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# Effect of fertilizer placement for different tillage options on the growth and yield of wheat

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**Key words:** Tillage options, Wheat yield, RCT, Fertilizer placement

## Abstract

To enhance the improvement of wheat yield, a two years field experiment was conducted to find the effect of fertilizer placement with different tillage options. The experiment was laid out in a randomized complete block design with fifteen treatments: i) zero tillage plus fertilizer in between rows, ii) zero tillage plus fertilizer in seed line, iii) zero tillage plus fertilizer in broadcast, iv) strip tillage plus fertilizer in between rows, v) strip tillage plus fertilizer in seed line, vi) strip tillage plus fertilizer in broadcast, vii) bed planting plus fertilizer in between rows, viii) bed planting plus fertilizer in seed line, ix) bed planting plus fertilizer in broadcast, x) PTOS plus fertilizer in between rows, xi) PTOS plus fertilizer in seed line, xii) PTOS plus fertilizer in broadcast, xiii) conventional tillage plus fertilizer in between rows, xiv) conventional tillage plus fertilizer in seed line and xv) conventional tillage plus fertilizer in broadcast. Using above treatments, the grain yields were recorded as 4.22, 3.89, 3.55, 4.39, 4.19, 3.84, 4.16, 3.89, 3.62, 4.01, 3.85, 3.94, 3.94, 3.44, 3.34 t ha$^{-1}$ respectively for 2010-2011 and 3.63, 3.57, 3.50, 3.50, 3.73, 3.63, 4.60, 4.20, 4.47, 3.80, 3.57, 3.63, 4.20, 3.63, 3.53 t ha$^{-1}$ respectively for 2011-2012 years. The maximum yield was found for strip tillage plus fertilizer placement in between rows in 2010-2011 and bed planting plus fertilizer placement in between rows in 2011-2012 years showing the strategy might be a significant tool for getting higher yield of wheat.

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## Introduction

Resource conserving technologies (RCT) are being introduced among the farmers and the farmers show interest to grow crop with RCT because, it reduces cultivation cost, protects degrading soil and saves water without any yield sacrifice. Moreover, resource conserving technologies have been found to offer the opportunity to plant wheat timely. Due to scarcity and high cost of labor and for reducing cultivation cost, RCT is essential for farming regarding the cultivation of wheat and other crops. Zero-till, bed planting strip tillage and PTOS tillage options have been recognized as RCT. However, for getting expected crop yields with RCT, a full package of production technologies especially fertilizer management should be provided. Wheat (*Triticum aestivum*) belongs to family gramineae and is the major staple food crop of the world (Yongqing, 2005). It is believed that wheat originated in south western Asia from where it spreads to other parts of Asia, Europe, Africa and America (Bertholdsson, 2005). Wheat crop is grown in the temperate regions of the world, where the annual rain fall averages between 10 to 70 inches. High rainfall accompanied with high temperature has been found to be hostile for wheat, because these conditions favor the development of diseases. Water conservation research has focused on the effects of tillage systems, row spacing, seeding rate, rotation and variety on yields of wheat. Tillage influences on wheat yield can be modified by soil type, soil moisture at tillage and climate. Higher yields of wheat are possible by direct seeding into previous crop residue. Efficient use of water under this system may depend on how the crop responds to various residue management practices. Several lines of evidences reveal that residue remaining on the soil surface as a consequence of reduced or conservation tillage can produce substantial changes in soil temperatures. This type of tillage is thought to take care of the soil health, plant growth and the environment (Busari *et al*., 2015). Conservation tillage has also been shown to be involved in alterations of soil water content (Wilhelm *et al*., 1986), soil microbial populations (Doran, 1980), and soil chemical properties (Schomberg *et al*., 1994).

These properties may have a direct or indirect effect on the availability of P for wheat production. The previous studies reveal that the interaction between P placement and tillage system in wheat production is an essential approach for cultivation and development (Nazim *et al*., 2008). A progressive increase in grain yield of wheat with each increment of P application has been noted in their findings. Therefore, it is important to gain understanding of the relationship between rate and placement of fertilizer and tillage system.

Broadcasting fertilizer enhances losses of fertilizer and reduces fertilizer use efficiency in tillage options especially in zero-till and bed planting practices. Low grain yield could be occurred due to the inappropriate planting method, seed rate and crop management. On the other hand, it has been shown from the previous investigation that fertilizer placement increases fertilizer use efficiency than broadcast (Kapoor *et al.,* 2008). Moreover, the work on fertilizer management with resource conserving technologies is rare in Bangladesh. Therefore, the current investigation was undertaken to find out the best fertilizer management practice in RCT tillage options for the improvement of wheat cultivation and yield in Bangladesh.

## Materials and methods

*Location and climate*

A two years field experiment was conducted at the farm of Regional Wheat Research Centre, Shyampur (RWRC), Rajshahi, Bangladesh (24°3'N, 88°41E, 18 m above sea level) to find out the best fertilizer management in resource conserving technologies (RCT) tillage options for wheat production. The site has a subtropical climate and is located in Agro Ecological Zone 11 (High Ganges River Flood Plan) on flood-free high land, with course-textured, highly permeable soil. The area receives 1,257 mm mean annual rainfall, about 97% of which occurs from May to September. Total rainfall was highest during the mungbean season and lowest in the wheat season in all years.

*Field experiment design*

The experiment was laid out in a randomized complete block design with three replications. The treatments were: i) zero tillage plus fertilizer in between rows, ii) zero tillage plus fertilizer in seed line, iii) zero tillage plus fertilizer in broadcast, iv) strip tillage plus fertilizer in between rows, v) strip tillage plus fertilizer in seed line, vi) strip tillage plus fertilizer in broadcast, vii) bed planting plus fertilizer in between rows, viii) bed planting plus fertilizer in seed line, ix) bed planting plus fertilizer in broadcast, x) PTOS plus fertilizer in between rows, xi) PTOS plus fertilizer in seed line, xii) PTOS plus fertilizer in broadcast, xiii) conventional tillage plus fertilizer in between rows, xiv) conventional tillage plus fertilizer in seed line and xv) conventional tillage plus fertilizer in broadcast.

*Plant and soil analysis*

The wheat variety, Prodip was used in this study and was planted in the last week of November, 2010 and 2011 and harvested in the last week of March 2011 and 2012. One pre-irrigation was applied to bring optimum moisture for planting and germination. The recommended dose of fertilizers was used following the recommendation time application with the planting machine except urea. Soil analysis has been done by Kjeldahl titration method (Kjeldahl, 1883). Mineral nutrient was available from grain and straw for NPK with Olsen titration method (Olsen *et al.*, 1954). Crop management practices were followed as per recommendation of Wheat Research Centre for normal growth and development of the crop.

## Results

*Analysis of soil composition*

Before experimentation, initial soil sample was collected and analyzed to know the nutrient status of soil and the results were presented in Table 1 and 2.

**Table 1.** Fertility status of initial soil sample of the experimental site at RWRC, BARI, Shyampur, Rajshahi.

| Sample | pH | OM (%) | Total N (%) |
|---|---|---|---|
| Value | 7.8 | 0.94 | 0.05 |
| Critical level | - | - | 0.12 |
| Interpretation | Slightly alkaline | Very low | Very low |

The soil was slightly alkaline (7.8 pH) having low organic matter content (0.94%) and the total N content, 0.05%. Different elements were also analyzed from the soil where medium K level (0.21 Meq/100 g) was observed. P, S and Zn contents in soil were 10, 23.3 and 0.14 µg/g respectively. In addition, the boron content was found to be very low (0.27µg/g). The results regarding the soil composition and other parameters reveal that the overall soil fertility status was low. Therefore, fertilizer management may play the critical role in improving wheat cultivation and soil fertility.

**Table 2.** Elemental analysis of initial soil sample of the experimental site at RWRC, BARI, Shyampur, Rajshahi.

| Sample | K | P | S | Zn | B |
|---|---|---|---|---|---|
| | Meq/100g | | | µg/g | |
| Value | 0.21 | 10 | 23.3 | 0.14 | 0.27 |
| Critical level | 0.12 | 10 | 10.0 | 0.60 | 0.20 |
| Interpretation | Medium | Low | Opt. | Very low | Very low |

*Yield and yield components*

Fertilizer rates and its placement are important factors to be considered to produce maximum yield of crops. However, there are multiple factors that cause decision making on fertilizer application to be a complex process. For instance, the rates of fertilizer application, the source of the nutrient and the associated availability to the crop, the time of application, and where the nutrient is placed are important considerations in nutrient management decisions. As shown in Table 3, the number of spikes, the number of grains per spike and 1000-GWT were examined in response to fertilizer placement in different tillage options. The higher number of spikes in Zero $^x$ BR option was 264 meter$^{-2}$. In Strip $^x$ BR, the value was 282, in Bed $^x$ SL, the value was 279, in PTOS $^x$ SL, the value was 311 and in Conv $^x$ BR, the value was 247 meter$^{-2}$. The number of grains spikes$^{-1}$ was examined in different options of tillage similarly. In Zero $^x$ SL option, the higher number of grains was recorded as 45.3 spike$^{-1}$. In Strip $^x$ SL, the value was 47, in Bed $^x$ BR, the value was 46.3, in PTOS $^x$ SL, the value was 43.0 and in Conv $^x$ BR, the value was 47.6 spike$^{-1}$. The total grain weight (TGW) spike$^{-1}$ in different tillage options was also analyzed.

**Table 3.** Effect of fertilizer placement for different tillage options on mean wheat yield contributing characters in 2010-11 and 2011-12.

| Treatments | Spikes $m^{-2}$ | Grains $spike^{-1}$ | Grain wt. $spike^{-1}$ (g) |
|---|---|---|---|
| Zero x BR | 244 | 41.6 | 57.5 |
| Zero x SL | 231 | 45.3 | 56.0 |
| Zero x BC | 264 | 41.3 | 57.2 |
| Strip x BR | 282 | 42.3 | 56.7 |
| Strip x SL | 279 | 47.0 | 58.0 |
| Strip x BC | 254 | 41.0 | 58.2 |
| Bed x BR | 257 | 46.3 | 57.3 |
| Bed x SL | 279 | 45.6 | 55.2 |
| Bed x BC | 233 | 45.0 | 57.2 |
| PTOS x BR | 280 | 41.6 | 55.5 |
| PTOS x SL | 311 | 43.0 | 55.0 |
| PTOS x BC | 245 | 42.7 | 56.8 |
| Conv x BR | 247 | 47.6 | 54.8 |
| Conv x SL | 247 | 44.3 | 56.8 |
| Conv x BC | 243 | 43.3 | 54.2 |
| CV (%) | 12.12 | 5.94 | 2.82 |
| LSD (0.05) | NS | NS | NS |

**Table 4.** Effect of fertilizer placement for different tillage options on wheat yield in 2010-11 and 2011-12.

| **Treatments** | **Yield t $ha^{-1}$** | |
|---|---|---|
| | **2010-11** | **2011-12** |
| Zero x BR | 4.22 ab | 3.63bc |
| Zero x SL | 3.89 abc | 3.57c |
| Zero x BC | 3.55 bcd | 3.50 c |
| Strip x BR | 4.39 a | 3.50 c |
| Strip x SL | 4.19 ab | 3.73 bc |
| Strip x BC | 3.84 abc | 3.63 bc |
| Bed x BR | 4.16 ab | 4.60 a |
| Bed x SL | 3.89 abc | 4.20 abc |
| Bed x BC | 3.62 bcd | 4.47 ab |
| PTOS x BR | 4.01 ab | 3.80 abc |
| PTOS x SL | 3.85 abc | 3.57 c |
| PTOS x BC | 3.94 abc | 3.63 bc |
| Conv x BR | 3.94 abc | 4.20 abc |
| Conv x SL | 3.44 cd | 3.63 bc |
| Conv x BC | 3.34 d | 3.53 c |
| CV (%) | 9.67 | 10.54 |
| LSD (0.05) | 0.694 | 0.843 |

The higher TGW in Zero x BR, Strip x BC, Bed x BR, PTOS x BC and Conv x SL options were recorded as 57.5 g, 58.2 g, 57.3 g, 56.8 g and 56.8 g respectively. Although variations of different yielding characters in different tillage were observed however, none were significantly responsive to imposed treatments.

Table 4 shows that grain yield (t $ha^{-1}$) was markedly influenced by the treatments. Fertilizer placement in broadcast, in seed line and in between rows with strip tillage produced similar higher yields than other treatments. Yield was statistically identical in treatments with fertilizer in between rows in combination with bed planting, zero and strip tillage. Similar yield with different fertilizer placement methods was produced by using the PTOS option. The yield in zero tillage option did not differ with different fertilizer placement methods. However, each tillage option in combination with fertilizer placement in between rows produced numerically higher yield than other fertilizers placement treatments. Again, the yield was similar in different tillage options with the combination of same type of fertilizer placement method. The highest yield was obtained with the treatment of PTOS plus fertilizer placement in between rows and was significantly higher than conventional tillage plus fertilizer in broadcast and in seed line, bed planting plus fertilizer in broadcast and zero tillage plus fertilizers in broadcast and fertilizer in seed line. The lowest yield was found from conventional tillage with fertilizer placement in broadcast.

The results indicate that fertilizer placement in between rows with any tillage options performed better than other fertilizer placement methods. Although sometimes yield was not significantly higher however, the best combination was found for fertilizers placement in between rows with strip tillage.

Fertilizer management has been shown to be involved in inducing the growth of wheat as demonstrated in Table 5. The higher plant height was recorded in Strip x SL option (104.7 cm). Similar trends were found in Zero x SL treatment where the plant height was 104.7 cm. The satisfactory growth of wheat was also observed in other treatments.

**Table 5.** Effect of fertilize placement for different tillage options on mean growth parameters in 2010-2011 and 2011-12.

| Treatments | Number of tiller/hill | Plant height (cm) |
|---|---|---|
| Zero x BR | 4.2 | 103.0 |
| Zero x SL | 5.4 | 104.7 |
| Zero x BC | 5.8 | 93.0 |
| Strip x BR | 4.6 | 95.0 |
| Strip x SL | 6.0 | 104.7 |
| Strip x BC | 4.4 | 96.7 |
| Bed x BR | 6.4 | 94.7 |
| Bed x SL | 5.2 | 99.0 |
| Bed x BC | 5.2 | 95.0 |
| PTOS x BR | 5.2 | 92.7 |
| PTOS x SL | 5.0 | 96.3 |
| PTOS x BC | 4.0 | 98.3 |
| Conv x BR | 4.2 | 94.3 |
| Conv x SL | 5.0 | 97.3 |
| Conv x BC | 5.2 | 99.7 |
| CV (%) | 7.701 | 9.59 |
| $LSD_{0.05}$ | 0.30 | 0.415 |

**Discussion**

*Analysis of soil composition*

K, P and S are essential nutrients for the growth of wheat and other plants. Deficiency of these nutrients causes the severe impairment of plant production, also causes other pathogenic syndromes. Potassium is utilized by plants in the activation of enzymes and co-enzymes (specialized proteins serving as catalysts and co-factors), photosynthesis, protein formation, and sugar transport. Potassium deficiency does not immediately result in visible symptoms (hidden hunger). Initially, there is only a reduction in growth rate, with chlorosis and necrosis occurring in later stages. Foliar application of K at critical growth stages improved the drought tolerance of plants and improved the growth and yield components (Aown *et al.*, 2012).

Plants require P for the development of ATP (Energy), sugars and nucleic acids. Phosphorus deficiency symptoms are usually more noticeable in young plants, which have a greater relative demand for P than more mature plants. Cool soils during the early growing season may also be a factor causing P deficiency. Phosphorus deficient plants generally turn dark green (both leaves and stems) and appear stunted. Phosphorus is also essential for cellular respiration, metabolism of starch and fats which has been investigated by many researchers. Appropriate and balanced fertilization on wheat and rice not only causes yield enhancement but also has good impact on phosphorus uptake by these crop plants (Rehman *et al.*, 2006). Sulphur deficiency in crop plants has been recognized as a limiting factor not only for crop growth and seed yield but also for poor quality of products, because sulphur is a constituent of several essential compounds such as cysteine, methionine, coenzymes, thioredoxine and sulfolipids. Sulphur deficiency significantly effects the production and quality of winter wheat (Györi, 2007). Moreover, Zn and B are considered to the micro nutrients and are substantial for the optimum growth of crops. Severe Zn deficiencies will cause leaves to turn gray white and fall prematurely or die. Because Zn plays a prominent role in internode elongation, Zn deficient plants generally exhibit severe stunting. Flowering and seed set is also poor in affected plants. Crop specific symptoms include smaller leaf size in alfalfa, gray or bronze banding in cereal leaves, reduced tiller production in wheat and other small grains, and abnormal grain formation (Wiese, 1993). Both zinc and boron are known to be required for all higher plants as essential crop nutrients and are well documented to be involved in photosynthesis, N-fixation, respiration and other biochemical pathways (Ali *et al.*, 2009). Zinc, in addition, is reported to be having possible role in reducing the toxic effects of excessive boron (Rajaie *et al.,* 2009). Therefore, for wheat cultivation, these elements play the vital role in augmenting yield and growth.

*Yield and yield components*

Fertilizer is the most important input which contributes significantly towards final grain yield of wheat and to exploit the inherited potential of a cultivar. Appropriate and balanced fertilization on wheat and rice not only causes yield enhancement but also has good impact on phosphorus uptake by these crop plants (Rehman *et al.* 2006). Placement of nutrients and fertilizer rates are important factors to be considered to produce maximum yield of crops. Particularly deep placement of nutrients might be beneficial to crop growth. Increased early growth has been observed with deeper P placement as well as by deep band placement of K when compared to broadcast application as demonstrated by Radhika *et al.* (2013). Wheat is the most important and widely cultivated crop of the entire world and is principal food of human beings. Wheat responds well to fertilizer application with balance N:P ratio for increased wheat productivity. Alam *et al.* (2003) has shown that the application of phosphorus fertilizer (SSP) to wheat crop has significantly increased the plant height, number of tillers plant$^{-1}$, straw and grain yield as well as P-uptake in grain over control. In the present study, the number of grains per spike, 1000-GWT and other yield characteristics were examined in response to fertilizer placement in different tillage options and were influenced in the investigation. The higher TGW was also recorded in response to fertilization placement in different tillage options. The findings are supported by Kaleem *et al.* (2009) who described that maximum NP fertilizer utilization recorded the highest yield effects due to maximum accumulation of photosynthesis.

Several lines of evidences reveal that fertilizer and other essential nutrient placement are involved in improving the cultivation and yield of crops. The placement method of fertilizer N influences crop yield and N uptake by cereal crops. Split application of N fertilizer has been shown to improve the yield, grain protein concentration and nitrogen use efficiency of wheat, compared to a single surface application (Duan *et al.*, 2015; López-Bellido *et al.*, 2005). Chen*et al.* (2016) observed that placement method and N rate effectively affected grain yield, straw yield and aboveground biomass of winter wheat. The grain yield of wheat was higher for band (3.83–5.42 t $ha^{-1}$) than for broadcast treatment (3.32–4.74 t $ha^{-1}$). Bandaogo et al. (2015) reported that placement of urea supergranules increased N use efficiency. The highest grain yield was obtained with 150 kg N $ha^{-1}$ as urea supergranules with 489 panicles $m^{-2}$ and 122 grains per panicle. The increase in vegetative parameters of plant height, number of leaves per plant, leaf area index and number of branches per plant in maize with application of nitrogen have been reported by Silwana *et al.* (2007) showing that maize is a nitrogen positive crop. Placement of fertilizer is an integral part of efficient crop management that can affect both maize crop yield and nutrient use efficiency. Deep placement of urea supergranules resulted in significantly higher rice grain yield, better NUE and apparent N recovery than split application of prilled urea as described by Bandaogo *et al.* (2015). Wu *et al.* (2017) reported that grain yield, straw biomass, grain N content , straw N content, PPN (productive panicles numbers), SNP (spikelet numbers per panicle), TGW, stem length, NRE (apparent recovery efficiency of N) had been influenced in response to nitrogen fertilizer deep placement. Their findings demonstrated that deep placement of urea fertilizer increased grain yield and apparent nitrogen recovery efficiency as compared to N broadcast application. In general, placing the fertilizer closer to the seed gives the greatest response to applied nutrients. Mallarino and Borges (2006) found that deep band placement of both P and K (at 5 to 15 cm depth) resulted in higher concentration of phosphorus and potassium than for inter band row placement with no tillage and chisel disk tillage system. The uptake pattern of various nutrients has been accepted as a criterion for fixing optimum time of fertilization. Yield and fertilizer recovery decreased in the order of ammonium phosphate> urea> calcium ammonium nitrate. Chen*et al.* (2016) reported that the N fertilizer application rate had a significant effect on grain yield, straw yield and aboveground biomass as well as on N uptake of wheat. High solute concentration at placement site with urea supergranules or urea mud ball lumps might have also inhibited nitrification because of osmotic pressure of the solute. Rehim *et al.* (2012) reported that band placement was more effective and economical than broadcasting. Improved grain yield, yield related traits, grain and straw P contents, total P uptake and phosphorus use efficiency (PUE) of wheat have been demonstrated in their experiment indicating the importance of different fertilizer placement methods. The $^{15}N$ recovery was 51.7 per cent with band placement compared with 47.8 per cent for neem-coated urea and 28.5 per cent for conventional split application of prilled urea (Devasenapathy and Palaniappan, 1996). Adjetey *et al.* (1999) found that the total N recovery was 93.8 per cent in the deep placement of 15N sources compared to shallow placement (79.9 per cent) in wheat, and these differences were due to differences in soil N recovery, as crop N recovery was approximately 48 per cent in both the treatments.

Therefore, it is obvious from the previous findings that placement of fertilizer is substantial to get higher yield of crops following the improvement of other yield components. Although different tillage options for wheat cultivation have been applied in the current investigation, fertilizer placement with any tillage in between rows preferentially strip tillage and bed planting in between rows was found to be involved in getting higher yield of wheat. Other yield components were also influenced by the different tillage options showing that placement of fertilizer and alterations of tillage are needed in improving wheat yield and the results are good agreement of the previous observations.

## Conclusion

Although various approaches on wheat cultivation for the development of wheat production were performed in different countries, however the current study involving the role of fertilizer placement for different tillage options was done in Bangladesh. The approaches employed on wheat cultivation might be a regulatory and effective to get higher yield of wheat. The experimental results indicate that fertilizer placement in between rows with any tillage option performed better than other fertilizer placement methods and the best combination was fertilizer placement in between rows with strip tillage. So, fertilizer placement in between rows following any tillage options with the preference of Strip, PTOS and Bed could be practices by the farmers to get higher yield of wheat.

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**References**

**Aown M, Raza S, Saleem MF, Anjum SA, Khaliq T, Wahid MA.** 2012. Foliar application of potassium under water deficit conditions improved the growth and yield of wheat (*Triticum aestivum* L.). Journal of Animal & Plant Sciences **22(2)**, 431-437.

**Ali S, Shah A, Arif M, Miraj G, Ali I, Sajjad F,Khan MY, Khan NM.** 2009. Enhancement of wheat grain yield and yield components through foliar application of zinc and boron. Sarhad Journal of Agriculture **25(1)**, 15-19.

**Alam SM, Azam S, Ali S, Iqbal M.** 2003. Wheat yield and P fertilizer efficiency as influenced by rate and integrated use of chemical and organic fertilizers. Pakistan Journal of Soil Science **22(2)**, 72-76.

**Adjetey JA, Campbell LC, Searleand PGE, Saffigna P.** 1999. Studies on depth of placement of urea on nitrogen recovery in wheat grown on a red-brown earth in Australia. Nutrient Cycling in Agro ecosystems **54(3)**, 227-232.
https://doi.org/10.1023/A:1009775622609

**Bandaogo A, Bidjokazo F, Youl S, Safo E, Abaidoo R, Andrews O.** 2015. Effect of fertilizer deep placement with urea supergranule on nitrogen use efficiency in Sourou Valley (Burkina Faso).Nutrient Cycling in Agroecosystems**102**, 79-89.
https://doi.org/10.1007/s10705-014-9653-6

**Busari MA, Kukal SS, Kaur A, Bhatt R, Dulazi AA.** 2015.Conservation tillage impacts on soil, crop and the environment. International Soil and Water Conservation Research **3(2),** 119-129.
https://doi.org/10.1016/j.iswcr.2015.05.002

**Bertholdsson NO.** 2005. Early vigor and Allelopathy-Two useful traits for enhancing barley and wheat competitiveness against weeds. Weed Research **45(20)**, 94.
https://doi.org/10.1111/j.1365-3180.2004.00442.x

**Chen Z, Wang H, Liu X, Liu Y, Gao S, Zhou J.** 2016. The effect of N fertilizer placement on the fate of urea-$^{15}$N and yield of winter wheat in Southeast China. PLoS One **11(4),** e0153701.
https://doi.org/10.1371/journal.pone.0153701

**Duan W, Shi Y, Zhao J, Zhang Y, Yu Z.** 2015. Depth of nitrogen fertiliser placement affects nitrogen accumulation, translocation and nitrate-nitrogen content in soil of rainfed wheat. International Journal of Plant Production **9(2)**, 237-256.

**Devasenapathy P, Palaniappan SP.** 1996. Urea-nitrogen on yield and NUE in lowland rice as affected by band placement of urea solution. Indian Journal of Agronomy **41(3),** 379-385.

**Doran JW.** 1980. Soil microbial and biochemical changes associated with reduced tillage. Soil Science Society of America Journal **44,** 765-771.
https://doi.org/10.2136/sssaj1980.03615995004400040022x

**Györi Z.** 2007. Sulphur content of winter wheat grain in long term field experiments. Communications in Soil Science and Plant Analysis **36,** 373-382.
https://doi.org/10.1081/CSS-200043098

**Kaleem S, Ansar M, Ali MA, Rashid M.** 2009. Effect of phoshorus on the yield and yield components of wheat variety "Inquilab-91" under rainfed conditions. Sarhad Journal of Agriculture**25(1)**, 21-24.

**Kapoor V, Singh U, Patil SK, Magre H, Shrivastava LK, Mishra VN, Das RO,Samadhiya VK, Sanabria J, DiamondR.** 2008. Rice growth, grain yield, and floodwater nutrient dynamics as affected by nutrient placement method and rate. Agronomy Journal **100**, 526-536.
https://doi.org/10.2134/agronj2007.0007

**Kjeldahl J.** 1883. A New method for the determination of nitrogen in organic substances. Zeitschrift für analytische Chemie **22(1)**, 366-382. http://dx.doi.org/10.1007/BF01338151

**López-Bellido L, López-Bellido RJ, Redondo R.** 2005. Nitrogen efficiency in wheat under rainfed Mediterranean conditions as affected by split nitrogen application. Field Crop Research **94(1)**, 86-97. https://doi.org/10.1016/j.fcr.2004.11.004

**Mallarino AP, Borges R.** 2006. Phosphorus and potassium distribution in soil following long term deep band fertilization in different tillage systems. Soil Science Society of America Journal **70**, 702-707. https://doi.org/10.2136/sssaj2005.0129

**Nazim H, Khan MB, Ahmad R.** 2008. Influence of phosphorous application and sowing time on performance of wheat in calcareous soils. International Journal of Agriculture and Biology**10(4)**, 399-404.

**Olsen SR, Cole CV, Watanabe FS, Dean LA.** 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular No. 939, United States Department of Agriculture, Washington, DC., USA., 1-18P.

**Radhika K, Hemalatha S, Maragatham S, Kathrine SP.** 2013. Placement of nutrients in soil: A review. Research and Reviews: Journal of Agriculture and Allied Sciences **2(2)**, 12-19.

**Rehim A, Farooq M, Ahmad F, Hussain M**. 2012. Band placement of phosphorus improves the phosphorus use efficiency and wheat productivity under different irrigation regimes. International Journal of Agriculture and Biology **14**, 727-733.

**Rajaie M, Ejraie AK, Owliaie HR, Tavakoli AR.** 2009. Effect of zinc and boron interaction on growth and mineral composition of lemon seedlings in a calcareous soil. International Journal of Plant Production **3(1)**, 39-50.

**Rehman O, Zaka MA, Rafa HU, Hassan NM.** 2006. Effect of balanced fertilization on yield and phosphorus uptake in wheat-rice rotation. Journal of Agricultural Research **44(2)**, 105-113.

**Silwana TT, Lucas EO, Olaniyan AB.** 2007. The effects of inorganic and organic fertilizers on the growth and development of component crops in maize/bean intercrop in Eastern Cape of South Africa. Journal of Food Agriculture and Environment **5**, 267-272.

**Schomberg HH, Ford PB, Hargrove WL.** 1994. Influence of crop residues on nutrient cycling and chemical soil properties. In: Unger P.W. (Ed.), Managing Agricultural Residues. CRC Press Inc., Boca Raton, Florida, 99-123 p.

**Wu M, Li G, Li W, Liu J, Liu M, Jiang C, Li Z.** 2017. Nitrogen fertilizer deep placement for increased grain yield and nitrogen recovery efficiency in rice grown in subtropical China. Frontiers in Plant Science **8**, 1227. https://doi.org/10.3389/fpls.2017.01227

**Wiese MV.** 1993. Wheat and other small grains. InNutrient Deficiencies and Toxicities in Crop Plants. St. Paul, MN. APS Press, 202 p.

**Wilhelm WW, Doranand JW, Power JF.** 1986. Corn and soybean yield response to crop residue management under no-till production systems. Agronomy Journal **78**, 184-189. https://doi.org/10.2134/agronj1986.00021962007800010036x

**Yongqing MA.** 2005. Allelopathic studies of common wheat (*Triticum aestivum*L.). Weed Biology and Management **5(3)**, 93-104. https://doi.org/10.1111/j.1445-6664.2005.00164.x