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Effect of Tillage and Crop Establishment Methods with Residue Retention on Growth, Yield attributes and Productivity of Wheat under Rice-Wheat Rotation in *Typic ustochrept*

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RKN and Vivek did the conceptualization and designing of the research work. Author Reenu Kumar performed the statistical analysis, managed execution of field experiment and data collection. Authors Vivek, RKN and SPS managed the analysis of data and interpretation. Authors Reenu Kumar, MSC and Rajendra Kumar did the preparation of manuscript and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted on sandy loam soil at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh during rabi season (December 2018 to April 2019) in randomised block design with three replications. The treatments comprised of twelve tillage crop establishment methods were used for the experimentation and different observations were recorded during the crop growth period. The results indicated that the growth characters of wheat were significantly higher under wide raised bed residue retention (T9) except narrow raised bed residue retention (T7) and conventional tillage residue incorporation (T11)

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compared to other treatments. The grain yield, biological yield, harvest Index, yield attributes and grain weight were higher in treatments T9, T7, and T11, respectively. The improvement in grain yield with the tune of 32.09%, 28.14% and 25.49% was under treatments T9, T7 and T11 as compared to T12. It can be concluded that among crop establishment methods, wide raised bed residue retention (T9) found excellent to increase growth, yield attributes and yield for sustainability of wheat crop.

Keywords: Conservation tillage; residue management; productivity

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important cereal and widely cultivated crop in world wide. India occupies second position in the world wheat production. It was grown over an area of 215.48 million ha across the world and produced 731.4 million metric tons of grain with an average productivity of 3.39 tonnes per ha^{-1} (USDA report, 2018-19). Wheat crop provides 21% of the food calories and 20% of the protein for more than 4.5 billion people worldwide. In India also, wheat contribute nearly one third of the total food grain production [1] and it covered area of 9.65 million ha with production of 102.21 million tonnes in 2018-19 [2]. Uttar Pradesh is India's leading wheat growing state of with an area of 9.65 million ha (36.6%), production of 29.67 million tonnes (39.9%) and productivity of 27.95 kg ha^{-1} (Anonymous 2019). The main reasons for its productivity are poor crop establishment and improper scheduling of irrigation. Ideal planting geometry is important for better and efficient utilization of plant growth resources get the optimum productivity of wheat. It is also well know fact that water management is one of the major factors responsible for achieving better harvest in crop production. Both crop establishment method and irrigation schedule are major causes of yield reduction in wheat, which also affect its water use efficiency. Farmers are always interested in getting higher yield which could not be possible without better crop management, good stand establishment and optimum utilization of resources. Crop production is influenced by its establishment and plant vigour representing the key factors towards crop development [3]. Raised bed planting is one of best method practiced in many parts of the world to reduce the cost of production and irrigation water [4]. Furrow irrigation used with raised beds requires growers to adopt a whole-farm planning approach to deal with drainage water and the integration of on farm drains and drainage water recycling systems, to increase both water use efficiency and drainage water quality control [5].

The purpose of the current study was conducted a field experiment to evaluate the effect of crop establishment methods on growth, yield and yield attributes of wheat in *Typic Ustochrept* of western Uttar Pradesh, India.

2. MATERIALS AND METHODS

The field experiment was conducted at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut during *Rabi* season (December 2018 to April 2019). The experiment was laid out in randomized block design (RBD) with three replication and twelve tillage crop establishment methods namely T_1-Zero tillage residue retention, T_2-Zero tillage without residue, T_3-Reduce tillage residue retention, T_4-Reduce tillage with residue, T_5-Roto till residue retention, T_6-Roto till without residue, T_7-Narrow raised bed residue retention,T_8-Narrow raised bed without residue,T_9-Wide raised bed residue retention, T_{10}-Wide raised beds without residue, T_{11}-Conventional tillage residue incorporation and T_{12}-Conventional tillage and wheat variety DBW-90 were tested. The soil of experimental field was sandy loam in texture with low in organic carbon (0.44%), available nitrogen (222.8 kg ha^{-1}) and medium in available phosphorus (16.7 kg ha^{-1}) and potassium (241.5 kg ha^{-1}) respectively. Irrigation water was applied by using the polyvinyl chloride pipes of 15-cm diameter and the amount of water applied to each plot was measured by using a water meter. Rainfall data was recorded using a rain gauge installed within the meteorological station. The total amount of water (input water) applied was computed as the sum of water received through irrigation and rainfall. The data collected from the experiment were analyzed statistically by analysis of variance (ANOVA) method for randomized block design (RBD) with weed management treatments as one factor, respectively. Whenever the treatment differences were found significant (F test), critical differences were worked out at five per cent probability level. For assessment variations in growth characters Duncan's Multiple Range Test – DMRT was used. Treatment differences that were non-significant were denoted by NS. The growth characters, yield attributes and yield data recorded, analysed and tabulated after statistical test.

3. RESULTS

3.1 Growth Characters

3.1.1 Plant height

The plant height recorded periodically at various crop growth stages 30, 60, 90 DAS and at harvest of wheat as influenced by different establishment methods (Fig 1). At 30 days crop stage, the plant height was recorded significantly highest in treatment T_9 wide raised bed with residue retention than all other treatments except T_7 narrow raised bed with residue retention and T_{11} conventional tillage residue incorporation. Treatment T_1, T_3 and T_{11} were superior over rest of the treatments. Treatments T_5 and T_{10} were at par. TreatmentsT_4 was significantly inferior to treatments T_2 and T_8 but, was significantly superior to treatments T_6 and T_{12} which were at par with each other, respectively. A similar trend was also observed at 60 DAS stage and at harvest, respectively. At 90 days of crop growth stage, maximum height (81.4 cm) of plants was obtained under treatment T_9 “Wide raised beds with residue retention” being significantly taller than those for the rest of the tillage establishment technique treatments except T_7 and T_{11} “Narrow raised beds residue retention and conventional tillage residue incorporation” and least (49.7 cm) under T_{12} “Conventional tillage”. Treatments T_1 was significantly superior from remaining of the treatments except T_3 and T_5. The difference in plant height between T_2 and T_{10} was at par during the year of experimentation.

The tiller’s number decreased with advancement in crop age except from 30 to 60 DAS stage. The decline in number of tillers after 60 DAS may be attributed to morality of late formed tillers. Average decrease in tillers m^{-2} from 60 to 90 DAS and 91 DAS to harvest was 11.0% and 16.3% tillers m^{-2}, respectively (Fig 2). Among the treatments, at 30 DAS, wheat sown on wide raised beds residue retention (T_9) produced significantly more number of tillers m^{-2} except narrow raised bed residue retention (T_7) and conventional tillage residue incorporation (T_{11}) which was recorded statistically at par. Though, the treatments T_1, T_2, T_3, T_5 and T_{10}, T_6 and T_8 were recorded at par with each other. However, the treatment T_{12} was resulted into least number of tillers during experimentation. Tillage crop establishment on wide raised beds residue retention (T_9) recorded maximum tillering at 60, 90 DAS and at harvest stages which was significantly superior than other methods of tillage crop establishment but, at par with narrow raised beds residue retention (T_7), zero tillage residue retention (T_1) and conventional till residue incorporation (T_{11}). Though, the treatments T_2, T_6, T_5 and T_3 were recorded significantly superior over rest of the treatments during the year of experimentation. However, the treatments T_4, $T_{8,}$ T_{10} and T_{12} were resulted into non- significant at all crop stages during experimentation.

Dry matter production and accumulation in leaves, stem and grains at 30, 60, 90 DAS and at harvest varied significantly under different establishment methods. The dry matter accumulation increased progressively with advancement of the crop age (Fig 3). Averaged over the different treatments the increase in dry matter between 30 to 60 DAS; 60 to 90 DAS; 90 DAS to harvest was 25.82, 85.85, 101.75 and 104.91 g m^{-2}, respectively during the year of study. Maximum dry matter accumulation took place between 60 to 90 DAS stage. Among methods of crop establishment, wide raised beds residue retention (T_9) accumulated more dry matter g m^{-2} which was statistically at par with narrow raised beds residue retention (T_7), zero tillage residue retention (T_1) and conventional till residue incorporation (T_{11}). However, the differences among T_7, T_3 and T_5 treatments were non-significant. Successive improvement in moisture supply brought significantly higher dry matter accumulation m^{-2} at 60, 90 DAS and at harvest stage of crop under wide raised beds residue retention (T_9) treatments over rest of the crop establishment methods except, zero tillage residue retention (T_1) and conventional till residue incorporation (T_{11}) during the year of study. At harvest stage maximum dry matter accumulation (1109.96 g m^{-2}) was obtained under T_9 plots and minimum (774.49 g m^{-2}) under conventional tillage (T_{12}) treatment during experimentation. However, the significant differences were found among $T_7$and T_{11} treatments and $T_1$was also significantly superior over T_5 and T_{12}.

3.1.2 Leaf area index

Leaf area was measured at 30 days intervals till the senescence of crop with the help of leaf area meter. The leaf area index was worked out by using the following formula:

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Land area}}$$

The LAI was influenced by different establishment methods as presented in Fig 4. An increasing trend in LAI was noted with the advancement of crop age up to 90 DAS during the year of study. The increase was more prominent during 60 to 90 days period as compared to 30 to 60 DAS stage, respectively. At 30 to 60 DAS among methods of crop establishment wide raised beds residue retention (T_9) obtained higher LAI which was statistically at par with zero tillage residue retention (T_1), narrow raised beds residue retention (T_7) and conventional tillage residue incorporation (T_{11}). Treatment reduced tillage residue retention (T_2) and roto till residue retention (T_5) were recorded significantly higher than those for the rest of the sowing methods. However, the differences among T_2, T_4, T_6 and T_8 treatments were non-significant. At 90 DAS stage, LAI under the treatment wide raised beds residue retention (T_9)showed successive improvement in moisture supply resulted statistically significant increase in LAI over rest of the crop establishment methods except zero tillage residue retention (T_1), narrow raised bed with residue retention (T_7) and lowest under conventional tillage (T_{12}) treatment during experimentation. However, the reduce tillage with residue retention (T_3), roto till with residue retention (T_5), wide raised beds without residue (T_{10}) treatments were significantly superior over narrow raised bed without residue (T_8), reduce tillage without residue (T_4) and roto till without residue (T_6) which were statistically at par.

Observations indicate that the CGR was lowest between 0 to 30 days and attained maximum value between 30 to 60 days and then declined consistently till 120 DAS (Fig 5). The CGR was significantly affected by planting methods during both the year of study. The successive increase in planting methods significantly increased the CGR at all the growth stages during experimentation. Whereas, maximum CGR observed at 120 DAS stage (8.35 g m^{-2} d^{-1}) with reduce tillage without residue (T_4) which was significantly greater than T_2> T_4> T_6>T_{12} “conventional tillage” and it were at par with T_1, T_7 and T_{11} during the year of study, respectively.

Relative growth rate (RGR, g g^{-1} day^{-1}) at various stages were analyzed statistically and the mean RGR data as influenced by different treatments (Fig 6). The data revealed that RGR attained maximum value between 0 to 30 and 30 to 60 days stage and then declined consistently till 120 DAS during the year of study. Among methods of crop establishment treatment wide raised beds residue retention (T_9) was found to be significantly superior to all the treatments except T_1, T_7 and T_{11}. Treatments T_3 and T_5 were at par with each other but recorded significantly lower relative growth rate over T_2 treatment. The highest values of relative growth rate (0.0003 g g^{-1} day^{-1}) and minimum (0.0002 g g^{-1} day^{-1}) were recorded under T_9 and T_{12} treatments during the year of study.

Net assimilation rate (NAR) g $m^{-2}day^{-1}$ of wheat crop, directly related to dry matter and leaf area index (Fig 7). Net assimilation rate exhibited an uprising trend with crop age up to 60 DAS and thereafter it declined consistently during the year of study. Among methods of crop establishment treatment T_9 (wide raised beds residue retention) was found to be significantly superior to all the treatments and recorded highest net assimilation rate (1.12 g $m^{-2}day^{-1}$) except T_1, T_3, T_5, T_7 and T_{11}. Treatments T_4 and T_6 were at par with each other, however, they recorded significantly lower net assimilation rate over T_{10}. Treatment T_{12} recorded minimum net assimilation rate (0.84 g $m^{-2}day^{-1}$) during experimentation.

3.2 Yield Contributing Characteristics

3.2.1 Spike length

The Spike length results revealed that T_9 treatment significantly increased spike length over all treatments but at par with T_7 treatment during the year of study (Table 1). However, T_{11} treatment produced significantly increased spike length as compared to rest of the treatments except T_1 and T_3, respectively.

The number of productive tillers m^{-2} varied with different tillage practices (Table 1) and significantly higher were recorded with raised beds residue retention FIRB (T_9) treatment which was at par with narrow raised beds residue retention (T_7) and conventional tillage residue retention (T_{11}) during the year of study and gave 9.6% and 21.9% more as compared to zero till residue retention (T_1) and conventional tillage (T_{12}), during experimentation, respectively.

The number of grains $spike^{-1}$ showed that T_9 treatment of wide raised beds residue retention tillage technique produced significantly more during the year of study over all other treatments but was statistically at par with T_7 narrow raised beds residue retention and T_{11} conventional tillage residue retention, respectively (Table 1).

3.2.2 Grain weight

The grain weight of wheat revealed that T_9 treatment of sowing techniques significantly increased grain weight over all other treatments but was statistically at par with T_7 and T_{11} treatments during the year of study (Table 1). However, T_{11} treatment produced significantly higher grain weight as compared to T_1, T_3 and T_5 respectively. The lowest test weight was recorded in T_{12} conventional tillage during experimentation.

3.3 Yield

3.3.1 Grain yield

The variations in grain yield due to main effects of various treatments were statistically significant during the year of study (Table 2). The tillage crop establishment influenced the maximum grain yield significantly in treatment T_9 (furrow irrigated wide raised beds residue retention) and T_7 (narrow raised beds residue retention, and T_{11} conventional till residue incorporation) (45.63 and 43.30 quintal ha^{-1}) remained statistically at par with it. The reduction in grain yield with establishment techniques application was 6.6% and 7.3% compared to T_1 (zero tillage) and T_3 (reduced tillage) application, respectively. However, raised beds registered 13.1 and 12.7% a significant yield improvement over conventional practices.

3.3.2 Straw yield

The straw yield showed that in the treatments of crop establishment residue management, all the treatments were significantly higher than conventional practices during experimentation (Table 2). Among the various sowing techniques treatment T_9 was found to be significantly superior to all the treatments except T_7 and T_{11} also recorded statistically significant straw yield (60.25 and 57.22 quintal ha^{-1}) as compared with T_1, T_3 andT_5 during the year of study. Treatment T_6 was at par with T_{12} treatment and T_{12} which recorded minimum straw yield during the year of study, respectively.

3.3.3 Biological yield

The highest biological yield (grain yield quintal ha^{-1} + straw yield quintal ha^{-1}) was obtained with T_9 treatment of sowing techniques which was statistically at par with T_7 and T_{11} treatments during the year of study (Table 2). However, T_7 treatment produced significantly higher biological yield as compared to rest of the treatments except T_1 and T_3. Treatment T_1 were at par with $T_{2,}$ T_4, T_6 and T_8 treatments during experimentation.

Table 1. Effect of tillage-cum-crop establishment methods on yield attributing characters of wheat

Treatments		Yield Attributes			
		Spike length (cm)	Productive tillers (m^{-2})	Grains spike^{-1}	Grain weight (g)
T_1	Zero tillage residue retention	10.78	209.2	40.20	37.10
T_2	Zero tillage without residue	9.68	202.4	36.28	35.67
T_3	Reduce tillage residue retention	10.60	207.5	40.05	36.80
T_4	Reduce tillage without residue	8.91	193.6	35.51	34.60
T_5	Roto till residue retention	10.47	205.3	39.61	36.32
T_6	Roto till without residue	8.65	187.1	35.10	34.32
T_7	Narrow raised bed residue retention	12.08	229.5	43.32	40.26
T_8	Narrow raised bed without residue	9.44	198.6	35.95	35.10
T_9	Wide raised bed residue retention	12.88	231.5	44.62	41.10
T_{10}	Wide raised beds without residue	10.23	203.7	36.88	35.84
T_{11}	Conventional tillage residue incorporation	11.69	225.7	42.54	39.69
T_{12}	Conventional tillage	7.72	180.8	28.40	33.82
SEm (±)		0.37	7.47	1.38	1.38
C.D. (P=0.05)		1.07	21.45	3.95	3.97

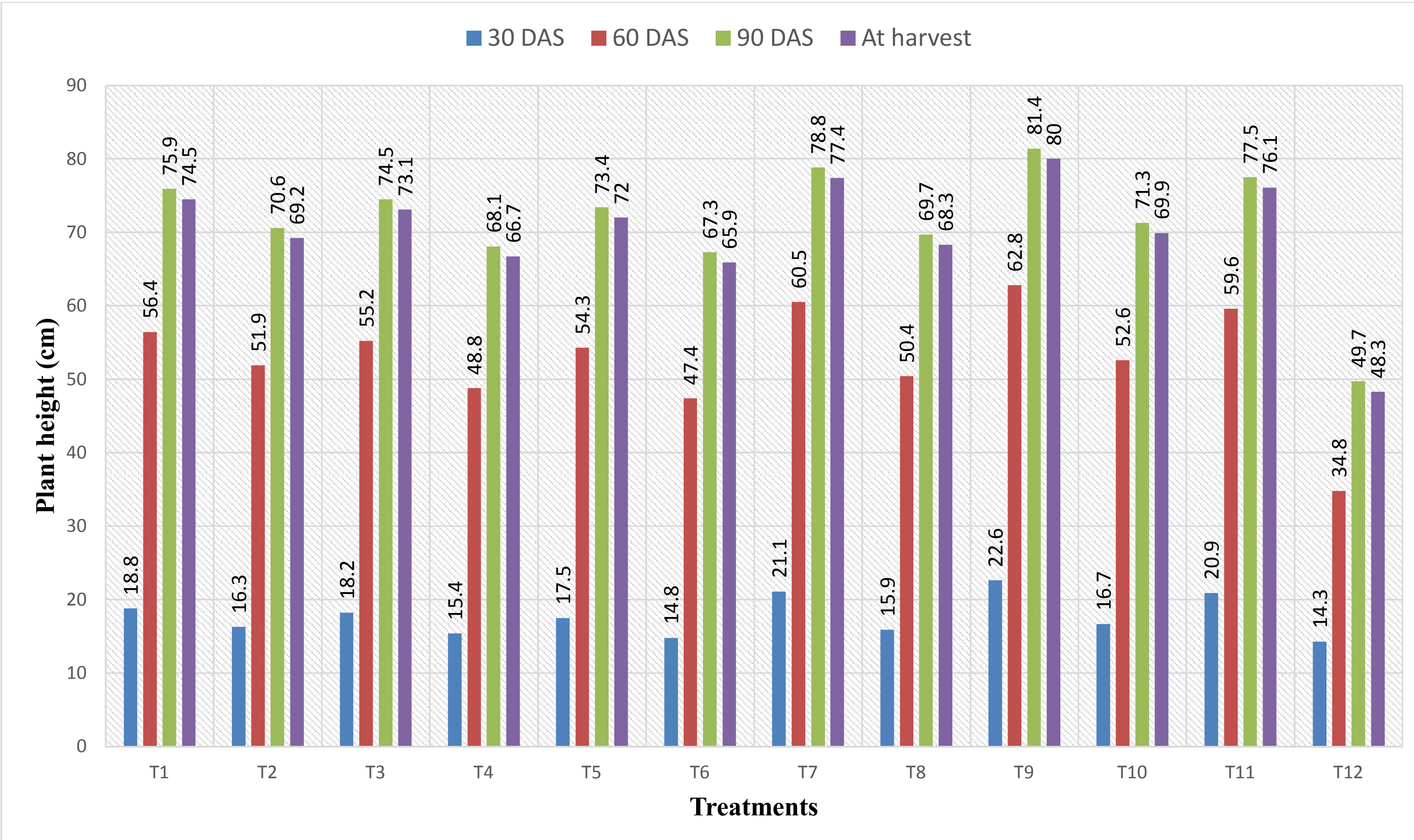

Fig. 1. Plant height (cm) of wheat as influenced by tillage crop establishment methods at different growth stages

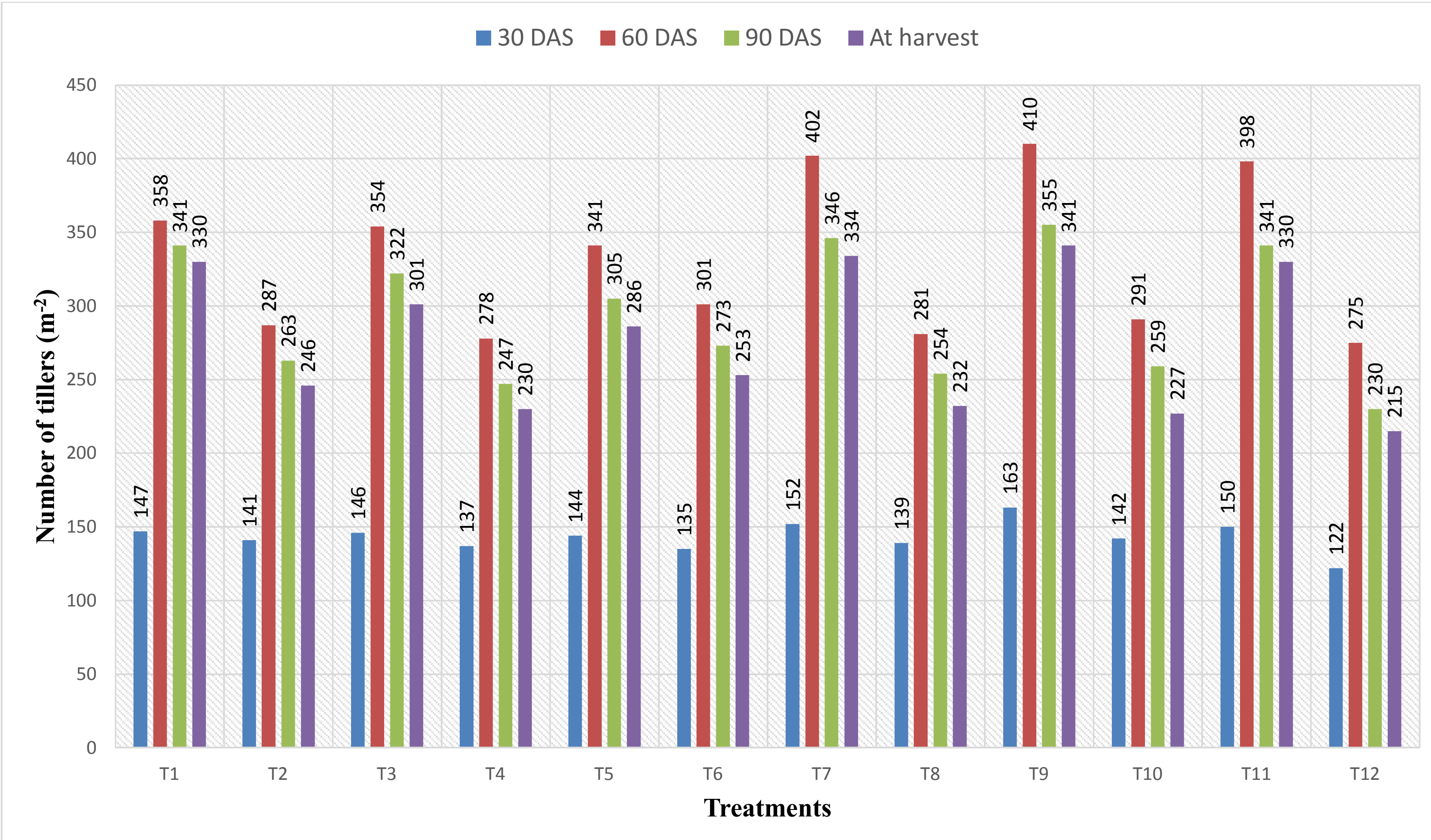

Fig. 2. Effect of tillage practices on number of tillers (m^{-2}) of wheat at different growth stages

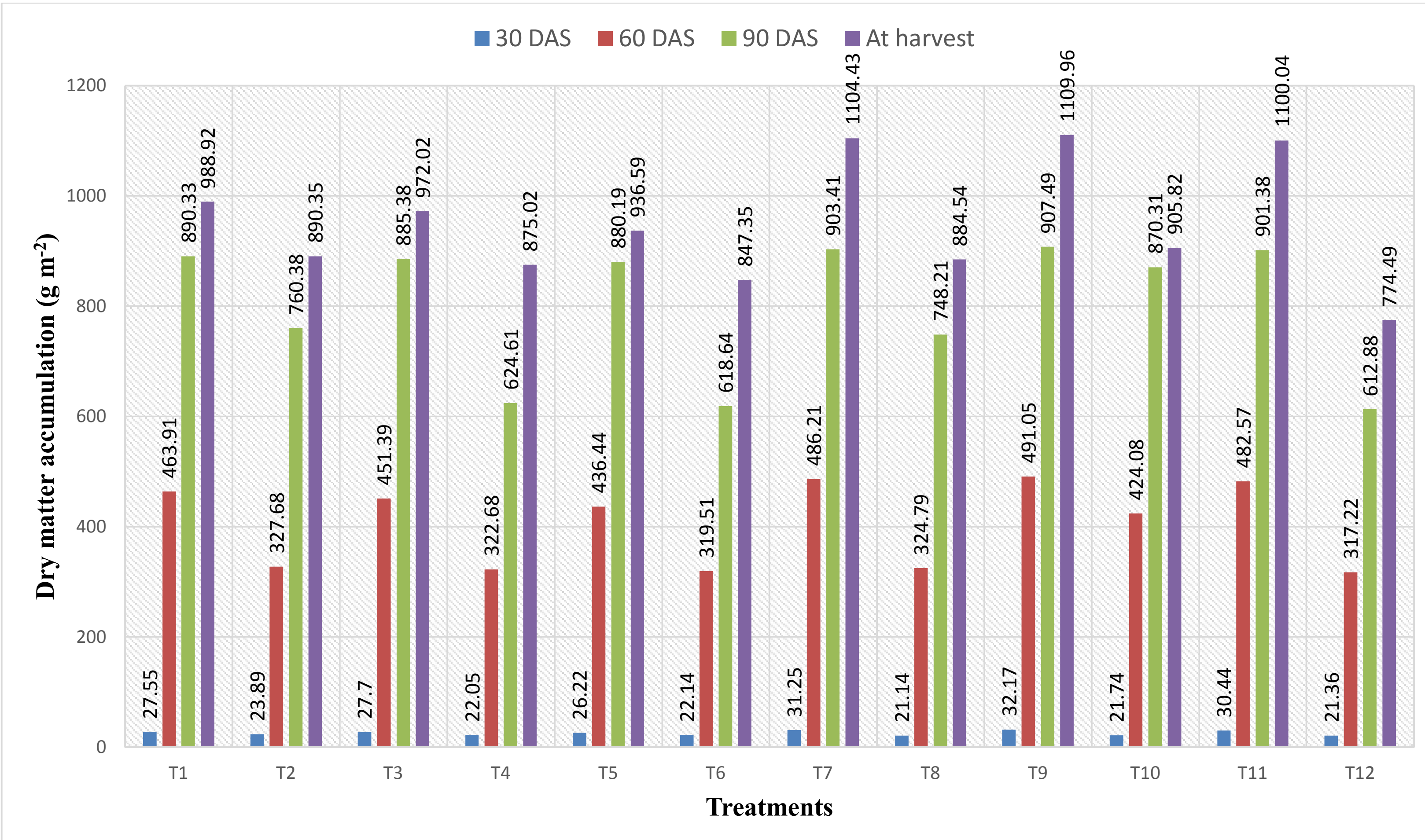

Fig. 3. Dry matter accumulation (g m^{-2}) of wheat as influenced by planting patterns at different growth stages

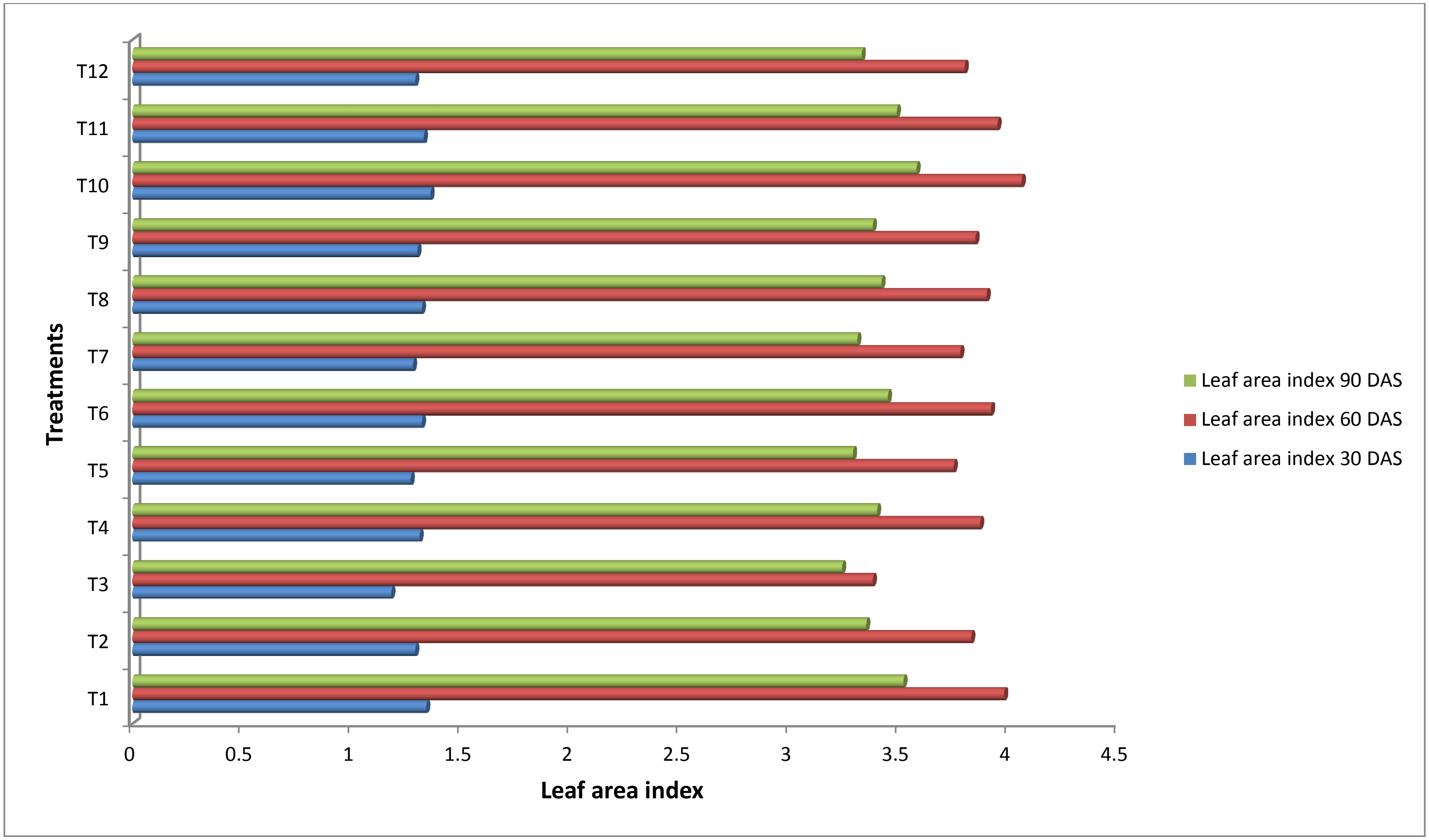

Fig. 4. Effect of tillage crop establishment methods on leaf area index of wheat at different growth stages

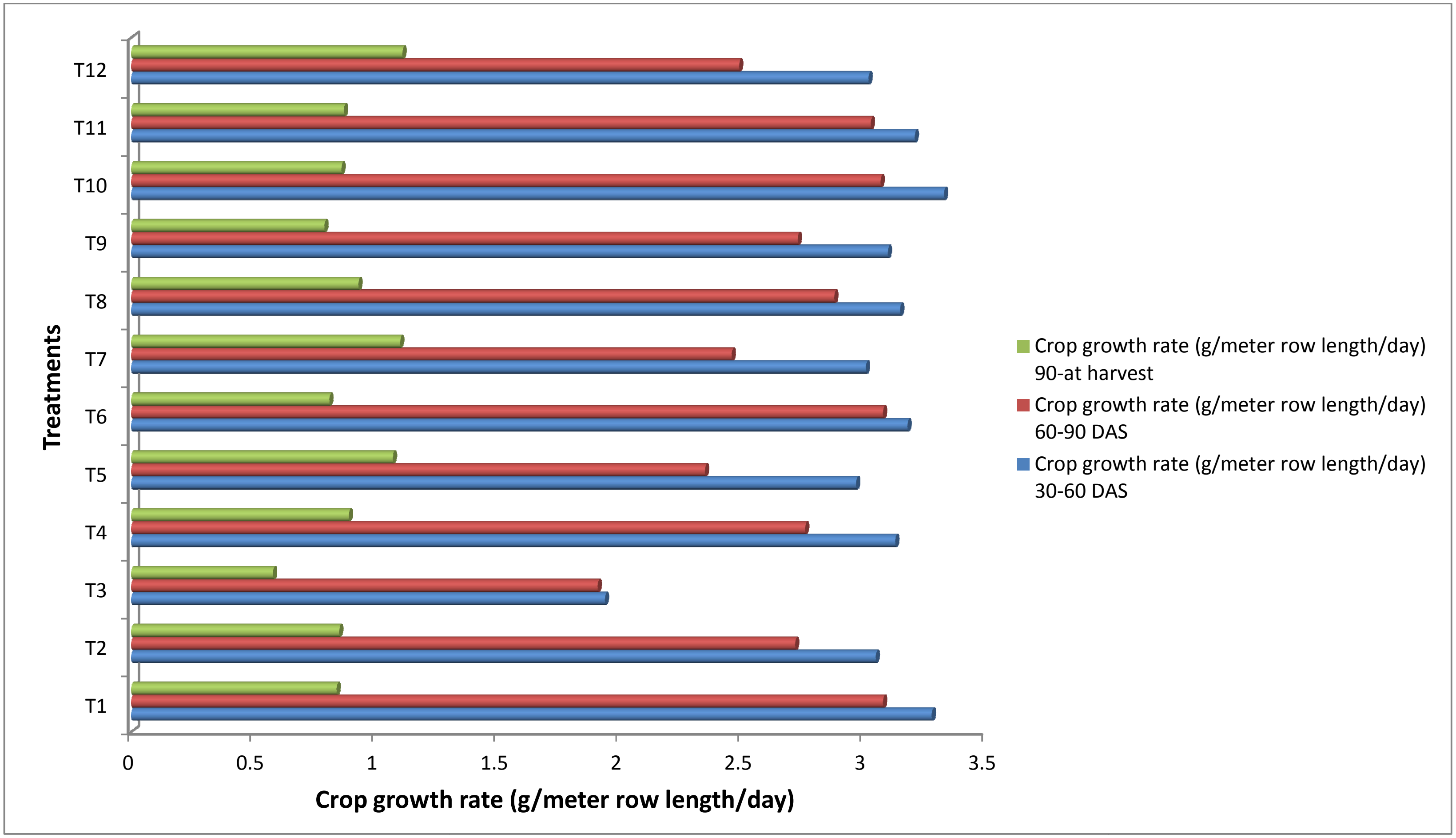

Fig. 5. Crop growth rate (g m^{-2} day^{-1}) of wheat at different intervals as influenced by establishment methods

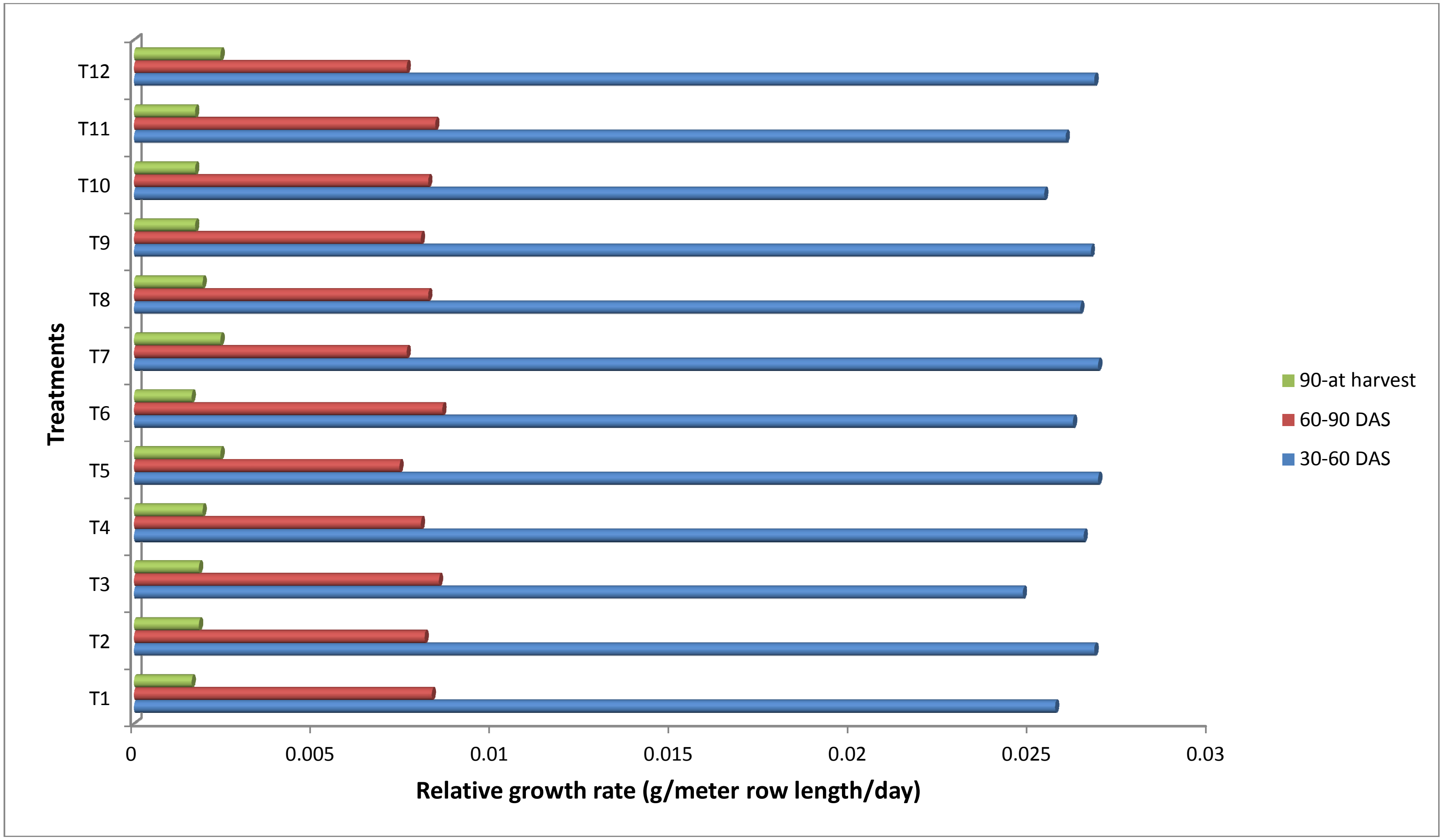

Fig. 6. Influence of relative growth rate (g $g^{-1}day^{-1}$) of wheat at different growth intervals under planting pattern

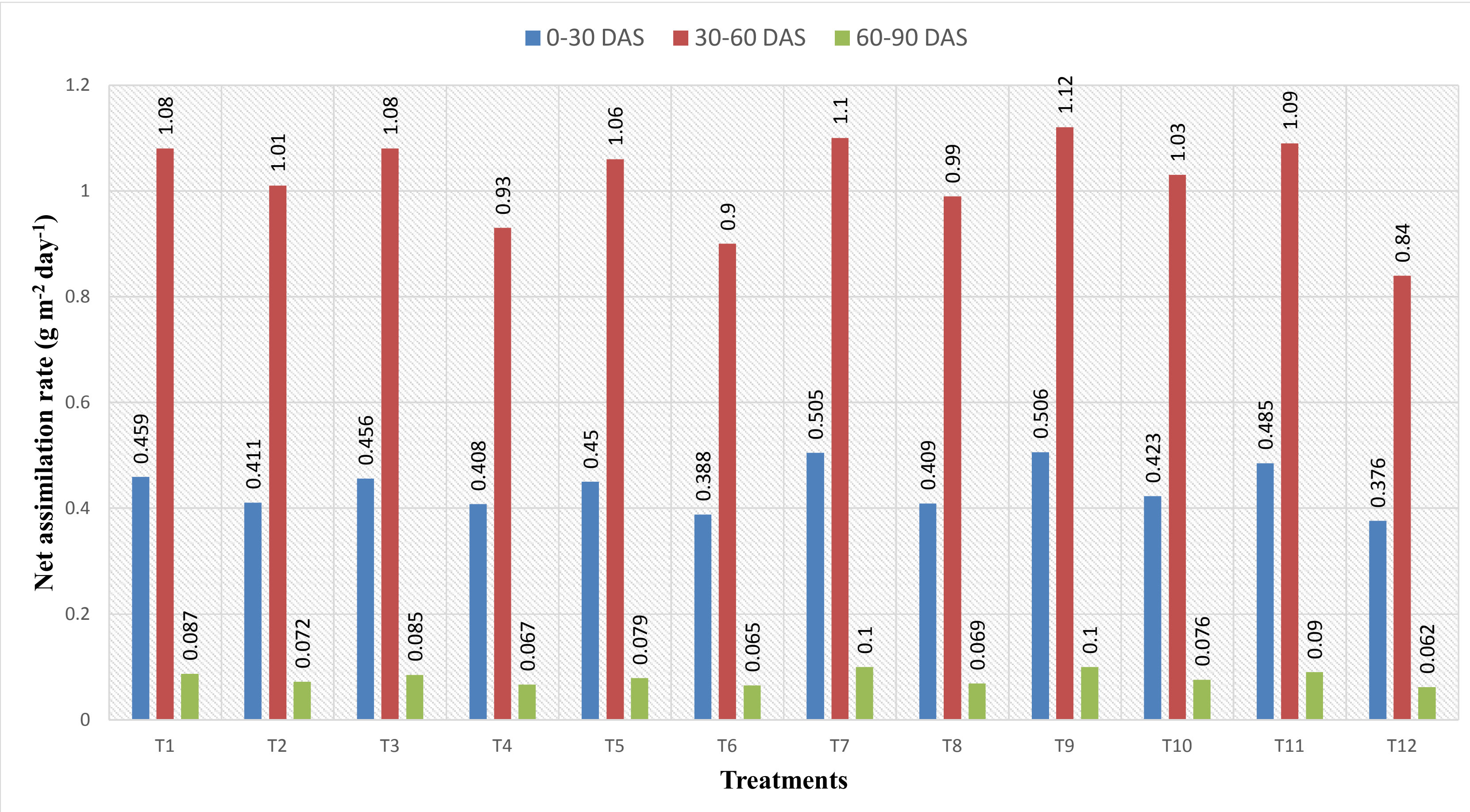

Fig. 7. Net assimilation rate (g m^{-2} day^{-1}) of wheat as influenced by tillage treatments

Table 2. Effect of different tillage practices on grain, straw, biological yield (q ha^{-1}) and harvest index (%) of wheat

Treatments		Yield (q ha^{-1})			Harvest index (%)
		Grains	Straw	Biological	
T_1	Zero tillage residue retention	40.87	56.72	97.59	41.88
T_2	Zero tillage without residue	36.31	52.74	89.05	40.77
T_3	Reduce tillage residue retention	39.58	55.81	95.39	41.49
T_4	Reduce tillage without residue	35.62	52.36	87.98	40.49
T_5	Roto till residue retention	38.62	54.84	93.46	41.32
T_6	Roto till without residue	34.20	50.62	84.82	40.32
T_7	Narrow raised bed residue retention	45.63	60.25	105.88	43.10
T_8	Narrow raised bed without residue	36.12	52.29	88.41	40.86
T_9	Wide raised bed residue retention	47.51	63.19	110.70	42.92
T_{10}	Wide raised beds without residue	37.16	53.14	90.30	41.15
T_{11}	Conventional tillage residue incorporation	43.30	57.22	100.52	43.08
T_{12}	Conventional tillage	32.26	42.14	74.40	40.02
SEm (±)		1.55	2.14	3.69	1.48
C.D. (P=0.05)		4.45	6.12	10.58	NS

3.3.4 Harvest index

No definite trend with respect to the planting techniques on harvest index was observed. However, the highest harvest index was obtained under T_7 and lowest under T_{12} treatment during the year of study.

4. DISCUSSION

The growth in terms of plant height and dry weight, LAI, CGR, RGR and NAR shows that the growth was slightly more during later growth stages. This higher growth might be due to more favourable weather condition prevailed like rainfall, sunshine hours, and temperature. The effect of different growth characters was negligible at early vegetative stage and it increased at later stage of crop development. Among the different treatments during the experimentation these variation in growth characters were because of cumulative seasonal effect and superimposing of different establishment treatments. The significantly higher plant growth under T_7 and T_9 during the year in later stages of crop growth was because of more moisture and less density resulting in higher transpiration rate to those plots and non-shading of lower leaves which have also increased the dry matter accumulation may be the reason of recording higher values of different growth characters in T_7 than T_9. The higher amount of available water kept the higher turgor potential, which leads to higher rate of photosynthesis due to larger opening of stomata for longer period of time. This has also increased for faster cell division and enlargement, which leads to higher growth rate. Increasing DMA at maturity and improving the contribution of post-anthesis DM to grain can increase the grain yield [6,7] also acknowledging that the DMA was more highly correlated to grain yield than DMR. Higher photosynthesis rate post-anthesis, especially at the mid and later grain filling stages, which promoted post-anthesis dry matter accumulation and grain filling, and finally increased the grain weight are likely the reason of high correlation coefficient between DMA and grain yield. These results corroborate the findings of [8,9].

The significant increase in grain, straw and biological yield increased with tillage practices. FIRB and zero tillage fulfilled the timely crop water requirement, which resulted into better growth in term of dry matter accumulation. The higher yield was recorded under residue retention treatments. This clearly indicated that in-situ of residue was beneficial in improving the productivity of wheat only with tillage operations, which were essentially required for retention/incorporating residue into soil for its proper and timely decomposition. The higher growth finally resulted into significant increase in grain yield through yield attributes namely number of effective tillers, number of grains per spike and test weight. Furrow irrigated raised beds and zero tillage practices increased the grain yield of wheat by about 10 and 9%, respectively. This increase was because of increased the number of grains per spike to the tune of 5.6 and 4.2% during the year of study. Similarly, the increase in test weight was also recorded in the range of 5.9 and 4.5%, respectively. Similar results have been reported by Dhaka et al. [10].

5. CONCLUSION

Among crop establishment methods and residue management wide raised bed residue retention (T_9) significantly improved wheat yield over conventional tillage. The improvement in grain yield with the tune of 32.09, 28.14 and 25.49% were under treatments T_9, T_7 and T_{11} as compared to T_{12}. It revealed that both tillage and residue systems affected in terms of yield and yield components which ultimately produced maximum yield due to its more photosynthesis and border effect The results of the present study showed that the wide raised beds with residue retention are a feasible management technology for farmers producing wheat in the agro-ecological zone studied. However, further research needs to be carried out on impact of different tillage practices under residue management on cereal based cropping systems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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