Wheat (Triticum aestivum l.) performance under residue management strategies in maize-wheat rotation

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Abstract: Intensive cereal based cropping especially maize and wheat with conventional practices has encouraged degradation of soil quality in Pakistan. Key element in this regard is scarcity of alternative organic amendments, incorporation of crop residue in fields can be considered as promoting physical, chemical and biological attributes of soil health in agricultural system of Pakistan. This field trial was conducted to investigate the effect of different maize residue management strategies along with different splitting levels of nitrogen on yield and yield components of wheat at the Agronomic Research Area, University of Agriculture, Faisalabad, during the year 2014-15. Four residue management strategies was T1: conventional cutting practice of maize, T2: Incorporation of lower 1/3 maize plant, T3: incorporation of lower 2/3 maize plant, T4: full plant incorporation and three nitrogen splitting levels viz; N1: N100 kg ha-1 as 1/2 basal application + 1/2 after 22 DAS, N2: N150 kg ha-1 1/2 basal + 1/2 after 22 DAS and N3: N150 kg h-1 as basal. Response of wheat yield and its components like number of productive tillers, 1000 grain weight was differ significantly under maize plant incorporation strategies compared to conventional cutting practice. Full plant incorporation along with N100 kg ha-1 in 2 splits remained superior regarding final yield. Maximum net rate of return (Rs.84336) and benefit cost ratio (1.25) was obtained in conventional cutting practice at N100 kg ha-1 in two splits. Through net return and benefit cost ratio was highest in conventional cutting practice but fertility status of soil increased significantly by addition of residue.

[Muhammad Faizan Aslam, Shabir Hussain, Kumail Fayaz, Hafiz Muhammad Zaid, Malik Ghulam Asghar, Muhammad Jahanzaib Shafi, Faisal Shabir, Zain Ul Abdin. **Wheat (Triticum aestivum l.) performance under residue management strategies in maize-wheat rotation.** *Nat Sci* 2018;16(11):139-148]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature. 19. doi:10.7537/marsnsj161118.19.

Key words: wheat, maize, rotation, residue.

Introduction

Wheat (Triticum aestivum L.) is the most important cereal and staple food of Pakistan and called, 'King of Cereals". Wheat contribution is 10.3% to the value added in agriculture and 2.2% to GDP. Currently, area of wheat is 9.039 million hectares with total production of 25.28 million tons with an average yield of 2797 kg ha-1 (Govt. of Pakistan, 2013-14). Present cultivars that are semi dwarf-statured have the potential of about 6-8 t ha-1 but are only producing 2.7 t ha-1. Maize is Pakistan 3rd important cereal crop and in 2013-14, maize cultivation increased 5.4 % than last year due to hybrid cultivation in autumn season (Govt. of Pakistan, 2013-14). Maize and wheat both are exhaustive crops and continuous cultivation of these led to deterioration of soil health. Conventional tillage with crop residue burning or removal can lead to excessive soil compaction, producing unfavorable conditions for crop growth resultantly reduction in yield (Mele and Crowley, 2008). This wide yield gap can be attributed to many factors including delayed sowing, non-availability of certified seed, and shortage of fertilizer, poor irrigation and weed interference. Among the reasons the most important are less organic matter and injudicious use of inorganic fertilizers (Oad et al., 2004). Organic matter contents in Pakistani soils are very low less than 0.5% due to arid climate which causes the rapid decomposition of organic matter which is not satisfactory amount to sustain soil health and fertility (Hashmi et al., 2013). Chemical fertilizers decrease enzyme activity of soil microbes, soil pH and soil structure (Bohme and Bohme, 2006) but the farmers are constantly increasing the rates of fertilizers to maintain higher crop productivity (Harrington, 1996). Regular and proper addition of organic matter (like crop residues) seemed to has positive effect on maintaining the health, fertility and productivity of agricultural soils (Bukert et al., 2000) not only by increasing nitrogen contents but also increasing the quantity of carbon in the soil which make favorable environment for plant growth, productivity soil microbes (Shannon et al., 2002). Among all plant nutrients, nitrogen is one of the nutrients they recycled through crop residues incorporation. Addition of organic matter is favorable way of improving the soil properties by providing favorable soil structure, enhancing soil cation-exchange capacity, increasing quantity and availability of soil nutrients and providing soil micro-organism with substrate (Dekiessa et al., 2008). Crop residues can suppress weeds through physical hindrance or by posing chemical effects (allelopathy). Although having advantages like destruction of injurious pests and clearing the field, burning/removal of crop residues results in losses of huge amount of N (up to 80%), P (25%), K (21%) and S (4-60%), air pollution (Co2 13 t ha-1) depriving soil organic matter (Mandal et al., 2004). There is an important and critical relationship exists between nitrogen and crop residues. Nitrogen immobilization takes place as residues leads to widening of C/N ratio of soil which ultimately causes a reduction in nitrogen use efficiency (Grahmann et al., 2013). To quickly reduce C/N ratio as increased by residue incorporation N at 15-20 kg ha-1 as first dose with straw incorporation increase yields of rice and wheat than burning (Mandal et al., 2004). Crop residue with nitrogen starter dose could effectively improve soil physical quality with potential for improving crop yield. Thus, proper management and utilization of crop residues can affect overall system productivity as well as sustainability and environment quality. The present study was conducted to investigate the relationship residue incorporation and nitrogen split levels.

Material and methods

The study was conducted at Agronomic Research Area, Department of Agronomy, University of Agriculture Faisalabad, Pakistan 2014-15. The experiment was conducted under (RCBD) with split plot arrangement having three replications and measuring a net plot size of 1.5 m × 6 m. Treatments were four maize incorporation strategies (T1: conventional cutting practice of maize, T2: Incorporation of lower 1/3 maize plant, T3: incorporation of lower 2/3 maize plant, T4: full plant incorporation) in main plots and three nitrogen splitting levels viz; N1: N100 kg ha-1 as 1/2 basal application + 1/2 after 22 DAS, N2: N150 kg ha-1 1/2 basal + 1/2 after 22 DAS and N3: N150 kg ha-1 as basal) in sub plots, respectively. The crop was sown manually with the help of a single row hand drill @ 100 kg ha-1 in the third week of November2014. Phosphorus and potash were applied @110 and 65 kg ha-1, respectively. All other cultural operations were kept normal and uniform except nitrogen splitting levels. Data collected on growth and yield parameters of the crop were analyzed statistically by using Statistic 8.1 and least significant difference test at 0.05 probability level was employed to compare the treatment means (Steel et al., 1984). At maturity an area of 1 m-2 was harvested from each plot to determine the total biomass and grain yield. A sample of 20 plants from each plot was taken randomly and average was calculated for the data: number of fertile tillers (m-2), plant height (cm), spike length (cm), number of spikelet's per spike, 1000 grain weight (g), grain yield (kg ha-1), biological yield (kg ha-1) and harvest index (%).

4.1.1. Germination count

Germination count has a substantial role in plant population and crop success mainly depends upon plant population per unit area. More the germination count per unit area more will be the plant population that ultimately contributes towards final yield. Factors responsible for affecting the germination count are; seed quality, seed health, sowing depth, soil temperature, aeration and moisture. A perusal of the table depicted that different residue management strategies and nitrogen had significant while interaction was non-significant. Data regarding germination counts for the growing season is presented in the table 4.1.1.

Wheat crop sown after maize residue incorporation and with recommended nitrogen application in 2 splits gave higher seedling emergence which was 15 % greater than conventional cutting practice of maize. The greater germination count was found where lower 1/3 plant residue were incorporated than conventional cutting practice was due to moisture availability and fine soil tilth. These result are supported by Morris *et al*. (2009) who reported that straw residue remained on the soil surface reduced moisture evaporation and improved seed-to-soil contact while in case of conventional cutting practice was not covered by residues that decreased seed germination. Lower 1/3 maize plant incorporation produced maximum germination (182.67) then lower 2/3, full plant incorporation and conventional cutting practice as (169.33, 164.89 and 158.33 m-2) respectively this might be due to the fact that in lower 2/3 and full plant incorporation had higher amount of residues and seed come in contact with plant residue which may decrease seed germination.

4.1.2. Total number of tillers

Plant population per unit area at the time of harvest is the crucial yield determining factor in wheat. Higher crop yield depends on the higher number of tillers per unit area. Data of the growing seasons have been in table 4.1.2. Significant differences were found in producing number of total tillers per unit area by various residue management strategies and nitrogen levels while their Interaction was found non-significant.

Residue incorporation produced maximum total tillers at N 150 kg ha^{-1} in 2 splits which was 10 % greater than conventional cutting practice of maize while lower 1/3 plant residue incorporation @ N 150 kg ha^{-1} produced 311 total tillers. Residue incorporation produced more number of total tillers was probably due to more soil organic matter and nutrients within 0-15 cm, which was helpful for growth and tillering than conventional tillage. These results are confirmed by Lopez-Fando and Pardo (2009). Our results were also in accordance with Alijani *et al*. (2012) who reported that spikes per m-2 and significantly increased with increased residues and N rates.

4.1.3. Number of unproductive tillers (m-2)

Data regarding number of unproductive tillers of wheat indicated that it varied significantly ($P \leq 0.05$) for different nitrogen splitting levels under different residue incorporation strategies. Residue incorporation and their interaction were found non-significant (Table 4.1.3). Maximum number of unproductive tillers (14.50) were counted where recommended nitrogen was applied as basal dose and less number of unproductive tillers 11.00, 8.00 of wheat where N 100 kg ha^{-1} in 2 and N 150 kg ha^{-1} in 2 splits was applied, respectively. Residue incorporation treatments were statistically at par. The more number of unproductive tillers in all basal application were due to less nitrogen contents at the time of booting stage or gain formation stage and plants were unable to extract the resource needed for the growth and healthy tiller production.

Table. 4.1.1: Germination count (m-2) of wheat planted under various residue management strategies with different splitting levels of nitrogen

A. Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	27.72	13.861	
Residue	3	2856.75	952.250	5.53*
Error Rep×Res	6	1033.83	172.306	
Fertilizer	2	1019.56	509.778	3.53*
Res× Fert	6	1422.00	237	1.64
Error Rep×Res× Fert.	16	2313.78	144.611	
Total	35	8673.64		

A. Individual comparison of treatment means

Treatments	N 100 Kg (2 splits)	N 150 Kg (2 splits)	N 150 Kg (Basal)	Means
T_0 (Control)	147.00	175.00	153.00	158.33 B
T_1 (lower 1/3)	182.33	180.67	185.00	182.67 A
T_2 (lower 2/3)	173.00	175.00	160.00	169.33 AB
T_3 (Full plant)	170.67	171.67	152.33	164.89 B
Means	168.25 AB	175.58 A	162.58 B	

LSD value, Residue = 15.141, Nitrogen = 10.407

Any two means not sharing a letter are differ significantly at $p \leq .05$

Table 4.1.2: Total number of tillers (m-2) of wheat at maturity planted under various residue management strategies with different splitting levels of nitrogen

Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	344.2	172.11	
Residue	3	2511.6	837.21	5.29*
Error Rep×Res	6	950.4	158.41	
Fertilizer	2	5780.2	2890.11	7.75**
Res× Fert	6	3385.1	564.19	1.51
Error Rep×Res× Fert.	16	5967.3	372.96	
Total	35	18939		

A. Individual comparison of treatment means

Treatments	N 100 Kg (2 splits)	N 150 Kg (2 splits)	N 150 Kg (Basal)	Means
T_0 (Control)	242.67	288.67	300.33	277.22 B
T_1 (lower 1/3)	280.33	311.00	306.00	299.11 A
T_2 (lower 2/3)	287.33	297.67	284.67	289.89 AB
T_3 (Full plant)	268.00	300.33	276.67	281.67 B
Means	269.58 B	299.42 A	291.92 A	

LSD value, Residue = 14.518, Nitrogen = 16.714

Any two means not sharing a letter are differ significantly at $p \leq .05$

Table. 4.1.3: Number of unproductive tillers (m-2) of wheat at maturity planted under various residue management strategies with different splitting levels of nitrogen

A. Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	6.50	3.250	
Residue	3	59	19.667	4.19
Error Rep×Res	6	28.167	4.694	
Fertilizer	2	254	127	5.54*
Res× Fert	6	240.667	40.111	1.75
Error Rep×Res× Fert.	16	366.667	22.917	
Total	35	955		

B. Individual comparison of treatment means

Treatments	**N 100 Kg (2 splits)**	**N 150 Kg (2 splits)**	**N 150 Kg (Basal)**	**Means**
T_0 (Control)	11.667	10	15.33	12.33
T_1 (lower 1/3)	7	11.33	16.67	11.67
T_2 (lower 2/3)	11	8.67	15.33	11.67
T_3 (Full plant)	14.33	2	10.67	9.00
Means	11.00 AB	8 B	14.50 A	

LSD value, Nitrogen = 4.1430

Any two means not sharing a letter are differ significantly at $p \leq .05$

4.1.4. Number of productive tillers (m-2)

Fertile tillers per unit area have a major yield contributor that has positive impact on the crop production. Significant effect of residue incorporation strategies and different nitrogen levels but their interaction on the productive tillers was found non-significant in the growing seasons (Table 4.1.4).

Residue incorporation of lower 1/3 plant produced the maximum productive tillers than conventional cutting practice. All residue incorporation practices produced higher productive tillers at N 150 kg ha^{-1} in two splits followed by N 150 kg ha^{-1} at basal, N 100 kg ha^{-1} in two splits. In the growing season higher number of productive tillers (299.67 m-2) were produced at N 150 kg ha^{-1} and lower number of tillers 231.00 m-2 in at 100 kg ha^{-1} in two splits. All residue incorporation practices produced more productive tillers than the conventional cutting practice due to fine soil seedbed which favored more germination that ultimately enhanced tillering. In case of residue incorporation extra amount of nitrogen from organic and inorganic sources affected the productive tillers. Our results confirmed the finding of Hemmat and Eskandari (2006) and Su-Juan *et al.* (2008) who observed in wheat happy seeder produced the higher number of productive tillers than the conventional.

4.1.5. Plant height at maturity

Plant height plays a vital role in crop yield that is a structural assign of a variety, which depends on plant genetic constitute, seed vigor, availability of soil nutrients and environmental conditions of area. Plant height was affected significantly by residue incorporation, nitrogen levels and their interaction was also found significant during the growing season (Table 4.1.5).

Nitrogen @ rate of 150 kg ha^{-1} in 2 splits gave the highest plant height followed by N 100, N 150 kg ha^{-1} applied as basal. In the growing season highest plant height (106.46 cm) was observed at N 150 kg ha^{-1} and lower number of tillers 100.12 cm at 150 kg ha^{-1} applied as basal respectively. Plant height for residue incorporation treatment was highest where full plant incorporation of maize was done 105.55 cm as compared to conventional cutting practice 99.84. Highest plant height was observed where full plant incorporated with 150 kg ha^{-1} in 2 splits 109.10 cm and lowest was in 96.75 cm where no residue plus 150 kg ha^{-1} basal nitrogen was applied. Nitrogen fertilization has an important role in cell division and enlargement of the plant observed by Keskins *et al.* (2005). Higher plant height might be attributed to more vegetative development that caused increased mutual shading and intermodal extension. These results substantiate findings of Mohsan (1999) and Rasheed *et al.* (2004) who reported the promotive effect of nitrogen on plant height.

Table. 4.1.4: Number of productive tillers (m-2) of wheat at maturity planted under various residue management strategies with different splitting levels of nitrogen

B. Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	257.1	128.53	
Residue	3	2433	810.99	5.22*
Error Rep×Res	6	932.3	155.38	
Fertilizer	2	6514.9	3257.44	9.31*
Res× Fert	6	3558.4	593.07	1.70
Error Rep×Res× Fert.	16	5596	349.75	
Total	35	19291.6		

C. Individual comparison of treatment means

Treatments	**N 100 Kg (2 splits)**	**N 150 Kg (2 splits)**	**N 150 Kg (Basal)**	**Means**
T_0 (Control)	231.00	278.67	285.00	264.89 B
T_1 (lower 1/3)	273.33	299.67	289.33	287.44 A
T_2 (lower 2/3)	276.33	289.00	269.33	278.22 AB
T_3 (Full plant)	253.00	298.33	266.00	272.67 B
Means	258.58 B	291.42 A	277.42 A	

Table. 4.1.5: Plant height (cm) of wheat at maturity planted under various residue management strategies with different splitting levels of nitrogen

A. Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	6.975	3.487	
Residue	3	196.485	65.495	7.64*
Error Rep×Res	6	51.465	8.577	
Fertilizer	2	252.697	126.349	40.30**
Res× Fert	6	72.132	12.022	3.83*
Error Rep×Res× Fert.	16	50.166	3.135	
Total	35	629.920		

B. Individual comparison of treatment means

Treatments	**N 100 Kg (2 splits)**	**N 150 Kg (2 splits)**	**N 150 Kg (Basal)**	**Means**
T_0 (Control)	100.43 bc	102.33 b	96.75 d	99.84 C
T_1 (lower 1/3)	102.77 b	104.00 b	97.55 cd	101.44 BC
T_2 (lower 2/3)	102.11 b	110.40 a	101.64 bc	104.72 AB
T_3 (Full plant)	103.00 b	109.11 a	104.54 b	105.55 A
Means	102.08 B	106.46 A	100.12 C	

4.1.6. Spike length at maturity

Spike length is a dominant yield contributing factor that is directly related with spikelet spike^{-1}. Longer spike more will be the number of spikelet spike^{-1} and higher will be the grain yield. Significant differences were observed in spike length by various nitrogen levels while non-significant for residue incorporation their interaction in the growing season (Table 4.1.6).

Significant effect of nitrogen produced greater spike length in N 150 kg ha^{-1} in two splits than N 150 kg ha^{-1} basal and N 100 kg ha^{-1} in 2 splits. In case of nitrogen the highest spike length of 10.577 cm was noted at N150 kg ha^{-1} and lowest 10.062 was found in case of N 100 kg ha^{-1} applied in 2 splits.

4.1.7. Number of spikelets per spike

Spikelet per spike is also an important yield-enhancing factor. Number of grains per spike is directly related to number of spikelets per spike. Higher the spikelet per spike, higher will be the number of grains per spike, which will ultimately increase grain yield. Significant effect of nitrogen splitting was observed but residue incorporation and their interaction were non-significant. Data regarding spikelet per spike for growing seasons is presented in (Table 4.1.7).

Higher number of spikelets per spike were produced at N 150 kg ha^{-1} than N100 kg ha^{-1} in 2 splits, N150 kg ha-1 applied as basal. In case of nitrogen the highest spikelets per spike of 16.333 cm was noted at N150 kg ha^{-1} applied in 2 splits and lowest 15.122 was found in case of N150 kg ha^{-1} applied as basal.

Table. 4.1.6: Spike length at maturity (cm) of wheat planted under various residue management strategies with different splitting levels of nitrogen

A. Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	0.1890	0.0945	
Residue	3	1.457	0.485	3.18
Error Rep×Res	6	0.916	0.152	
Fertilizer	2	1.920	0.960	6.10*
Res× Fert	6	1.453	0.242	1.54
Error Rep×Res× Fert.	16	2.518	0.157	
Total	35	8.454		

B. Individual comparison of treatment means

Treatments	**N 100 Kg (2 splits)**	**N 150 Kg (2 splits)**	**N 150 Kg (Basal)**	**Means**
T_0 (Control)	10.020	10.343	9.567	9.97
T_1 (lower 1/3)	9.973	10.337	10.263	10.19
T_2 (lower 2/3)	9.730	10.840	10.357	10.30
T_3 (Full plant)	10.523	10.790	10.287	10.53
Means	10.062 B	10.577 A	10.118 B	

Table. 4.1.7: Spikelets per spike of wheat planted under various residue management strategies with different splitting levels of nitrogen

A. Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	1.926	0.963	
Residue	3	3.931	1.310	0.91
Error Rep×Res	6	8.628	1.438	
Fertilizer	2	8.811	4.405	13.93**
Res× Fert	6	1.551	0.258	0.82
Error Rep×Res× Fert.	16	5.059	0.316	
Total	35	29.909		

B. Individual comparison of treatment means

Treatments	**N 100 Kg (2 splits)**	**N 150 Kg (2 splits)**	**N 150 Kg (Basal)**	**Means**
T_0 (Control)	15.067	15.500	14.900	15.156
T_1 (lower 1/3)	16.107	16.600	15.087	15.931
T_2 (lower 2/3)	15.667	16.800	15.033	15.833
T_3 (Full plant)	16.000	16.433	15.467	15.967
Means	15.710 B	16.333 A	15.122 C	

4.1.9 1000-Grain weight

The grain weight is also a major yield causative component that it is affected by soil moisture and nutrients status, irrigation availability at critical stages of growth and the abrupt environmental changes. Significant effect of residue incorporation and nitrogen on 1000-grain weight was observed while its interaction was found non-significant (Table 4.1.9).

1000-grain weight was highest in lower 2/3 maize incorporation treatment which was 4% higher than conventional cutting practice. The higher 1000 grain weight was recorded at N 150 kg ha^{-1} in two splits that was 3 % and 6 % than N 100 kg ha^{-1}, and N 150 basal kg ha^{-1} respectively. In our results nitrogen fertilization had increased the 1000-grain weight by increased the nitrogen rates. These results were quite in line with the findings of Mohsan, (1999) and Hussain *et al*., (2006); they reported that nitrogen fertilization had a positive effect on 1000-grain weight. The highest 1000-grain weight was obtained in the chisel treatment with incorporation of 25% residues and application of 150 kg N ha^{-1}, which is similar with the findings of Wiatrak *et al*. (2006) for N effects.

Table. 4.1.9: 1000-Grain weight (gm) of wheat planted under various residue management strategies with different splitting levels of nitrogen

A. Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	2.456	1.226	
Residue	3	13.136	4.378	4.98*
Error Rep×Res	6	5.272	0.878	
Fertilizer	2	37.095	18.547	12.74**
Res× Fert	6	6.411	1.068	0.73
Error Rep×Res× Fert.	16	23.28	1.455	
Total	35	87.656		

B. Individual comparison of treatment means

Treatments	**N 100 Kg (2 splits)**	**N 150 Kg (2 splits)**	**N 150 Kg (Basal)**	**Means**
T_0 (Control)	41.533	43.633	40.933	42.033 B
T_1 (lower 1/3)	43.167	43.633	42.467	43.089 AB
T_2 (lower 2/3)	44.200	44.867	42.100	43.722 A
T_3 (Full plant)	42.533	44.700	41.400	42.878 AB
Means	42.858 B	44.208 A	41.725 C	

LSD value, Residue = 1.0813, Nitrogen = 1.0441

Table. 4.1.10: Biological yield (Mg ha^{-1}) of wheat planted under various residue management strategies with different splitting levels of nitrogen

A. Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	5.961	2.980	
Residue	3	15.367	5.122	2.99
Error Rep×Res	6	10.278	1.713	
Fertilizer	2	19.537	9.768	4.18*
Res× Fert	6	21.029	3.504	1.50
Error Rep×Res× Fert.	16	37.375	2.3359	
Total	35	109.547		

B. Individual comparison of treatment means

Treatments	**N 100 Kg (2 splits)**	**N 150 Kg (2 splits)**	**N 150 Kg (Basal)**	**Means**
T_0 (Control)	12.500	11.860	8.960	11.107
T_1 (lower 1/3)	10.240	13.153	10.330	11.241
T_2 (lower 2/3)	10.313	10.047	9.587	9.982
T_3 (Full plant)	12.290	11.877	11.167	11.778
Means	11.336 A	11.734 A	10.011 B	

LSD value, Nitrogen = 1.3227

4.1.11. Grain yield

Grain yield is the most crucial parameter and ultimate mission of farmers. Grain yield is a result of various yield-contributing parameters like; number of fertile tillers, number of grains per spike and 1000-grain weight. Any alteration in these parameters will modify the grain yield (Langer, 1980). Significant effect of maize residue incorporation and nitrogen levels were found while interaction was non-significant.

Higher grain yield was obtained in residue incorporation than conventional cutting practice that was 15% higher than conventional cutting practice. Wheat sown with residue incorporation gave maximum grain yield due to more nutrients near the soil surface and moisture availability. These findings are supported the results of Younis *et al*. (2006). Moussa-Machraoui *et al*. (2010) who reported that residue retention was a feasible management technology to improve grain yield.

Maize residue incorporation @ N 100 kg ha^{-1} gave maximum grain yield which was 18% higher than applying all nitrogen as basal. Khan *et al*. (2000) observed that biological and grain yield increased by increasing nitrogen fertilization, but excess of nitrogen often decreased the yields because other yield components of wheat were decreased with an associated decreased in vegetative growth.

4.1.12 Straw weight

Maize residue incorporation, nitrogen splitting levels and their interaction were found non-significant (Table 4.1.12).

Highest straw weight was produced in the treatment where full maize plant was incorporated in combination with N 150 kg ha^{-1} applied in 2 splits followed by N 100 in two splits and N 150 kg ha^{-1} applied as basal. Our findings were supported by the results of Khan *et al*. (2000), they reported that biological and grain yields increased by increasing nitrogen fertilization, but excess of nitrogen often decreased the yields because other yield components of wheat were decreased with an associated decrease in vegetative growth. In the entire cases straw yield at N 150 kg ha^{-1} in 2 splits was higher than N 150 kg ha^{-1} as basal because better environmental conditions and in later growth stages lesser nutrients were available for straw weight to differ significantly. Straw yield difference was due to the variations in air temperatures, amount of rainfall and relative humidity.

4.1.13. Harvest index

Harvest index means the ability of crop to convert assimilate into economic parts. Higher the economic yield the more will be the harvest index. Significant affects of maize residue incorporation while non-significant effect nitrogen levels and their interaction were noted (Table 4.1.13).

Wheat sown with residue incorporation gave maximum harvest index because more number of grains per spike and higher 1000 grain weight due more nutrients availability and higher moisture. In both growing season the range of harvest index varied from 33.38 % to 43.10 %.

This result contradicts with Malecka and Blecharezyk (2008) who reported non-significant effect on harvest index by mulching materials due to climatic conditions. Overall harvest indices were higher that might be due to better environmental conditions and timely onset of rainfall at critical stages.

Table. 4.1.11: Grain yield (Mg ha^{-1}) of wheat planted under various residue management strategies with different splitting levels of nitrogen

A. Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	0.570	0.285	
Residue	3	1.619	0.539	8.10*
Error Rep×Res	6	0.399	0.066	
Fertilizer	2	2.749	1.374	7.48**
Res× Fert	6	0.835	0.139	0.76
Error Rep×Res× Fert.	16	2.942	0.183	
Total	35	9.117		

B. Individual comparison of treatment means

Treatments	**N 100 Kg (2 splits)**	**N 150 Kg (2 splits)**	**N 150 Kg (Basal)**	**Means**
T_0 (Control)	4.323	4.166	3.453	3.981 C
T_1 (lower 1/3)	4.860	4.02	4.046	4.311 AB
T_2 (lower 2/3)	4.340	4.213	4.046	4.200 BC
T_3 (Full plant)	4.913	4.613	4.183	4.570 A
Means	4.609 A	4.255 AB	3.932 B	

LSD value, Residue = 0.2978, Nitrogen = 0.3711

Table. 4.1.12: Straw weight (Mg ha^{-1}) of wheat planted under various residue management strategies with different splitting levels of nitrogen

A. Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	3.201	1.600	
Residue	3	11.855	3.951	3.21
Error Rep×Res	6	7.383	1.230	
Fertilizer	2	8.424	4.212	3.11
Res× Fert	6	14.204	2.367	1.75
Error Rep×Res× Fert.	16	21.649	1.353	
Total	35	66.719		

B. Individual comparison of treatment means

Treatments	N 100 Kg (2 splits)	N 150 Kg (2 splits)	N 150 Kg (Basal)	Means
T_0 (Control)	8.323	7.526	5.496	7.115
T_1 (lower 1/3)	6.203	8.286	6.273	6.921
T_2 (lower 2/3)	6.090	5.700	5.530	5.773
T_3 (Full plant)	7.667	6.953	6.973	7.197
Means	7.070	7.116	6.068	

Table. 4.1.13: Harvest index (%) of wheat under various residue management strategies with different splitting levels of nitrogen

A. Analysis of Variance

SOV	DF	SS	MSS	F
Rep	2	12.954	6.476	
Residue	3	158.587	52.862	4.69*
Error Rep×Res	6	67.575	11.262	
Fertilizer	2	23.947	11.973	1.63
Res× Fert	6	70.808	11.801	1.61
Error Rep×Res× Fert.	16	117.420	7.338	
Total	35	452.290		

B. Individual comparison of treatment means

Treatments	N 100 Kg (2 splits)	N 150 Kg (2 splits)	N 150 Kg (Basal)	Means
T_0 (Control)	37.277	33.380	38.677	36.444 B
T_1 (lower 1/3)	37.085	39.523	39.640	38.750 AB
T_2 (lower 2/3)	43.310	41.183	42.483	42.326 A
T_3 (Full plant)	41.480	37.743	37.463	38.896 AB
Means	39.788	37.957	39.566	

LSD value, Residue = 3.8710

Conclusion

Results showed that maximum grain yield (4570 kg ha-1) was recorded in case of full plant incorporation and lowest grain yield (3981 kg ha-1) in case of conventional cutting practice of maize. The best combination was T4 and N1. It's clear that there is a considerable span to exploit the yield potential of wheat under residue incorporation strategies in area of Pakistan.

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10/13/2018