Annals of Plant Sciences
ISSN: 2287-688X
OPEN ACCESS
www.annalsofplantsciences.com

Original Research Article

# Influence of various tillage option along with nutrient management practices in maize –wheat cropping system under mid hill situation of West Bengal

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**Received for publication:** March 27, 2015; **Revised** March 05, 2015; **Accepted:** March 17, 2015.

**Abstract:** A field experiment was conducted during 2010 to 2012 at the Regional Research Station (Hill Zone) of Uttar Banga Krishi Viswavidyalaya, Kalimpong (1250 m asl), to elucidate the influence of various tillage option along with nutrient management practices in maize –wheat cropping system under mid hill situation. The experiment was laid out in randomized block design with ten treatment comprising common control ($T_1$), zero tillage($T_2$), reduced tillage ($T_3$), conventional tillage ($T_4$), zero tillage + 75% RDF + 5 t/ha forest manure ($T_5$), reduced tillage + 75 % RDF + 5 t/ha forest manure ($T_6$), conventional tillage + 75 % RDF + 5 t/ha forest manure ($T_7$), zero tillage + 100 % RDF ($T_8$), reduced tillage + 100 % RDF ($T_9$), and conventional tillage + 100 % RDF ($T_{10}$) and replicated three times. The height of maize plant was maximum to be 187.25 cm in zero tillage followed by 100 % RDF treatment and was to the magnitude of 55.11 cm, 50.1 cm, 47.76 cm, and 47.08 cm higher in $T_8$, $T_6$, $T_{10}$ and $T_7$ treatments, respectively, over $T_1$ treatment. There appeared to be 71.47 per cent increase in grain yield of maize in $T_9$ (reduced tillage + 100 % RDF), 67.86 per cent with the application of conventional tillage + 75 % RDF + 5 t/ha forest manure, and 63.50 per cent with application of conventional tillage +100 % RDF and 62.38 (reduced tillage + 75 % RDF + 5 t/ha forest manure) as compared to control. All these treatments were at par to each other and significantly better to rest of the treatments. More maize stover yield was obtained with the reduced tillage followed by full dose of RDF, and was at par with the conventional tillage + 100 % RDF ($T_{10}$ ), zero tillage + 100 % RDF ($T_8$), reduced tillage + 75 % RDF + 5 t/ha forest manure ($T_6$ ) and significantly better to rest of the treatment practices. The grain yield of wheat was higher by 35.01 per cent in reduced tillage followed by full dose of RDF, 34.14 per cent in reduced tillage + 75 % RDF + 5 t/ha forest manure, 29.06 percent in conventional tillage + 100 % RDF and about 28.53 per cent in zero tillage + 100 % RDF treatment over the control. All these treatments were at part to each other and significantly better to rest of the treatments combination. Tillage and nutrient treatment combinations positively influenced the total productivity of maize-wheat cropping system. On an average, the yield of the system in terms of Maize Equivalent Yield (MEY) increased by 14.3 q $ha^{-1}$ productivity of treatments was increased by 51.47 % over control. The maximum system productivity (MEY 42.08 q $ha^{-1}$) was recorded with the use reduced tillage + 75 % RDF + 5 t/ha forest manure, at par with reduced tillage + 100 % RDF (Table 6). On the other hand, the significant difference was also recorded among the full inorganic fertilizers treatments for maize equivalent yield of the system. The system productivity in terms of MEY of maize - wheat cropping system varied significantly with different tillage and nutrient management treatments. Amongst various treatment measures maximum uptake of nutrient by the sytem was observed with the reduced tillage + 100 % RDF and was followed by conventional tillage + 100 % RDF. The system based inorganic nutrient management treatments along with reduced tillage (reduced tillage + 100 % RDF) practice registered higher gross return (Rs $ha^{-1}$ 50.82 x$10^3$), net returns (Rs $ha^{-1}$ 22.41 x$10^3$), benefit: cost ratio of 1.78 compared to Rs $ha^{-1}$ 25.44 x$10^3$, Rs $ha^{-1}$ 7.54 x$10^3$ and 1.42, respectively in control.

**Key words:** Maize, nutrient uptake, system, wheat, yield.

## Introduction

Maize cultivation is a way of life for most farmers in the hills of Darjeeling. It is a traditional crop cultivated as food, feed and fodder on slopping *Bari* land (rainfed upland) in the hills. It is grown under rainfed conditions during the summer (April-August) as a single crop or relayed with millet later in the season. In the terai, inner-terai, valleys, and low-lying river basin areas, maize is also grown in the winter and spring with irrigation. Maize (*Zea mays L.)* wheat (*Triticum aestivum* L.) is the most prevalent cropping system in mid hills of eastern Himalaya which has low productivity due to poor agronomic management practices. The soils of the region are structurally unstable, and the lands have undulating topography resulting in non-uniform moisture distribution. Thus, there is need to conserve soil moisture for improving crop yields in the area. The area is more hungry than thirsty which further adds to its low productivity. Loss of organic matter whether by erosion or uneven temperature in the rain-fed agro-ecosystem adds to

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impoverishment of soil resources of several elements essential for plant growth. However, the challenge of improving productivity in hill rain-fed areas can be addressed by efficient utilization of nutrients and natural resources. One of the ways is to use the nutrients in an integrated manner from all possible resources and maximizing the utilization of applied nutrients by crops (Acharya and Bandopadhyay, 2002). It, therefore, requires the development of need-based location-specific technologies to ecologically rehabilitate and obtain the production-potential on a sustained basis. Soil is one of our most precious natural resources. Proper soil management is a key to sustainable agricultural production. The conjunctive application of organics with inorganic sources of nutrients reduces the dependence on chemical inputs. Utilization of indigenous sources of organics, viz. FYM, obnoxious weeds, forest manure and green leaf manures may serve as alternatives and or supplements to chemical fertilizers and help in increasing the productivity of the maize based cropping system in hill zones of the country. The optimization of nutrient supply to the crop depends on manures or fertilizers applied to the individual preceding crop and their carryover effect on succeeding crop, which is generally ignored and recommended dose of manures or fertilizers are applied again to the next crop (Gangaiah *et al*., 2012). Besides, application of inorganic fertilizer to dry season crop is not very encouraging due to inherent problem of moisture shortage under rainfed uplands in northeastern hill region of the country. Soil management involves six essential practices: proper amount and type of tillage, maintenance of soil organic matter, maintenance of a proper nutrient supply for plants, avoidance of soil contamination, maintenance of the correct soil acidity, and control of soil loss (erosion). The potential for erosion of a specific soil type largely depends on the severity of the slope, the crops grown, and the number and types of tillage operations. Several techniques are available to reduce soil erosion, including residue management, crop rotation, contour tillage, grass waterways, terraces, and conservation structures. The techniques adopted must ensure the long-term productivity of the land, be environmentally sound, and, of course, be profitable. Conservation tillage and crop residue management are recognized as cost-effective ways to reduce soil erosion and maintain productivity. Crop response to various tillage systems is variable in both farmers’ fields and experimental plots. The variability is often difficult to explain because so many factors that directly affect crops are influenced by tillage. On an average, 10-20% increase in productivity has been achieved in West Bengal in ZT cultivation of wheat over conventional system and the improvement can be made even more if all the things and practices go in favour of successful adoption of this technology (Mondal *et al*., 2014).

In double cropping system, decreasing tillage is very important due to limited time for seedbed preparation and to keep the production cost low (Limon- Ortega *et al*., 2002). Effect of tillage practices and wheat residue management on maize yield and soil properties have been reported (Lal *et al.*, 1994). Deep tillage breaks up high-density of soil layers and improves water infiltration and movement in the soil, enhances root growth and development and increases crop production (Mukherjee, 2012). Scientist obtained minimum grain yield and maximum nitrogen, potassium and phosphorus in topsoil layer in minimum tillage. Soil and nutrient management practices are of paramount concern to conserve moisture, improve the productivity and reduce the menace of erosion in the sub-mountain of Darjeeling Himalaya. Because of the lack of knowledge about minimum or no tillage, the local farmers burn the straws to do extensive tillage by their conventional equipment easier. Therefore, due to the lack of scientific information and the limited time for seedbed preparation in the region, this study was conducted to determine the effect of tillage methods and nutrient management on grain yield of maize- wheat cropping system.

## Materials and Methods

The experiment was conducted during 2010-11 and 2011-12 at Regional Research Station (Hill Zone) under the aegis of Uttar Banga Krishi Viswavidyalay, Kalimpong with an altitude of 1250 m asl. The soil of the experimental site was alfisol, acidic in nature with pH 5.2 (1:2.5 soil: water, Jackson, 1973), high in organic carbon of 0.83% (Walkey and Black method, Jackson, 1973), medium in available N with 310 kg $ha^{-1}$ (modified Kjeldahl“s method, Jackson, 1973), low in available P with 8.23 kg ha-1 (Olsen“s method, Olsen *et al.,* 1956) and high in available K with 303.8 kg ha-1 (Flame photometer method, Jackson, 1973) at the start of experiment. The total rainfall recorded during crop growth period was 1309.2 and 1216.3 mm respectively in first and second year. Minimum temperature ranges from 1.6 to 13.6 $^0$C and 2.9 to 15.3, and maximum temperature 18.2 to 30.3 and 15.8 to 33.6$^0$ C during winter 2010-11 and 20011-12, respectively. The treatments were replicated thrice in randomized block design (RBD) in farm field. Treatment comprising common control ($T_1$), zero tillage($T_2$), reduced tillage ($T_3$), conventional tillage ($T_4$), zero tillage + 75% RDF + 5 t/ha forest manure ($T_5$), reduced tillage + 75% RDF + 5 t/ha forest manure ($T_6$), conventional tillage+ 75% RDF + 5 t/ha forest manure ($T_7$), zero tillage + 100% RDF ($T_8$), reduced tillage + 100% RDF ($T_9$), and conventional tillage + 100% RDF ($T_{10}$). Zero tillage (No tillage), as extreme in conservation tillage, where in the new crop is planted in the residue of the previous crop without any prior soil tillage or seed bed preparation and, weeds were controlled by blank application of glyphosate. Further, with reduced tillage two time disk harrow with the depth of 10-15 cm was done. In conventional tillage treatment, mouldboard plough with depth of 25-30 cm followed by disk harrow and planking was done. The recommended doses for maize, 125 kg N, 60 kg P, 40 kg K and 10 kg $ZnSO_4$ per hectare. In case of wheat recommended doses in the rain-fed region 100 kg N, 40 kg P, 30 kg K ha$^{-1}$ along with 10 kg $ZnSO_4$ per hectare. In the present experiments, N, P, K and Zn were applied through urea, single super phosphate, muriate of potash and zinc sulphate, respectively. Well decomposed forest manure was applied at the rate of 5 t ha$^{-1}$ in the respective treatment. However, the nutrient content of forest manure range from 0.79 – 0.98% N, 0.14 – 0.17% P and 0.37 – 0.45% K on dry weight basis. Pre-emergence application of pendimethalin 0.75 kg a.i ha$^{-1}$ was given 2 days after sowing followed by one hand weeding at 40 DAS (days after sowing) for complete check of weed during critical period of crop-weed competition in case of wheat. However in case of maize atrazin 1.5 kg a.i ha$^{-1}$ apply to check weed population along with succeeding hand weeding. Other management practices were adopted as per recommendations of the crop under rainfed situation. For working out the economics, prevailing market prices for maize seed (₹ 20.50/kg), wheat seed (₹ 13.25/kg) urea (₹ 9.75/kg), SSP (₹ 13.90/kg), MOP (₹ 8.15/kg) and cost of labour (₹ 152.50 /day) were considered. Data related to growth phase was recorded at maximum growth phase (60 and 90 DAS) and rest of the yield character was measured at the time of harvesting. The crop was harvested at maturity from each plot and the grains were separated and their yields were recorded. The plant samples were analyzed for their N, P, K using the procedures described by Prasad (1998) and nutrient uptake was computed using the data on grain and stover yield and their nutrient concentrations. The total nitrogen content of plants was analyzed by micro-Kjeldhal's method (Jackson, 1973) phosphorus by vanadomolybdo phosphoric acid and yellow colour method (Olsen *et al.,* 1956) and potassium was estimated by Flame photometry method (Jackson, 1973). The nutrient uptake was computed by multiplying the respective grain/straw yield with nutrient contents and expressed as kg/ha. The nutrient uptake was calculated by using the following formula:

**Nutrient uptake (kg ha$^{-1}$) = {Nutrient content (per cent) x Yield (kg/ha)} /100**

System productivity in terms of maize equivalent yield (MEY) was calculated by multiplying the economic yield of wheat with price per tonnage of wheat and divided by price per tonnage of maize in the local market. System benefit: cost ratio was also calculated as the gross income divided by the total cost of cultivation of maize–wheat cropping system (Mehmood *et al*., 2011). The analysis of variance (ANOVA) was done in randomized block design for various observations. The significance of treatment differences was tested by F (Variance ratio) test. Critical difference (CD) at 5 per cent level of significance (P=0.05) was worked out for comparison and statistical interpretation of treatments as per Gomez and Gomez (1988).

## Results and Discussion

### *Plant height and girth*

In *kharif*, plant height of maize at 60 DAS (days after sowing) increased in all the imposed treatments compared with farmers' practice (Table 1). Maximum increase of 36.47 per cent in plant height was observed with the application of conventional tillage + 100% RDF treatment followed by 34.70 per cent increase in treatment T9 (reduced tillage + 100% RDF), 33.81 per cent in $T_6$ (reduced tillage + 75% RDF + 5 t/ha forest manure), than that in control. All these treatment were at par to each other and significantly better to other set of practices and least height registered with farmer practice. At 90 DAS, plant height also increased in all the treatments than that in control. The height of maize plant was maximum to be 187.25 cm in zero tillage followed by 100% RDF treatment and was to the magnitude of 55.11 cm, 50.1 cm, 47.76 cm, and 47.08 cm higher in $T_8$, $T_6$, $T_{10}$ and $T_7$ treatments, respectively, over $T_1$ treatment. These treatments were at par with each other and significantly superior to rest of the treatments.

**Table 1:** Effect of different treatments on plant height of maize at 60 and 90 days after sowing (DAS) (pooled data of two years).

| Treatments | 60 DAS | | 90 DAS | |
|---|---|---|---|---|
| | Plant height (cm) | % increase over $T_1$ | Plant height (cm) | % increase over $T_1$ |
| $T_1$: Control | 74.25 | - | 130.25 | |
| $T_2$: Zero tillage | 76.84 | 3.48 | 135.26 | 3.84 |
| $T_3$: Reduced tillage | 77.38 | 4.15 | 133.33 | 2.36 |
| $T_4$: Conventional tillage | 83.65 | 12.65 | 149.87 | 15.06 |
| $T_5$: Zero tillage + 75% RDF + 5 t/ha forest manure. | 98.36 | 32.47 | 154.32 | 18.47 |
| $T_6$: Reduced tillage + 75% RDF + 5 t/ha forest manure | 99.36 | 33.81 | 180.35 | 38.46 |
| $T_7$: Conventional tillage + 75% RDF + 5 t/ha forest manure | 95.33 | 28.39 | 177.33 | 36.14 |
| $T_8$: Zero tillage + 100% RDF | 93.69 | 26.18 | 187.25 | 43.76 |
| $T_9$: Reduced tillage + 100% RDF | 100.02 | 34.70 | 185.36 | 42.34 |
| $T_{10}$: Conventional tillage + 100% RDF | 101.33 | 36.47 | 178.01 | 36.66 |
| SEm± | 2.69 | | 3.21 | |
| CD (5%) | 9.32 | | 10.36 | |

Plant girth both at 60 and 90 DAS was higher in imposed treatments with a maximum of 115.69 per cent in reduced tillage + 75% RDF + 5 t/ha forest manure treatment ($T_6$), 104.22 per cent in $T_5$ treatment, 103.82 per cent in $T_8$ and 96.30 per cent in $T_{10}$ at 60 DAS compared with control (Table 2). All these treatments were at par with each other. Maximum increase in girth to the magnitude of 1.77 cm was found in reduced tillage + 75% RDF + 5 t/ha forest manure treatments, respectively, over the control at 90 DAS (Table 2). Maximum plant girth was registered with the reduced tillage + 75% RDF + 5 t/ha forest manure, and statistically better to rest of the treatment combination at 90 DAS. The increase in plant height and girth may be due to increased moisture storage and better uptake of nutrients supplied for normal growth of plants.

**Table 2:** Effect of different treatments on plant girth of maize at 60 and 90 days after sowing (DAS) (pooled data of two years).

| Treatments | 60 DAS | | 90 DAS | |
|---|---|---|---|---|
| | Plant girth (cm) | % increase over $T_1$ | Plant girth (cm) | % increase over $T_1$ |
| $T_1$: Control | 0.75 | - | 1.05 | |
| $T_2$: Zero tillage | 0.96 | 27.70 | 1.22 | 20.59 |
| $T_3$: Reduced Tillage | 1.13 | 49.86 | 1.34 | 34.72 |
| $T_4$: Conventional tillage | 1.35 | 78.62 | 1.44 | 44.67 |
| $T_5$: Zero tillage + 75% RDF + 5 t/ha forest manure. | 1.54 | 104.22 | 1.61 | 59.30 |
| $T_6$: Reduced Tillage + 75% RDF + 5 t/ha forest manure | 1.63 | 115.69 | 1.77 | 76.41 |
| $T_7$: Conventional tillage + 75% RDF + 5 t/ha forest manure | 1.40 | 85.35 | 1.52 | 50.44 |
| $T_8$: Zero tillage + 100% RDF | 1.54 | 103.82 | 1.60 | 64.17 |
| $T_9$: Reduced tillage + 100% RDF | 1.35 | 78.10 | 1.45 | 44.87 |
| $T_{10}$: Conventional tillage + 100% RDF | 1.48 | 96.30 | 1.55 | 55.02 |
| SEm± | 0.08 | | 0.04 | |
| CD (5%) | 0.21 | | 0.12 | |

### *Grain and straw yield*

An increase in grain and straw yield of maize was observed with the application of different tillage and nutrient management treatments over the farmers' practice. There appeared to be 71.47 per cent increase in grain yield of maize in $T_9$ (reduced tillage + 100% RDF), 67.86 per cent with the application of conventional tillage + 75% RDF + 5 t/ha forest manure, and 63.50 per cent with application of conventional tillage +100% RDF and 62.38 (reduced tillage + 75% RDF + 5 t/ha forest manure) as compared to control (Table 3). All these treatments were at par to each other and significantly better to rest of the treatments. Application of forest manure not only known to efficiently conserve the soil moisture and better availability of nutrients but also improved the soil physical properties. Such an increase in maize grain yield through tillage operation and nutrient management practices has also been observed by Gaur, 2002. Kumar and Thakur (2004) also observed significant increase in grain yield of maize with the application of RDF along with 10 t FYM $ha^{-1}$ in the rain-fed mid-hill region. This increase in grain yield may be attributed to application of nutrients through inorganic and organic sources and the more availability and absorption of nutrients which caused cell elongation, root development and ultimately increased growth and yield of crop (Patil and Sheelavantar, 2000). Also, the tillage practice help to conservation of moisture has been known to help in photosynthesis, fertilization of flowers, seed setting, and protein synthesis and nitrogen metabolism thus improving the crop yields (Sakthivel *et al*., 2003). More stover yield was obtained with the reduced tillage followed by full dose of RDF, and was at par with the conventional tillage + 100% RDF ($T_{10}$), zero tillage + 100% RDF ($T_8$), reduced tillage + 75% RDF + 5 t/ha forest manure ($T_6$) and significantly better to rest of the treatment practices.

**Table 3:** Effect of different treatments on grain and straw yield of maize (pooled data of two years).

| Treatments | Grain yield | | Straw yield | |
|---|---|---|---|---|
| | q ha$^{-1}$ | % increase over $T_1$ | q ha$^{-1}$ | % increase over $T_1$ |
| $T_1$: Control | 40.14 | | 201.63 | |
| $T_2$: Zero tillage | 47.13 | 17.41 | 226.77 | 12.46 |
| $T_3$: Reduced tillage | 52.07 | 29.72 | 241.04 | 19.54 |
| $T_4$: Conventional tillage | 50.26 | 25.21 | 231.29 | 14.71 |
| $T_5$: Zero tillage + 75% RDF + 5 t/ha forest manure. | 60.07 | 49.62 | 253.30 | 25.62 |
| $T_6$: Reduced tillage + 75% RDF + 5 t/ha forest manure | 65.18 | 62.38 | 268.62 | 33.22 |
| $T_7$: Conventional tillage + 75% RDF + 5 t/ha forest manure | 67.38 | 67.86 | 251.32 | 24.64 |
| $T_8$: Zero tillage + 100% RDF | 61.61 | 53.48 | 272.61 | 35.20 |
| $T_9$: Reduced tillage + 100% RDF | 68.83 | 71.47 | 286.69 | 42.18 |
| $T_{10}$: Conventional tillage + 100% RDF | 65.63 | 63.50 | 274.60 | 36.19 |
| SEm± | 1.97 | | 6.32 | |
| CD (5%) | 5.75 | | 19.07 | |

More grain and straw yield of wheat was observed with the different treatment measures over the control. The grain yield of wheat was higher by 35.01 per cent in reduced tillage followed by full dose of RDF, 34.14 per cent in reduced tillage + 75% RDF + 5 t/ha forest manure, 29.06 percent in conventional tillage + 100% RDF and about 28.53 per cent in zero tillage + 100% RDF treatment over the control (Table 4). All these treatments were at part to each other and significantly better to rest of the treatments combination. Application of 100% RDF and 75% RDF + 5 t/ha forest manure increased the grain yield of wheat by 35.01 and 34.14 per cent over the control. This might be due to addition of forest manure, which has supplied available nutrients to the plants provided favourable soil environment and increase water holding capacity of soil for longer time and increase the yield and nutrient uptake by wheat (Jaga and Upadhyay, 2013). Not only the grain yield but also the straw yield of wheat increased significantly to the tune of 64.72, 63.68 and 62.69 per cent with reduced tillage + 75% RDF + 5 t/ha forest manure, reduced tillage + 100% RDF, conventional tillage + 100% RDF, respectively, over the control. This was perhaps due to abundant supply of plant nutrients which increased the protoplasmic constituents and accelerated the process of cell division and elongation. This in turn increased the values of growth and yield contributing attributes which finally reflected in increased grain and straw yield of wheat (Auti *et al*., 1999). Amongst various treatment measures, more wheat stover yield was obtained with the reduced tillage + 75% RDF + 5 t/ha forest manure, and was at par with the reduced tillage + 100% RDF and conventional tillage + 100% RDF.

**Table 4:** Effect of different treatments on grain and straw yield of wheat (pooled data of two years).

| Treatments | Grain yield | | Straw yield | |
|---|---|---|---|---|
| | q ha$^{-1}$ | % increase over $T_1$ | q ha$^{-1}$ | % increase over $T_1$ |
| $T_1$: Control | 24.36 | - | 35.63 | |
| $T_2$: Zero tillage | 28.25 | 15.96 | 46.32 | 30.01 |
| $T_3$: Reduced Tillage | 29.25 | 20.07 | 50.25 | 41.03 |
| $T_4$: Conventional tillage | 28.02 | 15.02 | 47.35 | 32.83 |
| $T_5$: Zero tillage + 75% RDF + 5 t/ha forest manure. | 29.36 | 20.52 | 51.01 | 43.17 |
| $T_6$: Reduced tillage + 75% RDF + 5 t/ha forest manure | 32.69 | 34.14 | 58.69 | 64.72 |
| $T_7$: Conventional tillage+ 75% RDF + 5 t/ha forest manure | 30.02 | 28.57 | 52.22 | 46.59 |
| $T_8$: Zero tillage + 100% RDF | 31.32 | 28.53 | 51.00 | 43.11 |
| $T_9$: Reduced tillage + 100% RDF | 32.89 | 35.01 | 58.32 | 63.68 |
| $T_{10}$: Conventional tillage+100% RDF | 31.44 | 29.06 | 57.97 | 62.69 |
| SEm± | 0.59 | | 0.87 | |
| CD (5%) | 1.69 | | 2.65 | |

Tillage and nutrient treatment combinations positively influenced the total productivity of maize-wheat cropping system. On an average, the yield of the system in terms of MEY increased by 14.3 q ha$^{-1}$ productivity of treatments was increased by 51.47% over control. The maximum system productivity (MEY 42.08 q ha$^{-1}$) was recorded with the use reduced tillage + 75% RDF + 5 t/ha forest manure, and was at par with reduced tillage + 100% RDF (Table 6). On the other hand, the significant difference was also recorded among the full inorganic fertilizers treatments for maize equivalent yield of the system. The system productivity in terms of MEY of maize - wheat cropping system varied significantly with different tillage and nutrient management treatments.

### Nutrient uptake

Fertilization of maize with application of nutrients through organic and/or inorganic sources significantly enhanced N, P and K uptake by the crop. The mean uptake of N by maize, wheat and system was increased by 83.38, 67.65 and 79.38 %, respectively with treatment combinations over control. Amongst various treatment measures maximum uptake of nitrogen by the sytem was observed with the reduced tillage + 100% RDF and was followed by conventional tillage + 100% RDF. Both of these treatments were at par to each other, and significantly superior to rest of the treatments combination. This might be due to higher availability of plant nutrients with fertilization, which resulted in enhanced nutrient content in plant tissues and more biomass production at higher total fertilizer application. Further, observation revealed that, the uptake of N by maize was significantly different among the organic sources of nutrients tried. Higher uptake of N by maize might be due to combined release of nutrient by forest manure decomposition might have led to enhanced mineralization of soil N (priming effect), which in association with spared soil N (Munda *et al*., 2011). The P uptake by maize and wheat was significantly higher with fertilization over absolute farmer practice (Table 5). The mean uptake of P by maize, wheat and system was increased by 130.50, 83.42 and 119.62 %, respectively with treatment combinations over control. Among the various organic treatments, significantly highest P uptake (42.21 kg ha$^{-1}$) by maize was recorded with reduced tillage + 100% RDF ($T_9$), and the system P uptake was significantly higher with reduced tillage + 100% RDF ($T_6$) followed by conventional tillage + 100% RDF ($T_{10}$). The greater P uptake was probably ascribed to mobilization of accessible soil P from deeper layers (Gangaiah *et al.,* 2012). Among the inorganic treatments, the P uptake was progressively increased with the increase of total fertilizer application, maximum being at 100% RDF in the system. The average K uptake by the maize, wheat and the system was increased by 114.90, 84.96 and 111.19 %, respectively with fertilization compared to usual control (Table 6). Significantly higher K uptake by system was registered with the reduced tillage + 100% RDF ($T_9$), and was significantly better to other set of treatments. However, application of different levels of inorganic fertilizer to maize and wheat had significant variations in K uptake by maize and wheat. The better growth and yield of maize and wheat led to higher K uptake.

**Table 5:** Effect of different treatments on nutrient uptake pattern of maize-wheat cropping system (pooled data of two years).

| Treatments | N uptake (kg ha$^{-1}$) | | | P uptake (kg ha$^{-1}$) | | | K uptake (kg ha$^{-1}$) | | | Total nutrient uptake (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maize | Wheat | System | Maize | Wheat | System | Maize | Wheat | System | Maize | Wheat | System |
| $T_1$: Control | 46.80 | 18.44 | 65.24 | 24.92 | 10.10 | 35.02 | 74.02 | 28.86 | 102.88 | 145.74 | 57.4 | 203.14 |
| $T_2$: Zero tillage | 52.44 | 21.01 | 73.45 | 25.46 | 13.31 | 38.77 | 78.08 | 43.12 | 121.29 | 155.98 | 77.44 | 233.42 |
| $T_3$: Reduced tillage | 51.52 | 25.54 | 77.06 | 26.13 | 13.26 | 39.39 | 76.76 | 40.35 | 117.11 | 154.41 | 79.15 | 233.56 |
| $T_4$: Conventional tillage | 48.63 | 22.77 | 71.43 | 25.96 | 12.91 | 38.87 | 75.85 | 39.55 | 115.45 | 150.44 | 75.23 | 225.67 |
| $T_5$: Zero tillage + 75% RDF + 5 t/ha forest manure. | 61.31 | 25.89 | 87.24 | 27.77 | 13.58 | 41.35 | 86.23 | 42.07 | 128.32 | 175.31 | 81.54 | 256.85 |
| $T_6$: Reduced tillage + 75% RDF + 5 t/ha forest manure | 63.34 | 28.14 | 91.48 | 28.44 | 18.35 | 46.79 | 87.91 | 47.33 | 135.24 | 179.69 | 93.82 | 273.51 |
| $T_7$: Conventional tillage + 75% RDF + 5 t/ha forest manure | 57.39 | 27.32 | 84.71 | 28.98 | 15.68 | 44.66 | 85.33 | 40.12 | 125.45 | 171.7 | 83.12 | 254.82 |
| $T_8$: Zero tillage + 100% RDF | 56.33 | 35.03 | 91.36 | 34.81 | 14.01 | 48.82 | 89.05 | 40.43 | 129.48 | 179.97 | 92.84 | 272.81 |
| $T_9$: Reduced tillage + 100% RDF | 69.11 | 38.08 | 107.19 | 42.21 | 19.74 | 61.95 | 93.85 | 49.56 | 143.41 | 205.17 | 107.38 | 312.55 |
| $T_{10}$: Conventional tillage + 100% RDF | 67.75 | 36.37 | 104.12 | 40.41 | 14.96 | 55.37 | 83.23 | 41.51 | 124.74 | 191.61 | 89.47 | 281.08 |
| SEm± | 1.81 | 1.54 | 3.21 | 0.68 | 0.87 | 1.23 | 2.98 | 2.32 | 2.65 | 4.36 | 2.88 | 4.98 |
| CD (5%) | 5.73 | 4.99 | 8.61 | 1.97 | 2.66 | 4.17 | 9.32 | 7.02 | 7.40 | 13.25 | 7.89 | 15.35 |

### Economics

The system based inorganic nutrient management treatments along with reduced tillage ($T_9$) practice registered higher gross return (Rs $ha^{-1}$ 50.82 $x10^3$), net returns (Rs $ha^{-1}$ 22.41 $x10^3$), and benefit: cost ratio of 1.78 compared to Rs $ha^{-1}$ 25.44 $x10^3$, Rs $ha^{-1}$ 7.54 $x10^3$ and 1.42, respectively in control (Table 6). Amongst integrated application of nutrient with tillage practices, the highest net return (Rs $ha^{-1}$ 19.19 $x10^3$) as well as benefit: cost ratio (1.75) was registered with reduced tillage followed by 75%RDF and 5 t/ha forest manure, and was followed by zero tillage + 75%RDF + 5 t/ha forest manure ($T_5$) with B: C ratio (1.70), which may be due to higher productivity of crops. The highest net return found under maize based crop sequence confirms the finding of Tetarwal *et al*., (2011).

**Table 6:** Effect of different treatments on system productivity and economics of maize -wheat cropping system (pooled data of two years).

| Treatments | System productivity (q $ha^{-1}$) | Gross return (Rs $ha^{-1}x10^3$) | | | Net return (Rs $ha^{-1}x10^3$) | | | Benefit: cost ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Maize | Wheat | System | Maize | Wheat | System | Maize | Wheat | System |
| $T_1$: Control | 27.78 | 15.06 | 10.38 | 25.44 | 5.73 | 1.81 | 7.54 | 1.61 | 1.21 | 1.42 |
| $T_2$: Zero tillage | 34.55 | 16.87 | 15.76 | 32.63 | 6.62 | 6.1 | 12.72 | 1.64 | 1.63 | 1.63 |
| $T_3$: Reduced tillage | 32.85 | 16.72 | 17.77 | 34.49 | 5.39 | 7.41 | 12.8 | 1.47 | 1.71 | 1.59 |
| $T_4$: Conventional tillage | 35.74 | 15.73 | 16.98 | 32.71 | 3.73 | 6.01 | 9.74 | 1.30 | 1.54 | 1.42 |
| $T_5$: Zero tillage + 75%RDF + 5 t/ha forest manure. | 40.25 | 22.46 | 17.95 | 40.41 | 10.13 | 6.59 | 16.72 | 1.82 | 1.58 | 1.70 |
| $T_6$: Reduced tillage + 75%RDF + 5 t/ha forest manure | 42.08 | 23.41 | 21.08 | 44.48 | 10.42 | 8.77 | 19.19 | 1.80 | 1.71 | 1.75 |
| $T_7$: Conventional tillage + 75%RDF + 5 t/ha forest manure | 39.25 | 21.08 | 20.44 | 41.52 | 6.13 | 7.53 | 13.63 | 1.40 | 1.58 | 1.48 |
| $T_8$: Zero tillage + 100%RDF | 36.10 | 26.17 | 21.08 | 47.25 | 12.57 | 7.86 | 20.43 | 1.92 | 1.59 | 1.76 |
| $T_9$: Reduced tillage + 100%RDF | 41.05 | 27.11 | 23.71 | 50.82 | 13.06 | 9.35 | 22.41 | 1.92 | 1.65 | 1.78 |
| $T_{10}$: Conventional tillage +100%RDF | 39.13 | 20.21 | 22.90 | 43.11 | 4.58 | 7.02 | 11.6 | 1.29 | 1.44 | 1.36 |
| SEm± | 0.56 | | | | | | | | | |
| CD (5%) | 1.78 | | | | | | | | | |

RDF = Recommended doses of fertilizers.

## Conclusion

From the two years field experiment, it could be concluded that the application of reduced tillage + 100%RDF to maize and wheat found to be beneficial in terms of growth, productivity, nutrient uptake and economics under maize-wheat cropping system under mid hills (1250 m asl) in dry terraces of Darjeeling hill. However for long term sustainable production point of view reduced tillage followed by 75%RDF and 5 t/ha forest manure is to be more suitable option for growers. Application of forest manure has supplied available nutrients to the plants provided favourable soil environment and increase water holding capacity of soil for longer time, and this will help to increase the biomass output, economic yield and nutrient uptake by maize – wheat cropping system.

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**Source of support:** Nil
**Conflict of interest:** None Declared