*Indian Journal of Agricultural Sciences* **88** (2): 216–21, February 2018/Article

# Productivity and economics of different cropping systems in relation to tillage, mulching and fertilizer management practices in north-western Indo-Gangetic Plains of India

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Received: 09 March 2017; Accepted: 20 October 2017

ABSTRACT

Diversification and intensification of existing rice-wheat cropping system in north-west Indo-Gangetic Plains with suitable resource conserving practices is the key answer for increasing profitability. Keeping this in view, a field experiment was conducted at Ludhiana during 2014-15 and 2015-16 to study the effect of tillage, mulching and fertilizer management practices on productivity and economics of different cropping systems. The results showed that minimum tillage produced significantly higher economic yield of maize (*Zea mays* L.) (42.98 and 44.86 q/ha), wheat (*Triticum aestivum* L.) (47.57 and 48.30 q/ha), potato (*Solanum tuberosum* L.) (252.42 and 254.93 /ha), vegetable pea (*Pisum sativum* L.) (132.42 and 137.08 q/ha) and spring maize (64.88 and 66.55 q/ha). Significantly higher maize equivalent yield (4.6 and 3.5%), higher net returns (₹ 153445 and 170803/ha) and B:C (1.33 and 1.43) was obtained under minimum tillage than conventional tillage. The productivity of maize-based cropping systems was significantly higher than conventional rice-wheat cropping systems. Maize-vegetable pea-spring maize produced 119 and 137% higher MGEY and higher net returns (₹ 218738 and 259235/ha), while maize-potato-spring maize showed 82 and 74% higher MGEY over rice-wheat cropping systems. Organic manures (FYM) in conjugation with inorganic fertilizers (75% RDF + 25% N through FYM) resulted in comparable MGEY with inorganic fertilizer (100% RDF). Application of mulch along with fertilizer treatments resulted in significantly higher MGEY as compared to fertilizer treatments without mulch. Gross returns were higher under mulch with fertilizer treatments, while the B:C ratio under mulch with fertilizer treatments was less as compared to fertilizer treatments without mulch.

**Key words**: Cropping systems, Fertilizer, FYM, Maize, MGEY, Mulch, Tillage

Rice (*Oryza sativa* L)–wheat (*Triticum aestivum* L.) is the major cropping system occupying 13.5 million hectares (m ha) in the Indo-Gangetic Plains (IGP) of India, Bangladesh, Nepal and Pakistan (Gupta and Seth 2007). This in turn is fundamental to employment, income and livelihood for millions of people in the region. In India alone, RW rotation occupies about 10.5 m ha and contributes to 40% of the country's total food grain production (Saharawat *et al.* 2011). Although rice-wheat is the most dominating crop sequence of Indo-Gangetic Plains, yet its continuous practicing has resulted in a number of ecological and management problems such as development of hardpan, low input use efficiency and nutrient deficiencies, besides insect-pests, disease and weed problems entailing use of pestisides. Continuous pumping of groundwater over the years to meet the high water requirement of flooded rice crop has resulted in a drastic decline in groundwater table. These detrimental factors have given impetus to pursuit for alternative crops and cropping systems, which are environment friendly and efficient in utilizing natural resources (Aulakh *et al.* 2012).

Maize has emerged as an alternative option to replace the rice in cereal based cropping systems. In the previous decade (2003–04 to 2012–13), the maize area expanded by 1.8% and production increased by 4.9% showing productivity growth at 2.6% per annum in India. Maize, an important crop for food and nutritional security in India, is grown in diverse ecologies and seasons on an area of 8.71 mha with production of 22.26 mt (GoI 2015). It has higher yield potential than any other cereal crop and adaptability to wide range of environments; thus referred to as the 'Miracle crop' or the 'Queen of cereals'. Among different cropping systems, maize-wheat is the 5$^{th}$ dominant cropping system of India occupying an area of 1.8 mha (Jat *et al.* 2011). Inclusion of pulses, oilseeds and vegetables in the system is more beneficial and economical than sole cereals based cropping systems (Gangwar *et al.* 2004). To meet the growing demands improved agronomic practices such as intensive tillage, optimized use of fertilizers, improved crop protection and incorporating crop residue into the soil are being adopted (Ghasemi *et al.* 2010).

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Among the different agro techniques, soil tillage is one of the greatest fossil fuel energy consumers and encompassing about 30% of the total energy use in crop production (Singh *et al.* 2008). So, in the current context of growing environmental concerns, reduced or zero tillage is essential as it can increase the benefit cost ratio. Hence, conservation agriculture (CA) based tillage and crop establishment practices play vital role in achieving the sustainability in soil fertility, crop productivity and environmental quality. To meet the urgent need for developing viable sustainable alternate cropping systems to rice-wheat cropping system with maize alternative in focus, the present study was conducted to evaluate the comparative performance of different cropping systems under tillage, mulching and fertilizer management practices.

## MATERIALS AND METHODS

The field experiment was conducted over two cropping cycles during rainy (*kharif),* winter (*rabi)* and spring seasons of 2014-2015 and 2015-2016 at Research Farm, Department of Agronomy, Punjab Agricultural university, Ludhiana ($30^o$ 56' N and $75^o$52' E with altitude of 247 m above mean sea level). Average annual rainfall of Ludhiana is 750 mm and greater portion (about 75%) of which is received in south-west monsoon from July to September. The soil of experimental site was loamy sand in texture, medium in organic carbon (0.42%), poor in available N (225.9 kg/ha) available potassium (128.8 kg/ha) and high in available phosphorus (23.6 kg/ha). The soil was slightly alkaline in reaction with pH 7.76. The experiment was laid out in split-plot design with four replications. The main plot treatments consist of combination of tillage, viz. minimum tillage (MT) and conventional tillage (CT) and cropping systems (rice-wheat, maize-vegetable pea-spring maize, maize-toria-spring maize, maize-potato-spring maize), whereas, sub plots consist of combination of fertilizer and mulch, viz. 100% recommended dose of fertilizers (100% RDF), 75% RDF + 25% N through FYM, 100% RDF plus mulch and75% RDF + 25% N through FYM plus mulch. After the complete emergence of crop, mulching was done as per the treatment combination. Crop residue of preceding crops was used on succeeding crops @ 5 t/ha. There was no mulch application in rice crop. Under conventional tillage treatments, except rice, the field was ploughed twice with disc harrows followed by planking, and then cultivation with tillers was done twice followed by planking. While under minimum tillage, the field was ploughed once with disc harrow and tine cultivator followed by planking. In potato, after tillage treatment ridges were made at 60 cm spacing and thereafter dibbling was done as per plant to plant spacing. For rice crop, the field was disked once and then dry tilled and after that plots were flooded with water. Under conventional tillage treatments, the field puddling with self-propelled puddler was repeated two times, while in minimum tillage puddling was done singly.The varieties used, seed rates and row spacing adopted for each crop as well as their fertilizer doses are given in Table 1.

The grain/seed yield of maize, rice, wheat, toria and spring maize from the net plot was recorded and expressed as q/ha. Green pod yield of vegetable pea from different picking was added to get the total pod yield and expressed as q/ha. In potato, tuber yield from net plot was recorded after removal of soil adhering to tubers. To compare the different cropping systems, the economic yield of different crops was converted into maize grain equivalent yield (MGEY) based on prevailing market prices as given in Table 1 and the system productivity was calculated by adding the MGEY of different crops in given cropping system.

$$\text{MGEY (t/ha)} = \text{Economic yield of a crop} \times \frac{\text{Price (₹/kg) of the same crop}}{\text{Price (₹/kg) of maize}}$$

$$\text{Production efficiency (kg/ha/day)} = \frac{\text{Total production (MGEY)}}{\text{365 days}}$$

The gross returns of systems was calculated by adding the gross returns of component crops based on prevailing market price of economic and by-product yield of different crops. The net returns were calculated by subtracting the cost of cultivation from the gross returns. By dividing the net returns with cost of cultivation, benefit cost ratio of the system was calculated. The two year data on crop productivity, system productivity, gross returns, net returns, benefit: cost were subjected to the analysis of variance (ANOVA) in a split plot design. The treatments mean were compared by using critical difference (P = 0.05).

Table 1 Details of the varieties used, seed rates, row spacing, fertilizer doses and prevailing market prices of different crops

| Crop | Variety | Spacing | Seed rate | 100% RDF (kg/ha) | | | Market price (₹/q) | |
|---|---|---|---|---|---|---|---|---|
| | | | | N | $P_2O_5$ | $K_2O$ | 2014-15 | 2015-16 |
| Maize | PMH 1 | 60×20 cm | 20 kg/ha | 125 | 60.0 | 30 | 1310 | 1325 |
| Rice | PR 121 | 20×15 cm | 20 kg/ha | 125 | 30 | 30 | 1360 | 1410 |
| Wheat | HD 2967 | 20 cm (Row to row) | 100 kg/ha | 125 | 62.5 | 30 | 1450 | 1525 |
| Toria | TL 17 | 30×10 cm | 3.5-4 kg/ha | 62.5 | 20 | | 3020 | 3290 |
| Vegetable pea | Punjab 89 | 30 ×10 cm | 75 kg/ha | 50 | 62.5 | | 1540 | 1650 |
| Potato | Kufri Jyoti | 60×20 cm | 30q/ha | 187.5 | 62.5 | 62.5 | 550 | 525 |
| Spring maize | PMH 1 | 60×20 cm | 20 kg/ha | 125 | 60.0 | 30 | 1310 | 1325 |

## RESULTS AND DISCUSSION

*Economic yield of crops*

The data given in Table 2 and 3 revealed that minimum tillage resulted in significant increase in the yield of maize, wheat, vegetable pea, potato and spring maize as compared to conventional tillage. The yields of toria and rice were comparable among different tillage practices. Minimum tillage resulted in 5.1 and 5.9 per cent higher maize yield than conventional tillage during *kharif* 2014 and *kharif* 2015, respectively. Under minimum tillage, the grain yield of wheat was 50.11 and 51.22 q/ha and for conventional tillage, the grain yield was 47.57 and 48.30 q/ha during 2014-15 and 2015-16, respectively. Minimum tillage resulted in 4.9 and 5.9 per cent higher green pod yield of vegetable pea and 4.3 and 7.4 per cent higher tubers yield of potato as compared to conventional tillage during 2014-15 and 2015-16, respectively. However, different tillage methods did not influence the seed yield of toria significantly. Though, the grain yield of rice was higher in conventional tillage, but it was not significantly different from minimum tillage. The higher yield in minimum tillage may be due to better soil physical and chemical environment, lower traffic compaction, greater root proliferation and efficient nutrient recycling occurred which was reflected in yield (Gangaiah *et al.* 2012). Prasad *et al.* (2016) also reported higher grain /seed yield of different crops under minimum tillage.

Fertilizers with and without mulch influenced the yield of different crops. Application of 75% RDF + 25% N through FYM resulted in higher grain yield as compared to 100% RDF (recommended dose of fertilizer). Integration of organic manures with inorganic fertilizers improved the physical, chemical and biological properties of the soil and solubilises the nutrients resulting in improvement in available nutrients ultimately led to higher crop growth and yield (Singh and Sekhon 2002). Ramesh *et al* (2016) reported higher productivity of sequential crops with integrated nutrient management as compared to recommended dose of fertilizers. Mulching along with different fertilizer treatments resulted in significantly higher yield as compared to respective fertilizer treatments. 75% RDF + 25% N through FYM plus mulch resulted 7.0 per cent and 5.4 per cent higher yield of maize, 4.9 and 5.0 per cent higher yield of wheat, 4.2 and 4.7 per cent higher pod yield in vegetable pea, 4.5 and 5.8 per cent higher tuber yield in potato as compared to 75% RDF + 25% N through FYM without mulch during 2014-15 and 2015-16, respectively. Mulch management helped in conservation of soil moisture in the root zone, increased root proliferation and availability of nutrients which ultimately led to higher grain yield. Also mulching has favorable effect on soil physical, chemical and biological properties. Sarkar and Singh (2007) and Choudhary *et al.* (2013) reported similar results.

*Systems productivity*

The data presented in Table 3 manifested that minimum tillage resulted in significantly higher MEY as compared to conventional tillage. Minimum tillage resulted in 4.6 and 3.5 per cent higher MGEY as compared to conventional tillage. Higher MGEY under minimum tillage may be due to the

Table 2 Effect of tillage, mulching and fertilizer management practices on yield of different crops

| Treatment | Maize (q/ha) | | Rice (q/ha) | | Wheat (q/ha) | | Vegetable pea (q/ha) | |
|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 |
| *Tillage* | | | | | | | | |
| MT | 45.19 | 47.54 | 63.00 | 64.09 | 50.11 | 51.22 | 138.98 | 145.30 |
| CT | 42.98 | 44.86 | 64.69 | 66.61 | 47.57 | 48.30 | 132.42 | 137.08 |
| SEm (±) | 0.53 | 0.47 | 0.43 | 0.79 | 0.49 | 0.62 | 1.09 | 1.45 |
| CD (P=0.05) | 1.59 | 1.40 | NS | NS | 2.27 | 2.89 | 5.10 | 6.74 |
| *Cropping systems* | | | | | | | | |
| Rice-wheat | | | 63.85 | 65.35 | 48.84 | 49.76 | | |
| M-VP-SM | 44.54 | 46.99 | | | | | 135.7 | 141.19 |
| M-T-SM | 43.68 | 45.38 | | | | | | |
| M-P-SM | 44.03 | 46.23 | | | | | | |
| SEm (±) | 0.65 | 0.57 | | | | | | |
| CD (P=0.05) | NS | NS | | | | | | |
| *Fertilizer × mulching* | | | | | | | | |
| 100% RDF | 42.33 | 44.48 | 63.32 | 64.10 | 47.08 | 48.20 | 131.63 | 137.00 |
| 75% RDF +25% N FYM | 43.19 | 45.26 | 64.40 | 65.88 | 48.13 | 48.84 | 134.33 | 138.89 |
| 100% RDF +Mulch | 44.64 | 47.21 | 63.16 | 64.94 | 49.53 | 50.60 | 136.60 | 143.21 |
| 75% RDF +25% N FYM + Mulch | 46.17 | 47.85 | 64.51 | 66.48 | 50.64 | 51.41 | 140.23 | 145.68 |
| SEm (±) | 0.53 | 0.46 | 0.64 | 0.92 | 0.69 | 0.69 | 1.37 | 1.82 |
| CD (P=0.05) | 1.50 | 1.32 | NS | NS | 2.07 | 2.07 | 4.10 | 5.44 |

Table 3 Effect of tillage, mulching and fertilizer management practices on yield of different crops and maize grain equivalent yield

| Treatment | Potato (q/ha) | | Toria (q/ha) | | Spring Maize(q/ha) | | MGEY (t/ha) | |
|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 |
| *Tillage* | | | | | | | | |
| MT | 263.41 | 273.81 | 8.95 | 9.41 | 68.91 | 71.36 | 18.71 | 19.92 |
| CT | 252.47 | 254.93 | 8.48 | 8.74 | 64.88 | 66.55 | 17.88 | 19.23 |
| SEm (±) | 2.24 | 3.78 | 0.22 | 0.23 | 0.76 | 0.77 | 0.11 | 0.12 |
| CD (P=0.05) | 10.44 | 17.62 | NS | NS | 2.30 | 2.31 | 0.32 | 0.36 |
| *Cropping systems* | | | | | | | | |
| Rice-wheat | | | | | | | 12.03 | 12.68 |
| M-VP-SM | | | | | 68.20 | 69.80 | 26.29 | 30.01 |
| M-T-SM | | | 8.72 | 9.08 | 65.74 | 67.99 | 12.95 | 13.59 |
| M-P-SM | 257.94 | 264.37 | | | 66.75 | 69.07 | 21.91 | 22.01 |
| SEm (±) | | | | | 0.93 | 0.94 | 0.15 | 0.18 |
| CD (P=0.05) | | | | | NS | NS | 0.45 | 0.52 |
| *Fertilizer × mulching* | | | | | | | | |
| 100% RDF | 250.68 | 255.31 | 8.27 | 8.28 | 90.27 | 66.80 | 17.76 | 18.93 |
| 75% RDF +25% N FYM | 254.28 | 258.33 | 8.50 | 8.83 | 92.09 | 67.53 | 18.09 | 19.21 |
| 100% RDF +Mulch | 260.53 | 269.5 | 8.91 | 9.48 | 94.86 | 70.17 | 18.46 | 19.91 |
| 75% RDF +25% N FYM + Mulch | 266.27 | 274.31 | 9.18 | 9.70 | 96.89 | 71.32 | 18.87 | 20.23 |
| SEm (±) | 3.27 | 3.66 | 0.31 | 0.54 | 0.71 | 0.70 | 0.15 | 0.14 |
| CD (P=0.05) | 9.78 | 10.94 | NS | NS | 2.97 | 2.00 | 0.42 | 0.39 |

compound effects of improved soil physical health, better water regimes, higher resource-use efficiency and efficient nutrient use. Dixit *et al.* (2015), Saad *et al.* (2015) also reported higher system productivity under zero or reduced tillage as compared to conventional tillage.

The maize-based cropping systems resulted in significantly higher MGEY as compared to traditional rice-wheat sequence. Maize-vegetable pea-spring maize gave significantly higher MGEY as compared to other cropping systems which was 119 and 137 per cent higher over the traditional rice-wheat cropping system during 2014-15 and 2015-16, respectively. Maize-toria-spring maize and maize-potato-spring maize also resulted in significantly higher MGEY as compared to rice-wheat cropping system. Maize-potato-spring maize produced 82 and 74 per cent higher MGEY as compared to conventional rice-wheat cropping sequence. Higher MEY under maize-based cropping systems was due to higher tonnage of crops and higher market value of vegetable pea and toria.This is well documented in literature by Gill and Ahlawat (2006), Walia *et al.* (2010), Walia *et al.* (2011), Upadhyay *et al.* (2011) and Gangwar and Singh (2011) that inclusion of vegetables, legumes or oilseed resulted in higher system productivity as compared to cereal-cereal cropping system.

Highest maize grain equivalent yield was recorded with 75% RDF + 25% N through FYM plus mulch which was at par with 100% RDF plus mulch, but significantly higher to 100% RDF and 75% RDF + 25% N through FYM without mulch. MGEY under 100% RDF plus mulch was significantly higher as compared to 75% RDF + 25% N through FYM without mulch during 2015-16, but no significant difference was recorded during 2014-15. Application of 75% RDF + 25% N through FYM without mulch resulted in higher MGEY as compared to 100% RDF but at par with each other.Crop residue mulch might have improved the physical properties of soil, moderated soil temperature, biodiversity of micro-organisms and increased the yield of individual crops and therefore maize grain equivalent yield. Higher system productivity with mulch application also reported by Sepat *et al.* (2015) and Ramesh *et al.* (2016).

*Production efficiency and economics of sytems*

Minimum tillage resulted in significantly higher production efficiency (51.25 and 54.57 kg/ha/day) of the system as compared to conventional tillage (49.00 and 52.67 kg/ha/day) owed to higher equivalent yield (Table 4). Among cropping systems, maize-based cropping systems resulted in higher production efficiency as compared to rice-wheat cropping systems. Inclusion of vegetable crops in cereal based cropping systems (maize-vegetable pea-spring maize and maize-potato-spring maize) led to higher production efficiency as compared to maize-toria-spring maize. Higher tonnage of economic yield of vegetable crops resulted in higher production efficiency. 100% RDF and 75% RDF + 25% N through FYM resulted in comparable production efficiency. Mulching along with fertilizer treatments resulted in significantly higher production efficiency as compared to fertilizers without mulch application.

Gross returns (₹ 272009 and 293634/ha), net returns (₹ 153445 and 170803/ha) and benefit cost ratio (1.33 and 1.43) were significantly higher with minimum tillage

Table 4 Effect of tillage, mulching and fertilizer management practices on production efficiency and economics of systems

| Treatment | Production efficiency (kg/ha/day) | | Gross returns (₹/ha) | | Net returns (₹/ha) | | B: C ratio | |
|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 |
| *Tillage* | | | | | | | | |
| MT | 51.25 | 54.57 | 272009 | 293634 | 153445 | 170803 | 1.33 | 1.43 |
| CT | 49.00 | 52.67 | 260207 | 278199 | 133297 | 146724 | 1.08 | 1.15 |
| SEm (±) | 0.29 | 0.34 | 1007 | 1286 | 1006 | 1272 | 0.01 | 0.01 |
| CD (P=0.05) | 0.87 | 1.00 | 2963 | 3785 | 2960 | 3742 | 0.04 | 0.03 |
| *Cropping systems* | | | | | | | | |
| R-W | 32.97 | 34.74 | 177080 | 188909 | 105666 | 115120 | 1.48 | 1.58 |
| M-VP-SM | 72.03 | 82.21 | 372816 | 418674 | 218738 | 259235 | 1.43 | 1.63 |
| M-T-SM | 35.48 | 37.23 | 199617 | 213816 | 100602 | 110788 | 1.02 | 1.07 |
| M-P-SM | 60.02 | 60.29 | 314917 | 322265 | 148476 | 149912 | 0.90 | 0.87 |
| SEm (±) | 0.42 | 0.48 | 1424 | 1820 | 1423 | 1799 | 0.01 | 0.01 |
| CD (P=0.05) | 1.24 | 1.42 | 4190 | 5354 | 4187 | 5293 | 0.05 | 0.04 |
| *Fertilizer × mulch* | | | | | | | | |
| 100% RDF | 48.65 | 51.87 | 258337 | 276664 | 138606 | 152321 | 1.20 | 1.26 |
| 75% RDF +25% N FYM | 49.56 | 52.64 | 263126 | 281014 | 145102 | 158570 | 1.27 | 1.34 |
| 100% RDF + Mulch | 50.58 | 54.55 | 268588 | 290555 | 141136 | 158699 | 1.14 | 1.24 |
| 75% RDF +25% N FYM + Mulch | 51.72 | 55.42 | 274379 | 295432 | 148639 | 165464 | 1.22 | 1.31 |
| SEm (±) | 0.41 | 0.38 | 1105 | 1431 | 1105 | 1414 | 0.01 | 0.01 |
| CD (P=0.05) | 1.16 | 1.06 | 3116 | 4035 | 3116 | 3988 | 0.04 | 0.03 |

as compared to conventional tillage. Reduction in cost of cultivation owed to less tillage operations higher economic yield of different crops with minimum tillage resulted in higher net returns and benefit cost ratio. Among cropping systems, maize-vegetable pea-spring maize system resulted in significantly higher gross (₹ 372816 and 418674/ha) and net returns (₹ 218738 and 259235/ha) as compared to other cropping systems. Net returns in maize-toria-spring maize and rice-wheat were at par with each other during both years of experimentation. Maize-vegetable pea-spring maize resulted in significantly higher benefit cost ratio (1.63) as compared to other cropping systems during 2015-16, but at par with rice-wheat during 2014-15. Significantly lowest benefit cost ratio was recorded in maize-potato-spring maize as compared to other cropping systems. Higher cost of cultivation and lower market price of potato resulted in less benefit cost ratio. Kang *et al.* (2009), Sharma *et al.* (2010) and Walia *et al.* (2014) reported higher net gross and net returns with different cropping systems as compared to rice-wheat cropping systems.

Integrated nutrient management practice, i.e. 75% RDF + 25% N through FYM produced significantly higher gross returns and net returns as compared to100% RDF during 2014-15 and 2015-16. Higher economic yield of different crops with integrated nutrient management resulted in higher gross returns. Dixit *et al.* (2015) also reported higher gross and net return with integrated nutrient management as compared to recommended dose in chickpea-sorghum cropping system. Application of fertilizers plus mulch resulted in significantly higher gross returns and net returns as compared to respective fertilizer management practices. Benefit cost ratio was higher in fertilizer treatments as compared to fertilizer plus mulch treatments. Increase in cost of cultivation due to high cost of crop residue used as mulch and application cost resulted in lower benefit cost ratio (Ramesh *et al.* 2016).

It may be concluded that reduction in tillage operations is not only viable but also increased the productivity of crops. Maize-based cropping systems can replace the existing conventional rice-wheat cropping system. Application of mulch in conjugation with fertilizers along with organic manures produced higher yield but economically less viable due to higher cost of straw and its application.

## ACKNOWLEDGEMENT

The authors are thankful to Department of Science and Technology, New Delhi for providing financial support through DST INSPIRE Fellowship vide IF 140502 during Ph D programme.

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