaction effect of cereal-legume-legume cropping system, CA practices and varietal sequences of hybrid maize, followed by lentil and mungbean was 8.6% higher (1.51) than that of cereal-cereal-cropping system, conservation agricultural practices and varietal sequences of hybrid maize, followed wheat and mungbean (1.39). So, the farmers of far western river basin agro-environment are suggested to adopt maize-lentil-mungbean cropping system, conservation agricultural practices and varietal sequence of hybrid maize, followed by lentil and mungbean variety to improve soil quality.

Keywords: conservation agriculture, cropping system, bulk density and soil organic carbon

INTRODUCTION

Agriculture sector has major challenges of increasing the food production per unit area without increasing the area of cultivation (Stevenson *et al.*, 2013). The effect of climate change has added challenges towards sustainable food production (Palm *et al.*, 2013; Paudel *et al.*, 2014). Agriculture Development Strategy has set the target for improving the soil organic matter from 1.96 to 3% and reducing the degraded lands by more than 20% up to year 2020 in Nepal (ADS, 2016). Conservation agriculture is such approach which contributes to minimize soil disturbance and improve soil aggregation and nutrient availability (Lal, 2004a, b). Conservation agriculture has been identified as the friendly technology for small farm holders. Conservation agriculture contributes by maintaining soil fertility and enhancing agricultural productivity from the resources (Barren *et al.,* 2003; Erkossa *et al.,* 2006; Wall, 2007; Hobbs *et al.,* 2008).

Most of the agricultural related problems of the small farming system can be addressed by using conservation agricultural technology (Stainer *et al.,* 1998; Fowler and Rockstorm,

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2001; Derpsch, 2003; Hobbs *et al*., 2008). Conservation agriculture (CA) has potential to change soil physical, chemical and biological soil quality parameters compared to conventional tillage (CT) systems. The beneficial effect of CA reflects not only in terms of increased crop productivity and labor saving but it also helps in achieving environmental sustainability beside soil and land regeneration. The CA has been reported to improve crop input-output relationship, conserving natural resources through lowering soil erosion, arresting water losses through reducing soil evaporation, sequestering atmospheric carbon in soil and reducing energy needs of agro-cultural sector (Jat *et al*., 2005; Yadav *et al*., 2016).

Application of conservation agriculture helps to resolve the issue of soil degradation, arised due to soil organic matter depletion and soil erosion (Stoorvogel and Smaling, 1998; Drepchsel *et al*., 2001). Soil carbon plays vital role in enhancing soil fertility, conserving soil moisture and improving productivity (Hobbs, 2007). Intensive tillage and burning or removal of crop residues contribute to loss of soil organic carbon (Lal *et al*., 2007; Ghimire *et al*., 2015). Intensive tillage, nutrient depletion, unbalanced fertilization and removal of crop residues are one of the reasons of low soil organic carbon in South Asia (Lal, 2004a). Ghimire *et al*. (2012) reported 9.89% higher soil organic carbon in 0-50 cm soil profile under no tillage condition than conventional tillage under rice-wheat cropping system in Nepal. Microbial activity, root growth, soil aggregation, temperature, nutrient and water availability effects on soil organic carbon accumulation (Lal *et al*., 2007). High rainfall and moderate to low temperature of high mountains facilitate to extensive vegetative growth and low decomposition of soil organic matter resulting higher soil organic carbon (Gami *et al*., 2001; Bhattacharya *et al*., 2012). The soil organic carbon in tropical region is relatively low compared to sub-tropical and temperate region of Himalaya (Ghimire *et al*., 2017).

Far western agriculture of the country is generally characterized by lower yields and lower inputs in comparison to develop regions. These areas are also prone to food insecurity due to climate extremes such as drought. There is, therefore, potential for CA to be practiced to improve crop productivity. There is need of scientific studies directly comparing conservation with conventional agriculture practices in different agro-ecological zones and cropping system of the country, particularly focusing on far western hills agro-environmental conditions. This study was conducted to improve yield of maize, wheat, lentil and mungbean by improving physical properties of the soil through conservation agriculture based environmental friendly sustainable agricultural technology in far western Nepal.

MATERIALS AND METHODS

Experimental location

This experiment was carried out in the research field of Regional Agricultural Research Station (RARS), Bhagetada, Dipayal, Doti from May 2014 to May 2016. It is located at the latitude of N 29^{0}15'16.4" and longitude of E 80^{0}55'59.3". This research station is situated at the bank of Seti River at the altitude of 546 meter above sea level and it represents for irrigated river basin agro-environment of far western hills of the country (Prasai *et al*., 2016; Prasai *et al.*, 2018).

Agrometeorological observation

Total rainfall of 2014, 2015 and 2016 was 911, 88.2 and 1025 mm, respectively. The rainfall from July to September of 2014 was observed more than 100 mm. Highest and lowest rainfall was observed in July (260.3 mm) and April (5.4 mm). There was no rain in November of 2014. The rainfall of March and June to August of 2015 was observed more than 100 mm and highest rainfall was observed in July (188.5 mm). There was no rain in November to December of 2015. In 2016, highest rainfall (300 mm) was observed in July and the rainfall of June was observed 167 mm. The rainfall from 120-139 was observed in September to October. There was no rain in November to December and the total rainfall of January and April was 0.2 and 0.3 mm, respectively (Figure 1).

Temperature

The maximum temperature of 2014 ranged from 22.7 to 39.1ºC and highest and lowest maximum tamperature was observed in June (39.1ºC) and January (22.8ºC). Maximum temperature of more than 35ºC was observed from April to June and 30-35ºC was observed from July to October of 2014. Minimum temperature ranged from 6.5 to 24.6ºC, and highest and lowest minimum temperature was observed in August (24.6ºC) and December (6.1ºC) of 2014. Similarly, minimum temperature of more than 20ºC was observed from June to September and more than 17ºC was observed from May to October of 2014.

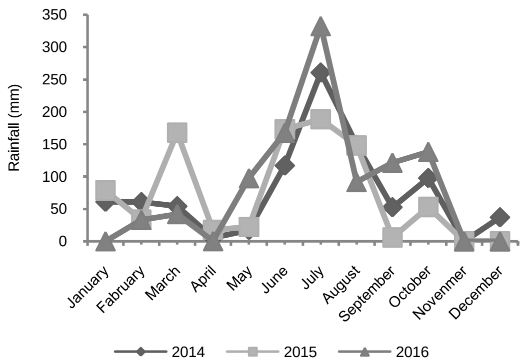

Figure 1. Rainfall of Dipayal, Doti during 2014-2016

In 2015, the maximum temperature ranged from 21.8 to 39.6ºC and highest and lowest maximum temperature was observed in May (39.6ºC) and January (21.8ºC). Maximum temperature of more than 35ºC was observed in May to June and more than 30ºC was found in April and July to October of 2015. Minimum temperature ranged from 4.8 to 23.9ºC and higest and lowest minimum temperature was observed in July (23.9ºC) and December (4.8ºC) of 2015. Minimum temperture of more than 20ºC in July to September and more than 15^{0}C in May and October of 2015.

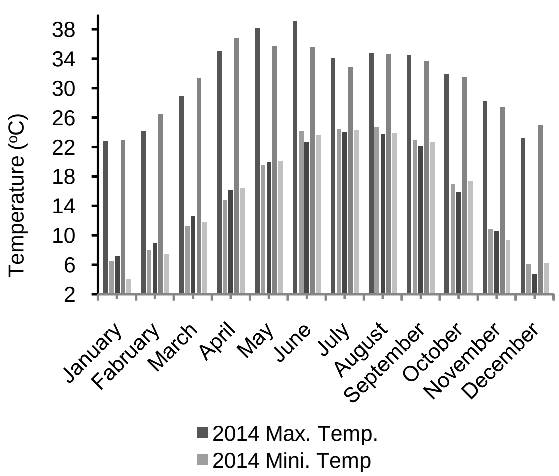

Figure 2. Maximum and minimum temperature of Dipayal, Doti during 2014-2016

Similarly in 2016, maximum temperature ranged from 22.9 to 36.8ºC and highest and lowest maximum temperature was observed in April (36.8ºC) and January (23.9ºC). Maximum temperature of more than 35ºC was found in April to June and more than 30ºC was found in March and July to October. Minimum temperature ranged from 4.1 to 23.6ºC and highest and lowest minimum temperature was observed in June (23.6ºC) and January (4.1ºC). The mimumum temperature of more than 20ºC was observed in May to September (Figure 2).

Experimental design

The split-split plot design with four replications was applied for this study. The plot area was 18 m^2. Three factors namely cropping system, cultural practices and variety was applied as main plot, sub-plot and sub-sub plot factors, respectively. Two cropping systems such as maize-wheat-mungbean and maize-lentil-mung bean cropping system were taken as main plot factor, two cultural practices that is conservation and conventional practices were applied as sub-plot factor. After harvesting of maize varieties, Dhaulagiri and WK 1204 varieties of wheat, followed by mungbean were sown in the experimental plots of maize-wheat-mungbean, cropping system, whereas Shimal and Khajura 1 varieties of lentil, followed by mungbean were sown in the experimental plots of maize-lentil-mungbean cropping system in both conservation and conventional agriculture practices plots in 2014-15 and 2015-16.

Table 1. Treatments detail of the experiment

S.No	Particulars
Main plot	Cropping system
1	Maize-wheat-mungbean (M-W-MB)
2	Maize-lentil-mungbean(M-L-MB)
Sub-plot	Cultural practices
1	Conservation agriculture (CA)
2	Conventional agriculture (ConvA)
Sub-sub plot	Variety
1	Rajkumar - Dhaulagiri and Shimal - Pratikshya
2	Rajkumar-WK 1204 and Khajura1-Pratikshya
3	Arun2-Dhaulagiri and Shimal-Kalyan
4	Arun2-WK 1204 and Khajura1-Kalyan

Crop history of the experimental site

Maize-wheat-fallow cropping system had been adopted in the experimental plots before conducting this CA experiment in the research field of Regional Agricultural Research Station, Dipayal, Doti. The research field used to till up to three times by tractor before seeding of each crop and crop residues used to remove from the field. The FYM fertilizer was used to apply at the rate of 5-10 t ha^{-1} depending upon the availability in neighbouring farmers. The chemical fertilizer used to apply at the rate of 80:40:20 NPK kg ha^{-1} (Prasai *et al*., 2018).

Cultural practices

In conservation practices, there was no tillage and residues of the crops were left in the plots whereas conventional experimental plots were tilled and residues of the crops were removed after harvest of each crop. Small furrows were open with the help of small kuto and farm yard manure and chemical fertilizers were placed into these furrows and were mixed with soil before seeding in the conservation experimental plots. Holes were made with the help of small peg and seed were placed into these holes. Three tillage was done by small hand tractor in the whole plots of the conventional practices. The farm yard manure fertilizer was spreaded in the conventional plots before tilling the plots and chemical fertilizers were applied and mixed with soil after tilling the plots. The maize stover and wheat straw was left in conservation plots after cutting 30 cm above ground during the harvesting period of maize and wheat whereas whole plants of maize and wheat were removed from the ground in the plots of conventional practices. Similarly, pods of lentil and mungbean were picked up from the plants and the plants were left in the field of conservation plots whereas whole plants were cut from their base in the field of conventional plots.

Measurement of soil parameters

Bulk density

The bulk density of the experimental plots was determined by using the protocol of Brady and Weil (2012). The height of the core ring was 13 cm. The bulk density was tested after harvesting of second year crops.

$$\text{Bulk density (g cm}^{-3}) = \frac{\text{Dry weight of bulk sample (g)}}{\text{Volume of the soil core (cm}^{-3})}$$

Volume of the soil core = $\pi r^2 h$, Where h= height of the core ring, r = radius of soil core

Organic matter

The organic matter test of soil sample was carried out at Regional Soil Testing Laboratory, Sundarpur, Kanchanpur, Nepal, following the protocol developed by Walkley and Black, (1934). Soil organic carbon was calculated by dividing organic matter with conversion factor (Nelson and Sommers, 1996).

$$\text{Soil organic carbon} = \frac{\text{Organic matter}}{1.724}$$

Statistical analysis

Statistical analysis was done by using MS Excel 2010 and Genestat Ver. 15 and Least significant difference (LSD $P \leq 0.05$) test was used for mean comparison to identify the significant components of the treatment means (Jan *et al*., 2009; Payne *et al*., 2009; Sharma *et al*., 2016; Dhami *et al*., 2018; Pal *et al*., 2018).

RESULTS

Bulk Density

Individual effect of cropping system, cultural practices and varietal sequence of maize, wheat, lentil and mungbean on bulk density of soil at conservation agricultural experiment

Effect of cropping system on soil bulk density at CA experiment

The bulk density of soil under the experimental plots of maize-lentil-mungbean cropping system was found higher (1.66 g/cm^{-3}) than the soil bulk density of the experimental plots of maize-wheat-mungbean cropping system (1.65 g/cm^{-3}). But the difference in soil bulk density between maize-wheat-mungbean and maize-lentil-mungbean was not significant (Figure 3).

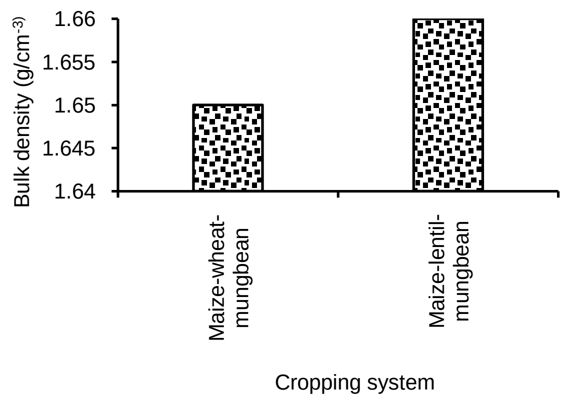

Figure 3. Effect of cropping systems on soil bulk density in CA experiment

Effect of cultural practices on soil bulk density at CA experiment

The bulk density of soil from the experimental plots of conservation agricultural practices (no tilled and residue retained) was found higher (1.67 g/cm^{-3}) than the soil bulk density from the experimental plots of conventional agricultural practices (tilled and residue removed) (1.65 g/cm^{-3}). The difference in soil bulk density between conservation and conventional agricultural practices was found significant (Table 2).

Table 2. Effect of cultural practices on bulk density of soil at conservation agriculture experiment in Bhagetada, Dipayal, Doti during 2015-2016

Cultural practices	**Bulk density (g/cm^{-3})**
Conservation agriculture (CA)	1.67
Conventional agriculture (ConvA)	1.65
Mean	1.66
F test	*
LSD	0.018

Effect of varietal sequence on bulk density of soil at CA experiment

The effect of varietal sequence of the varieties Rajkumar-Dhaulagiri and Shimal-Pratikshya, Rajkumar-WK 1204 and Khajura1-Pratikshya, Arun2-Dhaulagiri and Shimal-Kalyan and Arun2-WK1204 and Khajura1-Kalyan was found at par (1.66 g/cm^{-3}).

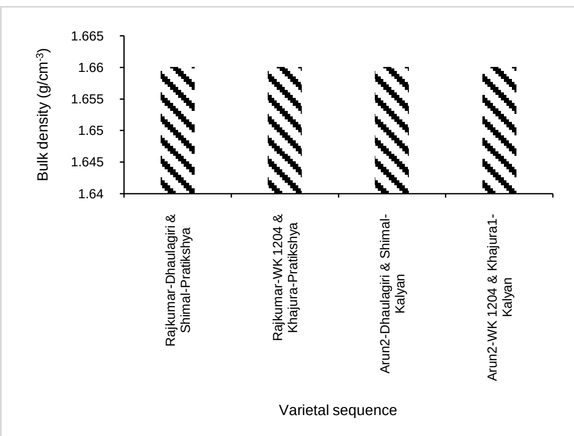

Figure 4. Effect of varietal sequence on soil bulk density in CA experiment

Interaction effect of cropping systems and cultural practices on bulk density of soil at CA experiment

Bulk density resulted from the interaction effect of maize-wheat-mungbean cropping system and conservation agricultural practices was found higher (1.67 g/cm^{-3}) than the soil bulk density obtained from the interaction effect of same cropping system and conventional agricultural practices (1.63 g/ cm^{-3}). Similarly, the soil bulk density obtained from the interaction effect of maize-lentil-mungbean cropping system and conservation agricultural practices was found higher (1.67 g/cm^{-3}) than the soil bulk density resulted from the interaction effect of same cropping system and conventional agricultural practices (1.66 g/cm^{-3}). The difference in soil bulk density was found significant ($P<0.05$) (Table 3).

Table 3. Interaction effect of cropping system and cultural practices on bulk density at conservation agriculture experiment in Bhagetada, Dipayal, Doti during 2015-2016

Cropping system	**Cultural practices**		
	Bulk density (g/cm^{-3})		
	Conservation agriculture	**Conventional agriculture**	**Mean**
M-W-MB	1.67	1.63	1.65
M-L-MB	1.67	1.66	1.66
Mean	1.67	1.64	1.65
F test	*		
CV%	0.9		
LSD	0.045		

Interaction effect of cropping systems and varietal sequences on soil bulk density at CA experiment

Interaction effect of maize-wheat-mungbean cropping system and varietal sequences of the varieties Rajkumar- Dhaulagiri- Pratikshya, Rajkumar-WK 204-Pratikshya, Arun2-Dhaulagiri-Kalyan and Arun2-WK1204-Kalyan produced at par bulk density (1.65 g/cm^{-3}). Similarly, the soil bulk density produced from the interaction effect of maize-lentil-mungbean cropping system and varietal sequences of the varieties Rajkumar-Shimal-Pratikshya, Arun2-Shimal-Kalyan and Arun2-Khajura1-Kalyan was found at par (1.67 g/cm^{-3}), whereas the soil bulk density produced from the interaction effect of maize-lentil-mungbean cropping system and varietal sequence of Rajkumar-Khajura1-Pratikshya was found 1.66 g/cm^{-3}. This result indicated that there is no interaction effect of cropping systems and varietal sequences on soil bulk density.

Interaction effect of cultural practices and varietal sequences on soil bulk density at CA experiment

The soil bulk density produced from the interaction effect of conservation agricultural practices and varietal sequences of the varieties Rajkumar-Dhaulagiri and Shimal-Pratikshya, Rajkumar-WK 1204 and Khajura1-Pratikshya, Arun2-Dhaulagiri and Shimal-Kalyan and Arun2-WK1204 and Khajura1-Kalyan was found at par

(1.67 g/cm^{-3}), whereas the soil bulk density produced from the interaction effect of conventional agricultural practices and varietal sequences of the varieties Rajkumar-Dhaulagiri and Shimal-Pratikshya, Arun2-Dhaulagiri and Shimal-Kalyan and Arun2-WK1204 and Khajura1-Kalyan was found at par (1.65 g/cm^{-3}) but the soil bulk density produced from the interaction effect of conventional agricultural practice and varietal sequence of Rajkumar-WK1204 and Khajura1-Pratikshya was found (1.64 g/cm^{-3}). This result also indicated that there is not interaction effect of cultural practices and varieties sequences on soil bulk density.

Interaction effect of cropping systems, cultural practices and varietal sequences on soil bulk density at CA experiment

The bulk density produced from the interaction effect of maize-wheat-mungbean cropping system, conservation agricultural practices and varietal sequences of the varieties Rajkumar-Dhaulagiri-Pratikshya and Rajkumar-WK 1204-Pratikshya was found at par (1.67 g/cm^{-3}) and higher than conventional agriculture (1.63 g/cm^{-3}). Similarly, interaction effect of same cropping system, conservation agricultural practices and the varietal sequences of Arun2-Dhaulagiri-Kalyan and Arun2-WK 1204-Kalyan produced the soil bulk density at par (1.68 g/ cm^{-3}) and higher than conventional agricultural practices (1.62 g/cm^{-3}). The soil bulk density produced from the interaction effect of maize-lentil-mungbean cropping system, conservation agriculture and the varietal sequences of Rajkumar-Shimal-Pratikshya and Rajkumar-Khajura1-Pratikshya was found at par (1.67 g/cm^{-3}) and higher than conventional agriculture (1.66 g/cm^{-3}) whereas the interaction effect of same cropping system, conservation agriculture and varietal sequences of Arun2-Shimal-Kalyan and Arun2-Khajura1-Kalyan produced the soil bulk density at par (1.66 g/cm^{-3}) and lower than conventional agriculture (1.67 g/ cm^{-3}).

Soil organic carbon

Individual effect of cropping system, cultural practices and varietal sequences on soil organic carbon at CA experiment in Bhagetada, Dipayal, Doti during 2014/15-2015/2016

Effect of cropping system on soil organic carbon at CA experiment

The soil organic carbon (SOC) of the experimental plots under maize-lentil-mungbean cropping system was found 1.04% in 2016 which was increased by 38.6% over the SOC of base year (0.75%) 2014. Similarly, the SOC of the experimental plots under maize-wheat-mungbean cropping system was found 0.99% in 2016 which was increased by 35.6% over the SOC of base year (0.73%) 2014 (Table 4). The ratio of the SOC increment in the experimental plots under maize-lentil-mungbean was found 1.5% higher (1.38) than maize-wheat-mungbean cropping system (1.36).

Table 4. Effect of cropping systems on soil organic carbon at conservation agriculture experiment in Bhagetada, Dipayal, Doti during 2014/15-2015/16

Cropping system	Soil organic carbon (%)		
	2014	2016	Ratio of SOC Increment
Maize-wheat-mungbean (M-W-MB)	0.73	0.99	1.36
Maize-lentil-mungbean (M-L-MB)	0.75	1.04	1.38
Mean	0.74	1.01	1.37
F test	ns	ns	ns
CV%	3.9	3.0	6.3

Effect of cultural practices on soil organic carbon at CA experiment

The soil organic carbon (SOC) of the experimental plots under conservation agricultural practices was found 1.07% in 2016 which was increased by 44.6% over the SOC of the base year (0.74) 2014, whereas the SOC of the experimental plots under conventional agricultural practices was found 0.97% in 2016 which was increased by 29.3% over the SOC of base year (0.75%) 2014 (Table 5). The ratio of SOC increment in the experimental plots under conservation agricultural practices was found 11.6% higher (1.44) than conventional agricultural practices (1.29).

Effect of varietal sequences on soil organic carbon in CA experiment

The soil organic carbon of the experimental plots under the varietal sequences of Rajkumar-Dhaulagiri and Shimal-Pratikshya and Rajkumar-WK 1204 and Khajura1-Pratikshya was found at par (1.03%) in 2016 which was increased by 39.2% over the SOC of base year (0.74%) 2014. Similarly, the SOC of the experimental plots under the varietal sequences of Arun2-Dhaulagiri and Shimal-Kalyan and Arun2-WK 1204 and Khajura1-Kalyan was found at par (1.0%) in 2016 which was increased by 35.1% over the SOC of base year (0.74%) 2014 (Table 6). The ratio of SOC increment in the experimental plots under the varietal sequences of Rajkumar-Dhaulagiri and Shimal-Pratikshya and Rajkumar-WK 1204 and Khajura1-Pratikshya was found 2.2% higher (1.38) than the varietal sequences of Arun2-Dhaulagiri and Shimal-Kalyan and Arun2-WK 1204 and Khajura1-Kalyan (1.35).

Table 5. Effect of cultural practices on soil organic carbon at conservation agriculture experiment in Bhagetada, Dipayal, Doti during 2014/15-2015/16

Cultural practices	Soil organic carbon (%)		
	2014	2016	Ratio of SOC Increment
Conservation agriculture (CA)	0.74	1.07	1.44
Conventional agriculture (ConvA)	0.75	0.97	1.29
Mean	0.74	1.02	1.36
F test	ns	ns	ns

Table 6. Effect of varietal sequence of maize, wheat, lentil and mungbean crops on soil organic carbon at CA experiment in Bhagetada, Dipayal, Doti during 2014/15-2015/16

Cultural practices	Soil organic carbon (%)		
	2014	2016	Ratio of SOC Increment
Rajkumar-Dhaulagiri and Shimal-Pratikshya	0.74	1.03	1.38
Rajkumar-WK 1204 and Khajura1-Pratikshya	0.74	1.03	1.38
Arun 2-Dhaulagiri and Shimal-Kalyan	0.74	1.00	1.35
Arun 2-WK 1204 and Khajura1-Kalyan	0.74	1.00	1.35
Mean	0.74	1.01	1.36
F test	ns	ns	ns

Interaction effect of cropping system and cultural practices on soil organic carbon at CA experiment

Interaction effect of maize-wheat-mungbean cropping system and conservation agricultural practices resulted 1.0% SOC in 2016 which was increased by 38.9% over the SOC of base year (0.72%) 2014 whereas interaction effect of same cropping system and conventional agricultural practices resulted 0.99% SOC in 2016 which was increased by 33.8% over the SOC of base year (0.74%) 2014. The ratio of SOC increment resulted from the interaction effect of maize-wheat-mungbean cropping system and conservation agricultural practices was found 3.7% higher (1.38) than conventional agricultural practices (1.33). The SOC obtained from the interaction effect of maize-lentil-mungbean cropping system and conservation agriculture was found 1.13% in 2016 which was increased by 50.7% over the SOC of base year (0.75%) 2014 whereas the SOC obtained from the interaction effect of same cropping system and conventional agricultural practices was found 0.94% in 2016 which was increased by 25.3% over the SOC of base year (0.75%) 2014 (Table 7). The ratio of SOC increment resulted from the interaction effect of maize-lentil-mungbean cropping system and conservation agricultural practices was found 20% higher (1.50) than conventional agricultural practices (1.25).

Table 7. Interaction effect of cropping system and cultural practices on soil organic carbon at conservation agriculture experiment in Bhagetada, Dipayal, Doti during 2014/15-2015/16

Cropping system	Cultural practices					
	Soil organic carbon (%)					
	Conservation agriculture			Conventional agriculture		
	2014	2016	Ratio of SOC Increment	2014	2016	Ratio of SOC Increment
M-W-MB	0.72	1.00	1.38	0.74	0.99	1.33
M-L-MB	0.75	1.13	1.50	0.75	0.94	1.25
Mean	0.73	1.06	1.44	0.74	0.96	1.29
F test	ns	ns	ns			
CV%	6.4	13.0	10.8			

Interaction effect of cropping systems and varietal sequences on soil organic carbon at CA experiment

Interaction effect of maize-wheat-mungbean cropping system and varietal sequences of Rajkumar-Dhaulagiri-Pratikshya and Rajkumar-WK 1204-Pratikshya resulted at par SOM (1.0%) in 2016 which was increased by 37% over the SOC of base year (0.73%) 2014. Similarly, the SOM resulted from the interaction effect of same cropping system and varietal sequences of Arun2-Dhaulagiri-Kalyan was found 0.98% which was increased by 34.2% over the SOC of base year (0.73%) and Arun2-WK 1204-Kalyan was found 0.99% which was increased by 32% over the SOM of base year (0.75%) 2014. The ratio of SOC increment obtained from the interaction effect of maize-wheat-mungbean cropping system and varietal sequences of Rajkumar-Dhaulagiri-Pratikshya (1.37) and Rajkumar-WK 1204-Pratikshya (1.37) was found 2.2 and 3.8% higher than Arun2-Dhaulagiri-Kalyan (1.34) and Arun2-WK 1204-Kalyan (1.32), respectively.

Interaction effect of maize-lentil-mungbea cropping system and varietal sequences of Rajkumar-Shimal-Pratikshya and Rajkumar-Khajura-Pratikshya resulted at par SOM (1.05%) which increased by 40 and 38% over the SOC of base year 2014, respectively. The SOC obtained from the interaction effect of same cropping system and varietal sequences of Arun2-Shimal-Kalyan and Arun2-Khajura1-Kalyan was found at par (1.02) which increased by 36 and 37.8% over the SOC of base year 2014, respectively. The ratio of SOC increment obtained from the interaction effect of maize-lentil-mungbean cropping system and varietal sequences of Rajkumar-Shimal-Pratikshya (1.39) and Rajkumar-Khajura1-Pratikshya (1.39) was found 2.2 and 1.46% higher than Arun2-Shimal-Kalyan (1.36) and Arun2-Khajura1-Kalyan (1.37), respectively (Table 8).

Interaction effect of cultural practices and varietal sequences on soil organic carbon at CA experiment

Interaction effect of conservation agricultural practices and varietal sequences of Rajkumar-Dhaulagiri and Shimal-Pratikshya and Rajkumar-WK 1204 and Khajura1-Pratikshya resulted at SOC (1.06%) in 2016 which was increased by 45.2% over the SOC of base year (0.73%) 2014 whereas the interaction effect of conventional agricultural practices and same varietal sequences resulted at par SOC (1.0%) in 2016 which was increased by 31.6 and 33.3% over the SOC of base year 2014, respectively. The ratio of SOC increment resulted from the interaction effect of conservation agricultural practices and varietal sequences of Rajkumar-Dhaulagiri and Shimal-Pratikshya was found 9.8% higher (1.45) than conventional agricultural practices (1.32) whereas the ratio of SOC increment obtained from the interaction effect of varietal sequence of Rajkumar-WK 1204 and Kajura1-Pratikshya was found 9% higher (1.45) than conventional agricultural practices (1.33).

Table 8. Interaction effect of cropping system and varietal sequence of maize, wheat, lentil and mungbean crops on soil organic carbon at conservation agriculture experiment in Bhagetada, Dipayal, Doti during 2014/15-2015/16

Varietal sequences	Soil organic carbon (%)		
	Cropping system		
	M-W-MB		
	2014	**2016**	**Ratio of SOC Increment**
Rajkumar-Dhaulagiri-Pratikshya	0.73	1.00	1.37
Rajkumar-WK 1204-Pratikshya	0.73	1.00	1.37
Arun2-Dhaulagiri-Kalyan	0.73	0.98	1.34
Arun2-WK 1204-Kalyan	0.75	0.99	1.32
Mean	0.73	0.99	1.35
M-L-MB			
Rajkumar-Shimal-Pratikshya	0.75	1.05	1.39
Rajkumar-Khajura1-Pratikshya	0.76	1.05	1.39
Arun2-Shimal-Kalyan	0.75	1.02	1.36
Arun2-Khajura1-Kalyan	0.74	1.02	1.37
Mean	0.75	1.03	1.38
F test	ns	ns	ns

Similarly, interaction effect of conservation agricultural practices and varietal sequence of Arun2-Dhaulagiri and Shimal-Kalyan resulted 1.08% SOC in 2016 which was increased by 44% over the SOC of base year (0.75%) 2014 whereas the SOC obtained from the interaction effect of conservation agricultural practices and varietal sequence of Arun2-WK 1204 and Khajura1-Kalyan was found 1.07% in 2016 which was increased by 42.7% over the SOC of base year (0.75%) 2014. Interaction effect of conventional agricultural practices and varietal sequence of Arun2-Dhaulagiri and Shimal-Kalyan resulted 0.93% SOC in 2016 which was increased by 27.4% over the SOC of base year 2014 and interaction effect of conventional agricultural practices and varietal sequence of Arun2-WK 1204 and Khajura1-Kalyan resulted 0.94% SOC which was increased by 27% over the SOC of base year (0.74%) 2014 (Table 9). The ratio of SOC increment resulted from the interaction effect of conservation agricultural practices and varietal sequences of Arun2-Dhaulagiri and Shimal-Kalyan and Arun2-WK 1204 and Khajura1-Kalyan was found 12.6% higher (1.43) than conventional agricultural practices (1.27).

Table 9. Interaction effect of cultural practices and varietal sequence of maize, wheat, lentil and mungbean crops on soil organic carbon at conservation agriculture experiment in Bhagetada, Dipayal, Doti during 2014/15-2015/16

Varietal sequence	Cultural practices					
	Soil organic carbon (%)					
	Conservation			Conventional		
	2014	2016	Ratio of SOC Increment	2014	2016	Ratio of SOC Increment
Rajkumar-Dhaulagiri and Shimal-Pratikshya	0.73	1.06	1.45	0.76	1.00	1.32
Rajkumar-WK 1204 and Khajura1-Pratikshya	0.73	1.06	1.45	0.75	1.00	1.33
Arun 2-Dhaulagiri and Shimal-Kalyan	0.75	1.08	1.43	0.73	0.93	1.27
Arun 2-WK 1204 and Khajura1-Kalyan	0.75	1.07	1.43	0.74	0.94	1.27
Mean	0.74	1.07	1.44	0.74	0.97	1.30
F test	ns	ns	ns			

Interaction effect of cropping systems, cultural practices and varietal sequences on soil organic carbon at CA experiment

Interaction effect of maize-wheat-mungbean cropping system, conservation agricultural practices and varietal sequences of Rajkumar-Dhaulagiri-Pratikshya resulted 1.03% SOC in 2016 which was increased by 39.2% over the SOC of base year (0.74%) 2014 and Rajkumar-WK 1204-Pratikshya resulted 0.99% SOC in 2016 which was increased by 39.4% over the SOC of base year (0.71%) 2014. Interaction effect of same cropping system, conventional agricultural practices and varietal sequences of Rajkumar-Dhaulagiri-Pratikshya resulted 0.98% SOC in 2016 which was increased by 38% over the SOC of base year (0.71%) 2014 and Rajkumar-WK 1204-Pratikshya resulted 1.01% SOC in 2016 which was increased by 36.5% over the SOC of base year (0.74%) 2014. Similarly, interaction effect of maize-wheat-mungbean cropping system, conservation agricultural practices and varietal sequences of Arun2-Dhaulagiri-Kalyan resulted 1.02% SOC in 2016 which was increased by 39.7% over the SOC of base year (0.73%) 2014 and Arun2-WK 1204-Kalyan resulted 1% SOC in 2016 which was increased by 35% over the SOC of base year (0.74%) 2014. Interaction effect of same cropping system, conventional agricultural practices and varietal sequences of Arun2-Dhaulagiri-Kalyan resulted 0.95% SOC in 2016 which was increased by 28.4% over the SOC of base year (0.74%) 2014 and Arun2-WK 1204-Kalyan resulted 0.97% SOC in 2016 which was increased by 29.3% over the SOC of base year 2014 (Table 10). The ratio of SOC increment resulted from the interaction effect of maize-wheat-mungbean cropping system, conservation agricultural practices and varietal sequences of Rajkumar-Dhaulagiri-Pratikshya was found 1.5% higher (1.39) than conventional agriculture (1.37), Rajkumar-WK 1204-Pratikshya was found 2.2% higher than conventional agriculture (1.36), Arun2-Dhaulagiri-Kalyan was found 7.7% higher (1.39) than conventional agriculture (1.29) and Arun2-WK 1204-Kalyan was found 4.6% higher (1.35) than conventional agriculture (1.29).

Interaction effect of maize-lentil-mungbean cropping system, conservation agricultural practices and varietal sequences of Rajkumar-Shimal-Pratikshya resulted 1.08% SOC in 2016 which was increased by 52% over the SOC of base year (0.71%) 2014 and Rajkumar-Khajura1-Pratikshya resulted 1.13% SOC in 2016 which was increased by 50.7% over the SOC of base year (0.75%) 2014. Similarly, interaction effect of same cropping system, conventional agricultural practices and varietal sequences of Rajkumar-Shimal-Pratikshya resulted 1.01% SOC in 2016 which was increased by 26.2% over the SOC of base year (0.80%) 2014 and Rajkumar-WK 1204-Pratikshya resulted 0.98% SOC in 2016 which was increased by 27.3% over the SOC of base year (0.77%) 2014. Interaction effect of maize-lentil-mungbean cropping system, conservation agricultural practices and varietal sequences of Arun-Shimal-Kalyan resulted 1.13% SOC in 2016 which was increased by 48.7% over the SOC of base year (0.76%) 2014 and Arun2-Khajura1-Kalyan resulted 1.14% SOC in 2016 which was increased by 50% over the SOC of base year (0.76%) 2014. Interaction effect of same cropping system, conventional agricultural practices and varietal sequences of Arun2-Shimal-Kalyan and Arun2-Khajura1-Kalyan resulted 0.91% SOC in 2016 which was increased by 24.6% over the SOC of base year (0.73%) 2014 (Table 10). The ratio of SOC increment resulted from the interaction effect of maize-lentil-mungbean cropping system, conservation agricultural practices and the varietal sequences of Rajkumar-Shimal-Pratikshya was found 19.8% higher (1.39) than conventional agricultural practices (1.37), Rajkumar-Khajura1-Pratikshya was found 18.9% higher (1.51) than conventional agricultural practices (1.27), Arun2-Shimal-Kalyan was found 18.4% higher (1.48) than conventional agricultural practices (1.25) and Arun2-

Khajura1-Kalyan was found 20.9% higher (1.50) than conventional agricultural practices (1.24).

Table 10. Interaction effect of cropping systems, cultural practices and varietal sequence of maize, wheat, lentil and mungbean crops on soil organic carbon at conservation agriculture experiment in Bhagetada, Dipayal, Doti during 2014/15-2015/16

Varietal sequence	Soil organic carbon (%)					
	Cropping system					
	Maize-wheat-mungbean					
	Cultural Practices					
	Conservation			Conventional		
	2014	2016	Ratio of SOC Increment	2014	2016	Ratio of SOC Increment
Rajkumar-Dhaulagiri-Pratikshya	0.74	1.03	1.39	0.71	0.98	1.37
Rajkumar-WK 1204 -Pratikshya	0.71	0.99	1.39	0.74	1.01	1.36
Arun 2-Dhaulagiri-Kalyan	0.73	1.02	1.39	0.74	0.95	1.29
Arun 2-WK 1204-Kalyan	0.74	1.00	1.35	0.75	0.97	1.29
Mean	0.73	1.01	1.38	0.73	0.98	1.33
Maize-lentil-mungbean						
Rajkumar-Shimal-Pratikshya	0.71	1.08	1.51	0.80	1.01	1.26
Rajkumar-Khajura1-Pratikshya	0.75	1.13	1.51	0.77	0.98	1.27
Arun 2-Shimal-Kalyan	0.76	1.13	1.48	0.73	0.91	1.25
Arun 2-Khajura1-Kalyan	0.76	1.14	1.50	0.73	0.91	1.24
Mean	0.74	1.12	1.50	0.76	0.95	1.25
F test	ns	ns	ns			
CV%	3.8	7.4	6.1			

DISCUSSION

The bulk density of the experimental plots under cereal-legume-legume cropping system and conservation agricultural practices was found higher than the bulk density of the experimental plots of cereal-cereal-legume cropping system and conventional agricultural practices. Regarding the interaction effect of cropping system and cultural practices on bulk density, interaction effect of both cropping systems and conservation agricultural practices resulted higher bulk density than conventional agricultural practices. The varietal sequence did not show effect on bulk density. Interaction effect of cereal-cereal-legume cropping system and varietal sequences of maize, wheat and mungbean crops showed lower bulk density than the bulk density resulted from the interaction effect of cereal-legume-legume cropping system and varietal sequences of maize, lentil and mungbean crops. Similarly, interaction effect of conservation agricultural practices and varietal sequences indicated higher bulk density than conventional. Interaction effect of both cereal-cereal-legume and cereal-legume-legume cropping systems, conservation agricultural practices and varietal sequences of maize-wheat-lentil and mungbean crops indicated higher bulk density than conventional agricultural practices. Various authors are agreed with these results. The effect of tillage and residue management on bulk density is mainly concentrated to the top soil. In deeper layer, soil bulk density is generally found similar in zero and conventional tillage (Yang and Wander, 1999; Hernanz *et al*., 2002; Balnco-Canqui and Lal, 2007; Gal *et al*., 2007; Thomas *et al*., 2007; D'Haene *et al*., 2008). Horne *et al*. (1992) reported higher bulk density under zero than conventional tillage. Hernanz *et al*. (2002) reported higher bulk density under zero than under conventional tillage from 0-10 cm with cereal monoculture and from 0-15 cm in a wheat-vetch rotation. Hussein *et al*. (1998) and Thomas *et al*. (2007) reported higher bulk density under zero than under conventional tillage in the top 8 cm and 10 cm.

The ratio of soil organic carbon (SOC) increment was found 1.5% higher in the studied cereal-legume-legume cropping system than cereal-cereal-legume cropping system. It was 11.6% higher in the studied conservation agricultural practices than conventional agricultural practices. Regarding the effect of varietal sequences on SOC, the ratio of SOC increment was found 2.2% higher under the experimental plots of the varietal sequences of hybrid maize followed by wheat, lentil and mungbean crops than the varietal sequences of open pollinated maize. Interaction effect of cereal-legume-legume cropping system and conservation agricultural practices resulted 20% higher ratio of SOC increment than conventional agricultural practices whereas interaction effect of cereal-cereal-legume cropping system and conservation agricultural practices resulted 3.8% higher ratio of SOC increment than conventional agricultural practices. This result of interaction effect indicated higher ratio of SOC increment can be achieved by adopting cereal-legume-legume cropping system and conservation agricultural practices. The mean showed that interaction of both cropping systems and conservation agricultural practices resulted 11.6% higher ratio of SOC increment (1.44) than conventional agricultural practices (1.29).

Interaction effect of cereal-cereal-legume cropping system and varietal sequence of hybrid maize, followed by wheat and mungbean crops resulted 2.2-3.8% higher ratio of SOC increment than the varietal sequence of OP maize, followed by wheat and mungbean crops whereas the interaction effect of cereal-legume-legume cropping system and varietal sequence of hybrid maize, followed by lentil and mungbean crops resulted 1.4-2.2% higher ratio of SOC increment than the varietal sequences of OP maize followed by lentil and mungbean crops. The mean ratio of SOC increment resulted from the interaction effect of cereal-legume-legume cropping system and varietal sequences of maize-lentil-mungbean varieties was found 2.2% higher (1.38) than cereal-cereal-legume cropping system and varietal sequences of maize-wheat-mungbean (1.35). This result obtained from the interaction effect of cropping systems and varietal sequences indicated that the higher ratio of SOC increment can be achieved by adopting cereal-legume-legume cropping system and including hybrid maize varieties in varietal sequences.

The ratio of SOC increment resulted from the interaction effect of conservation agricultural practices and varietal sequences of hybrid maize variety followed by wheat, lentil and mungbean varieties was found 9-9.8% higher than conventional agricultural practices whereas the interaction effect of conservation agricultural practices and varietal sequences of OP maize followed by wheat, lentil and mungbean varieties was found 12.6% higher than conventional agricultural practices. The mean ratio of SOC increment resulted from the interaction effect of conservation agricultural practices and varietal sequences of maize, wheat, lentil and mungbean crops was found 10.8% higher (1.44) than conventional agricultural practices (1.30). The result indicated that ratio of SOC increment was observed higher in both conservation and conventional agricultural practices with the varietal sequences of hybrid maize than OP maize variety. So, it suggests to adopt conservation agricultural practices and varietal sequences with hybrid maize for higher ratio of SOC increment.

Interaction effect of cereal-cereal-legume cropping system, conservation agricultural practices and varietal sequences of hybrid maize followed wheat and mungbean varieties indicated 1.5-2.2% higher ratio of SOC increment than conventional agriculture whereas the interaction effect of same cropping system, conservation agricultural practices and varietal sequences of OP maize followed by wheat and mungbean varieties resulted 7.7-4.6% higher ratio of SOC increment than conventional agricultural practices.

The mean ratio of SOC increment resulted from the interaction effect of cereal-cereal-legume cropping system, conservation agricultural practices and varietal sequences of maize, wheat and mungbean was found 3.8% higher (1.38) than the conventional agricultural practices (1.33). Similarly, interaction effect of cereal-legume-legume cropping system, conservation agricultural practices and varietal sequences of hybrid maize followed by lentil and mungbean crops variety resulted 18.9-19.8% higher ratio of SOC increment than conventional agricultural practices. Interaction effect of same cropping system, conservation agricultural practices and varietal sequence of OP maize followed by lentil and mungbean crops variety resulted 18.4-20.9% higher ratio of SOC increment than conventional agricultural practices. The mean ratio of SOC increment resulted from the interaction effect of cereal-legume-legume cropping system, conservation agricultural practices and varietal sequences of maize, lentil and mungbean crops was found 20% higher (1.50) than conventional agricultural practices (91.25). So, this result of interaction effect of cropping system, cultural practices and varietal sequences suggests to adopt cereal-legume-legume cropping system, conservation agricultural practices and varietal sequences of hybrid maize, followed by lentil and mungbean crops for higher ratio of SOC increment. Various authors are also agreed with these findings. Sisti *et al*. (2004) observed 17 Mg ha^{-1} higher SOC in zero tillage than conventional tillage by planting vetch as a winter green manuring crop. The same authors reported contribution of leguminous crop for nitrogen fixation in the cropping system was the major reason for the accumulation of carbon in the soil under zero tillage condition. Hobbs *et al.* (2008) and Kassam *et al*. (2009) reported increase in soil organic matter under conservation agriculture. Diels *et al*. (2004) and Zingore *et al*. (2007) indicated that soil organic matter is lost up to 50% within 10-15 years when forest land converted to agriculture land. Parage *et al*. (2007) observed small increase in soil carbon (0.1 to 0.2 t ha^{-1} yr^{-1}) in dry land condition of sandy soils in no tilled condition. Fine textured soils showed the strong positive effect on soil organic matter in reduced tillage condition

(Chivenge *et al*., 2007). Bassam and Marbet (2003) reported that no till soil achieved 13.6% more soil organic carbon whereas it was only 3.3% for conventional tilled soil of its original soil organic carbon in the soil horizon of 0-200 mm.

CONCLUSION

This study suggests that maize-lentil-mungbean cropping system, conservation agricultural practices and varietal sequences of hybrid maize improve soil quality in terms of soil organic carbon in river basin agro-environment of far western Nepal.

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