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Improvement in productivity of wheat with crop residue and nitrogen - a review

Avtar Singh*, Meenakshi Kaushal, Harmeet Singh

*Sr. Agronomist, Department of Agronomy, PAU, Ludhiana-141004, Punjab, India

E-mail : Avtar_bimbraw@yahoo.com ; asbimbraw@pau.edu Contact No : 0161-2401960 Ext. 308, M.No. 09463200829

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Abstract

Wheat (Triticum aestivum L.) is the world's number one cereal crop in all the six continents of the world. It is the staple food of billions of people and is widely treated as cash crop because it produce good yield per unit area in short growing season. In world, wheat was grown on 225.6 million hectare with a production of 685.6 million tons and average productivity was 3039 kg/ha-1 during 2009-10. In India, the area under wheat was 28.25 million hectare and production was 80.7 million tons with productivity 2839 kg/ha-1 during 2009-10. In Punjab area, production and productivity under wheat was 3.5 million hectare, 15.2 million tons and 4307 kg/ha-1 during 2009-10, respectively.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's number one cereal crop in all the six continents of the world. It is the staple food of billions of people and is widely treated as cash crop because it produce good yield per unit area in short growing season. In world, wheat was grown on 225.6 million hectare with a production of 685.6 million tons and average productivity was 3039 $kg ha^{-1}$ during 2009-10 [1]. In India, the area under wheat was 28.25 million hectare and production was 80.7 million tons with productivity 2839 kg ha^{-1} during 2009-10. In Punjab area, production and productivity under wheat was 3.5 million hectare, 15.2 million tons and 4307 kg ha^{-1} during 2009-10, respectively [2].

The rice-wheat system occupies more than 12 million hectare in the Indo-Gangetic plains of India and has emerged as the major contributor to national food security. Although more than half of dry matter produced annually in cereals (rice and wheat) is the inedible organic biomass. The consumption of chemical fertilizer nutrients (N, P, K) in India has registered a spectacular increase from nearly 65.6 thousand tons in 1951-52 to 16.8 million tons in 2003-04. Nevertheless, there is deficit of these nutrients to meet the crop demand which has to come from resources other than chemical fertilizers.

Crop residue is the significant resources of fiber, energy and plant nutrients. However, recycling of nutrients through crop residues is the primary importance in plant nutrition. Crop residue is excellent source of plant nutrients for the reasons; they benefit the soil physically, chemically as well as biologically, they require little or no transportation and can be applied in-situ. They do not cost since they are produced along with the grains and have no health hazard problem like heavy metal contamination, salinity, sodicity or nitrate contamination.

Despite enormous benefits of the crop residues, most of crop residues are removed and/or burnt. The residue burning has been identified as one of the key factors for non sustainable farming particularly in intensively cultivated irrigated system. In Punjab, for instance, about 37-40 million tons of the rice-wheat straw is produced. However, the wheat straw produced about 17-19 million tons and out of this more than 90 per cent used as wheat *bhusa* for animal feed, remaining burnt in the field whereas, the rice straw produced 20 to 22 million tons and about 17-19 million tons is being burnt in the open fields unlike wheat straw, rice straw is not used as cattle feed because of high silica and oxalate content in it.

Besides the loss of organic matter and plant nutrients, burning of crop residue also causes atmospheric pollution due to the emission of toxic gases like methane, CO_2 or nitrous oxide that fuses throughout to human and ecosystem health. So, depending upon their nutrient content and easily availability of rice residues can be recycled by direct sowing of wheat under no-till condition with different methods as zero-till drill, happy seeder and rotavator etc.

In Punjab, rice-wheat is the predominant cropping system. The problems associated with the productivity and sustainability of the predominant cropping systems is deterioration in soil quality, receding ground water table, declining factor productivity, environmental problems etc. The better soil quality mainly depends upon soil organic matter, tillage intensity, soil cover, plant diversity and pest management practices. The parameters that are responsible for healthy soil are under threat due to intensive tillage, non-cycling of crop residues, mono-cropping and imbalance use of agro-chemicals. In the conventional systems involving intensive tillage, there is gradual decline in soil organic matter through accelerated oxidation and burning of crop residues causing pollution, green house gases emission and loss of valuable plant nutrients. When the crop residues are retained on soil surface in combination with no-tillage, it initiates processes that lead to improved soil quality and overall resources enhancement. Therefore, conservation technologies like zero-tillage, happy seeder and rotavator lead to sustainable improvements in the efficient use of water and nutrients by improving nutrient balances and availability, infiltration, retention by soils, reducing water losses due to evaporation and improving the quality and availability of ground and surface water.

2.1 Residue management

A high level of cereal residues on the soil surface can reduce wheat yield due to various factors like weed competition, greater N immobilization, or decreased light intensity [3] and reduced early-spring soil temperature by 2 to 6°C under Pacific Northwest [4]. The favorable effect of residues might be due to the factors viz. increase in C, N, P, K, S and other nutrient supply pattern (slow release), humus substance, growth promoters and the improvement in soil physical conditions. It is also decreased root density and plant access to nutrients [5]. A non significant effect of crop residues on the available potassium concentration in soil was recorded in plave of reported by [6] and potassium added through crop residues was possibly leached from the soil, converted to unavailable forms, or taken up by the subsequent crops. However, an increase in availability of phosphorus and potassium in soil under rice-wheat rotation reported [7] from Bihar. A marked increase in organic carbon in sandy clay loam soils with residue incorporation after 4-5 years was observed [8]. However, an increasing trend was recorded in organic carbon content in soil with the incorporation of rice (*Oryza sativa*), soybean (*Glycine max*) and groundnut (*Arachia hypogaea*) crop residue [9]. Incorporation of straw reduce the bulk density [10] and its values in surface (0-15 cm) layers were more (1.44 g/cm^3) as compared to residue burnt (1.51 g/cm^3) and removed (1.48 g/cm^3). The low bulk density accrued as account of the incorporation of straw increase infiltration rate at Ludhiana.

In other study, it was observed that grain yield of wheat under mulches was higher due to longer rooting and higher moisture content in the upper soil layers [11-12]. Similarly, an increasing trend was recorded in wheat yield with the incorporation of rice (*Oryza sativa*), soybean (*Glycine max*) and groundnut (*Arachia hypogaea*) crop residue [9]. Winter wheat was grown in even years and spring wheat in odd years on the same site from 1984 to 1988. It was observed that standing stubble decreased grain yield of winter wheat by 13 per cent and straw yield by 15 per cent, compared with chopping or burning, it decreased spring wheat grain and straw yield < 5 per cent. In another study, found that growth, development, and yield of wheat were not affected by crop residue maintained at the soil surface with conservation systems, although test weight was reduced in the soil which was considered highly deficit in nitrogen and marginally deficit in phosphorus and sulphur for annual cereal production [13]. Incorporation, retention at soil surface and burning of rice residues in succeeding wheat field remarkably enhanced the grain yield over residue removal [14]. Deep incorporation of rice residue improved the growth and yield attributes which led to higher grain yield over others. Conservation tillage produced dwarf plants and smaller grains. Management of residue either by deep tillage or by conservation tillage yielded broader flag leaves.

2.2 Method of planting

It was reported in the literature that spring wheat yields under no-tillage were among the lowest of several tillage systems examined [15-16]. Similarly, [17] recorded less yields of wheat under zero tillage with poor seedling establishment. However, [18] in Kansas State University, Agronomy Farm at Manhattan, recorded that lack of adequate seed placement due to presence of surface residues under reduced and no tillage conditions decreased wheat yield. Increase in bulk density and resistance to penetration in no tillage treatments did not affect significantly on wheat yields when seed was placed at 4-5 cm deep. Similarly, [19-20] reported 9-10 percent lower yield of wheat under no tillage than conventional tillage, respectively. In another study, found that wheat sown after conventional tillage resulted in taller plants, longer and heavier ears, more grains/ ear and higher grain yield than wheat sown with zero tillage under rice-wheat cropping system [21-22]. However, conventionally sown wheat gave 10-13 and 28-35 percent higher grain yield than raised bed and zero tillage sown wheat, respectively in silty clay loam soil [23]. However, from Ludhiana, [24] reported that conventional tillage and drill sowing recorded the highest mean grain yield, followed by minimum tillage and drill sowing in wheat. In another study, [25] from Ludhiana reported that conventional tillage and deep tillage increased the depth and density of rooting, leaf area index and grain yield of wheat as compared to no tillage. The rooting density of wheat in surface 0-20 cm layer was 5.3 and 10.2 percent more under reduced and conventional tillage than zero tillage, respectively [26].

However, average grain yields with no-tillage and conservation tillage were significantly greater than yields using conventional tillage [27]. No tillage increased test weights while reducing tillage operations significantly reduced the number of spikelets per head, but increased the 100-seed weight. Tillage practice had no significant influence on heads/m^2, seeds per spikelets. Similarly, [28] from Canada and [29] India reported that greater grain yields of wheat under no-tillage were recorded than conventional tillage in clay loam and sandy clay loam soils, respectively. However, 7.1 per cent increase in the grain yield of wheat with zero tillage over conventional tillage when sown wheat on the same date and 16.7 per cent with the delay of sowing (2 weeks) conventional tillage wheat was recorded from Haryana, India [30]. Similarly from Haryana [31] and Bihar, India [32] reported that higher wheat yield of 2.0- 4.0 q/ha was obtained under zero tillage over conventional tillage, respectively.

In Fargo, [33] found that yield of wheat was higher in no-tillage (2270kg/ha) where wheat planted in 0.05 m stubbles and 4073 kg/ha where wheat planted in 0.20 m stubbles) than conventional tillage (455 kg/ha) and mulch tillage (2203 kg/ha). However, tillage systems had a significant effect on emergence rate and yield of wheat [34]. Emergence rate index and yield of wheat varied from 15.24 to 18.88 and from 3065 to 4265 kg/ha, respectively. The greatest emergence rate index and yield were obtained with stubble cultivator followed by disc harrowing treatment. From Faizabad, [35] reported higher yield of wheat planted with Chinese drill (40.17 q/ha and 23.98 percent) followed by Pantnagar zero till drill (26.90 q/ha and 12.24 percent) over surface and conventional systems in silty loam soils. At Karnal, India [36] compared the performance of zero tillage wheat under different methods of rice transplanting viz. broadcast in puddled condition, transplanting and dry seeding. They found that zero tillage under dry seeding of rice gave significant higher yield (49.6 q/ha) than conventionally filled plot of transplanted rice (43.3 q/ha). Sowing of wheat by Chinese seeder recorded significantly higher values of growth characters, yield attributes, yield and nitrogen uptake by wheat followed by Pantnagar zero till drill and lowest in conventional tillage [37]. Chinese seeder recorded 23.83 and 25.85 per cent more grain yield over CT during first and second year, respectively.

Wheat planted after cotton in zero tillage plots had plant height, dry matter per plant, effective tillers and grain yield similar to that recorded in conventional tilled plots in Hisar, Haryana [38]. In another study from Ranchi [20] reported that variation in tillage (Zero and conventional tillage) and technique of rice stubble management did not show significant differential effect on grain and straw yields of wheat under timely and late-sown conditions after the harvest of transplanted rice. However, zero tilled wheat produced more grain and straw energy than the conventional tilled plots with stubble incorporation and stubble removal. The zero tillage with stubble produced 315 and 350 percent more energy in timely -sown wheat and 287 and 307 percent more in late -sown wheat compared with conventional tillage with stubble incorporation. From Canada, reported similar root biomass under zero tillage and conventional tillage [39]. From Punjab, reported similar wheat grain yields under tilled and untilled condition[40-42]. However, based on 2-year data, inferred that there was no consistency in results of zero-tillage being on a par with that of tillage treatments [43]. Reduced tillage with two harrowing followed by two cultivators and one planking treatment was better economic return point of view. In another study evaluated tillage induced changes in soil physical properties and yield of rice and wheat in rotation and found that the total grain yield (rice + wheat) was highest (9447 kg /ha) in the ReP (reduced puddling by 2 passes of rotary puddler) plots of rice i.e reduced puddling by 2 passes of rotary puddler under zero tillage for wheat. These conditions caused minimum deterioration of soil structure [44].

The higher rooting in upper layer of tilled soil was reported from Canada [39]. In another study, higher root density in no tillage at surface 0-15 cm soil layer but at lower depth two tillage levels recorded similar root density at Ludhiana [45]. However, from Switzerland reported that slightly lower root length density and slightly larger mean root diameter under no tillage as compared to conventional tillage [46].

Conducted an experiment to compare the performance of the conventional tillage, reduced tillage (Chinese rotavator), zero tillage in wheat under varying sowing methods of rice and found that Chinese rotavator proved most effective and recorded markedly higher values of yield attributing characters, grain yield and output: input ratio [47]. In Haryana, found that wheat sown by rotavator drill or zero tillage gave significantly higher grain yield [48]. Grain yield depends upon the method of planting; crop sown early under no-till conditions enhanced the yield and late sown with zero tillage may reduce the yield as compared to conventional tillage.

A) Weed management

Optimum tilled plots had 21.3 to 28.0 percent [49] and 29.5 per cent [50] more number of weeds per unit area as compared to zero tilled plots. Whereas, from Uttaranchal[50] reported that more weed emergence in conventional tillage (146 per square m) and reduced tillage (141 per square m) than zero tillage (103 per square m) at 30 days stage. In another study at Varanasi recorded that population and dry weight of weeds was minimum in zero tillage and maximum in conventional tillage whereas, conventional tillage produced significantly higher grain yield than zero tillage and was at par with reduced tillage sown crop [51]. From Ludhiana, reported that number of annual weeds before and after spray was significantly less in zero tillage as compared to reduced and conventional tillage but dry matter of perennial weed, *Cynodon dactylon* was more in zero tillage as compared to reduced and conventional tillage[41]. However, from UP reportded significant reduction in dry weight of weeds under zero tillage over conventional tillage [52].

The population of *Phalaris minor* weed in zero tillage plots was 25 per cent [30] and 15 per cent [50] less of that observed in field sown using conventional tillage system. Similarly, the higher population of *Phalaris minor* in conventional tillage than zero and reduced tillage was reported [50, 53]. In another study recorded [54]from M.P. that zero till planting reduces the infestation of *Phalaris minor Retz* and *Chenopodium album* L. but increased the performance of wild oat *(Avena sterilities* sp. *ludoviciana*). However, grain yield was similar under all the tillage systems and seeds of *Phalaris minor* and *Chenopodium album* were higher in deep tillage and *Avena ludoviciana* and *Medicago hispida* in zero tillage which were mostly disturbed in upper 1 cm soil depth. It was also reported that no tillage technology is non-chemical approach to improve the environment by reducing the use of chemicals to control weeds. No tillage allows early sowing of wheat particularly in the end of last week of October to 1st week of November and generally has the less population of *Phalaris minor* due to the difference in the optimum time of *Phalaris minor* germination [55]. The results of various workers found that *Phalaris minor* population reduced in timely sown wheat under no-till conditions.

B) Effect of zero tillage on soil properties

The highest value of cumulative intake (12.05 cm/h) of water for 6 hrs recorded under zero tilled plots followed by one cultivation (8.85 cm/h) and 4 cultivations (7.90 cm/h) on a sandy soil of Ludhiana [54]. In another study observed no significant difference in infiltration rate between direct drilling and conventional tillage [57]. From Brazil, [58] reported higher in filterability of oxisol (low in exchangeable cations, 76-80 percent clay content, high iron oxide) under no tillage than conventional tillage or chisel plough. However, without soil cover the infiltration rate under no tillage was same as that of no tillage and chisel ploughing. Similarly [59] found that infiltration rate under no-till condition was more in different soils as compared to tilled conditions but higher infiltration rate in untilled plots than conventionally tilled plots in different cropping systems [60-63]. In another study, observed that steady stage infiltration was 60 percent higher in zero tillage than conventional tillage on a silty loam soil [64].

In study recorded lower available water in surface layer of clayey soil and at greater depth (0.6-1.2 m) under no tillage than in tilled soils [65]. However, [26] reported higher available soil water in zero tilled plot than conventionally tilled plots. In another study, [66] recorded improvement in soil water conservation in loamy soil by the zero tillage and minimum tillage as compared to conventional tillage.

In study, [67] found that high bulk density under zero tilled conditions might be a reason of poor growth of roots in the beginning. But bulk density of 1.4g/ cm^3 appeared to be more conducive for the growth and development of wheat. From Germany reported that bulk density was higher top layer of untilled soil compared with tilled soil but at 25-30 cm soil layer had high bulk density in tilled plots than any layer of untilled soil [68]. They were also reported that higher penetration resistance in the top layer of untilled loamy soil as compared with tilled soil. Similarly, [69] reported the bulk density was slightly higher in the top layer of untilled soil but generally lowest or similar bulk density in different profiles of soil observed under zero tillage as compared to conventional tillage. However, in Maryland found that no tilled soils generally had higher bulk density at all the soil depths [70]. In another study from Canada [63] recorded the higher bulk density of soil under zero tillage than that of conventional tillage in the tillage zone and were lower below the tillage zone. In study from Ludhiana, [26] reported that bulk density of soil in top 0-15 cm layer under zero tillage was higher (1.71g/cm^{-3}) than reduced (1.65 g/cm^{-3}) and conventional (1.60 g/cm^{-3}) tillage at harvest. In India, [71] reveals that higher bulk density at crown root initiation stage of wheat under zero tillage in the first year but in the second year no such trend was noticed. However, the bulk density decreased (1.49-1.23 g cc^{-1}) with increase in number of tillage operation reported [43] from U.P. In another study reported that tillage practices reduced the bulk density of soil than zero tillage [72]. Similarly, [73] reported that soil bulk density decreased significantly with conventional tillage (1.34 and 1.36 Mg/m^3 at 0-15 and 15-30cm soil depth, respectively) at both the soil depths, and after both rice and wheat crops.

In study, [74] indicated that no-tillage with residue retention substantially enhanced soil organic matter. Burning and removal of residue led to the lowest accumulation of organic carbon and available nitrogen in surface soil. In another study, observed that deep tillage decreased bulk density and soil strength (measured in the first year of experiment) in the tilled zone and increased the depth and density of rooting [75]. In both the cases, there were significant increases in dry matter accumulation and grain yield of wheat. However, from Hisar, [76] reported that higher stability of soil aggregates under zero tillage was observed due to accumulation of more organic matter resulted in reduced soil erosion. The increment in soil organic carbon, its allocation and protection within macro-aggregates leads to improved aggregate size distribution and stability while these two contribute to improved water infiltration under no tillage [64].

No tilled treatment with straw had the lowest proportion of finer soil aggregates in the seed bed and greater penetrometer resistance up to 20 cm depth [77]. In another study reported the tillage results in significant increase of penetration resistance from 0.8-5 M Pa in sandy loam and from 1.9-3.2 M Pa in silty clay loam soil [78]. It was also reported that tillage before wheat opened the soil and increase the permeability compared with relatively undisturbed soil under zero-tilled conditions [79]. From the results of various scientists, it can be concluded that soil properties like soil strength, infiltration rate and bulk density varied due to zero tillage and conventional tillage depending upon the soil type.

C) Nutrient uptake

Similar organic carbon and nitrogen in tillage systems were recorded but concentration of plant available phosphorous and potassium slightly increased in surface (0-2 cm) after 16 years of zero tillage in dark brown soil [80]. In another study, from USA reported [81] the uptake of surface applied fertilizer nitrogen by spring wheat was greater from the no till than tilled micro plots but no significant differences in dry matter production could be associated with tillage methods. Uptake of residual fertilizer nitrogen by winter wheat was similar for both tillage methods. No significant difference in nitrogen, phosphorus and potassium uptake by the wheat under zero and conventional tillage systems [82]. Similarly, the nutrient status of plants grown under no tillage was equal or superior to those grown under conventional tillage [83]. In another study found that the dominant effect on grain nitrogen concentration was an inverse relationship with grain yield [28]. However, when grain yields were similar between tillage systems, greater inorganic N with conventional tillage treatment was reflected in large grain nitrogen concentration. It was also reported that restricting nitrogen availability resulting from immobilization loses, however, reduced grain nitrogen concentration in no tillage relative to conventional tillage treatments [84]. Whereas, it is also observed that at 0-50 mm surface layer, organic carbon, total nitrogen and extractable phosphorus were approximately 64, 78, 110 percent higher under no tillage as compared to conventional tillage [85]. It can be stated that nitrogen uptake increased with course of time, surface application under no-till conditions. It was also observed that nitrogen availability restricted due to immobilization loses, however, reduced grain nitrogen concentration in no tillage relative to conventional tillage treatments.

D) Economics

From Bihar, [32] recorded that zero tillage resulted in early sowing of 9 days with the saving of Rs. 1400/ha from land preparation and increased yield of 4.0 q/ha over conventional method. However, [86] reported zero tillage with yield of 4688 and 3527 kg/ha out yielded as compared to conventional with yield of 3718 and 3075 kg/ha with the markedly better net returns, benefit: cost ratio and advancing sowing by 20 days. Whereas, [87] recorded zero tillage technology increased the farmer's margin to extent of Rs. 1882/ha and saving of inputs. The various research workers have reported 60-70 percent saving of time and 67-80 percent saving of fuel with zeo tillage seeding technique over conventional tillage [88, 22]. However, from Hisar [89] reported that wheat sown by no tillage system required 5.5 times less energy and cost of production and gave 17.09 percent higher yield than conventional tillage. Whereas, from New Delhi, [90] reported that there was 28 percent cost saving under zero tillage in wheat. The technology had positive and significant impact on environment and sustainability of system through improved soil quality and reduction in use of inputs like chemical fertilizers, irrigation water and energy resulted in higher profit.

2.3 Nitrogen Management

In no-till or minimum tillage systems sometimes exhibit suppressed yields because of lesser N availability [91]. Reduced N availability has been attributed to slower mineralization. However, the placement is an important factor affecting nitrogen utilization and observed a 20 per cent increase in nitrogen-use efficiency for band placement compared with surface broadcast [92]. They conducted that reducing fertilizer contact with residue can reduce immobilization and increase nitrogen uptake. In another study, [93] estimated that fast development of wheat under conventional tillage would have increased plant nitrogen requirements that were satisfied; principally by nitrogen from fertilizer due to low initial soil NO_3^--N levels. Greater N immobilization is generally observed under no tillage early crop stages. Whereas, [94] at Ranchi conducted two years field study 1982-83 and 1983-84 and reported that grain yield was significantly higher under conventional tillage with the application of 75 kg N ha^{-1} only, but such differences due to tillage were not seen at 100 kg N ha^{-1}, thus, indicating higher requirement of fertilizer N in no-tillage.

In another study, from Swift current, Saskatchewan observed that response to fertilizer nitrogen decreased with years, presumably because the available nitrogen supplying power of the soil improved under no-till management with adequate fertilization [95]. Studies conducted on fertility rate to evaluate the response of winter wheat to nitrogen application in more intensive no till cropping systems and found that more intensive cropping systems using no tillage may require higher rates of nitrogen fertilizer to maintain yield potential due to increased crop nitrogen removal as well as compensate for nitrogen sequestration in crop residue and surface soil due to lack of tillage [96].

Incorporation of straw with starter dose of 20 kg N ha^{-1} gave higher yield over rice straw alone because of positive effect on yield attributes [97] and the lowest values for above attributes were observed when the total 150 was applied in 2 equal splits (½ at sowing and ½ at CRI). All growth and yielding characters except 1000- grain weight increased with each increment in nitrogen dose [98]. However, grain and straw yields also showed the similar trend. Under no-till, grain yield was improved by 32 percent for surface broadcast (BL) and 15 percent for banded below the seed row (BT), and grain N content were increased by 33 percent for BL and 25 percent for BT with 60 kg Nha^{-1} as compared to the BR treatment [99].

Improvement in grain yield of wheat was observed with the application of higher dose (150 kg ha^{-1}) of nitrogen [9]. Maximum agronomic nitrogen use efficiency (ANUE) in rice crop (14.5 N/ha grain/kg N) was obtained with 120 kg while in succeeding wheat crop, it (28.3 kg grain/kg N) was obtained with 60 kg N/ha which was reduced with increasing levels of nitrogen [100]. All the growth characters, yield attributes, yield and nitrogen uptake of wheat (*Triticum aestivum* L.) sown after rice (*Oryza sativa* L.) was significantly higher with 150 over 120 kg N ha^{-1} reported from UP [37]. Root length density and root weight density of no-till wheat were positively influenced both by straw mulching and N levels. N uptake and apparent nitrogen recovery of applied N fertilizer were higher in mulch treatments M1 (surface application of rice straw mulch at 4.0 Mg/ha that was withdrawn at 20 days after sowing) and M2 (same level of mulch as M1 but allowed to be retained at the soil surface) as compared to M0 (no mulch). Also mulch treatment of M1 and M2 were equally effective in conserving soil moisture, suppressing growth of weed flora, promoting root development and thereby improved grain yield of no-till wheat [101]. Grain yield and number of effective tillers m^{-1} row increased significantly by 7.7 and 6.8 per cent under varying levels of nitrogen, with zero tillage over conventional tillage, respectively during winter season of 1999-2000 and 2000-2001 reported from UP [52]. It can be concluded that nitrogen requirement varies with the tillage; residue of previous crop, intensive cropping using no tillage, method of application of nitrogen, split application in wheat.

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