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WHEAT PRODUCTIVITY WITH INCORPORATION OF MAIZE RESIDUE AND INORGANIC NITROGEN FERTILIZER

S. A. Anjum[1*], A. Shakoor, F. Din, M. Shahid and M. Ishfaq

[1]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan

ABSTRACT

Wheat is an important cereal crop feeding human and livestock as well. Stagnant wheat yield has been observed over the time in maize-wheat intensive cereal rotation in Pakistan. Maize residue management might be a good choice over conventional burning/cutting practice. The present research was performed at Agronomic Research Area, University of Agriculture, Faisalabad to determine the most favorable residue incorporation level with the best nitrogen splitting level. The experimental treatments comprised of maize residue incorporation viz; control, lower 1/3, 2/3 and full maize plant incorporation along with nitrogen (N) fertilizer rates viz; 100 kg N ha^{-1} in 2 splits, 150 kg N ha^{-1} in two splits and 150 N kg ha^{-1} as basal dose. The experiment was laid-out in RCBD with split plot arrangement replicated thrice having net plot size of 1.8 m × 5 m. Data pertaining to growth and yield attributes of wheat were recorded following standard procedures. Response of wheat and its yield components like productive tillers (287.44 m^{-2}), 1000-grain weight (43.72 g) differed significantly under maize plant incorporation strategies compared to conventional cutting practice. Full plant incorporation along with 100 kg N ha^{-1} in 2 splits performed superior regarding final grain yield. However, maximum net returns (Rs. 83706 ha^{-1}) and benefit cost ratio (BCR) (1.72) was obtained in lower 1/3 plant incorporation at 100 kg N ha^{-1} in two splits. Hence, the farmers may adopt this strategy to enhance the productivity and profitability of wheat in mix cropping zone of Punjab.

Keywords: maize-wheat, net returns, nitrogen fertilizer, residue incorporation, wheat yield

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a major staple crop of Pakistan and dominates all crops in acreage and production (Tahir *et al*., 2009). It accounts for 9.9% of the value addition and 2% of GDP of Pakistan (Govt. of Pakistan, 2016). Maize cultivation has been substantially increased during previous years in mix cropping zone of Punjab, Pakistan. Maize residue management is a serious problem of wheat growers in maize-wheat rotation. Removal/ burning of maize residues is a common practice in this region. Collection and transportation of maize residues from the field require labor, that causes soil compaction and erosion, while depletes organic matter in the soil (Wilhelm *et al*., 2004). Moreover, maize residues left as such on the soil surface results in poor germination and disease (Rieger *et al*., 2008). On the other side, burning of crop residues is prohibited due to high loss of organic matter and mineral nutrients and greenhouse gas emission resulting in air pollution, global warming and decreased soil microbial population (Kumar and Goh, 2000). During the past few decades, use of synthetic inorganic fertilizer, irrespective of environment risks like nitrate leaching and N_2O emissions has increased. It has been common due to their lower cost, easy application and quicker response to crop yields (Yang *et al*., 2015). Nitrate leaching and run-off is the major source of environmental pollution (Raun and Johnson, 1999). Soil incorporation of crop residues is also an old practice which ensures better soil quality and fertility (Moreno-Cornejo *et al*., 2014). Crop residues are the main input to soil for organic carbon contents (Li *et al*., 2013). Maize residues contain 1.7 times more carbon contents than other crop cereals like wheat and rice (Wilhelm *et al*., 2004). Crop residues also provide nitrogen to the soil and thus improve the fertility status of soil and also check down the use of inorganic nitrogen fertilizers (Singh *et al*., 2004). However, most of the nitrogen from crop residues is organic in nature and not directly available to plants. After decomposition of crop residues, organically bound nitrogen becomes

Corresponding author:shakeelanjum1034@gmail.com

available for the growth of plants and microbes through the process of mineralization (Van Den Bossche *et al*., 2009).

Farmers complain about delayed decomposition of maize residues when left on farmlands, which cause N immobilization in the short term (Partey *et al*., 2013). Application of maize residues with inorganic nitrogen fertilizers might be an efficient approach (Smaling *et al*., 2002). The overall benefit is that the crop residues along with nitrogen help to minimize the risk of yield reduction in wheat production. There are not widely reported studies regarding the crop residue management strategies in maize-wheat rotation system in Pakistan. The current research was carried out to estimate the effects of different levels of maize residue incorporation on wheat yield in post-harvest maize field and to optimize split application of nitrogen under different residue management strategies.

MATERIALS AND METHODS

The experiment was performed at Agronomic Research Area, Department of Agronomy, University of Agriculture Faisalabad, Pakistan located at latitude 31.25° N and longitude 73.09° E and at an altitude of 184 m with clay loam soil by texture and semi-arid to subtropical climate. The experiment was laid out into Randomized Complete Block Design (RCBD) with split plot arrangement replicated thrice with net plot size of 1.8m × 5m. The study comprised of two factors: maize residue incorporation (main plot) having treatments T_0= Normal cutting practice, T_1= Lower 1/3 maize plant incorporated, T_2= Lower 2/3 maize plant incorporated and T_3= Full plant incorporated. The second factor was fertilizer management (sub-plot) with treatments: N_1= 2/3 of recommended nitrogen dose in 2 splits (Basal + 22 DAS), N_2= Recommended nitrogen dose in 2 splits (Basal + 22 DAS) and N_3= Recommended nitrogen dose basal application. The recommended nitrogen dose was 120 kg ha^{-1} (Marinaccio *et al*., 2016). Meteorological data were collected (Figure 1) from the Meteorological Observatory Dept. of Agronomy, University of Agriculture Faisalabad, Pakistan.

The previous maize crop was cut and maintained manually in all the plots and incorporated into the soil on 15th November, 2014. Before incorporation biomass of maize was taken from every 12 plants from each main plot and their average was taken. The average of samples of lower 1/3 plant weight was 609 g, 2/3 weight was 1090 g, full plant was 1146 g and then this was converted into kg ha^{-1}. Maize biomass was incorporated into the soil with the help of rotavator. The wheat crop was planted on 20th November 2014 with the help of rabi drill. The wheat cultivar Punjab-2011 was sown 22.5 cm apart rows using 100 kg of seed ha^{-1}. Phosphorous and potash were broadcasted @ 110 and 65 kg ha^{-1}, respectively (Jacob *et al*., 2014). The full dose of phosphorous and potash were applied at sowing. Nitrogen was applied according to treatments. All other inputs were kept constant. The data regarding germination count (m^{-2}), total tillers (m^{-2}), productive tillers (m^{-2}), plant height (cm), spike length (cm), spikelet per spike, grains per spike, 1000-grain weight (g), grain yield (t ha^{-1}), biological yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index (%) of wheat were recorded following standard procedures and were analyzed statistically by using statistical program Statistix (8.1). Fisher analysis of variance technique and Least Significant Difference (LSD) test at 5% probability was employed to compute variability in data and to compare the treatment means, respectively (Steel *et al*., 1997).

RESULTS AND DISCUSSION

The perusal of data indicated that different maize residue incorporation levels significantly influenced majority of the growth and yield parameters in wheat (Table 1). However, spike length, spikelets spike^{-1}, grains spike^{-1}, biological yield and straw yield were not significantly influenced by the different levels of incorporated maize residues. Different N levels and splitting treatments also significantly influenced most of the growth and yield parameters of wheat except straw yield and harvest index. Interactive effects of maize residue incorporation and different splitting rates of N fertilizer were found to be non-significant for most of the growth and yield attributes of wheat. However, plant height and grains spike^{-1} were influenced by the interaction of maize residue incorporation and different splitting rates of N fertilizer.

The greater germination count (182.67 m^{-2}) was found where lower 1/3 plant residues were incorporated than conventional cutting while statistically minimum count was found in control which was statistically at par with 2/3 (169.33 m^{-2}) and full maize plant incorporation. Application of 150 kg N ha^{-1} in two equal splits gave maximum germination count (175.58 m^{-2}) in wheat followed by (168.25 m^{-2}) 100 kg N ha^{-1} application in two splits but was statistically same. Application of 150 kg N ha^{-1} as basal dose gave minimum germination count in (162.58m^{-2}) wheat. Higher wheat seed germination at lower 1/3 maize plant incorporation might be due to proper soil moisture conservation. In full plant and 2/3 plant incorporation seed soil contact might be low due to the fact that higher amount of residues was present which might decrease the seed germination. Less germination was observed in crop residues due to allelo-chemicals and low soil temperature at 0-15 cm soil depth (Rahman *et al*., 2005).

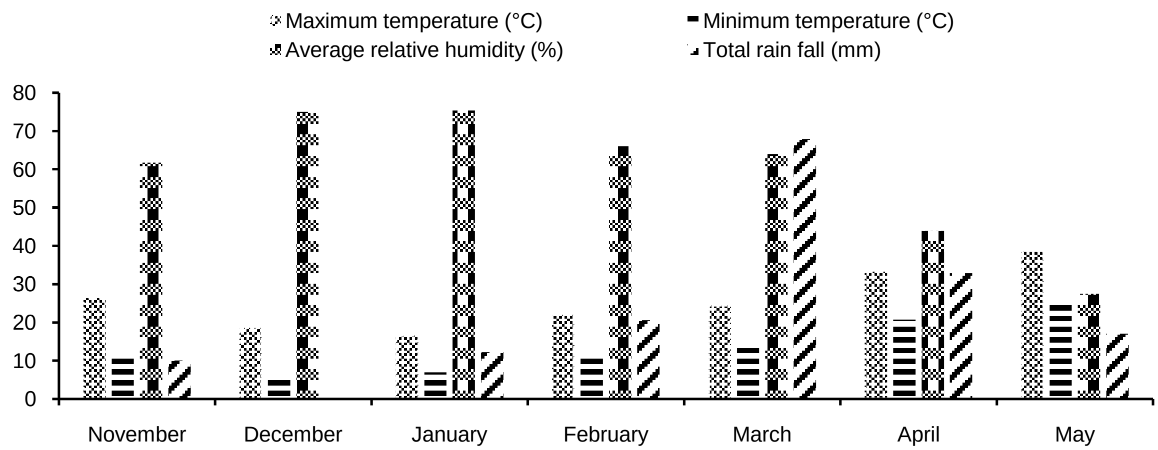

Figure 1. Weather conditions during wheat crop growth period 2014-15

Table 1. Effect of different maize residue incorporation strategies and nitrogen splitting levels on growth and yield of wheat planted in maize-wheat rotation during 2014-15

Treatment	Germination count (m^{-2})	Total tillers (m^{-2})	Productive tillers (m^{-2})	Plant height (cm)	Spike length (cm)	Spikelets $spike^{-1}$	Grains $spike^{-1}$	1000-grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
T_0	158.33b	277.22b	264.89b	99.84c	9.97	15.15	45.87	42.03b	3.98c	10.39	6.41	38.40ab
T_1	182.67a	299.11a	287.44a	101.44bc	10.19	15.93	47.08	43.08ab	4.31ab	11.87	7.56	36.39 b
T_2	169.33ab	289.89ab	278.22ab	104.72ab	10.30	15.83	46.44	43.72a	4.20bc	9.97	5.77	41.75a
T_3	164.89b	281.67b	272.67b	105.55a	10.53	15.96	47.00	42.87ab	4.57a	11.77	7.20	38.77ab
LSD	15.14	14.51	14.37	3.37	NS	NS	NS	1.08	0.29	NS	NS	3.45
N_1	168.25ab	269.58b	258.58b	102.08b	10.06b	15.71b	47.88a	42.85b	4.60a	11.68a	7.08	39.64
N_2	175.58a	299.42a	291.42a	106.46a	10.57a	16.33a	46.39b	44.20a	4.25ab	11.31a	7.07	37.77
N_3	162.58b	291.92a	277.42a	100.12c	10.11b	15.12c	45.53c	41.72c	3.93b	10.06b	6.08	39.07
LSD	10.40	16.71	16.18	1.53	0.34	0.48	0.82	1.04	0.37	0.94	NS	NS
$T_0 \times N_1$	147.00	242.67	231.00	100.43bc	10.02	15.06	46.83bc	41.53	4.33	10.54	6.21	41.08
$T_0 \times N_2$	175.00	288.67	278.67	102.33b	10.34	15.50	46.10b	43.63	4.16	11.68	7.53	35.58
$T_0 \times N_3$	153.00	300.33	285.00	96.75c	9.57	14.90	44.70ab	40.93	3.45	8.95	5.50	38.54
$T_1 \times N_1$	182.33	280.33	273.33	102.77b	9.97	16.10	48.86a	43.16	4.87	13.19	8.33	36.85
$T_1 \times N_2$	180.67	311.00	299.67	104.00b	10.33	16.60	46.86b	43.63	4.02	12.10	8.09	33.19
$T_1 \times N_3$	185.00	306.00	289.33	97.55c	10.26	15.08	45.53a	42.46	4.04	10.31	6.28	39.14
$T_2 \times N_1$	173.00	287.33	276.33	102.11b	9.73	15.66	48.83a	44.20	4.34	10.43	6.09	41.61
$T_2 \times N_2$	175.00	297.67	289.00	110.40a	10.84	16.80	44.53c	44.86	4.21	9.91	5.70	42.48
$T_2 \times N_3$	160.00	284.67	269.33	101.64b	10.35	15.03	45.96a	42.10	4.04	9.58	5.54	41.17
$T_3 \times N_1$	170.67	268.00	253.00	103.00b	10.53	16.00	47.00ab	42.53	4.91	12.58	7.67	39.03
$T_3 \times N_2$	171.67	300.33	298.33	109.11a	10.79	16.43	48.06a	44.70	4.61	11.57	6.96	39.84
$T_3 \times N_3$	152.33	276.67	266.00	104.54b	10.28	15.46	45.93a	41.40	4.18	11.16	6.98	37.45
LSD	NS	NS	NS	4.19	NS	NS	2.09	NS	NS	NS	NS	NS

Means sharing different letters indicates significant difference at $P \leq 0.05$, T_0 = Conventional cutting, T_1 = 1/3 lower part incorporation, T_2 = 2/3 lower part incorporation, T_3 = Whole plant incorporation, N_1 = 100 kg N ha^{-1} in two equal splits, N_2 = 150 kg N ha^{-1} in two equal splits, N_3 = 150 kg N ha^{-1} as single basal dose

Table 2. Effect of different maize residue incorporation strategies and nitrogen splitting levels on total cost, net returns and benefit-cost ratio of wheat planted in maize-wheat rotation during 2014-15

Treatments	Grain Yield (t ha^{-1})	Grain value (Rs. ha^{-1})	Straw yield (t ha^{-1})	Straw Value (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Total variable cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Net Returns (Rs. ha^{-1})	BCR
$T_0 \times N_1$	4.33	140725	6.21	31044	171769	40560	105981	65788	1.62
$T_0 \times N_2$	4.17	135525	7.53	37665	173190	43985	109406	63784	1.58
$T_0 \times N_3$	3.46	112450	5.50	27513	139963	42210	107631	32332	1.30
$T_1 \times N_1$	4.87	158275	8.33	41644	199919	50791	116212	83706	1.72
$T_1 \times N_2$	4.02	130650	8.09	40428	171078	52491	117912	53166	1.45
$T_1 \times N_3$	4.05	131625	6.28	31405	163030	52566	117987	45043	1.38
$T_2 \times N_1$	4.34	141050	6.09	30471	171521	56481	121902	49619	1.41
$T_2 \times N_2$	4.22	137150	5.70	28509	165659	60006	125427	40232	1.32
$T_2 \times N_3$	4.05	131625	5.54	27690	159315	59581	125002	34313	1.27
$T_3 \times N_1$	4.92	159900	7.67	38355	198255	58748	124169	74086	1.60
$T_3 \times N_2$	4.61	149825	6.96	34795	184620	61798	127219	57401	1.45
$T_3 \times N_3$	4.18	135850	6.98	34893	170743	60723	126144	44599	1.35

BCR = Benefit Cost Ratio, Fixed cost= Rs. 65421 ha^{-1}, T_0 = Conventional cutting, T_1 = 1/3 lower part incorporation, T_2 = 2/3 lower part incorporation, T_3 = Whole plant incorporation, N_1 = 100 kg N ha^{-1} in two equal splits, N_2 = 150 kg N ha^{-1} in two equal splits, N_3 = 150 kg N ha^{-1} as single basal dose

Maximum number of total tillers (299.11 m^{-2}) and productive tillers (287.44 m^{-2}) of wheat was observed in those plots where lower 1/3 plant residue were incorporated; while statistically minimum number of total (277.22 m^{-2}) and productive tillers (264.89 m^{-2}) was found in control which was statistically at par with 2/3 and full maize plant incorporation. Maximum total tillers and productive tillers were produced where 150 kg N ha^{-1} was applied in 2 equal splits which was statistically at par with 150 kg N ha^{-1} as basal. Highest plant height (110.40 cm) was observed where full plant incorporated with 150 kg N ha^{-1} in 2 equal splits was applied and lowest plant height (96.75 cm) was in those plots where no residue plus 150 kg ha^{-1} basal nitrogen was applied (Table 1).

Residue incorporation produced more number of total and productive tillers (Jan and Khan, 2000) which might be the result of higher soil organic matter and nutrients within the soil at the depth of 15 cm, which resulted into improved growth and tillering over control (Alijani *et al*., 2012). Su-Juan *et al*. (2008) reported higher number of productive tillers in zero tilled wheat with happy seeder after rice than the conventional tillage. Nitrogen increases cell division and cell enlargement in plants (Bojovic and Stojanovic, 2006). Higher maize plant height might be associated with more vegetative growth (Sheikh *et al*., 2003). Residue incorporation and nitrogen fertilizer attained higher plant height over control that was due to the fact that conventional cutting causes soil surface compaction causing poor root growth and also reduce the uptake of water and mineral nutrients (Mele and Crowley, 2008). Hemmat and Eskandari (2006) reported that higher plant height of wheat plant was due to rice straw mulching effect which increased soil moisture. In another study, wheat plant height after rice was observed highest with happy seeder (crop residues) with the application of 150 kg N ha^{-1} as a single basal dose (Gangwar *et al*., 2006).

Statistically highest spike length (10.57 cm) and spikelets spike^{-1} (16.33) were produced in wheat at 150 kg N ha^{-1} than 100 kg N ha^{-1} in 2 splits (10.06 cm) and in 150 kg N ha^{-1} applied as basal (15.12). Higher spike length and spikelets spike^{-1} were produced in wheat when 150 kg N ha^{-1} was applied in 2 equal splits than 100 kg N ha^{-1} in 2 splits and 150 kg N ha^{-1} as single basal dose. Higher spike length of wheat was observed in rice crop residues along with extra nitrogen than recommended (Gangwar *et al*., 2006). Maize residues didn't affect spike length and spikelets spike^{-1} significantly as reported by Sheikh *et al*. (2003).

Highest number of grains spike^{-1} were found in lower 1/3 residue incorporated in combination with 100 kg N ha^{-1} in 2 splits while lowest was found in lower 2/3 plant incorporated at 150 kg N ha^{-1} in 2 splits.1000-grain weight was highest in lower 2/3 maize incorporation treatment which was 4% higher than conventional cutting practice. Number of grains increased as nitrogen dose increases but excessive nitrogen often resulted into less yield and yield components of wheat due to toxic and antagonistic effects (Rasheed *et al*., 2004). Non-significant effect of maize residue incorporation on grains spike^{-1} was observed and this might be due to the favorable climatic conditions as reported by the Bakhsh *et al*. (2005).

The higher 1000-grain weight was recorded @ 150 kg N ha^{-1} in 2 splits that was 3% and 6%

higher than 100 kg N ha^{-1} (2 splits) and 150 basal kg N ha^{-1}, respectively. However, statistically highest grain yield was obtained in full plant incorporation than conventional cutting practice that was 15% higher than conventional cutting practice. However, 1000-grain weight increased as nitrogen rate increased that was affected by the different splitting rates of application as concluded by Hussain *et al*. (2006). The 1000-grain weight of rice significantly increased by residues and different level of starter doses of nitrogen (Arshadullah *et al*., 2012). The results also confirmed the earlier findings of Singh *et al*. (2004) who verified that 1000-grain weight of rice also increased with wheat residues incorporation and maximum grain weight was achieved with 25% wheat at the application of 150 kg N ha^{-1}.

Maize residue incorporation @ 100 kg N ha^{-1} (2 splits) gave highest grain yield which was 18% higher than applying all nitrogen as basal. The maximum yield was achieved with 25% maize residue incorporated and 150 kg N ha^{-1}. Wheat sown in those plots where maize residues were incorporated performed best in terms of final grain yield and it might be due to the maximum availability of mineral nutrients and moisture in the root zone. Crop residue incorporation was an efficient residue management technology in terms of grain yield as reported by Moussa-Machraoui *et al*. (2010). However, Rahman *et al*. (2011) stated that all nitrogen applied as single basal dose produced less grain yield in wheat without incorporation of crop residues. In our experiment, splitting of N dose performed better as supported by Rahman *et al*. (2002).

The maximum biological yield was recorded @ 100 kg N ha^{-1} in 2 splits that was 3.27% greater than 150 kg N ha^{-1} in 2 splits. Wheat sown with lower 2/3 maize residue incorporation gave maximum harvest index which was statistically at par with control and full maize plant incorporation. The minimum harvest index was recorded where lower 1/3 maize plant residues were incorporated which was statistically at par with control and full maize plant incorporation (Table 1). The higher biological yield was recorded @ 100 N kg ha^{-1} in 2 splits that was 3.27% greater than 150 N kg ha^{-1} in 2 splits. The increased biological yield might be an outcome of better nutrient acquisition, fertilization and translocation of assimilates under the effect of residue incorporation treatments. Nitrogen levels didn't affect the harvest index of wheat significantly as supported by Sabir *et al*. (2000).

The combined economic analysis of both maize residue incorporation and N fertilizer application revealed that lower 1/3 maize plant incorporation with 100 kg N ha^{-1} application was most profitable with maximum net returns (Rs. 83706 ha^{-1}) and highest benefit cost ratio (BCR) (1.72). However, the minimum net returns (Rs. 32332 ha^{-1}) and benefit cost ratio (BCR) (1.30) was noted in conventional cutting practice with 150 kg N ha^{-1} application as single basal dose (Table 2). Economic analysis revealed that lower 1/3 plant incorporation @ 100 kg N ha^{-1} in 2 equal splits was most profitable because of lower totals costs from less use of N fertilizer but sustained wheat yield.

CONCLUSION

It is concluded that full maize plant residue incorporation gave 15% higher grain yield than conventional cutting practice and application of 100 kg N ha^{-1} in 2 equal splits gave 17% higher grain yield than other splitting levels of nitrogen. But in terms of maximum net returns and benefit cost ratio, lower 1/3 maize plant incorporation with application of 100 kg N ha^{-1} in 2 equal splits was found to be most economical and profitable.

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