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# Effect of long term zero tillage and different moisture regimes on NPK uptake by wheat in legume based cropping systems of north-western Indo-gangetic plains

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**Abstract**
A field experiment “Effect of long term zero tillage and different moisture regimes on NPK uptake by wheat in legume based cropping systems of north-western Indo-Gangetic Plains” was conducted during 2017-18 and 2018-19 on an on-going long term experiment on ‘Effect of varying moisture regimes in zero-till wheat succeeding mungbean and sorghum’ since 2006 at, CCS HAU, Hisar. The experiments consisted of two cropping systems (mungbean-wheat, MW and sorghum-wheat, SW), three tillage practices *viz*. CT-CT (conventional tillage in both *kharif* & *rabi* seasons), CT-ZT (conventional tillage in *kharif* & zero tillage in *rabi* seasons) and ZT-ZT (zero tillage in both *kharif* & *rabi* seasons); and three moisture regimes {IW/CPE = 0.60(M0.60), 0.75 (M0.75) and 0.90 (M0.90)}. The adoption of ZT-ZT practice increased uptake of nitrogen, phosphorus and potassium as compared to CT-ZT and CT-CT practices in all the moisture regimes under mungbean-wheat and sorghum-wheat cropping systems. The uptake of nitrogen was significantly higher in mungbean-wheat cropping system (41.83 and 57.21%) as compared to sorghum-wheat cropping system by grain and straw, respectively. It was significantly highest in ZT-ZT (109.44 and 99.46; 156.91 and 117.34%) as compared to CT-CT over all the moisture regimes under mungbean-wheat and sorghum-wheat cropping systems by grain and straw, respectively. In present study, uptake of nitrogen was significantly highest at M0.90 (36.79 and 17.84; and 49.68 and 24.43%) as compared to M0.60 over all the tillage practices in mungbean-wheat and sorghum-wheat cropping systems by grain and straw, respectively. The similar trends were observed for uptake of phosphorus and potassium by the wheat grain and straw. Therefore long term zero tillage with inclusion of legumes can be a promising alternative to sustainably increase uptake of nutrients in soil for cereal-cereal cropping systems which ultimately plays a pivotal role to sustain the crop productivity and optimum ecosystem functioning with improving soil health.

**Keywords:** Zero tillage, moisture regimes, legumes, soil health, sustainability, nutrient uptake

## Introduction
Due to conventional production practises, the sustainability of cereal-cereal cultivation systems in the IGP of India is at risk. In the beginning zero tillage practice was aimed to conserve soil, water, to reduce cost of production (Holland 2004). Beyond this, the practice has multiple benefits in increasing the overall system performance (Kakraliya *et al*. 2018) [19]. In recent years, water, energy and labour scarcity, the increasing production costs, decreasing farm profitability and variability caused by climate change are major challenges facing farmers in India's Indo-Gangetic Plains (IGP). Wheat is India's second most important cereal crop after rice, occupying an area of 31.2 million ha and producing 95.8 million tonnes. For better crop production, the common perception among farmers is to plough the soil 2-3 times after harvesting the rainy season crops. This has, however, contributed to the growth of hard-pan and low efficiency of input use (Das *et al*. 2014) [6]. Therefore, conventional production practises need to be enhanced or replaced with resource-conserving technologies (RCTs) by repeated ploughing adopted in wheat under the rice-wheat or maize-wheat cropping system to adapt to evolving climate changes and to increase productivity and farm profitability and soil health on a sustainable basis (Ladha *et al*. 2014) [22].

It's necessary to increase crop production on a sustainable basis while keeping resources like the environment and our resources for food sources. In India, the cradle of the Green Revolution, the Indo-Gangetic Plains (IGP) covers about 20% and 27% of the total geographical and net cultivated area, respectively, and produces about half of the food consumed in the country (Dhillon *et al*., 2010, Das *et al*., 2018) [9]. By 2050, the world's population will be over 9 billion and 37% will live in China and India, requiring an expected 59% to 98% increase in food demand, putting more pressure on natural resources. India will have to double its cereal production to feed the 1.6 billion people of India by 2050 (Swaminathan and Bhavani, 2013) [30]. The challenge is to reach this aim with less resources and with a lower environmental footprint while buffering the risks of climate variability to ensure long-term sustainability. Over the next 50 years, five of the top ten issues facing humanity (i.e. food, electricity, water, the atmosphere and poverty) are directly linked to soil health. The growing concern for food security by improved soil management practises therefore calls for the adoption of conservation agriculture. Conservation agriculture is a resource-saving system for agricultural crop production that, in this era of climate change, aims to offer equal benefits along with high and sustainable levels of production while at the same time protecting the environment (FAO, 2010) [14]. Several studies have shown that we can increase the nutrient uptake by crops by introducing zero tillage systems (Powlson *et al*. 2012) [26]. Zero tillage method has major effect on nutrient availability to the crops and uptake by the plants. In zero tillage, nutrients near the soil surface increased and hence uptake by plants also increased (Bhatt *et al*., 2016) [2]. In the literature, there's far less attention given to the effect of tillage on plant nutrient uptake as compared to other properties of soil. Tillage increases the decomposition of crop residues because it facilitates nutrient supply and enables closer interaction between plant tissue and soil aggregate surfaces, the primary biome of soil microbes (Bronick and Lal 2005) [3]. In addition, avoiding soil disturbance in zero tillage protect the soils and improve the preservation of carbon, thereby increasing availability and uptake of essential nutrients in the soil (Corbeels *et al*. 2006) [5]. Sustainable intensification of cereal (rice/maize/pearlmillet) systems focused on conservation agriculture (CA) integrated with mungbean enhanced soil organic carbon and chemical properties (Choudhary *et al*., 2018) [4]. Legumes with their inherent characteristics such as leaf dropping, deep root, biological N fixation, and greater root exudate release enhance soil health (Hazra *et al*., 2018; Kakraliya *et al*. 2018a) [16, 18]. In wheat after mungbean, the enhanced carbon and other nutrient concentration improve the soil's overall consistency (Singh *et al*. 2015). The inclusion of legumes in cereal-cereal rotation shifts the balance of nutrient input-output, nutrient and carbon input through non-harvested crop residues (root carbon) that are likely to impact long-term productivity (Hazra *et al*., 2014) [17]. The use of legume crops and zero tillage systems has been shown to greatly reduce the risk of soil erosion (Lentz and Bjorneberg, 2003) [23]. Good soil health plays a pivotal role to sustain the crop productivity and optimum ecosystem functioning. Improved soil aggregation and higher soil organic carbon (SOC) stock are the essential components of good soil health (Denef *et al*., 2001) [10]. In fact, land use pattern and crop management practices have a differential influence on soil carbon and aggregate dynamics (Pinheiro *et al*., 2004) [25]. The rate of N and P uptake by wheat, sown after pearl millet was significantly at par to each other and significantly higher than that of pearl millet, sown after cowpea and cluster bean (Singh *et al*., 2003) [28]. The N uptake was higher by 16.7 and 13.1 percent and P uptake by 22.2 and 16.5 percent when cowpea and cluster bean were grown after wheat, respectively, compared to pearl millet. In the research conducted by Balyan (1997) [1], wheat grown after legume crop either alone or as an intercrop during *kharif* was observed to have higher N uptake than wheat grown after pearl mill*et al*one. Irrigation scheduling based on IW/CPE improved nitrogen absorption by grains. According to Singh and Singh (2001) [29], the higher content of nitrogen in the treatment resulted in lower protein. The amount of the nutrient absorption by crops increased with the rise in the irrigations (Dhindwal *et al*., 1993) [12]. Therefore, location–specific management practices are required in tillage and residue management practicessuitable to varying soils, crops, and climatic conditions.

Our study goal was to research how nutrient uptake in wheat is affected by long term zero tillage and different moisture regimes in cereal-cereal based cropping systems of north-western Indo-Gangetic Plains. In evaluating its suitability for crop production, the properties of a soil play a significant role. Properties of soil including support strength, soil air space or root penetration, microbial properties, nutrient availability, nutrient uptake and water use efficiency are all closely connected with each other. There is a lot of literature available on the impact of zero tillage practises on soil chemical properties but there is little knowledge on the combined effect of zero tillage adoption and the introduction of legumes into the cropping system and moisture regimes on chemical properties of soil in various cropping systems. It was hypothesised that, for a few uninterrupted years, the adoption of zero tillage in the agricultural production system in general and in wheat, particularly with different crop rotations, might significantly improve the soil macro- and micronutrient, eventually affecting sustainability of the system. The present investigation was therefore conducted to tackle this issue.

## Material and Methods

### Study site characteristics

The present investigation was carried out at an on-going long-term experiment at Soil Research Farm, Department of Soil Science, CCS HAU, Hisar. The coordinates of the experimental site is $29.10^0$N, $75.46^0$E and at an altitude of 215.2 meters above mean sea level. The experimental soil was sandy loam (71.5% sand, 9.3% silt and 19.2% clay) and classified as Typic Haplustepts. The experimental soil was slightly alkaline, low in organic carbon content, low in available nitrogen, medium in available phosphorus and high in available potassium (Kumar, 2008) [21]. The experimental site has a semi-arid climate with hot and dry summer and extremely cold winter. The mean monthly maximum and minimum temperature show a wide range of fluctuations during summer as well as winter seasons. The mean maximum and minimum temperature was 39.0 °C in May, 2018 and 12.4 °C in January, 2018 and 42.2 °C in May 2019 and 13.0 °C in February, 2019, respectively. Total rainfall received during study period was 29.9 mm and 44.1 mm from November, 2017 to April, 2018 and November, 2018 to April, 2019, respectively.

### Treatments and experimental design

The experiment was carried out with two main-plot treatments, *viz*. (i) Mungbean-wheat and, (ii) Sorghum-wheat cropping systems and with three sub-plot treatments *viz*. (i) Conventional tillage in both *kharif* & *rabi* seasons, (ii) conventional tillage in *kharif* & zero tillage in *rabi* seasons and, (iii) zero tillage in both *kharif* & *rabi* along with three sub-sub-plot treatments of soil moisture regimes *viz*, IW/CPE of 0.60, 0.75 & 0.90. The experimental design was split-split-plot and replicated thrice in CT-CT plots, the fields were ploughed during both *kharif* and *rabi* seasons. In CT-ZT plots, the fields were ploughed during *kharif* only and no tillage was done during *rabi* season. In ZT- ZT plots, no tillage was done during both the *kharif* and *rabi* seasons. In CT practice, the residues of the preceding crop i.e. wheat/mungbean/sorghum were manually removed, and seed bed tilth for wheat/mungbean/sorghum was prepared by two disc to about 10 cm followed by planking (leveling with a 3 m long wooden block) of the fields. In plots with ZT practice, the crop was harvested and no tillage was done for preparation of seed bed for the succeeding crop, and crop was sown with zero till machine. The wheat (WH 1105) was sown on November 23, 2017 during 2017-18 and on November 25, 2018 during 2018-19. The wheat was harvested on 25 April 2018 during 2017-18 and on 24 April 2019 during 2018-19.

**Measurement for uptake of nutrients by the Crop**

The uptake of macro nutrients (N, P, K) by the grain and straw of the wheat crop for both the years i.e. 2017-18 and 2018-19 (data has been showed as pooled of both years in results) was obtained by multiplying the nutrient concentration in grain and straw with their respective yield using the following formula:

Nutrient uptake (kg ha-1) = Nutrient concentration in grain/straw (%) × grain/straw yield (kg ha-1)/100

**Statistical analysis**

Data were exposed to analysis of variance for split-split plot design to know the significant difference among the treatments. Least significant difference values were used to compare the treatment means at p= 0.05 using OPSTAT software (Sheoran *et al*., 1998) [27].

## Results and Discussion

### Nitrogen uptake

Uptake of nitrogen by wheat grain and straw affected by long term zero tillage in wheat under different moisture regimes in mungbean-wheat and sorghum-wheat cropping systems are presented in Table 1. The continuous adoption of ZT-ZT practice for twelve years increased uptake of nitrogen as compared to CT-ZT and CT-CT practices in all the moisture regimes under mungbean-wheat and sorghum-wheat cropping systems. The uptake of nitrogen was significantly higher in mungbean-wheat cropping system (41.83 and 57.21%) as compared to sorghum-wheat cropping system by grain and straw, respectively. It was significantly higher in ZT-ZT (109.44 and 99.46; 156.91 and 117.34%) and CT-ZT (64.64 and 47.24 and 45.18 and 24.43%) as compared to CT-CT over all the moisture regimes under mungbean-wheat and sorghum-wheat cropping systems by grain and straw, respectively. In present study, uptake of nitrogen was significantly higher at $M_{0.90}$ (36.79 and 17.84; and 49.68 and 24.43%) and $M_{0.75}$ (15.66 and 5.84; and 22.01 and 12.00%) as compared to $M_{0.60}$ over all the tillage practices in mungbean-wheat and sorghum-wheat cropping systems by grain and straw, respectively. The uptake of nitrogen by grain was higher as compared to the wheat straw. The interactive effects of cropping system and tillage; cropping system and moisture regimes; tillage and moisture regimes; and cropping system, tillage and moisture regimes was observed significant for nitrogen uptake by wheat grain and straw. This higher uptake of nitrogen by wheat grain and straw occurred due to more availability of nutrients, as a result grain and straw yield was higher and consequently nitrogen uptake was increased under zero tillage. More crop residues under zero tillage caused high soil organic matter and favourable soil environmental conditions. Higher moisture regimes and legume based cropping system had more organic matter; therefore, more nitrogen uptake was in case of mungbean-wheat cropping system as compared to sorghum-wheat cropping system. These results are in accord with the findings of Gupta and Seth (2007) [15]. More organic residues on the surface caused more root growth and resulted in increased uptake of nutrients by crops (Thiagalingam *et al*., 1991) [31]. These results are in agreement with the results of Dwivedi and Thakur (2000) [13]. The nutrient uptake by crop increased with the increase moisture regimes mainly owing to higher yield (Dhindwal *et al*., 1993) [12]. The increase in nitrogen uptake was more due to higher yield under zero tillage and in mungbean-wheat system at higher moisture regimes and the results is consistent with the results of Singh *et al.* (2003) [28] and Kumar *et al.* (2000) [20].

**Table 1:** Effect of long-term zero tillage on nitrogen uptake (kg $ha^{-1}$) by grain and straw at different moisture regimes under mungbean-wheat and sorghum-wheat cropping systems

| Moisture Regime (IW/CPE) | Sorghum-Wheat | | | Mean | Mungbean-Wheat | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | CT-CT | CT-ZT | ZT-ZT | | CT-CT | CT-ZT | ZT-ZT | |
| **Grain** | | | | | | | | |
| $M_{0.60}$ | 100.92 | 164.68 | 235.28 | 166.96 | 140.17 | 235.02 | 277.26 | 217.48 |
| $M_{0.75}$ | 111.07 | 177.82 | 241.27 | 176.72 | 164.03 | 257.64 | 332.93 | 251.53 |
| $M_{0.90}$ | 150.97 | 191.91 | 247.39 | 196.76 | 180.86 | 305.92 | 405.70 | 297.50 |
| Mean | 120.98 | 178.14 | 241.31 | 180.15 | 161.69 | 266.19 | 338.63 | 255.50 |
| CD (p= 0.05) | A= 9.51, B =2.35, A x B =3.32, C =3.79, A x C= 5.36, B x C =6.56, A x B x C=9.28 | | | | | | | |
| **Straw** | | | | | | | | |
| $M_{0.60}$ | 19.78 | 24.75 | 42.98 | 29.17 | 25.62 | 39.64 | 59.26 | 41.51 |
| $M_{0.75}$ | 21.81 | 29.38 | 46.82 | 32.67 | 29.39 | 43.40 | 79.15 | 50.64 |
| $M_{0.90}$ | 24.00 | 32.13 | 52.76 | 36.30 | 37.18 | 50.79 | 98.41 | 62.13 |
| Mean | 21.86 | 28.75 | 47.52 | 32.71 | 30.73 | 44.61 | 78.94 | 51.43 |
| CD (p= 0.05) | A=2.26, B=0.99, A x B= 1.40, C=0.76, A x C= 1.07, B x C= 1.31, A x B x C=1.85 | | | | | | | |

CT = conventional tillage, ZT = zero tillage, $M_{0.60}$ = moisture regime at IW/CPE=0.60, $M_{0.75}$= moisture regime at IW/CPE= 0.75, $M_{0.90}$= moisture regime at IW/CPE=0.90; A= cropping factor, B= tillage factor, C= moisture regime factor

## Phosphorus uptake

The adoption of ZT-ZT practice increased uptake of phosphorus as compared to CT-ZT and CT-CT practices in all the moisture regimes under mungbean-wheat and sorghum-wheat cropping systems (Table 2). The uptake of phosphorus was significantly higher in mungbean-wheat cropping system (44.20 and 34.37%) as compared to sorghum-wheat cropping system by grain and straw, respectively. It was significantly higher in ZT-ZT (116.64 and 105.54; 81.72 and 58.21%) and CT-ZT (68.10 and 55.15 and 39.75 and 26.90%) as compared to CT-CT over all the moisture regimes under mungbean-wheat and sorghum-wheat cropping systems by grain and straw, respectively. In present study, uptake of phosphorus was significantly higher at $M_{0.90}$ (33.11 and 24.19; and 24.78 and 15.95%) and $M_{0.75}$ (19.73 and 8.59; and 9.46 and 6.16%) as compared to $M_{0.60}$ over all the tillage practices in mungbean-wheat and sorghum-wheat cropping systems by grain and straw, respectively. Uptake of phosphorus by grain was significantly higher as compared to straw of wheat. The interactive effects of cropping system and tillage; cropping system and moisture regimes; tillage and moisture regimes; and cropping system, tillage and moisture regimes were found significant for phosphorus uptake by grain but interactive effects of tillage and moisture regimes; and cropping system, tillage and moisture regimes were observed non-significant by straw in wheat. This higher uptake of phosphorus by wheat grain and straw occurred due to more availability of nutrients, as a result grain and straw yield was higher and consequently phosphorus uptake was increased under zero tillage. More crop residues under zero tillage caused high soil organic matter and favourable soil environmental conditions. Higher moisture regimes and legume based cropping system had more organic matter; therefore, more phosphorus uptake was in case of mungbean-wheat cropping system as compared to sorghum-wheat cropping system. These results are in accord with the findings of Mukherjee (2008) [24]. These results are in agreement with the results of Dwivedi and Thakur (2000) [13], and Das *et al*. (2001) [8]. The nutrient uptake by crop increased with the increase moisture regimes mainly owing to higher yield (Dhindwal *et al*., 1993) [12]. The increase in phosphorus uptake was more due to higher yield under zero tillage and in mungbean-wheat system at higher moisture regimes and these results is consistent with the results of Singh *et al*. (2003) [28].

**Table 2:** Effect of long-term zero tillage on phosphorus uptake (kg $ha^{-1}$) by grain and straw at different moisture regimes under mungbean-wheat and sorghum-wheat cropping systems

| Moisture Regime (IW/CPE) | Sorghum-Wheat | | | Mean | Mungbean-Wheat | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | CT-CT | CT-ZT | ZT-ZT | | CT-CT | CT-ZT | ZT-ZT | |
| **Grain** | | | | | | | | |
| $M_{0.60}$ | 8.81 | 14.90 | 20.75 | 14.82 | 12.60 | 21.20 | 26.65 | 20.15 |
| $M_{0.75}$ | 9.33 | 16.40 | 22.54 | 16.09 | 14.20 | 25.35 | 32.83 | 24.13 |
| $M_{0.90}$ | 14.25 | 17.66 | 23.29 | 18.40 | 17.20 | 27.42 | 35.85 | 26.82 |
| Mean | 10.80 | 16.32 | 22.19 | 16.44 | 14.67 | 24.66 | 31.78 | 23.70 |
| CD (p= 0.05) | A=1.17, B=0.50, A x B= 0.71, C=0.43, A x C= 0.61, B x C= 0.75, A x B x C=1.06 | | | | | | | |
| **Straw** | | | | | | | | |
| $M_{0.60}$ | 4.02 | 5.14 | 6.63 | 5.26 | 4.72 | 6.75 | 8.97 | 6.81 |
| $M_{0.75}$ | 4.24 | 5.61 | 6.91 | 5.59 | 5.29 | 7.33 | 9.76 | 7.46 |
| $M_{0.90}$ | 4.94 | 6.01 | 7.35 | 6.10 | 6.20 | 8.58 | 10.73 | 8.50 |
| Mean | 4.40 | 5.59 | 6.96 | 5.65 | 5.40 | 7.55 | 9.82 | 7.59 |
| CD (p= 0.05) | A=0.144, B=0.051, A x B= 0.072, C=0.118, A x C= 0.167, B x C= NS, A x B x C=NS | | | | | | | |

CT = conventional tillage, ZT = zero tillage, $M_{0.60}$ = moisture regime at IW/CPE=0.60, $M_{0.75}$= moisture regime at IW/CPE= 0.75, $M_{0.90}$= moisture regime at IW/CPE=0.90; A= cropping factor, B= tillage factor, C= moisture regime factor

## Potassium uptake

Uptake of potassium by wheat grain and straw as affected by long term zero tillage in wheat under different moisture regimes in mungbean-wheat and sorghum-wheat cropping systems are presented in Table 3. Uptake of potassium was significantly higher in mungbean-wheat cropping system (20.70 and 31.37%) as compared to sorghum-wheat cropping system by grain and straw, respectively. It was significantly higher in ZT-ZT (49.34 and 6.41; 66.79 and 26.91%) and CT-ZT (23.95 and 10.43 and 20.50 and 7.84%) as compared to CT-CT over all the moisture regimes under mungbean-wheat and sorghum-wheat cropping systems by grain and straw, respectively. In present study, uptake of potassium was significantly higher at $M_{0.90}$ (18.65 and 16.15; and 29.27 and 16.17%) and $M_{0.75}$ (10.58 and 7.75; and 7.54 and 4.59%) as compared to $M_{0.60}$ over all the tillage practices in mungbean-wheat and sorghum-wheat cropping systems by grain and straw, respectively. Uptake of potassium by grain was significantly lower as compared to straw of wheat. The interactive effects of cropping system and tillage; cropping system and moisture regimes; and cropping system were observed significant for potassium uptake by grain and straw but tillage and moisture regimes significantly affected the uptake of potassium by wheat straw not grain. This higher uptake of potassium by wheat grain and straw occurred due to more availability of nutrients, as a result grain and straw yield was higher and consequently potassium uptake was increased under zero tillage. More crop residues under zero tillage caused high soil organic matter and favourable soil environmental conditions. Higher moisture regimes and legume based cropping system had more organic matter; therefore more potassium uptake was in case of mungbean-wheat cropping system as compared to sorghum-wheat cropping system. These results are in accord with the findings of Gupta and Seth (2007) [15] and Mukherjee (2008) [24]. The nutrient uptake by crop increased with the increase moisture regimes mainly owing to higher yield (Dhindwal *et al.*, 1993) [12]. The increase in potassium uptake was more due to higher yield under zero tillage and in mungbean-wheat system at higher moisture regimes and these results is consistent with the results of Singh *et al*. (2003) [28].

**Table 3:** Effect of long-term zero tillage on potassium uptake (kg $ha^{-1}$) by grain and straw at different moisture regimes under mungbean-wheat and sorghum-wheat cropping systems

| Moisture Regime (IW/CPE) | Sorghum-Wheat | | | Mean | Mungbean-Wheat | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | CT-CT | CT-ZT | ZT-ZT | | CT-CT | CT-ZT | ZT-ZT | |
| **Grain** | | | | | | | | |
| $M_{0.60}$ | 17.14 | 19.33 | 25.10 | 20.52 | 19.63 | 24.68 | 28.80 | 24.37 |
| $M_{0.75}$ | 18.97 | 21.19 | 26.18 | 22.11 | 21.10 | 26.90 | 32.83 | 26.95 |
| $M_{0.90}$ | 21.60 | 23.20 | 26.71 | 23.84 | 23.75 | 28.33 | 34.66 | 28.91 |
| Mean | 19.23 | 21.24 | 25.99 | 22.16 | 21.49 | 26.64 | 32.10 | 26.74 |
| CD (p= 0.05) | A=1.08, B=0.58, A x B= 0.82,C=0.45, A x C= 0.63, B x C= NS, A x B x C=1.10 | | | | | | | |
| **Straw** | | | | | | | | |
| $M_{0.60}$ | 148.79 | 162.03 | 186.29 | 165.70 | 166.16 | 207.57 | 248.20 | 207.31 |
| $M_{0.75}$ | 157.35 | 171.79 | 190.78 | 173.31 | 176.80 | 216.67 | 275.37 | 222.95 |
| $M_{0.90}$ | 170.18 | 179.86 | 227.46 | 192.50 | 197.91 | 227.54 | 378.53 | 267.99 |
| Mean | 158.78 | 171.23 | 201.51 | 177.17 | 180.29 | 217.26 | 300.70 | 232.75 |
| CD (p= 0.05) | A=6.37, B=4.06, A x B= 5.75,C=4.15, A x C= 5.87, B x C= 7.19, A x B x C=10.16 | | | | | | | |

CT = conventional tillage, ZT = zero tillage, $M_{0.60}$ = moisture regime at IW/CPE=0.60, $M_{0.75}$= moisture regime at IW/CPE= 0.75, $M_{0.90}$= moisture regime at IW/CPE=0.90; A= cropping factor, B= tillage factor, C= moisture regime factor

## Conclusion

The results from the present investigation concluded that long term zero tillage practices had potential to enhance nutrient uptake in wheat under mungbean-wheat and sorghum-wheat cropping systems. The results also concluded that legume based cropping system is better as compared to non-legume based cropping system at different moisture regimes in arid and semi-arid climatic conditions in sandy loam soils. Adoption of long term zero tillage in wheat and inclusion of legumes in the cropping systems would be beneficial for improving the soil health on sustainable basis and consequently NPK uptake in wheat of north-western Indo-Gangetic Plains.

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