WEED CONTROL AND NUTRIENT PROMOTION IN ZERO-TILLAGE WHEAT THROUGH RICE STRAW MULCH

Sanaullah Chaudhary[1] and Javed Iqbal[1]*

ABSTRACT

Field trials were conducted to study the allelopathic potential of rice straw mulching at different doses for weed control and nutrients status improvement of soil in zero-till wheat at the Adaptive Research Farm, Gujranwala, Punjab, Pakistan during Rabi season 2008-09 and 2010-11. Rice straw mulch was used at the rate of 7.5, 10.0, 12.5, 15.0, 17.5 and 20.0 t ha^{-1} the next day after sowing (DAS). A control plot was kept without rice straw mulch for comparison. It was observed that rice straw mulch had significantly increased the soil organic matter content, the available P, K and decreased the soil pH. Minimum broad leaved weeds (9.89, 11.22, and 12.11 plants m^{-2}), narrow leaved weeds (15.45, 18.89 and 21.22 plants m^{-2}) and dry weed biomass (45.73, 58.01 and 65.68 g m^{-2}) were recorded in plots treated with 20.0, 17.5 and 15.0 t ha^{-1} rice straw mulch, respectively. Reduction in plant population was observed with increasing rate of rice mulch. However, number of tillers m^{-2}, grains spike^{-1}, 1000-grain weight and grain yield were all significantly higher in the treated plots as compared to the control plots. Maximum grain yield (4.58 t ha^{-1}) was recorded for 15.0 t ha^{-1} rice straw mulch plots followed by 17.5 t ha^{-1} of rice straw mulch (4.37 t ha^{-1}) plots. It can be concluded that using rice straw mulch may be a good alternate source of weed management, soil fertility supplement and a source of bio-herbicide.

Key words: Allelopathy, mulching, nutrients, Pakistan, rice, weed control, wheat, zero tillage

Citation: Chaudhary, S. and J. Iqbal. 2013. Weed control and nutrient promotion in zero-tillage wheat through rice straw mulch. Pak. J. Weed Sci. Res. 19(4): 465-474.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important crop throughout the world including Pakistan. Weed management during the wheat crop season has been a serious problem for many years and is a key factor for most agricultural systems. Application of herbicides was a major factor enabling the intensification of agriculture in past decades,

---

[1]Adaptive Research Farm, Gujranwala, Pakistan.
*Corresponding author's email: 68javed@gmail.com

but there has been many reports of herbicide resistance development in weeds and wide spread concern about adverse environmental effects of herbicides. Sowing of wheat crop after the rice crop is often delayed in the Punjab province of Pakistan because of the number of tillage operation needed for a good seedbed preparation. As a result, cost of production rises and farmer’s profit margin decreases. Data show that wheat yield declined by nearly 0.7-1.5% per day of delay from optimum planting time of the crop (Ortiz-Monasterio *et al.,* 1994). Zero tillage of wheat can enhance the chances of planting in time and can also save irrigation water. It can reduce N leaching and can also reduce the grassy weeds infestation levels (Malik *et al.*, 1998). Mulching at early growth stage could be effective in no–till wheat production. Rice straw increased the organic matter (OM) and chemical properties of the soil and significantly decreased the weeds populations (Abdelhamid *et al.*, 2004). Rehman *et al.* (2005) reported that rice straw mulch had a significant effect on conserving initial soil moisture, weed growth suppression, promote root system growth and thereby improve grain yield of no-till wheat. Chung *et al.* (2001) found that allelopathy in rice cultivars could play a key role for weed control under field conditions as they can actively release certain phytotoxins during their growth or even after dying via straw degradation. This suggestion is reconciled with the results obtained by many authors, who indicated that allelochemicals are present in all plants involving different organs and tissues that could be successfully used for weed control in agricultural crops (Cheema and Khaliq, 2000). Allelopathy can be used in weed management either by incorporation or by applying residues and straw as mulch (He *et al.*, 2012). Olofsdotter, (2001) revealed that allelopathic cultivars of rice can control both mono and dicot weeds with some selectivity observed amongst such weeds, suggesting that certain compounds with selective action might be implicated in rice allelopathy. The plant–derived compounds from rice straw are another promising issue where it could be served as a renewed source of natural herbicides or probably as a good skeleton to build up new groups of synthetic herbicides (Duke *et al.,* 2002; Chung *et al.,* 2003). El-Shahawy *et al.* (2006) suggested that phenolic acids might be considered the key factor of rice allelopathy against suppressing a wide range of mono and dicotyledonous weeds in various crops. The ground straw substantially inhibited fresh and dry weight of shoot biomass of broad leaved weeds by up to 89.6% and in narrow leaved weeds by upto 86.6%.

Traditionally in Pakistan, rice and wheat straw are removed from the fields and used for cattle feed and other purposes. Recently, with the advent of mechanized harvesting, crop residues interfere with tillage and seeding operations for the subsequent crop. Farmers burn large quantity of crop residues left in the field, causing loss of nutrients and OM. Burning of rice straw can create huge losses of N (80%), P (25%), K (21%), S (60%) and depriving soil OM. This practice can also cause significant air pollution and killing of beneficial soil insects and micro organisms. Singh *et al.* (2006) concluded that rice straw can be efficiently managed as straw mulch in zero–till wheat. It will enhance N use efficiency and soil health in rice–wheat system. A major proportion of crop residues can be recycled. Many of the plant nutrients remains in the straw (approximately 35-40% of nitrogen, 30-35% of phosphorus, 80-85% of potassium and 40-50% of sulphur), much of this can be recycled for subsequent crop growth after its decomposition (Dobermann and Fairhurst, 2002; Byous *et al.,* 2004). A rice-wheat sequence that yield 7 t ha^{-1} of rice and 4 t ha^{-1} of wheat remove more than N 300, P 30 and K 300 kg ha^{-1} from the soil. Another estimate shows that a 10 t ha^{-1} crop removes 730 kg NPK from the soil that is often not returned to the soils (Gupta *et al.,* 2002). In many studies, recycling of crop residues is reported to increase the organic carbon, nutrient contents and crop yields (Eagle *et al.,* 2000). Application of crop residues and its subsequent decomposition in soil released plant nutrients in slow manner throughout the crop growth period causing better uptake of nutrients by crop. Thus it increased the values of yield- attributing characters of crop (Rajput and Warsi, 1991; Das *et al.,* 2003). Sarwar *et al.* (2011) observed that OM, N percentage and potassium contents in plant samples increased with the application of green compost. Akhtar *et al.* (2011) reported that organic manure may replace the inorganic material partly or completely. It is therefore, important to promote economically viable and environmental friendly intervention for sustainable agriculture. The study has been planed for alternative weed control and nutrient management and to minimize the risk to agro-ecosystem by serving in a complementary fashion with herbicides. Further more, it is a step for production of chemical free food through organic agriculture.

MATERIALS AND METHODS

Field experiments were conducted at the Adaptive Research Farm, Gujranwala, Pakistan in three successive seasons during Rabi 2008-09 to 2010-11 in Randomized Complete Block Design and each treatment being replicated three times. Plot size was 8 x 25 m for each individual treatment. The crop was planted with tractor driven zero-till wheat drill having 15 cm line to line distance. This is a simple wheat drill made in Pakistan which opens the soil for planting without tillage. Wheat variety (Faisalabad-2008) at the recommended seed rate (125 kg ha^{-1}) was sown in the second week of November during each year in good soil moisture. NPK fertilizers were applied @ 136-114-62 kg ha^{-1}. Full dose of P, K and 1/3 dose of N was applied at the time of sowing with zero tillage machine. The other two doses of N (each 1/3) were applied during the first and second irrigation. Manually harvested rice straw was chopped and applied at the rate of 7.5, 10.0, 12.5, 15.0, 17.5 and 20.0 t ha^{-1} one day after sowing. One control plot was kept without rice straw mulch for comparison with the other treatments. All other agronomic practices were kept uniform in all treatments. Weed count data were recorded before the harvesting of crop from 1 m^2 area randomly selected from each plot and weed kill percentage was calculated using the following formula;

$$\text{Mortality (\%)} = \frac{(A - B) \times 100}{A}$$

A is the weed density (m^{-2}) in the control plots and B is the weed density (m^{-2}) in treated plots

Dry weight of weeds was recorded after drying the samples in an oven at 70°C for 48 hours. The wheat seed germination count was taken after the completion of germination. Other parameters (tillers count, grains $spike^{-1}$, 1000-grain weight and grain yield) were all recorded at harvesting. At the end of the experiment after three years, soil samples at 20 cm depth were collected and analyzed from soil and water testing laboratory, Gujranwala. The data were statistically analyzed by Fishers analysis of variance method and the treatments means were compared with LSD test at 5% level of significance (Steel *et al.,* 1997).

RESULTS AND DISCUSSION

Effect on soil chemical properties

Nutrient concentrations in the soil by the addition of rice straw mulch are summarized in Table-1. Organic matter and available PK were both increased as the quantity of rice straw mulch was increased. However, the soil pH decreased and showed non-significant effect on N availability. Maximum OM (2.09%) was recorded with the application of rice straw mulch at 20.0 t ha^{-1} and followed by 17.5 t ha^{-1} (2.04%) and these treatments were at par with each other. The minimum OM (0.92%) was recorded for the control plots (without rice straw mulch). Optimum quantity of OM in soil is essential for better plant growth, seed bed preparation and for a good growth of plants root system. It also can improve the water holding capacity and porosity of the soil. Special management practices are required to promote addition of soil OM (crop residues/mulching incorporation, green manure and farmyard manure). Management of crop residue can improve soil OM and hence increase crop yield. These results are in line with those of

Abdelhamid *et al.* (2004) and Sarwar *et al.* (2011) who indicated that rice straw can increase the soil OM contents.

Highest quantity of available P (26.34, 25.40 and 23.18 ppm) and available K (162.09, 160.71 and 157.15 ppm) were recorded by the addition of 20.0, 17.5 and 15.0 t ha^{-1} rice straw mulch, respectively (Table–1) and these treatments were at par with each other. Lowest available P (13.850 ppm), K (120.770 ppm) and N (0.046%) were recorded for the control plots. Different doses of rice straw mulch did not differ significantly in addition of N. Whereas, level of NPK increased by the addition of rice straw mulch. Straw is organic mulch that can add nutrients to the soil. Minimum soil pH (7.92) was recorded in plots receiving 20.0 t ha^{-1} rice straw mulch followed by 17.5 t ha^{-1} (7.93), 15.0 t ha^{-1} (7.95) and 12.5 t ha^{-1} (7.98). Maximum soil pH (8.12) was recorded for the control plots. Soil pH is of great significance because it determines the availability of plant nutrients and growth of crops. The pH of fertile soils ranges between 4.0 and 8.5 but most of the agricultural soil of Pakistan are alkaline (pH 7.0 – 8.5). Rice straw mulching could play a key role in soil OM improvement which could bring the pH down. These results are in a great agreement with those of Abdelhamid *et al.* (2004) and Sarwar *et al.* (2011) who concluded that recycling of crop residues increased the organic carbon and nutrient contents.

Reduction in weeds

The data in Table-2 shows significant reduction of weeds by the application of rice straw mulch at different doses. Minimum number of broad leaved weeds (9.89, 11.22 and 12.11 m^{-2}) and narrow leaved weeds (15.45, 18.89 and 21.22 m^{-2}) were recorded in plots that were applied with 20.0, 17.5 and 15.0 t ha^{-1} mulch, respectively. These treatments gave 80.61, 78.00 and 76.25% reduction of broad leaved weeds and 67.05, 59.71 and 54.74% reduction of grassy weeds, respectively. However, the broad leaved weeds control was more than the grassy weeds. Maximum broad leaved weeds (51.00m^{-2}) and grassy weeds (46.89 m^{-2}) were recorded in control plot. However, there was no significant difference between control plot and rice straw mulch applied at the rate of 7.5 t ha^{-1} for controlling grassy weeds (43.56 m^{-2}). Rice straw mulching gave promising results in controlling both the broad leaved and grassy weeds. These effects could be explained in term of certain phytotoxic compounds in rice straw which have the ability to accumulate into the soil medium in sufficient amount and probably with enough persistence to attain such significant control of weeds. Thicker layers of mulch will help to conserve moisture in the soil and smother weeds typically by shading and or through allelopathic effects (Bilalis *et al*., 2003). These results are in accordance with those of Malik *et al.* (1998), Abdelhamid *et al.* 2004 and Rehman *et al.* (2005).

Table-1. Effect of rice straw mulch on organic matter, available NPK and soil pH

Treatments	OM content (%)	Available P (ppm)	Available K (ppm)	Available N (ppm)	pH
Check (No rice residues applied)	0.92d	13.85d	120.77d	0.046	8.12a
Rice straw mulching @7.5 t ha^{-1}	1.21c	15.16cd	124.40d	0.061	8.09a
Rice straw mulching @10.0 t ha^{-1}	1.28c	19.07bc	138.58c	0.064	8.05ab
Rice straw mulching @12.5 t ha^{-1}	1.75b	21.01b	149.42b	0.088	7.98bc
Rice straw mulching @15.0 t ha^{-1}	1.90ab	23.18ab	157.15ab	0.095	7.95c
Rice straw mulching @17.5 t ha^{-1}	2.04a	25.40a	160.71a	0.102	7.93c
Rice straw mulching @20.0 t ha^{-1}	2.09a	26.34a	162.09a	0.105	7.92c
LSD at <0.05	0.285	4.262	8.970	*NS	0.105

Means having same letter in a column do not differ significantly ($p < 0.05$)
*NS: Non-significant, OM = Organic Matter

Table-2. Effect of rice straw mulching on broad and narrow leaved weeds and dry weed biomass of wheat (average of three years 2008-09 to 2010-11)

Treatments	Broad leaf weeds (m^{-2})	Reduction in weeds (%)	Grassy weeds (m^{-2})	Reduction in weeds (%)	Dry weed biomass (g m^{-2})
Check (No rice residues applied)	51.00a	-	46.89a	-	211.34a
Rice straw mulching @7.5 t ha^{-1}	33.44b	34.43	43.56a	7.10	165.27b
Rice straw mulching @10.0 t ha^{-1}	24.78c	51.41	38.67b	14.45	134.92c
Rice straw mulching @12.5 t ha^{-1}	17.56d	65.57	31.00c	33.89	98.84d
Rice straw mulching @15.0 t ha^{-1}	12.11de	76.25	21.22d	54.74	65.68e
Rice straw mulching @17.5 t ha^{-1}	11.22e	78.00	18.89d	59.71	58.01e
Rice straw mulching @20.0 t ha^{-1}	9.89e	80.61	15.45d	67.05	45.73e
LSD at <0.05	5.586	-	6.849	-	24.218

Means having same letter in a column do not differ significantly ($p < 0.05$)

Dry weed biomass

The rice straw mulching substantially inhibited the dry weed biomass of weeds as compared to control (Table-2). Dry weed biomass was more important than their density. Application of rice straw mulch at 20.0, 17.5 and 15.0 t ha^{-1} produced minimum dry weed biomass (45.73, 58.01 and 65.68 g m^{-2}), respectively. Applying rice straw mulch at different doses suppressed the weed growth and reduced the dry weed biomass. As the quantity of mulch increased, the dry weed biomass significantly reduced. Maximum dry weed biomass (211.34 g m^{-2}) was recorded in the control treatment. These results are in agreement with the findings of Cheema and Khaliq (2000), Rehman *et al.* (2005) and El-Shahawy *et al.* (2006) who reported that rice straw mulching had a significant effect on suppressing weed growth.

Number of crop plants (m^{-2})

Reduction in germination count by the application of rice straw mulch at different doses is given in Table-3. Application of high dose of rice straw mulch hindered the crop plant germination. Lowest plants (198.78 and 207.11 m^{-2}) were found in plots where rice straw mulch was applied at the rate of 20.0 and 17.5 t ha^{-1}. Statistically at par plants were noted in control plot (235.56 m^{-2}), rice straw mulch was applied at the rate of 7.5 t ha^{-1} (233.00 m^{-2}), 10.00 t ha^{-1} (228.44 m^{-2}) and 12.5 t ha^{-1} (224.33 m^{-2}). Whereas, application of rice straw mulch applied at the rate of 15.0 t ha^{-1} gave 220.67 plants m^{-2} and subsequently this treatment gave maximum number of tillers m^{-2}. The increase in the tillers production may be attributed to better management at appropriate rate of residues. High rate of residues application reduced the seed germination. Earlier studies (e.g. Mohler, 1996) showed that the cereal crop plants can release allelochemicals that can inhibit seed germination and seedling growth in both weeds and crops.

Yield components

The application of rice straw mulch at the rate of 15.0, 17.5 and 20.0 t ha^{-1} gave promising results as compared to the control treatment (Table-3). Maximum tillers (319.55 m^{-2}) were recorded where 15.0 t ha^{-1} rice straw mulch was applied followed by 17.5 t ha^{-1} (313.11m^{-2}). Minimum tillers (292.78 m^{-2}) were recorded in the control treatment. Grains $spike^{-1}$ (40.12, 39.84 and 39.69) and 1000-grain weight (36.89, 36.51 and 36.14 g) were recorded by the application of rice straw mulch at the rate of 15.0, 17.5 and 20.0 t ha^{-1}, respectively. Significantly lesser grains $spike^{-1}$ (37.03) and 1000-grain weight (33.61 g) was recorded in control treatment. Several previous studies have also reported similar results (Rajput and Warsi, 1991; Das *et al*., 2003; Rehman *et al*., 2005).

Table-3. Effect of rice straw mulching on yield and yield components of wheat (average of three years 2008-2009 to 2010-2011)

Treatments	Number of plants (m^{-2})	Tillers (m^{-2})	Grains $spike^{-1}$	1000-grain Weight (g)	Yield ($t\ ha^{-1}$)
Check (No rice residues applied)	235.56a	292.78d	37.03e	33.61d	3.48d
Rice straw mulching @7.5 t ha^{-1}	233.00a	303.22c	37.34de	34.15d	3.67cd
Rice straw mulching @10.0 t ha^{-1}	228.44ab	308.67bc	38.21cd	35.23c	3.93c
Rice straw mulching @12.5 t ha^{-1}	224.33ab	310.45b	38.97bc	35.38bc	4.21b
Rice straw mulching @15.0 t ha^{-1}	220.67b	319.55a	40.12a	36.89a	4.58a
Rice straw mulching @17.5 t ha^{-1}	207.11c	313.11ab	39.84ab	36.51a	4.37ab
Rice straw mulching @20.0 t ha^{-1}	198.78c	296.00d	39.69ab	36.14ab	3.90c
LSD at <0.05	11.706	7.132	1.148	0.845	0.260

Means having same letters in a column do not significantly different ($p< 0.05$)

Grain yield

Grain yield was significantly higher in plots that received the rice straw mulch than the control plot (Table-3). The application of rice straw mulch at 15.0 t ha^{-1} significantly increased the yield (4.58 t ha^{-1}) as compared to control plot. This was followed by the application of rice straw mulch at 17.5 t ha^{-1} (4.37 t ha^{-1}). Less response was obtained with the lower rate of the rice straw mulch (less than 12.5 t ha^{-1}). The treatments 15.0 to 17.5 t ha^{-1} rice straw mulch application improved the crop grain yield. Organic farming is a useful practice to reduce the use of chemical fertilizers and herbicides. Earlier researchers (e.g. Verma and Bhagat, 1992; Das *et al*., 2003) have also reported rice straw mulching to be effective in promoting the grain yield of wheat crop.

CONCLUSION

This study suggests that the application of rice straw mulch at appropriate quantity and in time could prove as a new useful and environment friendly strategy for weed management in wheat crop. It can be concluded that the most suitable quantity of rice straw mulch may be between 15.0 to 17.5 t ha^{-1} for achieving the desirable level of weed control to improve the wheat crop productivity. In addition, the use of mulching may also improve the soil organic matter contents and nutrient level.

REFERENCES CITED

Abdelhamid, M.T., T. Horiuchi and S. Oba. 2004. Composting of rice straw with oilseed rape cake and poultry manure and its effects on faba bean (*Vicia faba* L.) growth and soil properties. Bioresource Technol. 93(1): 183-190.

Akhtar, N., A. Ali, Z. Ali, J. Iqbal, M. A. Nadeem and A. Sattar. 2011. Effect of integrated use of organic manures and inorganic fertilizers on grain yield of wheat. J. Agric. Res. 49(2): 181-186.

Bilalis, D., N. Sidiras, G. Economou and C. Vakali. 2003. Effect of different level of wheat straw soil surface coverage on weed flora in *Vicia faba* crop. J. Agron. Crop Sci. 189(4): 233-241.

Byous, E.W., J.E. Williams, G.E. Jonesa, W.R. Horwarth and C. Kessel. 2004. Nutrient requirements of rice with alternative straw management. Better Crops 86(1): 6-11.

Cheema, Z. A. and A. Khaliq. 2000. Use of sorghum allelopathic properties to control weeds in irrigated wheat in semi arid region of Punjab. Agric. Ecosyst. Env. 79(1): 105-112.

Chung, I. M., J. K. Ahn and S. J. Yun. 2001. Identification of allelopathic compounds from rice (*Oryza sativa* L.) straw and their biological activity. Can. J. Pl. Sci. 81(2): 815-819.

Chung, I. M., K.H. Kim, J.K. Ahn, S.B. Lee, S.H. Kim and S.J. Hahn. 2003. Comparison of allelopathic potential of rice leaves, straws and hull extracts on Barnyardgrass. Amer. Agron. J. 95(4): 1063-1070.

Das, K., D.N. Medhi and B. Guha. 2003. Application of crop residues in combination with chemical fertilizers for sustainable productivity in rice (*Oryza sativa*)-Wheat (*Triticum aestivum*) system. Ind. J. Agron. 48(1): 8-11.

Dobermann, A. and T.H. Fairhurst. 2002. Rice straw management. Better Crops Int. 16(Special supplement): 7-9.

Duke, S.O., F.E. Dayan, A.M. Rimando, K.K. Schroder, G. Aliotta, A. Oliva and J.G. Romagani. 2002. Chemicals from natural for weed management. Weed Sci. 50(1): 138-151.

Eagle, A.J., J.A. Bird, W.R. Horwaath, B.A. Linquist, S.M. Brouder, J.E. Hill and C.V. Kessel. 2000. Rice yield and nitrogen utilization efficiency under alternative straw management practices. Amer. Agron. J. 92(4): 1096-1103.

El-Shahawy, T. A., K. G. El-Rokiek, F. A. Sharara and K. A. Khalaf. 2006. Efficacy of rice straw extract against broad and narrow leaved weeds in (*Cucumis sativa* L.). Int. J.Agri. Biol. 8(2): 262-268.

Gupta, R. K., A. K. Shukla, M. Ashraf, Z. U. Ahmed, R. K. P. Sinha and P. R. Hobbs.2002. Options for establishment of rice and issues constraining its productivity and sustainability in eastern Gangetic plains of Bihar, Nepal and Bangladesh. Rice-Wheat Consortium Traveling Seminar Report Series 4. New Delhi, India: Rice Wheat Consortium for the Indo-Gangetic Plains. p. 36.

He, H. B., H. B. Wang, C. X. Fang, Z. H. Lin, Z. M. Yu. 2012. Separation of allelopathy from resource competition using rice/barnyard grass mixed-cultures. Plos one, 7(5): 37201.

Malik, R. K., G. Gill and R. R. Hobbs. 1998. Herbicide resistance: a major issue for sustaining wheat productivity in rice-wheat cropping system in the Indo-Gangetic plains. Rice-Wheat Consortium. New Delhi, India. p.36.

Mohler, C. L. 1996. Ecological bases for the cultural control of annual weeds. J.Prod.Agric.9(3):468-474

Olofsdotter, M. 2001. Rice-A step toward use of Allelopathy. Amer. Agron. J. 93(1): 3-8.

Ortiz-Monasterio, J. I., S. S. Dhillon and R. A. Fischer.1994. Date of sowing effects on grain yield and yield components of irrigated spring wheat cultivars and relationships with radiation and temperature in Ludhiana. Ind. Field Crops Res.37 (1):169-184.

Rajput, A. L. and A. S. Warsi. 1991. Contribution of organic materials to nitrogen economy in rice production. Ind. J. Argon. 36(3): 455-456.

Rehman, M. A., J. Chikushi, M. Saifizzaman and J. G. Lauren, 2005. Rice straw mulching and nitrogen response of no-till wheat following rice in Bangladesh. Field Crops Res. 91 (1): 71-81.

Sarwar, G., H. Schmeisky, M. A. Tahir, Y. Iftikhar and N. U. Sabah. 2011. Application of green compost for the improvement of dry matter yield and chemical composition of *Lolium perenne* (grass). J. Anim. Pl. Sci. 21(4): 710-714.

Singh, Y., B. Singh, J. K. Ladha, R. Gupta and R. Pannu. 2006. Tillage and residue management effects on yield and nitrogen use efficiency in wheat following rice in the Indo- Gangetic Plains of India. 18th world congress of soil science July 9-15, Philadelphia, Pennsylvania, USA. p. 155-177.

Steel, R. G. D., J. H. Torrie and D. A. Dickey. 1997. Principles and procedure of Statistics. 3rd Ed. McGraw Hill Book Co. Inc. Tokyo, Japan. p. 172-176.

Verma, T. S. and R. M. Bhagat. 1992. Impact of rice straw management practices on yield, nitrogen uptake and soil properties in a wheat-rice rotation in northern India. Fertilizer Res. 33 (1): 97-106.