Environment Conservation Journal 24 (2):257-265, 2023

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Growth analysis and yield evaluation under tillage and weed management practices in maize-wheat cropping system

Sachin Kumar ✉

Centre of Geo-Informatics, College of Basic Science, CSK HPKV, Palampur, H.P, India.

Surinder Singh Rana

Department of Agronomy, CSK HPKV, Palampur, H.P, India.

Neelam Sharma

Department of Agronomy, CSK HPKV, Palampur, H.P, India.

Abha Sharma

Department of Agronomy, CSK HPKV, Palampur, H.P, India.

ARTICLE INFO

Received : 21 March 2022
Revised : 16 August 2022
Accepted : 18 September 2022

Available online: 07 March 2023

Key Words:
Biological yield
Cereal crops
Conservation agriculture
Crop dry matter accumulation
Crop growth rate
Weeds management

ABSTRACT

Integrated weed management strategies combine tillage systems and weed control strategies. Conservation agriculture (CA) and sustainable intensification cropping systems are potential sources of improved growth and overall productivity. This study evaluated tillage and weed management strategies effects on crop growth parameters and biological yields in maize-wheat cropping system in North Western Himalayan region. Different tillage (five) and weed management practices (three) were evaluated from 2018 to 2020 on growth indices and yield with fifteen treatments. Conservation agriculture (CA) based production system (ZT, zero tillage; crop rotation and intensification; residue management i.e. ZTR-ZTR) had higher crop dry matter accumulation (DMA), relative growth rate (RGR), crop growth rate (RGR) and biological yield of maize (28698 kg/ha) and wheat crops (18750 kg/ha). The zero tillage in maize and wheat (ZT-ZT) resulted in lowest maize (24677 kg/ha) and wheat biological yield (14009 kg/ha. Among weed management treatments, application of recommended herbicides in maize and wheat crop (H-H) resulted in higher crop DMA and biological yield of maize (27652 kg/ha) and wheat crop (19540 kg/ha). Therefore, for North Western Himalayan conditions, ZTR+H-ZTR+H (Conservation tillage combined with herbicide application in maize and wheat) is superior to other combinations for growth and yield.

Introduction

Food security for a steadily rising population and soothing poverty while sustaining agricultural production systems under the current scenario of over exhausting of natural resources, adverse effects of climatic variability, high cost of inputs and fickle prices of agricultural commodities are the primary challenges in front of most of the Asian countries. The uncertainty and insecurity of food resources and change of livelihood pattern resulting from climate change may even be a threat to national security as it may become an enigma for developing countries to have a poor resource base (Food and Agriculture Organization, 2008). Non-sustainability of agricultural production systems may be due to the soil erosion, reduction in organic matter of the soil, soil salinization and acidity whichis mainly caused by continuous deep tillage which reduce soil organic matter, degradation of soil structure, reduction in water infiltration rate, surface crusting and compaction. Therefore, significant change in agricultural production system is imperative for approaching farming productivity and sustainability of the available natural resources. Conservation agriculture (CA) a concept that appeared as a concern of sustainability of agriculture globally has cover about ~8 per cent of the world arable land (Food and Agriculture Organization, 2012). Maize-wheat cropping system is popular in many parts of

Corresponding author E-mail: *schnagri@gmail.com*
Doi:https://doi.org/10.36953/ECJ.11522301

India including the northern belt of wheat growing region. In Himachal Pradesh, the system is followed up to an elevation of 2500 m above mean sea level. Nearly 85 per cent of the total food share in the state comes from these two cereal crops (Bharti, 2013); mostly under rainfed conditions as 80 per cent of the cultivated areas of the state have scarcity of irrigation facilities resulting in lower crop productivity (Ramesh *et al.*, 2016). Therefore, boosting the viability of maize-wheat cropping sequence holds the key to the transformation of an agricultural scenario in Himachal Pradesh (Bharti, 2013). Poor socio-economic conditions, small and scattered land holdings, limited mechanization and soil and climatic constraints prevent hill farmers from taking up modern agricultural technology as practiced by their counterparts in the adjacent plains. Besides declining labour availability in agriculture, tremendous pressure on resources and fluctuations in market scenario warrants the use of available resources and technology frugal. Despite the significant achievement made in research and development, the productivity of maize-wheat cropping sequence is very low. Many production technologies have been developed, yet the farmers have failed in taking full advantage of these technologies. Farmers in the state pursue a subsistence type of agriculture. Although, conventional tillage systems may not be suitable for hilly areas due to highly prone for excessive soil erosion hazards (Ramesh *et al.*, 2016). In a hilly state of India, about 70 per cent of farmers are marginal land holders and have average land holding less than 0.4 ha (Department of Economic and Statistics, 2017). Poor socio-economic conditions, small and scattered land holdings, limited mechanization and soil and climatic constraints prevent hill farmers from taking up modern agricultural technology as practiced by their counterparts in the adjacent plains. Besides declining labour availability in agriculture, tremendous pressure on resources and fluctuations in market scenario warrants the use of available resources and technology frugal. Resource conserving techniques should be the component in regional strategy for food and livelihood security, sustainability of natural resources, rural development and enhancement of profitability and improved environmental quality. Crop biomass burning is responsible for greenhouse gases emissions, reduction in soil productivity and degrading air quality (Venkatramanan *et al.*, 2021). This has become a major issue due to combine harvesting of crops and short time span between the harvesting and sowing of crops (Ravindra *et al.*, 2019). Residue burning releases pollutants, particulate matter, dust particles (Chawala and Sandhu, 2020), aerosols which retard the soil nutritious value (Jat *et al.*, 2020), human health and quality of the air (Sahu *et al.*, 2021). Other major problems like imbalance use of pesticides, nutrients deficiencies or imbalances, high energy and labour requirement and weed shift cause threat to the sustainability of cereals based cropping system (Pathak *et al.*, 2011; Ram *et al.*, 2012). Many studies have shown that continuous no-tillage for long term increases soil organic matter (Bhattacharyya *et al.*, 2009; 2015), soil health, improve soil structure (Jat *et al.*, 2018) and increases crop yield substantially than intensive tillage practices (Cannell and Hawes, 1994). Therefore, conservation strategies and modern farming techniques must be incorporated in the indigenous production systems for environmental protection, economic and social development and ecologically sustainability (Singh and Rao, 2002).Therefore, an experiment on maize-wheat cropping sequence was conducted to study the effect of tillage in relation to weed management on crop DMA, growth indices and biological yield in the North-Western Himalayas.

Material and Methods

Study area

The site of experiment was at Research Farm (32°6′ N, 76°3′ E), Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (H.P.), India during *kharif* 2018 to *rabi* 2019-20. The experimental location has a sub-temperate mid hill zone at 1290 m above mean sea level. Experimental site has silty clay loamy soil (21% clay, 43% silt and 36% sand), according to USDA classification. The soil properties of the experimental site have been given in Table 1.The crops were irrigated whenever needed with a good drainage system.

Experimental details

The brief detail of the experimental treatments has been given in Table 2. The experiment was

Table 1: Soil properties at 0-15 cm depth before the commencement of the experiment

Particulars	Sand (%)	Silt (%)	Clay (%)	BD (g/m^3)	SOC (g/kg)	Av. N (kg/ha)	Av. P (kg/ha)	Av. K (kg/ha)
Content	21	43	36	1.18	11.0	323.0	25.8	276.4
Analytical Method employed	International pipette method (Piper, 1966)			Core Method (Singh, 1980)	Walkley and Black' rapid titration method (Piper, 1966)	Alkaline permanganate method (Subbiah and Asija, 1956)	Olsen' method (Olsen *et al*., 1954)	Ammonium acetate extraction method (AOAC, 1970)

SOC: Soil organic carbon; Av. N: Available Nitrogen; Av. P: Available Phosphorus; Av. K: Available Potassium

Table 2: Treatments detail of the maize-wheat cropping system

a)	**Tillage and residue management (Horizontal plot) treatments**			
	Maize crop		**Wheat crop**	
	Tillage	**Residue retention**	**Tillage**	**Residue retention**
	T_1 - Conventional tillage (CT)	No	T1 - Conventional tillage (CT)	No
	T_2 - Conventional tillage (CT)	No	T2 - Zero tillage (ZT)	No
	T_3 - Zero tillage (ZT)	No	T3 - Zero tillage (ZT)	No
	T_4 - Zero tillage (ZT)	No	T4 - Zero tillage + residue (ZTR)	Yes; maize residue
	T_5 - Zero tillage + residue (ZTR)	Yes; wheat residue	T5 - Zero tillage + residue (ZTR)	Yes; maize residue
b	**Weed management (Vertical plots) treatments**			
	Weed management	**Intercropping**	**Weed management**	**Intercropping**
	W1 - Recommended herbicides (atrazine *fb* 2,4-D)	No	W1 - Recommended herbicides (isoproturon *fb* 2,4-D)	No
	W2 – IWM (Intercropping* + pendimethalin spray + hand weeding)	Yes; Soybean intercropping	W2 - IWM (Intercropping** + isoproturon spray + hand weeding)	Yes; Sarson intercropping
	W3 – Hand weeding (one hand weeding)	No	W3 – Hand weeding (one hand weeding)	No

*** intercropping of soybean in maize, ** intercropping of sarson in wheat**

conducted in strip plot design with three replications. Treatment combinations comprised five tillage and three weed control techniques. Maize crop was sown in *kharif* and wheat was *in* rabi season. Pre sowing irrigation at depth 5 cm was delivered during both *kharif* and *rabi* seasons of both the years. Except for zero tillage treatment, the plots were prepared with the help of a rotary power tiller. During seedbed preparation, crop stubble and weeds were removed to facilitate the planting operation. The left-over weeds were removed and the plots were levelled to have uniform sowing and germination thereof. The conventional tillage (CT) plots were ploughed to a fine tilth before the start of experiment. This was achieved using ploughing once, harrowing twice, and levelling. The seeds of maize variety 'Kanchan 51 hybrid' were sown in rows 60 cm apart in the first week of June and harvested in the mid to end of September every year. Sowing was done with hand plough by the kera method. Common dosage of 120 kg N, 60 kg P_2O_5, and 40 kg K_2O/ha respectively, was supplied through urea (46% N), IFFCO (12:32:16), and MOP (60% K_2O). Intercrop of soybean grown in additive series was not given any additional fertilizer dose. The net plot size was 2.7 m × 4.5 m. The crops water requirement was fulfilled according to the prevailing climatic conditions. In wheat crop, four irrigations were given in order to avoid drought stress. In both crops, all other production practices, except tillage and weed control treatments were followed as per recommendations in the package of practices. All the crops (main crops and intercrops) were harvested manually.

Soil analysis: A composite soil sample (0 to 15 cm depth) from each plot was made after the sampling from four corners of a plot with the help of tube auger and mix up it well before the commencement of the experiment i.e. before *kharif* 2018. The soil samples were air dried, processed and passed through 2 mm sieve and properly stored in polythene bags. The stored samples were later analysed for soil texture i.e. sand, silt and clay (international pipette method), soil organic carbon (rapid titration), available N (alkaline potassium permanganate), P (0.5 N Bicarbonate extraction) and K (Neutral ammonium acetate extraction).

Dry matter accumulation: The selected plant samples were taken from the sample rows of each plot from either side of net plot for recording dry matter accumulation for both the years and then pooled. At each observation, fresh plant samples (from 1 m row length) cut from the ground level were kept in the paper bags and dries at 70°C in hot air oven till constant weight is attained. The dry matter accumulation per square metre was then calculated by multiplying with the factor of 5. Total biological yield (grain + straw) from each net plot was recorded by weighing the sun-dried harvested crop.

Growth analysis: Crop growth rate (CGR) and relative growth rate (RGR) were determined using the formulas given by (Aliabadi *et al.*, 2008). However, harvest index was calculated according to the Maurya *et al.* (2021).

Statistical Analysis: The data were subjected to statistical analysis and were tested at a 5% level of significance to interpret the treatment differences. We estimated further statistical validity of the differences among treatment means by using the Fisher's Least Significant Differences (LSD) comparison method.

Results and Discussion

Weather

The average weather data for both the experimental years have been given in Figure1. The second year was relatively hotter and humid, whereas, first year received higher amount of rainfall. During 2018-19, ~20% higher rainfall (3228 mm) was received than 2019-20 (2135 mm). August month received highest rainfall 629 mm and 635 mm during 2018 and 2019, respectively. June month of the year was hotter than other months of the year. Weather conditions were felicitous during the growth and development of maize and wheat crop during both the years.

Crop DMA, CGR and RGR

Pooled data on crop DMA (g/m^2) by maize crop at 30, 60 and 90 DAS was statistically (p=0.05) influenced by tillage practices, whereas, weed management methods could not influence the DMA by crop plants (Table 3). Crop DMA increased progressively during the crop growth period. Conservation tillage in combination with residue application (ZTR-ZTR) had maximum crop DMA for all the observational periods.

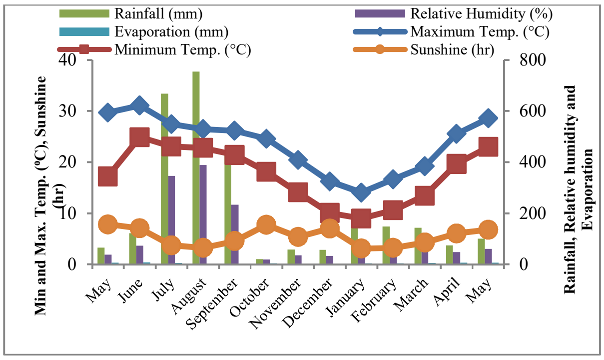

Figure 1: Pooled monthly weather data of experimental site (2018-2020)

However, CT-CT had higher crop DMA than ZT-ZT and ZT-ZTR at 30 DAS which got reduced as crop growth proceed up to harvest of the crop. Application of crop residue with zero tillage increased crop DMA during all the observational period compared to the zero tillage without residue incorporation resulted in lower DMA in all the observational periods. Data pertaining to CGR (g/m^2/day) and AGR (cm/day) had significant (p=0.05) variation for 30-60 DAS under tillage treatments, whereas weed management practices could not affect significantly. ZTR-ZTR had maximum CGR (1.96 g/m/day) which remained statistically at par with ZT-ZTR (1.80 g/m^2/ day). Minimum CGR was recorded in ZT-ZT where residue was not incorporated. Significantly higher AGR was recorded in ZTR-ZTR, CT-CT and ZT-

Table 3: Effect of tillage and weed management treatment on crop dry matter accumulation (g/plant), crop growth rate (g/m^2/day) and absolute growth rate (cm/day) of maize crop (pool data of 2 year's)

Treatment	CDMA			CGR		AGR	
(Maize -wheat)	30 DAS	60 DAS	90 DAS	30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS
Tillage							
CT-CT	8.4^{b}	43.0^{bc}	108.2^{c}	1.58^{bc}	1.52	5.54^{a}	3.73
CT-ZT	7.5^{bc}	39.6^{cd}	110.1^{c}	1.47^{c}	1.70	4.40^{bc}	4.12
ZT-ZT	6.5^{c}	36.7^{d}	103.1^{c}	1.35^{c}	1.56	4.12^{c}	4.71
ZT-ZTR	7.1^{c}	45.7^{b}	119.7^{b}	1.80^{ab}	1.86	5.25^{ab}	3.60
ZTR-ZTR	9.7^{a}	53.0^{a}	128.8^{a}	1.96^{a}	1.84	5.41^{a}	3.96
SEm±	0.3	1.5	2.2	0.08	0.09	0.29	0.28
LSD (*p*=0.05)	1.0	5.0	7.1	0.26	NS	0.96	NS
Weed management							
H-H	8.1	43.4	117.4	1.64	1.69	5.33	3.49
IWM-IWM	8.1	43.1	111.7	1.60	1.74	4.73	4.78
HW-HW	7.3	44.3	112.9	1.66	1.65	4.78	3.81
SEm±	0.4	1.6	3.4	0.03	0.03	0.15	0.26
LSD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS

CT, conventional tillage; ZT, zero tillage; R, residues; H, herbicide; IWM-IWM, integrated weed management; HW, hand weeding; figures with same sign as superscript in the table in a same factor mean statistically at par with each other

Table 4: Effect of tillage and weed management treatment on crop dry matter accumulation (g/plant), crop growth rate (g/m^2/day) and absolute growth rate (cm/day) of wheat crop (pool data of 2 year's)

Treatment	CDMA					CGR				AGR			
(Maize wheat)	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS
Tillage													
CT-CT	16.7^{b}	19.8^{c}	70.8^{bc}	463.4^{b}	909.0^{a}	0.106^{c}	1.698^{a}	13.087^{ab}	14.853	0.543^{ab}	0.956	1.477^{a}	0.360
CT-ZT	20.5^{a}	23.3^{b}	78.4^{ab}	484.3^{ab}	956.8^{a}	0.094^{c}	1.837^{a}	13.530^{ab}	15.748	0.593^{a}	1.033	1.254^{bc}	0.116
ZT-ZT	12.4^{c}	16.0^{d}	61.7^{cd}	419.9^{bc}	799.1^{b}	0.122^{bc}	1.523^{b}	11.939^{b}	12.641	0.445^{c}	0.935	1.106^{c}	0.377
ZT-ZTR	16.1^{b}	21.4^{bc}	52.4^{d}	379.4^{c}	748.6^{b}	0.175^{b}	1.034^{c}	10.901^{b}	12.304	0.463^{c}	1.019	1.329^{ab}	0.375
ZTR-ZTR	22.0^{a}	29.9^{a}	81.5^{a}	557.7^{a}	978.2^{a}	0.263^{a}	1.720^{a}	15.872^{a}	14.019	0.470^{bc}	0.912	1.416^{ab}	0.274
SEm±	0.7	0.9	2.9	23.5	23.2	0.016	0.085	0.843	1.144	0.023	0.030	0.052	0.076
LSD (*p*=0.05)	2.2	2.8	9.6	76.6	75.6	0.053	0.278	2.750	NS	0.074	NS	0.170	NS
Weed management													
H-H	18.4^{ab}	23.6^{a}	73.9^{a}	494.5	905.2^{a}	0.173	1.675^{a}	14.022	13.690	0.434^{b}	1.047^{a}	1.360	0.282
IWM-IWM	15.0^{b}	19.4^{b}	67.7^{b}	419.9	836.9^{b}	0.146	1.610^{a}	11.741	13.901	0.438^{b}	0.922^{b}	1.298	0.310
HW-HW	19.2^{a}	23.3^{a}	65.4^{b}	468.4	892.9^{a}	0.137	1.403^{b}	13.435	14.148	0.637^{a}	0.944^{b}	1.291	0.308
SEm±	0.8	0.7	1.4	15.4	11.1	0.012	0.043	0.496	0.810	0.022	0.017	0.091	0.039
LSD (*p*=0.05)	3.0	2.6	5.3	NS	43.4	NS	0.171	NS	NS	0.086	0.065	NS	NS

CT, conventional tillage; ZT, zero tillage; R, residues; H, herbicide; IWM-IWM, integrated weed management; HW, hand weeding; figures with same sign as superscript in the table in a same factor mean statistically at par with each other

Table 5: Effect of tillage and weed management treatment on biological yield of maize and wheat crop (kg/ha) and harvest index (%) (pool data of 2 year's)

Treatment (Maize -wheat)	Maize biological yield (kg/ha)	Maize harvest index (%)	Wheat biological yield (kg/ha)	Wheat harvest index (%)
Tillage				
CT-CT	26654[b]	28.1	16827[b]	32.9
CT-ZT	26222[bc]	27.7	16950[b]	34.1
ZT-ZT	24677c	28.2	14009[d]	33.2
ZT-ZTR	24712c	28.3	15318[c]	32.6
ZTR-ZTR	28698[a]	27.0	18750[a]	31.8
SEm±	523	0.4	229	1.4
LSD (p=0.05)	1705	NS	747	NS
Weed management				
H-H	27652	27.4[b]	19540[a]	32.2
IWM-IWM	25605	29.6[a]	10229[b]	32.7
HW-HW	25322	26.5[b]	19343[a]	33.8
SEm±	622	0.3	595	0.7
LSD (p=0.05)	NS	1.3	2336	NS

CT, conventional tillage; ZT, zero tillage; R, residues; H, herbicide; IWM-IWM, integrated weed management; HW, hand weeding; figures with same sign as superscript in the table in a same factor mean statistically at par with each other

ZTR compared to the ZT-ZT and CT-ZT. Weed management treatments could not significantly affect the CGR and AGR of maize crop at different observational periods.

This might be due to the reason that different weed management treatments could not significantly affect the crop dry matter and height which results in non significant results for CGR and AGR. In conservation agriculture, DMA, CGR and RGR were higher than in CT plots and ZT plots without residue might be due to better soil health and micro-environment created by the continuous adoption of these resources conserving practices (Ram, 2006; Memon *et al.*, 2014).Data on effect of tillage and weed management practices on wheat crop DMA at 30, 60, 90, 120 and 150 DAS have been given in Table 4. However, progressive DMA has been presented in Figure 2.The significantly (p=0.05) higher DMA was recorded in the ZTR-ZTR at all the stages of observations. ZTR-ZTR recorded statistically similar crop DMA as CT-ZT during 30, 90, 120 and 150 DAS. ZT-ZT resulted in lower crop DMA during all the observational periods. Among weed management treatments, HW-HW had significant (p=0.05) higher crop DMA during initial days which otherwise was higher in H-H during vegetative and reproductive stages. IWM-IWM recorded lowest wheat DMA during all the observational periods.Wheat crop growth was triggered under different tillage and weed management practices however such an increase was more pronounced for ZTR-ZTR compared to CT-CT. Temporal increase in crop growth rate under ZTR-ZTR was observed with maximum values (14.019 g/m^2/day) achieved at 120-150 DAS. Tillage treatments had significant (p=0.05) variation in CGR (g/m^2/day) at all stages except 120-150 DAS. ZTR-ZTR resulted in higher CGR between 30-60 DAS which was higher in CT-ZT during later stages. CT-ZT had statistical (p=0.05) similar crop growth rate as ZTR-ZTR and CT-CT between 60-90 DAS. Weed management treatments could significantly affect the CGR between 60-90 DAS. H-H had highest CGR which was statistically at par with IWM-IWM. Application of recommended herbicides recorded maximum crop growth rate in wheat crop (Khaliq *et al.*, 2013). The tillage treatments significantly affected AGR (cm/day) during 30-60 DAS and 90-120 DAS of wheat crop. CT-ZT had statistical similar AGRas CT-CT during 30-60 DAS. However, between 90-120 DAS, CT-CT had higher absolute growth rate which remaining statistically similar with ZTR-ZTR and ZT-ZTR. Among weed management treatments, HW-HW had maximum

AGR which remained statistically at par with IWM-IWM and H-H at 30-60 DAS. However, H-H had maximum AGR followed by HW-HW and IWM-IWM at 60-90 DAS. Improved growth attributes in herbicide treatments may be attributed to reduction in crop-weed competition. In conservation agriculture systems (ZTR-ZTR), the absence of weed competition led to canopy closure, which resulted in faster plant growth and accumulation of biomass led to a greater biological yield.

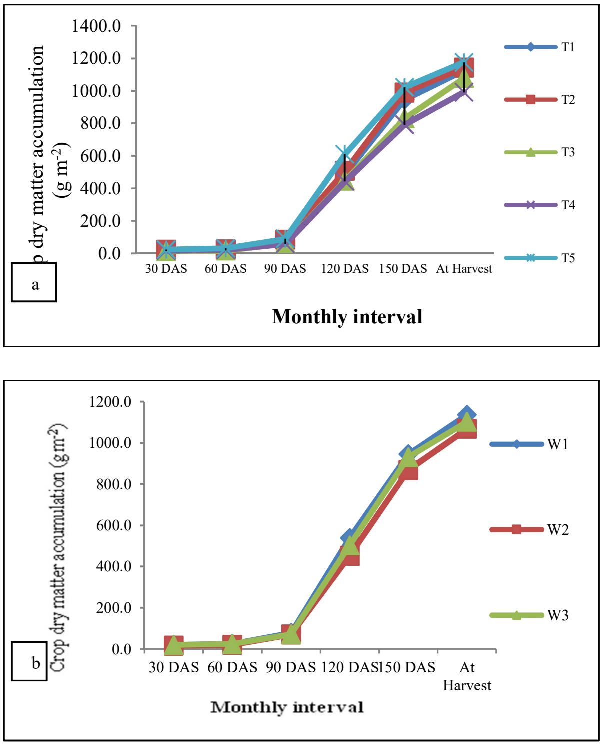

Figure 2: Progressive dry matter accumulation of wheat crop under (a) tillage and (b) weed management treatments (Pooled data for 2018-19 & 2019-20).

Biological yield and harvest index

Maize biological yield was higher in ZTR-ZTR, whereas, ZT without residue resulted in lower HI among tillage treatments. The low yield in ZT plots might be due to more weed infestation. Among weed management treatments, H-H had higher maize biological yield. In a long term field trial, Kaskarbayev *et al*., (2002) found that zero tillage (ZT) resulted in 16% yield reduction against deep CT in maize crop. Similarly, lower biological yield of maize under ZT compare to CT might be due to poor crop stand and dry matter accumulation. Singh *et al*., (2007); Singh *et al*., (2011); Wang *et al*., (2015) also reported lower biological yield under ZT. Wheat biological yield was maximum in ZTR-ZTR, whereas, CT-CT and CT-ZT remained statistically at par with each other. H-H and HW-HW resulted in higher wheat biological yield among weed management treatments. Furthermore, Sime *et al*., (2015) reported that conservation tilled plots (ZTR-ZTR) had higher yield of maize under maize-wheat cropping system than CT-CT. However, higher biological yield in herbicide applied plots may be due to the efficient weed control efficiency (Baghestani *et al*., 2008; Chhokar *et al*. 2008; Santos, 2009). Harvest index (HI) was higher in ZT-ZTR followed by ZT-ZT in maize crop. IWM-IWM resulted in significantly (p=0.05) higher HI, whereas, H-H had statistically similar HI. Pariyar *et al*. (2019) also reported that ZTR resulted in higher HI than conventional tillage. In wheat crop, tillage as well as weed management treatments could not significantly affect the HI. Ion *et al*., (2015) also found that HI of maize crop varies from 0.20-0.56 under different conditions.

Conclusion

Results from the present study showed that conservation agriculture-based maize-wheat cropping system resulted in higher crop dry matter accumulation and crop growth rate and relative growth rate under different observational periods in maize and wheat crop. ZTR-ZTR had higher biological yield in maize and wheat crop. This might be due to the reason that conservation agriculture had improved soil properties, better crop establishment and minimum lodging. Similar results were reported by Jat *et al*. (2017) and Chaudhary *et al*. (2018). Although, harvest index was higher in ZT-ZTR in maize and CT-ZT in wheat crop. Among weed management treatments, H-H resulted in higher crop DMA in maize and wheat crops. CGR was initially higher in H-H which later stages in HW-HW in wheat crop, whereas, AGR was higher in HW-HW during initial months which was in H-H as crop reach towards maturity. Although, biological yield was higher in H-H for both the cereals. Therefore, based on the results of the present study, it is suggested to follow ZTR+H-ZTR+H among all the combinations for better growth and yield from maize-wheat cropping system.

Acknowledgement
This study was under taken under All India Co-ordinated Research Project on weed management (ICAR-06-16). The authors are thankful to Head, Department of Agronomy, CSKHPKV, Palampur for conducting field trial and laboratory analysis.

Conflict of interest
The authors declare that they have no conflict of interest.

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