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Use of Conservation Technology for the Improvement in Production of Chickpea in Comparison to Wheat

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ABSTRACT

In the last four decades, the area, production and productivity of chickpea fluctuated widely. There is a general perception that chickpea is a *rabi* crop and requires low temperature and prolonged winter season thus more fit for cultivation in northern India. Chickpea area was earlier confined to northern and central India. However, the scenario of chickpea cultivation has drastically changed in India during the past few decades. Pulses have very low productivity due to several reasons. However, the obvious reasons are cultivation under energy starved conditions on marginal and sub-marginal lands with no or low input management, late sowing, higher degree of susceptibility to both abiotic and biotic stresses, unavailability of quality seeds of high yielding varieties, poor or no use of plant protection measures, improper management practices, lack of winter precipitation and inadequacy of stored soil moisture, etc. Wheat 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. Similarly, chickpea is an important pulse crop of the semi-arid tropics, particularly in the rainfed area of the Indian sub-continent. Conservation technology plays important role to increase the productivity of wheat. Keeping the above in considerations try to know the role of conservation technology for the increase in the production of chickpea in comparison to wheat in this paper.

Keywords: Chickpea, Conservation technology, Productivity, Pulse crop, Staple food, Wheat.

INTRODUCTION

Chickpea or Bengal gram or gram (*Cicer arietinum*) is an important pulse crop of the semi-arid tropics, particularly in the rainfed ecology of the Indian subcontinent (Ali and Kumar, 2005). In ndia, chickpea is grown on an area of about 9.93 million ha, producing 9.53 million tonnes of grain with productivity of 960 kg ha^{-1} during 2013-14. In Punjab, chickpea is grown on an area of 1.9 thousand ha, producing 2.3 thousand tonnes of grain with an average productivity of 1211 kg ha^{-1} during 2013-14 (Anonymous, 2014-15). The daily per capita availability of 14 g chickpea is a source of about 2.3 per cent energy (56 Kcal) and 4.7 per cent protein (2.7 g) to Indian population, besides being an important source of Ca and Fe (10-12 per cent). The chickpea contains 21.1 per cent protein, 61.5 per cent carbohydrate, 4.5 per cent fat and is also rich in Ca, Fe and niacin. Malic and oxalic acids secreted from leaves, stems and pods have medicinal applications for bronchitis, catarrh, cutamenia, cholera, constipation, diarrhoea, digestive disorders, snakebite, sunstroke and warts. These acids are known to lower blood cholesterol level as well. Chickpea is used for human consumption as well as for feeding the animals. The seeds are also cooked as vegetable (chhole). Chickpea flour (besan) is used in the preparation of various types of sweets. Chickpea also plays an important role in sustaining soil productivity by improving its physical, chemical and biological properties and trapping atmospheric nitrogen in their root nodules (Ali and Kumar, 2005). A good crop of chickpea could fix up to 141 kg N ha^{-1} which economizes nitrogen application for succeeding cereals to the tune of 56-58 kg N ha^{-1} (Ahlawat *et al.,* 1981). There are two main types of chickpea cultivars desi or brown gram (microsperma, small seeded with yellow to brown testa) which constitute about 85 per cent of the total production and Kabuli (macrosperma, large seeded with Solomon white testa) with 15 per cent of the total production.

In the last four decades, the area, production and productivity of chickpea fluctuated widely. Some of the states like Punjab, Haryana, Uttar Pradesh and Bihar have lost considerable area of chickpea whereas other states like Andhra Pradesh, Maharashtra, Karnataka have brought additional area. There is a general perception that chickpea is a *rabi* crop and requires low temperature and prolonged winter season thus more fit for cultivation in northern India. It was probably true for the older varieties which were bred for cooler and long-season environments. Chickpea area was earlier confined to northern and central India. However, the scenario of chickpea cultivation has drastically changed in India during the past few decades, primarily because of two factors - (1) the green revolution that intensified wheat cultivation in northern India replacing rabi season pulses, particularly chickpea, and (2) development of short duration chickpea varieties which are better adapted to warmer and short-season environments, like central and southern India. There has been a major shift (about 4.0 million ha) in chickpea area from northern India (cooler, long-season environments) to central and southern India (warm, short-season environments). There has been an impressive growth in area, production and productivity of chickpea in India during the past decade. It is interesting to note that the growth rate of chickpea production was 5.89 % during last one decade which is much higher than other crops. During 2013-14, chickpea production exceeded 9.5 million tones attaining highest peak in production in the history of its cultivation in India (Anonymous, 2014-15).

Pulses have very low productivity due to several reasons. However, the obvious reasons are cultivation under energy starved conditions on marginal and sub-marginal lands with no or low input management, late sowing, higher degree of susceptibility to both abiotic and biotic stresses, unavailability of quality seeds of high yielding varieties, poor or no use of plant protection measures, improper management practices, lack of winter precipitation and inadequacy of stored soil moisture, etc (Ali and Mishra, 2000).

Among different components of production, use of improved varieties and planting method may prove beneficial to improve productivity of chickpea. Sowing or planting method influences the crop architecture through altering the plant geometry. Bed planting has been recently introduced as a planting method for cultivation of chickpea. The new concept of bed planting has proved better as it helps in better light interception, irrigation management, water use efficiency, root development and ultimately high yield.

The yield of chickpea may increase with zero tillage over conventional tillage due to significant reduction of weeds under zero tillage over conventional tillage. Crop establishment is a major production constraint of rainfed post-rainy-season crops in a poorly structured seedbed after lowland rice, because the soil may be wet or dry. When the soil is wet, germination may be inhibited due to poor aeration. A delay in sowing, however, increases the risk of the seedbed becoming too dry for successful germination. Moreover, as the puddled soil dries, it may become compact and hard, thus inhibiting both seedling emergence and root growth. Soil mechanical impedance and lack of aeration can both be alleviated by conventional tillage, although this may accelerate loss of soil moisture (Agrawal *et al.,* 1989; Gupta and Woodhead, 1989). Therefore, zero or minimum tillage could be beneficial (Khan *et al.,* 1981; Syarifuddin, 1979). Establishment of crops in zero tillage not only eliminates the problems associated with creating an adequate seedbed but also the turnaround time and cultivation cost may be reduced (Rathore *et al.,* 1998).

Late planting is also one of the factors for low productivity of crop. The advance seeding of chickpea can be made possible by planting under zero tillage conditions on residual soil moisture after the harvest of rice. Studies have reported that grain yield of wheat increased significantly (7.7 per cent) with zero tillage over the conventional tillage under such situations (Yadav *et al.,* 2005).

In northern part of India, rice- chickpea is the predominant cropping system next to rice - wheat system. Inclusion of chickpea not only increases the overall productivity of the system but also improve physico-chemical properties of the soil due to N saving from fertilizer source and build up soil fertility through biological source of N (Arya *et al.,* 2005).

Soil moisture is the key factor in increasing the productivity of crops which is scarce in *Rabi.* Its efficient utilization is possible by the application of surface mulches which reduces the water requirement of crops substantially through evaporation control without any reduction in yield (Bhan, 1976).

Low productivity of chickpea is also due to infestation of weeds and their competitive effects at all the stages of crop growth. According to Blackshaw (1994) cultivars for sustainable system should be high yielding and competitive against weeds.

Amongst pulses, chickpea though constitutes the major portion in area and production in country, yet cost - effective technologies are required to improve the quality of chickpea to compete in the international market which may be made possible by evaluation of different planting techniques (Singh and Kler, 2005). Keeping in view the above points, there is need to evaluate the role of conservation technology in the increase of production of chickpea in comparison to wheat.

Effect of planting techniques
Chickpea
Yield and yield attributing characters

A field experiment was carried out at the Indian Institute of Pulses Research, Kanpur to study the effect of tillage in chickpea (*Cicer arietinum L.)* raised after rice (*Oryza sativa L.*) (Arya *et al.,* 2005). Results revealed that deep ploughing with spade (23 cm deep) recorded significantly higher plant height, number of functional leaves, dry matter per plant, total number and dry weight of root nodules per plant, pods per plant and 100-seed weight, grain and straw yields than normal ploughing. The increase in grain and straw yields of chickpea in deep ploughing was 14.9 and 10.0 per cent over normal ploughing, respectively.

The research work was also conducted during 2002-03, in Haymana, Turkey (Kayan and Adak, 2005) with the chickpea cultivar Gokce and treatment were soil tillage, i.e. traditional tillage (TT), mouldboard plough at 15-20 cm depth and minimum tillage (MT), rotatry tiller at 8-10 cm depth and reported that TT recorded significantly higher grain yield than MT. Similar results were reported by Roy *et al*. (2014). They reported that chickpea sown without seed bed preparation with Pantnagar zero till drill produced the highest seed yield of 20.3 qha^{-1} followed by zero tillage after removal of stuble (18.7 qha^{-1}), zero tillage with happy seeder (18.7 qha^{-1}) and reduced tillage (18.0 qha^{-1}) as compared to conventional tillage with paddy straw incorporation (16.4 qha^{-1}).

In Karak, Pakistan conducted field experiment by Khattak and Khan (2005) during 2002-05 to evaluate the effect of tillage practices like no-tillage (NT), chisel ploughing once and tine cultivator 2 times (CPTC2), mould board ploughing once and tine cultivator 2 times (MBTC2), disc harrowing once and tine cultivator 2 times (DHTC2) and tine cultivator 3 times (TC3) on Chickpea yield under sandy loam condition. The maximum yield of chickpea was obtained from CPTC2 (19.68 q ha^{-1}) which was 18.98 per cent more than NT treatment (16.95 q ha^{-1}), which might be due to better control of weeds, improved soil moisture and nutrients.

In Maragheh, Iran during 1995-98 studied the effect of conventional planting, mechanized planting and direct drilling on the chickpea yield (Eskandari, 2004). Direct drilling and mechanized planting produced higher seed yield (8.91 and 8.11 q ha^{-1}, respectively) compared with conventional method of planting i.e. broadcasting and disc harrowing and broadcasting + mould board ploughing (6.27 and 5.55 q ha^{-1}, respectively). Conducted another field experiment to determine the effect of five tillage systems (moldboard plowing + disking as conventional tillage; chisel plowing + disking as reduced tillage; sweep plowing as minimum tillage; no tillage without and with previous crop residue on crop yield in a winter wheat-chickpea rotation during a 3-year period on a clay loam in Iran (Hemmat and

Eskandari, 2004). The highest yield of chickpea in three years was greatest under no tillage with or without residue. A reduced tillage chickpea yield was 27 per cent higher than conventional tillage. No-tillage chickpea yield was significantly greater (24 -57 per cent) than reduced, minimum or conventional tillage.

Conducted studies during 2000-02 in a typical semiarid Mediterranean environment (Silicy, Italy). Stringi *et al.* (2004) to evaluate the effect of different soil management practices such as no tillage (NT), mulch tillage (MT) and conventional tillage (CT) on the productivity of chickpea. They observed that average grain yield was significantly higher (21.5 per cent) under NT than CT. No significant differences were recorded between CT and MT. In Raipur, Chhatishgadh, Tripathi *et al.* (2004) conducted an experiment during 1999-2000 to 2000-01 to study the impact of ploughing intensity on the establishment and productivity of chickpea cv. JG-74. Treatments consisted of direct sowing, ploughing once and sowing on the same day, ploughing twice and sowing on the same day, two ploughings at different days and sowing, three ploughings at different days and sowing and farmer's practice (two ploughing of field and broadcasting and mixing by desi plough). They found that both ploughing once and sowing on the same day and ploughing twice and sowing on the same day gave higher yield than other treatments.

Conducted a field experiment to determine the feasibility of reduced tillage in silty clay loam soil where an average of 490 mm annual rainfall by Barzegar *et al.* (2003). This study compared the effects of three tillage systems, viz. moldboard plow (MP) followed by disc harrowing, single point chisel plow (CP), and sweep point chisel plow (SCP) on chickpea (*Cicer arientinum* L.) growth and yield. The highest and lowest chickpea grain yield was found in CP (6.20 q ha^{-1}) and MP (5.41 q ha^{-1}), respectively. CP also resulted in the highest biomass (13.08 q ha^{-1}) compared to two other tillage treatments. Overall, chisel plow was the most effective tillage tools for improving topsoil physical properties and increasing chickpea dry matter and grain yield compared to other tillage tools evaluated.

Dash and Verma (2003) conducted an experiment on wheat at Varanashi, to evaluate three tillage systems (zero tillage, zero tillage with mulching and conventional tillage). The zero tillage with mulching resulted significantly higher grain yield (32.4 q ha^{-1}) over the sole tillage and remained at par with conventional tillage operations. However, Hasan *et al.* (2003a) conducted field experiment under different combinations of tillage and mulch treatments, viz., no mulch and conventional tillage (farmer's practice), mulch and conventional tillage (country plough), deep tillage (30 cm depth) without mulch and deep tillage with mulch, showed that early harvest of rice varieties left enough residual moisture due to tillage amendments and mulch application. Available profile moisture left was able to meet up approximately two-thirds of the water requirement of chickpea (cv. BINA Sola and Hyperosola).

Maximum grain (28.7 q ha^{-1}) and straw (33.9 q ha^{-1}) yield of chickpea recorded by Jadhav and Pawar (1999) on ridges and in furrows than that of flat bed. However, Singh *et al. (*1998) conducted field experiment during 1992-93 to 1994-95 at New Delhi, to study the effect of tillage practices on the growth and yield of wheat and reported that wheat sown after conventional tillage resulted in taller plants, longer and heaviest ears, more grains per ear and higher grain yield than the wheat sown with zero tillage.

Studied the effect of zero, minimum and conventional tillage with and without rice straw mulch under rainfed conditions for three years (1990-91 to 1992-93) in a deep clayey soil in Raipur (Rathore *et al.,* 1998). Average grain yield of the three years under minimum tillage (MT), i.e. rotovating twice to stir the soil to 2-4 cm depth followed by planking, direct drilling in zero tillage (ZT) between the rows of preceding rice and direct drilling between the rows of preceding rice in zero tillage followed by inter-row tilling (ZTIRT) down to 3-5 cm depth in order to create soil mulch were statistically similar, but they were significantly superior over conventional tillage (CT), i.e. two cultivations to stir the soil to 8-10 cm depth with a cultivator operated with a 6 hp power tiller followed by levelling of the soil with a wooden plank. A significantly lower yield in CT was mainly due to poor plant population and subsequently poor growth of plant characteristics like plant height and number of pods per plant

The tillage practices had more effect on chickpea grain yield than N_2 fixation (Dalal *et al.,* 1997). This may have been due to below average rainfall years from 1992 to 1995. The zero tillage practice enhanced grain yields by about 20 per cent compared with conventional tillage. Horn *et al.* (1996) conducted study in conjuction with a long-term soil fertility restoration project at Warra, on the western Darling Downs and examined the effect of tillage practices; conventional tillage (CT) and Zero tillage (ZT) on dry matter yield, grain yield in chickpea and found that the effects of tillage practice were variable, depending on growth stage. At harvest, ZT plots produced greater total dry matter yield (42.0 q ha^{-1}) and grain yield (19.4 q ha^{-1}) than CT plots (30.1 and 12.9 q ha^{-1}, respectively).

Weed management

Hassan *et al.* (2003b) compared the performance of chickpea under zero tillage with conventional tillage in a rice based system and found that conventional tillage plots showed relatively lower weed infestation as compared to zero tillage. As a consequence of lesser weed competition, the higher seed yield was realized in the conventional tillage.

Root parameters

Rathore *et al.* (1998) reported that root density of chickpea was maximum in minimum tillage (MT), i.e. rotovating twice to stir the soil to 2-4 cm depth followed by planking at all the soil layers, followed by conventional tillage (CT), i.e. two cultivations to stir the soil to 8-10 cm depth with a cultivator operated with a 6 hp power tiller followed by levelling of the soil with a wooden plank, direct drilling between the rows of preceding rice in zero tillage followed by inter-row tilling (ZTIRT) down to 3-5 cm depth in order to create soil mulch and direct drilling in zero tillage (ZT) between the rows of preceding rice. In chickpea, the root density was higher up to 60 cm soil layers. This might be the reason for more extraction of soil water from deeper layers by chickpea.

Bulk density

Khan *et al.* (2006) studied the effect of various tillage practices in chickpea viz. no till (NT), chisel plough once and tine type cultivar twice (CPTC2), mould board plough once and tine type cultivator twice (MBTC2) and tine cultivator 3 times (TC3). They reported that CPTC2 and MBTC2 resulted in higher soil moisture content, lower bulk density and soil strength as compared to no till and shallow tillage treatment. However, Arya *et al.* (2005) reported that deep ploughing with spade (23 cm) reduced bulk density and particle density, however, water holding capacity and pore space were increased over normal ploughing in chickpea.

Nutrient uptake

Roy *et al*. (2014) reported that chickpea sown without seed bed preparation with Pantnagar zero till drill showed the highest NPK uptake as compared to other methods. However, Arya *et al.* (2005) recorded significantly highest nitrogen and potassium uptake by chickpea in deep ploughing with spade (23 cm deep) than normal ploughing (3 ploughing with harrow). At Punjab Agricultural University, Ludhiana, Singh and Kler (2005) conducted field experiment during 2001-02 to study the effect of three planting techniques (Bed II. Bed I i.e. 2 and 1 row bed and conventional flat sowing) and reported that nitrogen content in grain and straw of chickpea was highest in bed II (3.51 and 0.64 per cent) followed by Bed I (3.32 and 0.57 per cent) and flat (3.19 and 0.54 per cent), respectively. Similar trend was observed for protein content. Soil nitrogen status after harvest of crop at 0-15 cm soil depth showed non-significant increase at 15-30 cm soil depth. In Cordoba (Spain), Bellido *et al.* (2004) conducted field experiment) on a vertisol to determine the effects of tillage system (no-tillage and conventional tillage) and residual N on spring chickpea N uptake, soil nitrate content. The weather had a marked influence on chickpea N uptake. Total N uptake ranged from 60 to 90 kg ha^{-1}, of which between 42 and 82 per cent was removed by the seed. Total N uptake and seed N uptake were correlated with rainfall during the preceding fallow period and during the flowering and seed-filling period. Straw N uptake decreased with the increase of seed yield. The chickpea crop leaves poor above-ground N residues due to a high N harvest index. Seed N concentration ranged from 3.6 to 4.1 per cent, while straw N levels ranged from 0.8 to 1.4 per cent. The mean N utilization efficiency was 28.4 kg kg^{-1} (ranging from 11.4 to 22.8 per cent) and N harvest index (NHI) was 68 per cent (ranging from 45 to 82 per cent). Chickpea N uptake was directly related to soil nitrate content; it was greater under conventional tillage than under no tillage. However, Jadhav and Pawar (1999) recorded significantly more protein content in grain (25.49 per cent) on ridges and furrows than that of flat bed sown chickpea.

Economics

Arya *et al.* (2005) at Kanpur recorded maximum net return and benefit: cost ratio in deep ploughing with spade (23 cm deep) compared to normal ploughing in chickpea. Singh *et al.* (2005) conducted an experiment during rainy season of 2000 to winter season of 2003 at Meerut, U.P. and reported that strip tilling was most cost effective and energy efficient method, requiring lowest specific energy (430 kcal kg^{-1}) and specific cost (Rs 1.91 kg^{-1}), providing maximum benefit : cost ratio (3.67) and energy output : input ratio (6.98) and conventional sowing was least cost effective and energy efficient, requiring maximum specific energy (543 kcal kg^{-1}) and specific cost (Rs 2.52 kg^{-1}), and providing minimum benefit :cost ratio (2.81) and energy output : input ratio (5.52).

Effect of cultivar

Roy *et al*. (2014) reported that chickpea variety PBG 5 gave the higher seed yield of 20.9 qha^{-1} as compared to GPF 2 (17.0 qha^{-1}), BG 1053 (17.8 qha^{-1}) and L 550 (16.8 qha^{-1}) and also showed higher straw yield, biological yield, harvest index, NPK uptake and protein content. Carried a field experiment at the Indian Institute of Pulses Research, Kanpur by Kumar *et al.* (2006) to study the effect of tillage management on growth, yield and yield attributes of chickpea (*Cicer arietinum L.*) genotypes under rain fed conditions and found that growth attributes of chickpea was significantly higher in 'KWR 108' genotype than 'Pant G 114'. Chickpea cv. 'KWR 108' recorded significantly higher number of pods per plant, grains per pod, 100-seed weight, grain and straw yields of chickpea than 'Pant G 114'. In Rajasthan, Khan and Singh (2005) conducted field studies to determine the effect of cultivars and mulching on the production potential of chickpea under water harvesting conditions. Treatment combination comprised of 2 cultivars ('RSG 44' and local) and 3 mulches (no mulches, weed straw mulch and polythene mulch). They reported that cultivar 'RSG-44' exhibited superiority in all growth and yield parameters and polythene mulching produced highest seed yield as well as economic returns. At BHU, Varanasi, Singh *et al.* (2004) conducted field experiment during 1996-97 and 1997-98 to study the influence of 3 cultivars viz., 'Avrodhi', 'Radhey', 'Pant G114' on crop weed competition in chickpea at Agricultural Research Farm, Varanasi, Uttar Pradesh. They found that chickpea cultivar 'Avrodhi' proved better competition for space, soil moisture and nutrient compared to 'Radhey' and 'Pant G144'. Variety 'Avrodhi' recorded the highest grain yield (21.14 q ha^{-1}), net return and benefit: cost ratio (Rs.20564 ha^{-1} and 4.61) compared to 'Radhey' (Rs 18,964 ha^{-1} and 4.34) and 'Pant G-114 (Rs 18,134 ha^{-1} and 4.23). In another study, Khan *et al.* (2003) conducted field study to assess the effect of improved Vs traditional practices on the seed yield of improved chickpea cv. NIFA-88 and local (desi). Yield components i.e. pods per plant, 1000-seed weight and seed yield obtained with improved cv. NIFA-88 were significantly higher than local variety with traditional practices. However, Bahadur *et al.* (2002) carried a field experiment during 1998-99 to study the effect on growth and yield of three chickpea varieties (Nabin, Barichola-5, Hyperchola). Seed yield was maximum in the variety 'Barichola-5' followed by 'Nabin' with 15.7 q ha^{-1} and 13.8 q ha^{-1}, respectively. Whereas, Shivkumar (2001) reported that 'Biogreen' gave significantly higher plant height and dry matter accumulation than 'BG 256' and 'BG 209' which were at par with each other. The green seeded variety 'Biogreen' recorded significantly higher seed yield over 'BG 256' and 'BG 209'.

Jadhav and Pawar (1999) reported that 'Vijay' gave significantly maximum grain yield (29.2 q ha^{-1}) and straw (35.4 q ha^{-1}) which was 12 and 18 per cent higher than that of 'Vishal'. However, 'Vishal' gave maximum protein content (27.88 per cent) in grain and protein yield (7.3 q ha^{-1}) than that of 'Vijay'. However, Thakur *et al.* (1998) reported that 'JG 315' gave significantly higher yield and yield attributing characters such as pods per plant, grains per pod and 1000- grain weight than 'Ujjain 21'. Whereas, Mulik *et al.* **(**1995) in Maharashtra reported that use of improved cultivar ('Vikas') significantly increased the seed yield compared with local cultivar ('Chafa') during 1988-89. Dixit *et al.* (1993) conducted a field experiment during 1985-86 and 1986-87 at Pawarkheda and reported that 'Radhey' chickpea gave 2.61 and 1.54 q ha^{-1} higher straw and grain yields, respectively than 'Ujjain 21'. The net return was also higher in 'Radhey'.

Effect of planting techniques
Wheat
Yield and yield attributing characters

An experiment was conducted to determine the effect of tillage on wheat (*Triticum aestivum L.)* productivity under rice (*Oryza sativa L*.) –wheat growing system. Among the three tillage crop establishment methods, zero-tillage (ZT) and conventional tillage (CT) provided about 3 q ha^{-1} higher wheat grain yield over farmer's practice of CT-broadcast sowing (Chhokar *et al.,* 2007). It might be due to the better weed management and proper placement of seed in line than broadcasting method. There may be the reason of lodging to shallow placement of seed in broadcasting. However, another field experiment was carried out during 2001-02 to 2002-03 at Uttaranchal on a sandy clay loam soil to study the effect of tillage (conventional and zero) on productivity of wheat and found that performance of pooled yield in conventional and zero tillage was at par but 4 per cent higher in conventionally tilled plot (Bhattacharyya *et al.,* 2006). Here may be the reason of higher yield due to the well drained soil and placement of seed at proper depth as compared to conventional tillage. In another field studies, investigated the effects of conservation tillage using reduced tillage (RT), no tillage with mulching (NT), subsoil tillage with mulching (ST), conventional tillage (CT) on crop yield from 1999-2005 (Su *et al.,* 2007). They reported that average wheat yield over six years on NT or ST plots were significantly higher than in CT or RT plots. CT and RT yields did not vary significantly between them. Higher yield under NT or ST could be the soil water retention for longer period due to availability of residue of previous crop in NT and mulching in ST.

Three year field study was conducted to determine the effect of three tillage practices (conventional, zero and reduced/strip) and three crop residue management practices (removal, burning and incorporation) in secondary strips in wheat after rice (Gangwar *et al.,* 2006). Reduced tillage resulted in significantly higher overall mean wheat yield compared to conventional and zero tillage. Residue incorporation resulted in highest mean yield during third year. Maximum mean yield was obtained in reduced tillage followed by conventional tillage.

Conducted an experiment during 2001-02 and 2002-03 on clay loam soil at Kaul, Haryana by Ram *et al.* (2006) to evaluate the effect of three methods of tillage (sowing with zero till drill, sowing with rotavator drill and conventional sowing) on wheat for getting higher grain productivity, sowing by rotavator drill (reduced tillage) or by zero-till drill (zero tillage) gave significantly higher grain yield (47.4 and 49.6 q ha^{-1}, respectively) than conventional method (45.2 q ha^{-1}).

At Patna, carried out an experiment during 2000-01 to 2002-03 by Singh *et al.* (2006) to determine the effect of tillage practices (zero tillage, bed planting and conventional tillage) on yield of wheat and found that highest grain yield of 36.6 q ha^{-1} in zero tillage, followed by conventional tillage (34.1 q ha^{-1}) and bed planting (31.5 q ha^{-1}) However, Dhillon *et al.* (2005) at Ludhiana reported significantly higher grain yield, grains per ear and test weight of bed planted wheat as compared to conventional tillage wheat. An experiment conducted during 1997-98 and 1998-99 at Faizabad, Uttar Pradesh by Kumar and Yadav (2005) to determine the effect of tillage on productivity of wheat after rice. Sowing of wheat by Chinese seeder recorded significantly higher values of growth characters, yield attributes and yield of wheat followed by Pantnagar zero till drill and lowest in conventional tillage. Chinese seeder recorded 23.83 and 25.85 per cent more grain yield over conventional tillage during first and second year, respectively. A study at Meerut, U.P. conducted by Singh *et al.* (2005) during rainy season of 2000 to winter season of 2003 to evaluate the performance of the zero till drilling, strip till drilling, bed planting and conventional sowing in wheat under varying sowing or planting methods of rice. In wheat, strip till drilling resulted higher growth, grain (56.7 q ha^{-1}) and straw (78.2 q ha^{-1}) yields, followed by zero till drilling, conventional sowing and bed planting.

A field experiment was carried out by Yadav *et al.* (2005) during 1999-2000 and 2000-01 to assess the performance of zero tillage in wheat. Results revealed that grain yield and number of effective tillers per m row increased significantly by

7.7 and 6.6 per cent, respectively with zero tillage over conventional tillage.

At Ludhiana, Dhillon *et al.* (2004) found that grain yield was statistically similar under zero and conventional tillage in both bed and flat planting methods. However, it was significantly higher in flat planted wheat as compared to bed planted wheat. Whereas, conventional tillage recorded the highest mean yield of wheat followed by reduced tillage and zero tillage (Gangwar *et al.,* 2004). The yield reduction was in the order of 11·28 and 6·31 per cent under zero tillage and reduced tillage, respectively.

Carried out an experiment in Bihar by Gautam *et al.* (2002, found that higher wheat yield of 4.0 q ha^{-1} was obtained under zero tillage over conventional tillage. However, Bisen *et al.* (2002) in Varanasi reported that conventional tillage produced significantly higher grain yield of wheat than zero tillage and was at par with reduced tillage sown crop. Whereas, Mahey *et al.* **(**2002) at Ludhiana in Punjab recorded that grain yield of wheat was not significantly affected under zero (41.88q ha^{-1}), reduced (45.53 q ha^{-1}) and conventional (43.38 q ha^{-1}) tillage in loamy sand soil. But Sen *et al.* (2002) in Varanasi investigated that zero tillage gave significantly higher grain yield of wheat than conventional tillage in sandy clay loam soil.

A field trial was conducted during 1998-99 and 1999-2000 at Varanasi by Sharma *et al.* (2002), to compare the performance of conventional tillage, reduced tillage (Chinese rotavator), zero tillage in wheat and reported that Chinese rotavator proved most effective and recorded markedly higher values of yield-attributing characters, grain yield and output: input ratio. Conventional tillage though resulted in higher grain yield than zero tillage. From Hisar, Singh *et al.* (2002) reported that average grain yield of wheat increased by 5.5 per cent by sowing with bed planting technique (2 or 3 rows per bed) compared to conventional sowing.

An experiment conducted by Tripathi and Chauhan (2001) to study the effect of tillage on productivity of wheat and found that zero tillage (46.2 q ha^{-1}) recorded significantly higher yield (13.2 per cent) and its attributing parameters as compared with yield and its component characters recorded under conventional tillage (40.1 q ha^{-1}). However, Limon-Ortega *et al.* (2000) reported that higher grain yield was obtained from the wheat planted on permanent bed than the conventional till bed (fresh). Increase in wheat yield was recorded due to higher nitrogen use efficiency. Whereas, Rath *et al.* (2000) investigated that conventionally sown wheat gave 10 -13 and 28-35 per cent higher grain yield than raised bed and zero tillage sown wheat, respectively in silty clay loam soil. At Ludhiana, Samra and Dhillon (2000) conducted an experiment to improve production potential of rice – wheat system under different methods of crop establishment and found that conventional tillage and drill sowing recorded the highest mean grain yield, followed by minimum tillage and drill sowing in wheat. Conducted field experiment during 1991-92 and 1992-93 by Sharma *et al.* (1995) and reported that tillage practices, viz reduced and conventional, did not affect the grain yield of wheat significantly during both the years and gave grain yield of 52.3 and 53.2 q ha^{-1} under reduced tillage (with 1 harrow + 1 cultivator) and conventional tillage (with 2 harrows + 2 cultivators), respectively.

Weed management

Chhokar *et al.* (2007) found that *Rumex dentatus* was significantly higher (12.1 plants m^{-2}) in wheat under zero tillage (ZT) compared to conventional tillage (CT) (1.9 plants m^{-2}). CT favored *Phalaris minor*. The average *Phalaris mino*r dry weight under ZT and CT was 234.7 and 386.5 g m^{-2}, respectively. This differential response reflected was due to variation in seed distribution during puddling performed for rice transplanting. Recorded highest weed dry weight in wheat at 30 days after sowing under zero tillage (Gangwar *et al.,*2006) and lowest under conventional sowing. Rice straw mulching had a significant effect on conserving initial soil moisture (Rahman *et al.,* 2005) and reducing weed growth in wheat. At Ludhiana, Dhillon *et al.* (2005) recorded significantly less weed population and weed dry matter in bed planted wheat as compared to conventionally flat planted wheat. Weed biomass was markedly lower on raised beds than under conventionally sowing wheat (Aggarwal and Goswami, 2003). However, Singh *et al.* (2002) from Haryana reported that bed planting technique provides the possibility of mechanical weed control and may reduce the dependence on herbicides.

At Faizabad, Yadav *et al.* (2005) and Bisen *et al.* (2002) in Varanasi reported that significant reduction in dry weight of weeds was observed with zero tillage over conventional tillage sown wheat. However, Mahey *et al.* (2002) at Ludhiana reported that number of annual weeds in wheat before spray and after spray was significantly less in zero tillage as compared to reduced and conventional tillage. Singh *et al.* (2001) in Uttranchal reported more weed emergence in conventional tillage (146 m^{-2}) and reduced tillage (141 m^{-2}) than zero tillage (103 m^{-2}) at 30 days stage of wheat.

Root parameters

Singh *et al.* (2006) found that root characters of wheat like area (10.5 cm^2) and length (48.1 cm) were highest in bed planting, followed by conventional and zero tillage at tillering as well as flowering stage. However, Gangwar *et al.* (2004) studied the effect of tillage; conventional tillage (CT), reduced tillage (RT), zero tillage (ZT)) on crop growth, yield and nutrient use in wheat (*Triticum aestivum* L.) grown after different methods of rice (*Oryza sativa* L.) and reported that greater root density in terms of root dry weight (7·50 Mg per 20 cm row length) was recorded in CT and the lowest root dry weight (5·80 Mg per 20 cm row length) was obtained in ZT during 2000-01.At Switzerland, Qin *et al.* (2004) reported the slightly lower root length density and slightly larger mean root diameter of wheat under no-tillage as compared to conventional tillage. However, Singh (1996) reported that root mass density of wheat in surface 0-20 cm layer was 5.3 and 10.2 per cent more under reduced and conventional tillage than zero tillage, respectively. Whereas, Gajri *et al.* (1992) at 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.

Rahman *et al.* (2005) conducted field experiment in Dinajpur, Bangladesh to evaluate rice straw as mulch for no-till wheat. The treatments included three levels of mulching: no mulch (M_0), surface application of rice straw mulch at 4.0 Mg ha^{-1} that was withdrawn at 20 days after sowing (M_1), the same level of mulch as M_1 but allowed to be retained on the soil surface (M_2) and reported that root length density and root weight density of wheat were positively influenced both by straw mulching.

Infiltration rate

Infiltration rate is an important parameter which is expressed to be influenced by tillage operations. Gangwar *et al.* (2006**)** recorded the highest infiltration rate (1.50 cm hr^{-1}) under residue incorporation followed by residue burning (1.44 cm hr^{-1}) and lowest (0.75 cm hr^{-1}) under zero tillage sown wheat.

Ram (2006) reported higher infiltration rate under bed planting system (fresh beds) in wheat. However, Aggarwal and Goswami (2003) reported lower infiltration rate on raised beds than under flat sowing of wheat.

Arshad *et al.* (1999) reported that steady stage infiltration in wheat was 60 per cent higher in zero tillage than conventional tillage on a silt loam soil. 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. However, Singh (1996) observed higher intake of water during first hour under zero tillage (10.48 cm hr^{-1}) as compared to reduced tillage (9.18 cm hr^{-1}) and conventional (8.63 cm hr^{-1}) tillage at harvest of wheat.

Hullugalle *et al.* (1994), Lawrence *et al.* (1994), and Narang *et al.* (1992) reported higher infiltration rate in untilled plots than conventionally tilled plots in different cropping systems. However, Chang and Lindwall (1992) reported no difference in infiltration rate among the zero tillage and conventional tillage.

Bhattacharyya *et al.* (2006) reported that soil bulk density decreased significantly with conventional tillage than zero tilled plots of wheat. Pandey *et al.* (2005) in Bihar reported that tillage practices reduced the bulk density of soil than zero tillage in wheat. Kumar (2000) in Uttar Pradesh reported that bulk density decreased (1.49 to 1.23 g cm^{-3}) with increase in number of tillage operation in wheat. Gill and Aulakh (1990) in Zambia investigated that highest grain yield of wheat and lowest bulk density were observed under zero tillage among other tillage systems (harrowing, conventional ploughing, chiseling at planting and residue removed). However, Gangwar *et al.* (2006)

reported the highest soil bulk density under zero tillage and lowest under residue incorporation in wheat. Singh (1996) reported at Ludhiana that bulk density of soil in top 0-15 cm layer under zero tillage was higher (1.71 g cm^{-3}) than reduced (1.65 g cm^{-3}) and conventional (1.60 g cm^{-3}) tillage at harvest of wheat. Hill (1990) in Maryland found that no-tilled soils generally had higher bulk density at all the soil depths. Chauhan *et al.* (2002) in Hisar found that higher stability of soil aggregates under zero tillage in wheat was observed due to accumulation of more organic matter resulted in reduced soil erosion. However, Ram (2006) reported lower bulk density under bed planting system (fresh beds) in wheat. Aggarwal and Goswami (2003) reported lower bulk density on raised beds than under flat sowing of wheat.

Nutrient uptake

Gangwar *et al.* (2004) recorded significantly lower values of available soil N and higher values of soil P and K under CT whereas ZT recorded higher values of available soil N and lower values of available soil P in wheat. From Alberta, Canada Carefoot *et al.* (1990) reported that the dominant effect on grain nitrogen concentration was an inverse relationship with grain yield. However, when grain yields were similar between tillage systems, greater inorganic N with conventional tillage treatment was reflected in large grain nitrogen concentration.

Economics

Ram *et al.* (2006) reported that sowing of wheat with rotavator resulted in higher benefit: cost ratio and net returns, followed by zero tillage, whereas conventional tillage was found to be the least remunerative. At Varanasi, Dash and Verma (2003) reported that zero tillage with mulching gave higher net benefit: cost ratio of 1.56:1 in wheat compared with 1.14: 1 in zero tillage alone. However, Gautam *et al. (*2002) in Bihar reported that zero tillage resulted in early sowing of 9 days with saving of Rs. 1400 ha^{-1} from land preparation and increased yield of wheat 4.0 q ha^{-1} over conventional method. However, Nagarajan *et al.* (2002) recorded that zero tillage technology increased the farmer's margin to extent of Rs. 1882 ha^{-1} and saving of inputs. The various research workers have reported 60-70 per cent saving of time and 67-80 per cent saving of fuel with zero tillage seeding technique over conventional tillage (Rauntaray, 2002; Sharma *et al.,* 2002). In Bihar, Prasad *et al.* (2002) reported that during the two year of study, zero tillage with yield of 46.88 and 35.27 q ha^{-1} out yielded as compared to conventional tillage with yield of 37.18 and 30.75 q ha^{-1} with markedly better net returns, benefit : cost ratio and advancing sowing by 20 days.

CONCLUSION

The research work related to conservation technology in case of wheat was done in irrigated areas particularly in the rice-wheat predominant areas. It was found that conservation technology like zero tillage and minimum tillage increase the grain yield due to the effective control of weeds and improve in the physical and chemical properties of soil. Although, the research work on conservation technology in chickpea was done limited as compared to wheat but results were found like the wheat. It is known chickpea was sowing deep as compared wheat that is why chickpea gave better performance under the zero tillage and minimum tillage by placing the seed at proper depth and soil moisture, which resulted in better yield in chickpea.

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