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Response of Sowing Dates, Crop Establishment Methods and Mulching on Growth, Productivity and Profitability of Spring Wheat at Rampur, Chitwan, Nepal

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Abstract

Intensive tillage with no crop residue after rice harvest in conventional wheat cultivation increases the turn around time, delays sowing and affects the yield. A field experiment was carried out to assess the effect of sowing dates, establishment methods and mulching and their interaction on growth, productivity and profitability of spring wheat at agronomy farm of AFU, Rampur Chitwan, Nepal from November 2020 to April 2021. The experiment was laid out in strip-split plot design, with three dates of sowing (20th November, 5th December and 20th December) in vertical plots, two establishment methods (Zero tillage and Conventional tillage) in horizontal plots and two levels of mulching (0 t ha-1 and 5 t ha-1 of rice straw mulch) in sub-plots and replicated thrice with Vijay as test variety. Data regarding the phenology, growth parameters, yield attributes and yield were recorded, analysed and presented. The research results revealed that date of sowing and mulching significantly influenced phenology, growth, yield attributes, yield and their interactions. The higher grain yield was obtained in 5th December as well as 20th November sowing in conventional tillage with mulch (4511.49 & 4492.12 kg ha-1 respectively). These grain yields were statistically at par with 5th December and 20th November sowing in zero tillage with mulch (4363.74 & 4129.97 kg ha-1 respectively). Net return and B:C ratio were significantly higher on 5th December and 20th November sowing with mulch in zero tillage than 20th December sowing in conventional tillage without mulch.

Keywords: Date of sowing; mulch; zero tillage; conventional tillage; grain yield

Introduction

Wheat (*Triticum aestivum* L.) is a crucial food crop that is grown extensively around the world comprising an area over 219 million hectares of land with total production of more than 760 million tons, and global average yield of 3.47 t ha^{-1} (FAOSTAT, 2022). After rice and maize, wheat is the third most important cereal crop in Nepal in terms of area and production (MOALD, 2021). It is grown on 0.70 million hectares of land with a production of 2.18 million tons and productivity 3.09 t ha^{-1} (MOALD, 2021).

Although the widespread cultivation of high yielding cultivars coupled with improved agronomic management practices (irrigation and fertilizer) during the Green Revolution burgeoned the global wheat production, the recent evidence has underscored the continuous stagnation in yield. The stagnation in wheat production is imposing a constant threat to sustainability of wheat production. Furthermore, the profitability of wheat is also declining along with growing environment concerns, thereby putting the sustainability of wheat production at risk. The productivity and sustainability of wheat have been threatened by delay planting (Giri, 1988; NARC, 2002), increasing cost of cultivation, terminal heat and moisture stress (Khatri *et al*., 2019).

Late sown wheat, induced by long turn around period due to one or combination of multiple factors like difficulty in land preparations, delay in rice harvest, constrains of power supply and intensive farming system, is one of the major bottlenecks for sustainable wheat production (Giri, 1998; NARC, 2002). The delay in planting faces dual problem of poor vegetative growth ascribed by low temperature during germination and reduced grain filling duration imputed by high temperature at flowering (Baloch *et al*, 2012; Yadav *et al*., 2018). Although, optimum sowing date of wheat is considered from November 20 to December 5, it hinges on several factors like weather, topography, and harvesting of the preceding crop (Joshi *et al*., 2007). The delaying planting from November 15 to December 15 reduces grain production by 27-33% (NARC, 2002). The late sown wheat faces terminal heat and moisture stresses during anthesis and post-anthesis phase, which reduces yield by 30 to 50 kg^{-1} $hectare^{-1}$ day^{-1} (Giri, 1998). Terminal heat stress reduces mobility and accumulation of starch by 25.6 mg $gram^{-1}$ during early grain filling while moisture stress shortens the grain filling duration that ultimately engenders forced maturity of crop (Dwivedi *et al*., 2017; Ali *et al*., 2010). This not only decreases the yield but also produces shriveled grains due to shortened grain filling period coupled with high humidity and prevailing high temperature (McDonald *et al*., 1984). Thapa, Ghimire, Adhikari, Thapa, and Thapa (2020) reported significantly lower grains per spike in late sown wheat due to short growing duration accumulating less photosynthates. Furthermore, late sown wheat is reported to be irresponsive of nutrient.

Excessive tillage has led to soil erosion, soil carbon loss and greenhouse gas emissions from fossil fuels used up by tillage implements, which not only affects farm profitability and deteriorates the environment (Ghimire, Dhungana, Krishna, Teufel, & Sherchan, 2013). Rising cost of cultivation due to increased prices of fuel and labor further exacerbates the problem of low wheat profitability (Sidhu *et al*., 2007). To address the burning issue, many researches have strongly advocated shifting the conventional method of wheat establishment to zero tillage (Jat *et al*., 2014; Sah *et al*., 2013). The zero tillage not only enhances input use efficiencies but also reduces the turnaround time of rice harvest to wheat sowing, which facilitates the early sowing. The emerging zero tillage has potential to supersede the conventional method of wheat establishment in terms of agronomic and economic benefit.

Furthermore, threats to sustainable wheat production include moisture stress, weed proliferation, and soil deterioration. Cheap and easily available organic mulches serve as a good source of organic matter, suppresses weed growth and also have beneficial effects of soil conservation, temperature moderation and improvement of soil structure (Shah *et al*., 2011). In relatively short periods of time, mulching minimizes moisture loss and increases soil organic matter content. Additionally, it lessens the need for extra irrigations throughout crop growth since the retained residue's organic matter concentration improves the soil's ability to hold water (RWC, 2004). In wheat growing areas, crop residue retention combined with zero-till techniques offers a crucial soil restorative management option that is anticipated to have a long-term beneficial impact on soil quality and crop yield (Naresh *et al*., 2013). Furthermore, carbon sequestration is increased with lower emission of carbon levels due to CA (FAO, 2001).

Therefore, optimum sowing dates for different establishment methods and application of mulch should be identified through different researchers. In this scenario, to address the above-mentioned problems and fill the research gap, the present research was carried out with the following objectives:

- To assess the effect of sowing dates, establishment methods, mulching and their interaction on growth and productivity of spring wheat.
- To evaluate the economics of sowing dates, establishment methods, mulching and their interaction in spring wheat.

Materials And Methods

Location

The experiment was conducted at Agronomy Research farm of Agriculture and Forestry University (AFU), Rampur Chitwan, Nepal during wheat growing season from November 2020 to April 2021. It is located at 27º38' North latitude and 84º21' East longitude with an elevation of 184.86 m above mean sea level (Google, 2022) (https://goo.gl/maps/e9q2zMJeumnkg7bx9).

Weather and Physico-chemical properties of the soil at the experimental site

The Climate of the location is subtropical and humid type. The average maximum temperature during the experiment ranged from 24.04 ºC to 35.42 ºC which was highest in April and lowest in November. Similarly, the mean minimum temperature ranged from 8.73 ºC (November) to 16.62 ºC (April). The total rainfall was received only 33.8 mm in the month of April. The relative humidity was maximum in November and it ranged from 50% in April to 82% in December. The experimental field was under Rice-Wheat cropping system for the past three years. The soil of the experimental site was sandy loam in texture, slightly acidic in pH (5.4), medium in total nitrogen (0.10%) and available potassium (132 kg ha^{-1}) and low in organic matter (2.03%) and available phosphorus (20.90 kg ha^{-1}).

Layout and Experimental Design

The experiment was laid out in strip-split plot design, with three dates of sowing (20th November, 5th December and 20th December) in vertical plots, two establishment methods (Zero tillage and Conventional tillage) in horizontal plots and two levels of mulching (0 t ha^{-1} and 5 t ha^{-1} of rice straw mulch) in sub-plots and replicated thrice. The individual plot size was 4 m × 3 m. There were 16 rows of wheat within the plot. The recommended dose of fertilizer was 120-50-50 kg N, P_2O_5, K_2O ha^{-1} applied through urea, di-ammonium phosphate (DAP) and muriate of potash (MOP) respectively. Full doses of phosphorus and potash and half dose of nitrogen were applied at the time of final land preparation as basal application. The remaining half dose of nitrogen was top-dressed in two equal splits; one at 35 days after sowing and the other at before heading stage for all the sowing dates.

Field Management Practices

The field was ploughed twice before sowing of wheat in the field where conventional tillage was followed, and weeds were removed manually. Fine tilth of soil was made one day before sowing at the time of final land preparation. The variety Vijay was sown with seed rate of 120 kg ha^{-1} at 25 cm row spacing. For zero tillage, wheat seed was sown in no-till soil, where weeds were killed by the application of Glyphosate @ 1 kg a.i. ha^{-1}. Then the soil was scrapped with a hoe, and seed along with fertilizers were placed in a line before covering it with soil. Mulching was done after the seeding in each plots which received mulching treatment. To reduce early crop-weed competition, the post emergence herbicide (2,4-D) was applied at the rate of 1 kg a.i. ha^{-1} in 600 litres of water per hectare at 32 days after sowing for weed management. Chloropyriphos (50% EC) + Cypermethrin (5% EC) was used at the rate of 2.5 ml per litre of water at 50 DAS for insect pest management. Two irrigation was given at the crown root initiation stage 22 days after sowing and at flowering stage for crop sown on each date through an irrigation pump.

Observations and statistical analysis

Data regarding phenological observations, biometrical observations, yield and yield attributes were recorded during the experimental period. The harvest index (HI) was calculated by dividing the grain yield by the biological yield after converting both grain and straw to 0 % moisture level. Economic analysis of the wheat production was done on the current market price of the product. All the collected data were entered into MS-Excel which was used for simple statistical analysis, construction of graphs and tables. The compiled data were subjected to Analysis of Variance (ANOVA) using R-studio. A simple correlation and regression were established among the selected parameters using MS-Excel. ANOVA was constructed and significant data were subjected to Duncan's Multiple Range Test (DMRT) for mean comparison at 0.05 probability levels with reference to Gomez and Gomez (1984).

Results And Discussions

Phenological and growth attributes

Unlike mulching and establishment methods, days to attain heading, physiological maturity and grain filling period were significantly influenced by date of sowing (Table 1). Early sown wheat took longer days to attain heading, physiological maturity and grain filling period than latter sowing dates. Late sown wheat is subjected to forced maturity at anthesis due to increase in temperature which accelerates growth and development of wheat (Baloch *et al*., 2012). Delay in phenology of early sown wheat was also reported by Haider *et al*. (2003) and Liu *et al*. (2021). Plant height, LAI at 60 and 90 DAS were significantly influenced by date of sowing and mulching (Table 1). Significantly taller plant height was recorded in 5th December than other dates of planting. Shorter plant height at delayed sowing might be due to shorter growing period while favourable climatic conditions increased plant height for early sowing dates. This result was also supported by Tahir *et al*. (2009) and Shirinzadeh *et al*. (2017). Similarly, significantly taller plant height was observed in mulch plots than non-mulched plots. Dahal *et al*. (2013) and Ranjit *et al*. (2014) also reported positive effect of mulch on plant height due to favourable growing condition. Highest LAI at 60 DAS was produced in 5th December which was statistically at par with 20th November and significantly higher than 20th December. At 90 DAS, highest LAI was recorded in 5th December and was statistically superior to other dates of planting. Optimum climatic condition during vegetative growth might have led to leaf development and improved LAI on early sown wheat. Similar result was also obtained by Sattar *et al*. (2010). Significantly higher LAI was observed for mulch at 60 and 90 DAS. Ram, Dadhwal, Vashist, & Kaur (2013) also found positive effect of straw mulch on LAI of wheat. AGDM production was influenced only by mulching and significantly higher AGDM was found in mulching. Higher leaf area index might have led to accumulate more AGDM. Lower AGDM at delayed sowing might also be due to slow emergence at low temperature (Liu *et al*., 2021). This result was also in conformity with Alam *et al*. (2013) and Ferrise *et al*. (2010). Stagnari *et al*. (2014) found that straw mulch corresponds to more plant population and total biomass per unit ground area thus contributing for more dry matter accumulation.

Table 1: Phenology and growth attributes of wheat as influenced by sowing dates, establishment methods and mulching in 2020-21 at AFU, Rampur, Chitwan, Nepal

Treatments	Days to heading (75%)	Days to physiological maturity (75%)	Grain filling period (days)	Plant height	LAI (60 DAS)	LAI (90 DAS)	AGDM (90 DAS)
Sowing dates							
20th November	89.83[a]	135.33[a]	45.50[a]	109.01[b]	2.83[a]	1.78[b]	1286.75
5th December	81.42[b]	123.92[b]	42.50[b]	118.42[a]	2.86[a]	2.36[a]	1442.16
20th December	77.33[c]	114.42[c]	37.08[c]	105.72[b]	2.11[b]	1.56[b]	1320.81
SEm (±)	0.60	0.30	0.44	0.87	0.16	0.12	117.77
LSD (0.05)	2.35	1.19	1.74	3.42	0.61	0.42	ns
CV, %	2.50	0.84	3.68	2.72	20.74	19.46	30.22
Establishment methods							
Zero tillage	82.72	124.17	41.44	111.17	2.62	1.82	1232.12
Conventional tillage	83.00	124.94	41.94	110.93	2.58	1.98	1467.70
SEm (±)	0.08	0.55	0.48	0.25	0.23	0.13	76.31
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns
CV, %	0.40	1.89	4.84	0.97	37.36	28.67	23.98
Mulching							
Without mulch	82.28	124.17	41.89	109.87[b]	2.19[b]	1.62[b]	1204.57[b]
With mulch	83.44	124.94	41.50	112.24[a]	3.01[a]	2.19[a]	1495.24[a]
SEm (±)	0.52	0.38	0.56	0.58	0.21	0.10	78.32
LSD (= 0.05)	ns	ns	ns	1.77	0.64	0.30	241.32
CV, %	2.66	1.31	5.68	2.20	33.86	21.61	24.61
Grand mean	82.86	124.56	41.69	111.05	2.60	1.90	1349.91

Note: ns, non-significant; treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance

Yield attributing characters

Effective tillers per square meter

5th December sowing wheat had significantly higher number of effective tillers per square meter than that of 20th December sowing (Table 2). Effective tillers per square meter at 20th November sowing wheat was at par with 5th December and 20th December. This might be due to higher soil moisture at grain filling stage for early sowing dates. Significantly higher effective tillers per square meter at early sowing dates than delayed sowing was also reported by Madhu *et al*. (2018) and Sattar *et al*. (2010). Establishment methods had no significant effect on effective tillers per square meter. This result was in line with Imran *et al*. (2013) and Ram, Singh, Saini, Kler, and Timsina (2013). Mulch plots had significantly higher effective tillers per square meter than non-mulch plots. Higher effective tillers per square meter was also observed in mulching by Ram *et al*. (2013); Ranjit *et al*. (2014) and Stagnari *et al*. (2014).

Number of grains per spike

The number of grains per spike was significantly higher in early sown wheat (20th November) followed by later sowings (5th December and 20th December respectively). Establishment methods and mulching had no influence on number of grains per spike (Table 2). The increase in number of grains per spike with early sowing was due to more number of days available for grain formation and crop escape post anthesis drought. Sattar *et al*. (2010) stated that temperature at anthesis is crucial for formation of grain number. In delayed sowing increasing temperature minimizes number of grains per spike (Alam *et al*., 2013). Non- significant effect of establishment methods on number of grains per spike were also reported by Imran *et al*. 2013; Jat *et al*. (2014) and Ram *et al*. (2013). Similarly Ehsanullah *et al*. (2013) and Ranjit *et al*. (2014) also found non-significant effect of mulch.

Thousand grain weight

The thousand grain weight was found significantly higher for early sown wheat (20th November and 5th December) than later sowing (Table 2). Grain filling period is shorter for delayed sowing and grains are exposed to heat stress which produces shriveled grains ultimately lowering thousand grain weight. This finding is strongly supported by Tahir *et al*. (2009) and Yadav *et al*. (2018). Establishment methods had no significant effect on TGW. Haroon *et al*. (2017) and Ram *et al*. (2013) also reported non-significant result. Non mulch plot had higher TGW than mulch plots. This might be due to higher effective tillers per square meter and slightly higher grains per spike in mulch plot so photosynthate assimilation might have reduced on each grain. Dahal *et al*. (2013) and Ehsanullah *et al*. (2013) also reported relatively higher TGW in non-mulch plot.

Sterility percentage

Sowing dates, establishment methods and mulching had statistically non-significant effect on sterility percentage (Table 2). Non-significant effect of sowing dates on sterility was also obtained by Acharya *et al*. (2017), Marahatta *et al*. (2018) and Marasini *et al*. (2016).

Grain and straw yield

Grain yield

Early two sowing dates (20 November and 5 December) were found to yield much more grain than late sowing dates (Table 2). Early two sowing dates had greater effective tillers per square meter, thousand grain weight, number of grains per spike and grain weight per spike, all of which contributed to increased grain production. Early planting dates increase grain filling duration, extend the crop's growth cycle and assist the crop avoid anthesis's terminal heat and moisture stress. Longer growth period provides more days for grain filling due to which more photosynthates are partitioned to sink (grain) which leads to higher yield. This result was in conformity with Ali *et al*. (2010), Said *et al*. (2012), Sharma (1993) and Yadav *et al*. (2018). Grain yield was not significantly affected by establishment methods. Zero and conventional tillage had statistically similar grain yield. The effect of zero tillage is pronounced only in long term trials because of improvement in soil fertility with retained residue (Marahatta *et al*., 2018). Similar grain yields at early years of conservation agriculture with conventional tillage was also reported by Das *et al*. (2018), Jat *et al*. (2014), Kumar *et al*. (2015) and Mitra & Patra (2019). Gangwar *et al*. (2004) also observed that there was a relatively larger grain yield with conventional tillage compared to no tillage and reduced tillage. With the exception of thousand grain weight, other yield metrics such as spikelet per spike and effective tillers per square meter were significantly higher under mulch. This result was in line with those obtained by Dahal *et al*. (2013), Ranjit *et al*. (2014) and Shah *et al*. (2011).

Straw yield

Straw yield was found significantly higher in early two sowing dates (20th November and 5th December) than in late sowing (Table 2). The difference in the yield of straw between sowing dates may be the result of a shorter vegetative development period for delayed seeding, which produced fewer tillers per square meter. The yield of straw was not significantly affected by establishment methods, although the yield of straw was much higher in mulched plots than in non-mulched plots. The difference in straw yield was caused by a mulched plot's greater leaf area index, above-ground dry matter and number of tillers per square meter (Shah *et al*., 2011).

Harvest index

Harvest index was insignificant for sowing dates, establishment methods and mulching (Table 2). The influence of sowing dates on harvest index was shown to be insignificant by Marasini *et al*. (2016) and Yadav *et al*. (2018). Similar results of the harvest index as impacted by establishment methods was reported by Imran *et al*. (2013) as well.

Interaction effects between sowing dates, mulching and establishment methods

There was significant interaction between establishment methods and mulching & sowing dates, establishment methods and mulching (Fig. 1). In late sown condition, mulching in ZT produced significantly higher yield as compared to non-mulched plots in ZT. Similar result was also reported by Głab & Kulig (2008).

Economics

The cost of cultivation of all sowing dates were same as all the inputs and agronomic operations carried out was common. The early two sowing dates significantly outperformed the delayed sowing in terms of gross return, net return and B:C ratio (Table 3). Tomar *et al*. (2014) also found lower profitability under late sown condition. There was non-significant effect of establishment methods on gross return and net return of wheat production. This result was in line with those obtained by Ram *et al*. (2013). Gross return was higher for mulch plots. Shah *et al*. (2011) also reported higher gross return for mulch plots. Higher grain and straw yield fetch more income at early sowing dates with mulching. Zero tillage with mulch had a higher B:C ratio than conventional tillage with mulch.

Table 2: Number of effective tillers per square meter and thousand grain weight (g) of wheat as influenced by sowing dates, establishment methods and mulching in 2020-21 at AFU, Rampur, Chitwan, Nepal

Treatments	Number of effective tillers m^{-2}	Grains $spike^{-1}$	Thousand grain weight (g)	Sterility (%)	Grain yield	Straw yield	Harvest Index
Sowing dates							
20th November	302.75^{ab}	38.87^{a}	49.04^{a}	37.50	4112.44^{a}	5421.42^{a}	0.40
5th December	325.17^{a}	37.23^{b}	49.68^{a}	38.84	4344.43^{a}	5767.24^{a}	0.40
20th December	282.92^{b}	35.01^{c}	43.07^{b}	37.71	3240.15^{b}	4406.00^{b}	0.39
SEm (±)	7.56	0.20	0.42	0.36	121.12	132.46	0.003343
LSD (0.05)	29.69	0.80	1.67	ns	475.57	520.09	0.013
CV, %	8.63	1.91	3.11	3.26	10.76	8.83	2.91
Establishment methods							
Zero tillage	303.39	37.17	47.14	38.49	3741.34	4931.39	0.40
Conventional tillage	303.83	36.91	47.39	37.54	4056.67	5465.05	0.40
SEm (±)	11.54	0.92	0.20	0.43	74.20	140.44	0.002474
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns
CV, %	16.12	10.54	1.77	4.79	8.07	11.46	2.64
Mulching							
Without mulch	280.00^{b}	36.45	48.17^{a}	38.06	3767.69^{b}	4944.58^{b}	0.40
With mulch	327.22^{a}	37.63	46.35^{b}	37.98	4030.32^{a}	5451.86^{a}	0.39
SEm (±)	8.87	0.68	0.48	0.63	75.91	105.93	0.003617
LSD (0.05)	27.32	ns	1.47	ns	233.91	326.41	0.011
CV, %	12.39	7.81	4.28	7.02	8.26	8.65	3.86
Grand mean	303.61	37.04	47.26	38.02	3899.01	5198.22	0.40

Note: ns, non-significance; treatments mean followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance

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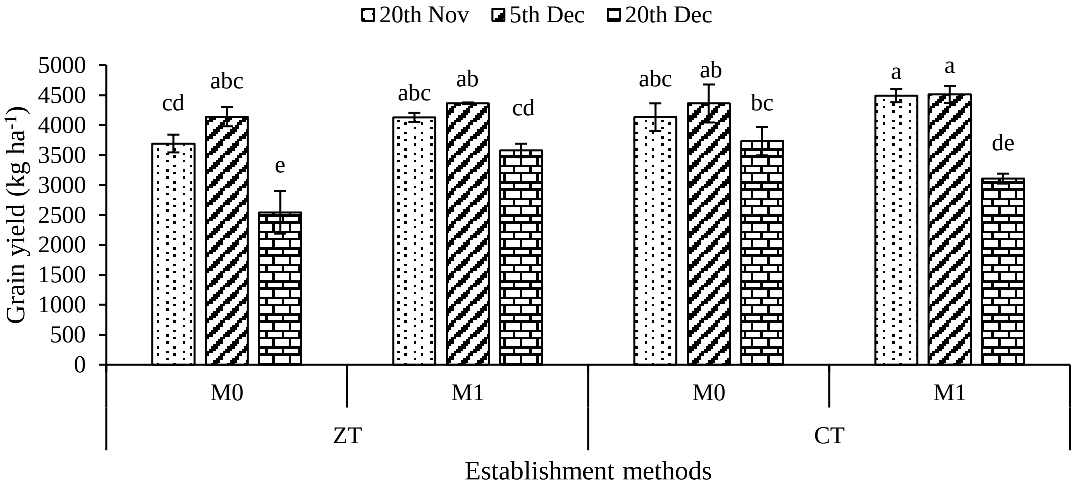

Fig. 1. Grain yield of wheat as influenced by interaction among sowing dates, establishment methods and mulching in 2020-21 at AFU, Rampur, Chitwan, Nepal

Table 3: Cost of cultivation (NRs. ha^{-1}), gross return (NRs. ha^{-1}), net return (NRs. ha^{-1}) and B:C ratio of wheat as influenced by sowing dates, establishment methods and mulching in 2020-21 at AFU, Rampur, Chitwan, Nepal

Treatments	Total variable cost of cultivation (NRs. '000 ha^{-1})	Gross return (NRs. '000 ha^{-1})	Net return (NRs. '000 ha^{-1})	B:C ratio
Sowing dates				
20th November	70.19	169.92a	99.73a	2.44a
5th December	70.19	179.54a	109.35a	2.59a
20th December	70.19	134.01b	63.82b	1.92b
SEm (±)		4.97	4.97	0.07
LSD (= 0.05)		19.50	19.50	0.29
CV, %		10.68	18.91	11.06
Establishment methods				
Zero tillage	62.29	154.58	92.29	2.48a
Conventional tillage	78.09	167.73	89.64	2.15b
SEm (±)		3.10	3.10	0.05
LSD (= 0.05)		18.84	18.84	0.28
CV, %		8.16	14.46	8.37
Mulching				
Without mulch	67.29	155.65b	88.36	2.32
With mulch	73.09	166.66a	93.57	2.31
SEm (±)		3.11	3.11	0.05
LSD (= 0.05)		9.59	9.59	0.14
CV, %		8.19	14.51	8.46
Grand mean	70.19	161.16	90.96	2.31

Note: ns, non-significant; treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance

Conclusions

Earlier sowing from 20th November to 5th December is better for higher yield of wheat in Chitwan. Zero tillage and conventional tillage produce similar yield but the cost of cultivation was lower in zero tillage and also net return and B:C ratio were higher in zero tillage. Therefore, zero tillage wheat cultivation is economically profitable in Chitwan like climate. In general, mulching produced better yield attributes and yield and therefore conservation agriculture with residue retention seems better option for wheat cultivation.

Author's Contribution

Shrawan Kumar Sah, Santosh Marahatta, Tulsi Parajuli designed the research plan & prepared the manuscript; Amrit Aryal, Anil Balchhaudi, Rabin Khadka performed experimental works, collected the required data & critical revised and finalized the manuscript. Final form of manuscript was approved by all authors.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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