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**Research Paper**

# Weed dynamics, productivity and soil health under different tillage and weed-control practices in wheat (*Triticum aestivum*)–maize (*Zea mays*) cropping sequence

C. SHEKHAR[1], D. SINGH[2], A.K. SINGH[3], V. NEPALIA[4] AND J. CHOUDHARY[5]

*Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313 001*

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## ABSTRACT

A field experiment was conducted during 2009–10 and 2010–11 at Rajasthan College of Agriculture, Udaipur, to study effect of 5 tillage systems and 3 weed-control practices on weed dynamics, productivity, and to workout most viable tillage practices in wheat [*Triticum aestivum* (L.) Emend. Fiori & Paol.]–maize (*Zea may* L.) cropping sequence. Weed density, grain yield of wheat, maize and wheat-equivalent yield were found statistically equal in continuous conventional tillage and adoption of rotated zero tillage in wheat and conventional tillage in maize under wheat–maize cropping sequence. Adoption of zero tillage in wheat and conventional tillage in maize also proved economically beneficial with the highest net returns (₹73,868/ha) and benefit: cost ratio (2.11) compared to net returns (₹72,476/ha) and benefit: cost ratio (1: 94) recorded under continuous conventional tillage in both crops. Amongst the weed-control practices, use of isoproturon (0.75 kg/ha) in wheat and atrazine (0.5 kg/ha) followed by 1 hoeing in maize significantly reduced weed density, dry matter and recorded significantly higher wheat–maize and wheat-equivalent grain and straw yields than 2 hand weedings and weedy check. Application of isoproturon (0.75 kg/ha) in wheat and atrazine (0.5 kg/ha) in maize resulted in the highest net returns of ₹82,749/ha and benefit: cost ratio 2.41 and proved significantly higher over 2 hand-weedings by ₹5,876/ha and benefit: cost ratio 0.43. At the end of 2 cycles adopting zero tillage in wheat and conventional tillage in maize significantly enhanced organic carbon content by 4.0% over continuous conventional tillage; however, did not influence status of available nitrogen and phosphorus significantly in soil. The weed-control practices did not influence available nitrogen status of soil; however, organic carbon and available phosphorus status of weedy check plots increased significantly over rest of the weed-control treatments.

***Key words :*** Soil health, Tillage, Wheat–maize sequence, Weed control, Yields

Wheat and maize are the most important integral components of food security at global level. Amongst different wheat-based cropping systems, wheat–maize ranks first with 1.8 million ha area that contributes about 3% in the total foodgrain production of India. In Rajasthan, wheat and maize are grown in 3.06 and 1.00 million ha with annual production of 10.76 and 1.04 million tonnes with average yields of 3.52 and 1.68 t/ha respectively (Government of Rajasthan, 2012). At present soil, a natural resource, is under great stress in the country. Repeated conventional tillage caused degradation of our soil over the past 50-60 years and much of soil has lost up to one-half of its native organic matter content (Malik *et al*., 2006). If we are to counter the effects of soil degradation caused by excessive tillage of the soil, we must find and adopt new methods of tillage. Hence in recent past years, major research thrust has been given to improve or reduce aforesaid technological component without sacrificing productivity of crop. Zero-tillage seeding is one method adopted to achieve this goal of conservation. Zero tillage offers the benefit of saving of fuel, time, labour, retained surface residue, improve organic carbon (OC), nutrient, reduced soil water losses, protects the soil from sun, rain, wind and allows soil micro-organisms, fauna, reduces the breakdown of soil structure, involves protection of the soil compaction by machinery and from changes to its chemistry through acidification or salinization (Bisen and Singh, 2008; Jha *et al.,* 2011). Decline in population of a notorious weed under zero tillage had *Phalaris minor* set cases

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[1]**Corresponding author Email:** dilipagron@gmail.com

[1]Ph.D. Scholar, [2&4]Professor, [5]Assistant Professor, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan; [3]Principal Scientist, Directorate of Maize Research, New Delhi

of acceptance of this technology in north India (Mahajan *et al.,* 2002) and looks set to become one of the best technologies after green revolution (Gupta *et al.,* 2011). Further, extensive research has clearly established that the FIRB (Furrow irrigated raise bed) and bed planting is one of the low-cost sustainable planting systems of wheat–maize which helps crop to utilize solar radiation efficiently, saves water, reduces crop lodging and reduces population of herbicide resistant weed like *Phalaris minor* (Kumar *et al.,* 2010). Therefore, it seems that diverting from conventional to zero-tillage, rotated tillage or FIRB-bed system, there may be change in weed dynamics. Hence there is urgent need to evaluate tillage and weed control on productivity of wheat–maize cropping sequence in southern Rajasthan.

## MATERIALS AND METHODS

A field experiment was carried out during winter (*rabi*) rainy season (*kharif*) seasons of 2009–10 and 2010–11 at Udaipur (23°34'N, 73°42'E and 582.1 m above the mean sea-level). The soil was clay loam, having pH 7.3, organic carbon 0.66%, available nitrogen 268.4 kg/ha, phosphorus 19.5 kg/ha and potassium 365.5 kg/ha in the plough layer. The well-distributed rainfall of 585 and 460 mm was recorded during *kharif* 2010 and 2011. The treatment, combination of 5 tillage systems, viz. Continuous conventional tillage in wheat–maize (CT); continuous zero tillage in wheat–maize (ZT); ZT–CT, zero tillage in wheat–conventional tillage in maize; CT-ZT, conventional tillage in wheat–zero tillage in maize and furrow-irrigated raised bed planting of wheat–bed planting of maize) (FIRB-bed): and 3 weed-control practices (weedy check, recommended practices of weed control in both crops, viz. Isoproturon 0.75 kg/ha in wheat and atrazine 0.5 kg/ha in maize and 2 hand-weeding) were tested in 3 replication in split-plot design keeping tillage in main plots and weed control in subplots on a fixed site. The recommended practice of weed control in wheat–maize cropping sequence of southern Rajasthan, viz. application of isoproturon 0.75 kg/ha at 32 days after sowing in wheat and pre-emergence application of atrazine 0.75 kg/ha followed by 1 hoeing at 25 days after sowing (DAS) in maize were used as recommended practices of weed control in both crops. The wheat 'Raj 4037' and maize 'PEHM 2' were used as test varieties. During both the years, wheat and maize crop were sown in first fortnight of November and July using 100 and 20 kg seed/ha respectively. In conventionally prepared field furrow were opened at 23 cm and 70 cm apart for wheat and maize respectively and seeds were placed at a depth of 3–4 cm manually. However, in zero tillage, crop was planted by direct seeding using zero till ferti-seed drill at 23 cm and 70 cm row spacing in wheat and maize crop respectively. In FIRB system, beds were opened at 70 cm and 2 rows of wheat and 1 row of maize was planted on each bed using tractor-drawn multi-seeder. The wheat and maize crops were harvested during the second fortnight of April and October respectively, during both the years. Thinning of maize was carried out 15 days after sowing to maintain required plant population. The recommended dose of fertilizers was given to both the crops. In each plot grassy weeds, broad-leaf weeds and sedges were counted from 2 randomly selected area of 0.25 $m^2$ using 0.5 m × 0.5 m quadrate. Weed count was expressed as number/$m^2$ and subjected to square-root transformation to normalize their distribution. The weeds removed from above mentioned 0.25 $m^2$ areas were dried at 65°C to obtain constant weight and the weight was expressed in g/$m^2$. Net returns and benefit: cost ratio were calculated on basis of prevailing market prices of inputs and produce. Crop growth rate (CGR) and soil status of different nutrient were worked out by using standard methods for analysis and formula (Redford, 1967).

### *Weed flora*

The important weeds of the experimental site in the winter (*rabi*) were grassy weeds, viz. *Phalaris minor* Retz., *Cynodon dactylon* (L.) Pers., *Avena fatua* (L.); broad-leaves weeds, viz. *Chenopodium album* (L.), *Chenopodium murale* (L.), *Convolvulus arvensis* (L.), *Melilotus indica* (L.) All., *Parthenium hysterophorus* (L.) and sedges viz., *Cyperus rotundus* (L.). In the rainy season, important weeds noticed were grassy weeds, *Echinochloa crus-galli* (L.) Beauv., *Echinochloa colonum* (L.) Link., *Cynodon dactylon* (L.) Pers; and broad-leaves, viz. *Phyllanthus niruri* Hook f., *Digera arvensis* Forsk., *Commelina benghalensis* L., *Trianthema portulacastrum* (L.), *Parthenium hysterophorus* (L.) among broad-leaf weeds; and sedges, viz. *Cyperus rotundus* (L.).

## RESULTS AND DISCUSSION

### *Weed density*

Adopting ZT in both the crops significantly increased the population of grassy weeds in wheat crop over rest of tillage systems. At the same time, the rest of the tillage systems were statistically similar with each other in this respect. Different tillage systems in wheat–maize crop sequence had no significant effect on density of broad-leaf weeds. Adoption of continuous ZT in wheat–maize proved statistically on par with ZT-CT in wheat–maize cropping and both of these practices enhanced sedges population significantly over continuous CT, CT-ZT and FIRB-bed in wheat-maize system. Alike wheat crop, adoption of ZT in both wheat–maize crop rotation significantly increased the density of grassy weed in maize crop over rest of tillage systems. The highest density of broad-leaf weeds were recorded under FIRB-Bed in wheat–maize cropping, which was at par with continuous ZT in both crops and ZT-CT in wheat–maize cropping, however, proved significantly higher over rest of tillage systems. The highest density of sedges was recorded with the adoption of continuous ZT in both the crops, being significantly higher over rest of tillage systems. The improvement in density of grassy weeds under continuous zero tillage in wheat–maize cropping might be due to higher deposition of seed in upper layer of soil (0–10 cm) with no disturbance of the top soil. However, under continuous conventional tillage and rotated tillage lower grassy weed population could be ascribed to comparatively less number of seeds of this category on top 0-10 cm layer of soil due to burying of seed into deeper layer and killing of newly emerged weeds with repeated tillage operation, viz. ploughing, harrowing and cross cultivator (Mahajan *et al.* 2002).

In both the crops minimum density of all 3 categories of weeds were observed under 2 hand-weedings and application of recommended herbicides in both the crops which were significantly lower compared to weedy check treatment. Under 2 hand-weeding treatment, the lower density of weeds could be due to removal of 2 flushes of weeds manually 25 and 50 days after sowing and later on good numbers of functional leaves might have smothering effect on the third flush of all categories of weeds could be possible reason for decrease in density of weeds at 60 DAS (Bisen and Singh, 2008). On the contrary, little higher weed density under isoproturon treatment could be due to its application at 32 DAS, which controls only 1 flush of weeds. Similarly, in maize, pre-emergence application of atrazine followed by 1 hoeing at 25 DAS controlled 2 flushes of weeds; however, later on wide spacing of crop encouraged weed at later stages of crop growth.

### *Weed dry-matter*

In wheat**,** the highest dry matter of grassy weeds was recorded under repeated ZT in wheat–maize cropping system, which was significantly higher over rest of the tillage systems, whereas in maize the density of grassy weeds was statistically at par in all tillage systems. Contrary, the dry matter of broad-leaf weed recorded in wheat crop was at par in tillage system, whereas in maize its highest value was recorded under bed planting, which was statistically at par with continuous ZT, ZT-CT in wheat–maize system, however, proved significantly higher over rest of the tillage systems. The dry matter of sedges recorded in continuous CT in both crop was significantly higher over rest of tillage systems.

The maximum reduction in dry matter of all 3 categories of weeds were recorded in 2 hand-weedings treatment, which was significantly lower compared to isoproturon and weedy check in wheat crop. However, in maize the minimum dry matter of all categories of weeds were recorded under 2 hand-weedings, which was statistically at par with pre-emergence application of atrazine 0.5 kg/ha followed by 1 hoeing at 25 DAS, and both these treatments proved caused significantly lower weed dry-matter compared to weedy check. The dry matter is being a function of weed density followed the same trend in both the crops (Jain *et al.,* 2007).

### *Nutrient content and uptake by weeds*

Nitrogen and phosphorus content and uptake recorded from total population of weeds in wheat and maize crop at harvesting failed to record significant variation under different tillage systems. It might be on account hardy roots of weeds which easily grow under soil prepared by different tillage systems and extract nutrient and moisture from deeper layer (Kumar, 2000). The data of dry matter of total weeds recorded at harvest though not presented in tables but it was statistically at par in different tillage system. The Nutrient uptake being a function of dry-matter followed the same at harvest in both the crops (Jain *et al.,* 2007).

Nitrogen and phosphorus content recorded in total weeds obtained under treatment of 2 hand-weedings and recommended herbicide in case of wheat–maize system were statistically equal and significantly lower than the weedy check during both the years. In weedy plots, the weeds were well established in soil with proper root development compared to shallow root in ispproturon, atrazine + 2 hand-weedings plot wherein the weeds are of third flush and unable to extract nutrient from deeper layer of soil (Kumar, 2000). However, the nutrient uptake, being a function of dry-matter, followed the trend of dry-matter of total weeds at harvesting stage in both the crops (Jain *et al.,* 2007) and thus its accumulation by total weeds under hand-weeding treatment were significantly lower than the recommended herbicide application and weedy check in both the crops

### *Growth parameters*

Different tillage systems under test did not differ significantly for their effect on plant height and crop-growth rate of wheat. The wheat crop accumulated the highest biomass under continuous conventional tillage which was at par with rotated ZT-CT and CT-ZT in wheat–maize but proved significantly higher over rest of the tillage systems. However, in maize the highest plant height, dry-matter accumulation and crop-growth rate recorded in continuous conventional tillage were at par with rotated ZT-CT and

FIRB-Bed planting in wheat–maize system but significantly higher over the rest of tillage systems. In general overall improvement in growth under conventional tillage, and rotated ZT-CT, CT-ZT in wheat–maize system seems to be due to better tilth, aeration, improved water-holding capacity of soil, better root growth and its proliferation, which might have promoted growth of leaves by virtue of enhanced cell-division and increased better interception, absorption and utilization of radiant energy, thereby resulting in higher photosynthesis and better CGR and finally growth parameters (Bisen and Singh, 2008).

Highest plant height in wheat and maize, biomass and crop growth rate in wheat found under 2 hand-weedings, were at par with isoproturon and both of these proved significantly superior to the weedy check. Whereas in maize dry-matter accumulation and crop growth rate recorded under atrazine were significantly higher than that recorded under 2 hand-weedings and weedy check. The better growth parameters were owing to significant reduction in weed density and dry-matter yield of weeds under treatments of hand-weeding and recommended herbicides in both crops, and indirectly it might be on account of results of better plant growth, greater penetration of solar radiation in the crop canopy, which can be reasoned for greater rate of photosynthesis and more accumulation of dry matter and crop growth rate (Singh *et al.*, 2010).

### *Yield attributes and yields*

The highest test weight was recorded under bed planted wheat, being significantly higher than rest of the tillage systems, whereas number of effective tillers/m$^2$ consequently wheat grain yield under continuous CT, rotated ZT-CT and CT-ZT in wheat–maize cropping sequence were statistically at par and significantly higher over continuous ZT and bed-planted wheat. The highest straw yield of wheat was recorded under continuous CT, which was at par with rotated ZT-CT and CT-ZT in wheat–maize cropping sequence, but was significantly higher over continuous ZT and bed planted wheat. In maize, grains/cob consequently grain and stover yields recorded under continuous adoption of conventional tillage, rotated ZT-CT and bed planting were at par and proved significantly higher over continuous ZT and rotated CT-ZT in wheat–maize sequence. Tillage systems failed to record perceptible variation in test weight of maize. Wheat-equivalent grain and stover yields recorded under continuous CT was the highest which was statistically at par with rotated ZT-CT in wheat–maize

**Table 1.** Effect of tillage systems and weed control on weed density and weed dry matter at 60 DAS in wheat–maize cropping sequence (pooled data of 2 years)

| Treatment | Weed density at 60 DAS (No./m$^2$) | | | | | | Weed dry matter at 60 DAS (g/m$^2$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wheat | | | Maize | | | Wheat | | | Maize | | |
| | Grassy | Broad leaf | Sedges | Grassy | Broad leaf | Sedges | Grassy | Broad leaf | Sedges | Grassy | Broad leaf | Sedges |
| *Tillage systems* | | | | | | | | | | | | |
| Wheat (CT)–Maize (CT) | 4.37(19.8) | 10.41(115.9) | 2.95(8.3) | 7.46(73.0) | 5.67(35.5) | 2.63(6.9) | 3.57 | 24.13 | 0.149 | 25.77 | 12.03 | 2.110 |
| Wheat (ZT)–Maize (ZT) | 4.83(24.6) | 10.26(111.5) | 3.32(10.8) | 8.63(91.8) | 5.02(28.5) | 3.44(12.3) | 5.04 | 24.05 | 0.237 | 32.08 | 9.59 | 3.396 |
| Wheat (ZT)–Maize (CT) | 4.51(21.3) | 10.09(107.6) | 3.21(10.0) | 7.53(74.1) | 5.61(34.6) | 2.75(7.4) | 4.15 | 23.67 | 0.207 | 27.18 | 11.67 | 2.225 |
| Wheat (CT)–Maize (ZT) | 4.42(20.2) | 10.34(111.9) | 3.02(8.7) | 7.57(75.8) | 5.42(32.8) | 2.92(8.6) | 3.75 | 23.98 | 0.165 | 28.70 | 11.21 | 2.571 |
| Wheat (FIRB)–Maize (Bed) | 4.47(21.0) | 10.96(127.7) | 3.05(8.9) | 7.56(74.4) | 5.80(37.1) | 2.65(7.0) | 3.96 | 26.22 | 0.163 | 26.89 | 12.46 | 2.142 |
| SEm± | 0.018 | 0.322 | 0.062 | 0.170 | 0.089 | 0.074 | 0.163 | 0.883 | 0.008 | 1.17 | 0.338 | 0.111 |
| CD (P=0.05) | 0.242 | NS | 0.186 | 0.510 | 0.266 | 0.223 | 0.488 | NS | 0.024 | NS | 1.013 | 0.333 |
| *Weed control* | | | | | | | | | | | | |
| Weedy check | 6.16(37.6) | 13.85(192.0) | 3.39(11.1) | 13.68(187.1) | 8.25(67.7) | 3.88(14.9) | 7.62 | 43.28 | 0.232 | 70.54 | 22.99 | 3.480 |
| Isoproturon (0.75 kg/ha)*/ Atrazine (0.5 kg/ha)** | 3.82(14.1) | 9.31(87.4) | 3.36(10.9) | 4.90(24.3) | 4.23(17.6) | 2.36(5.2) | 2.58 | 17.47 | 0.209 | 7.08 | 5.86 | 1.999 |
| 2 hand-weedings | 3.58(12.4) | 8.08(65.4) | 2.57(6.2) | 4.67(22.2) | 4.03(15.9) | 2.39(5.3) | 2.08 | 12.47 | 0.111 | 6.75 | 5.32 | 1.988 |
| SEm± | 0.041 | 0.104 | 0.037 | 0.088 | 0.053 | 0.054 | 0.116 | 0.618 | 0.006 | 0.799 | 0.244 | 0.080 |
| CD (P=0.05) | 0.117 | 0.297 | 0.106 | 0.250 | 0.153 | 0.156 | 0.331 | 1.765 | 0.016 | 2.284 | 0.697 | 0.228 |

Values are transformed and actual values are in parentheses; *in wheat and **in maize; DAS, days after sowing

**Table 2.** Effect of tillage systems and weed control on nutrient content and uptake in weeds and growth character of wheat crop (pooled data of 2 years)

| Treatment | Nutrient status in weeds plant in wheat crop a harvest | | | | Nutrient status in weeds plant in maize crop at harvest | | | | Growth and yield attributes of wheat | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Content (%) | | Uptake (kg/ha) | | Content (%) | | Uptake (kg/ha) | | Plant height (cm) | DM at 60 DAS (g/m$^2$) | CGR* | Effective tillers (m$^2$) | Test weight (g) |
| | N | P | N | P | N | P | N | P | | | | | |
| *Tillage system* | | | | | | | | | | | | | |
| Wheat (CT)–Maize (CT) | 2.064 | 0.289 | 10.23 | 1.46 | 1.235 | 0.191 | 6.17 | 0.94 | 84.0 | 434.6 | 9.74 | 317 | 40.90 |
| Wheat (ZT)–Maize (ZT) | 1.931 | 0.283 | 9.67 | 1.42 | 1.005 | 0.188 | 6.55 | 1.03 | 80.7 | 412.8 | 9.12 | 310 | 39.35 |
| Wheat (ZT)–Maize (CT) | 1.985 | 0.280 | 9.51 | 1.37 | 1.235 | 0.197 | 6.25 | 0.94 | 82.5 | 427.3 | 9.78 | 315 | 39.73 |
| Wheat (CT)–Maize (ZT) | 2.012 | 0.284 | 9.95 | 1.42 | 1.197 | 0.191 | 6.68 | 1.00 | 83.3 | 422.7 | 9.47 | 314 | 39.96 |
| Wheat (FIRB)–Maize (Bed) | 2.066 | 0.283 | 11.51 | 1.65 | 1.232 | 0.193 | 6.47 | 1.01 | 86.0 | 388.1 | 8.90 | 270 | 42.49 |
| SEm± | 0.035 | 0.003 | 0.369 | 0.052 | 0.017 | 0.004 | 0.220 | 0.040 | 1.7 | 6.8 | 0.38 | 4.1 | 0.39 |
| CD (P=0.05) | NS | NS | NS | NS | 0.052 | NS | NS | NS | NS | 20.6 | NS | 12.5 | 1.16 |
| *Weed control* | | | | | | | | | | | | | |
| Weedy check | 2.195 | 0.326 | 18.09 | 2.69 | 1.567 | 0.233 | 16.04 | 2.38 | 79.8 | 366.0 | 8.19 | 278 | 37.16 |
| Isoproturon (0.75 kg/ha)*/ Atrazine (0.5kh/ha)** | 1.940 | 0.265 | 7.13 | 0.97 | 1.000 | 0.175 | 1.71 | 0.30 | 84.8 | 435.8 | 9.77 | 314 | 41.57 |
| 2 hand-weedings | 1.900 | 0.261 | 5.30 | 0.73 | 0.975 | 0.170 | 1.53 | 0.27 | 85.4 | 449.6 | 10.24 | 324 | 41.73 |
| SEm± | 0.017 | 0.002 | 0.253 | 0.039 | 0.011 | 0.002 | 0.163 | 0.028 | 1.12 | 5.2 | 0.23 | 2.25 | 0.21 |
| CD (P=0.05) | 0.052 | 0.005 | 0.724 | 0.112 | 0.032 | 0.006 | 0.465 | 0.080 | 3.21 | 15.0 | 0.66 | 6.44 | 0.61 |

*in wheat, ** in maize *CGR, crop growth rate from 30–60 days after sowing (g/m/day); N, Nitrogen; P, phosphorus; DM, dry-matter

system and proved significantly superior to rest of tillage systems. The better growth might have developed each reproductive structures consequently yield under continuous CT, rotated ZT-CT and CT-ZT (Jha *et al.,* 2011). Under FIRB planting system, similar number of plants were accommodated under reduced area by 33% compared to rest of the tillage systems. This might have resulted in inter-and intra-row competition for various growth inputs and thus in spite of good growth of plant, the number of effective tillers/ m$^2$ were very low causing poor yield under FIRB system of planting wheat (Kumar *et al.,* 2010).

In comparison to least value under weedy check, 2 hand-weedings and application of isoproturon in wheat and atrazine in maize resulted significant increase in of growth, yield attributes, yields and wheat-equivalent yield. The increase were obviously owing to better weed control which rendered favourable conditions like increased availability of nutrients, moisture, light and other to crop plants, which resulted in better growth and higher yields (Jain *et al.,* 2007).

### *Economics*

Rotated ZT-CT in wheat–maize system fetched the highest net returns, being at par with continuous CT, proved significantly better than rest of the tillage systems. However, the highest benefit: cost ratio was recorded under rotated ZT-CT in wheat–maize system, which was at par with continuous ZT but proved significantly higher over rest of tillage systems. Application of recommended herbicides for both the crop recorded the highest net returns and benefit: cost ratio, which were significantly higher over 2 hand-weedings and weedy check.

### *Soil properties*

At the end of second cropping sequence, the highest organic carbon content was obtained under continuous adoption of zero tillage, which was at par with rotated ZT-CT and CT-ZT in wheat–maize system, however proved significantly higher over FIRB-bed in wheat–maize system and conventional tillage in both crops. The tillage systems failed to record perceptible variation in available nitrogen and phosphorus status of soil. Similarly organic carbon and available phosphorus content recoded in plots of recommended herbicides for both the crop and 2 hand-weedings was significantly lower compared to weedy check. The weed-control methods failed to record perceptible variation in available nitrogen status of the soil. Better soil aggregation due to weed residue

**Table 3.** Effect of tillage systems and weed control on growth character of maize, yields, system economics and soil properties (pooled data of 2 years)

| Treatment | Growth and yield attributes of maize | | | | | Yield (t/ha) | | | | | | System | | Soil properties | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Plant height (cm) | Dry-matter (g/plant) | CGR* | Grains/ cob | Test weight (g) | Wheat Grain | Wheat Straw | Maize Grain | Maize Stover | Wheat equivalent Grain | Wheat equivalent Straw | Net returns ($\times 10^3$/ha) | Benefit: cost* ratio | Organic carbon* (%) | Available nutrient (kg/ha) N | Available nutrient (kg/ha) $P_2O_5$ |
| *Tillage system* | | | | | | | | | | | | | | | | |
| Wheat (CT)–Maize (CT) | 201 | 91.3 | 15.4 | 232 | 190 | 5.08 | 6.84 | 3.55 | 5.57 | 7.75 | 13.81 | 72.47 | 1.94 | 0.75 | 248 | 21.2 |
| Wheat (ZT)–Maize (ZT) | 183 | 76.5 | 12.5 | 205 | 186 | 4.85 | 6.52 | 2.93 | 4.43 | 7.06 | 12.07 | 66.54 | 2.03 | 0.78 | 253 | 21.9 |
| Wheat (ZT)–Maize (CT) | 197 | 89.9 | 15.0 | 231 | 191 | 5.04 | 6.76 | 3.55 | 5.45 | 7.70 | 13.59 | 73.86 | 2.11 | 0.77 | 250 | 21.4 |
| Wheat (CT)–Maize (ZT) | 192 | 82.3 | 13.5 | 218 | 187 | 4.93 | 6.63 | 3.20 | 4.88 | 7.33 | 12.73 | 68.44 | 1.95 | 0.77 | 250 | 21.8 |
| Wheat (FIRB)–Maize (Bed) | 199 | 90.6 | 15.2 | 232 | 190 | 4.49 | 6.08 | 3.52 | 5.51 | 7.13 | 12.97 | 63.55 | 1.68 | 0.75 | 248 | 21.4 |
| SEm± | 1.98 | 1.6 | 0.25 | 4.0 | 2.7 | 0.07 | 0.09 | 0.06 | 0.10 | 0.08 | 0.16 | 1.15 | 0.03 | 0.005 | 1.8 | 0.26 |
| CD (P=0.05) | 5.94 | 4.9 | 0.07 | 11.9 | NS | 0.22 | 0.27 | 0.19 | 0.32 | 0.25 | 0.49 | 3.45 | 0.10 | 0.016 | NS | NS |
| *Weed control* | | | | | | | | | | | | | | | | |
| Weedy check | 182 | 58.2 | 9.6 | 159 | 184 | 4.14 | 5.51 | 2.12 | 3.16 | 5.74 | 9.46 | 47.31 | 1.44 | 0.78 | 251 | 22.0 |
| Isoproturon (0.75 kg/ha)*/ Atrazine (0.5 kh/ha)** | 199 | 104.7 | 17.4 | 271 | 191 | 5.12 | 6.89 | 4.19 | 6.48 | 8.26 | 15.00 | 82.74 | 2.41 | 0.76 | 250 | 21.3 |
| 2 hand-weedings | 202 | 95.4 | 15.9 | 242 | 191 | 5.37 | 7.29 | 3.74 | 5.87 | 8.18 | 14.64 | 76.87 | 1.98 | 0.75 | 249 | 21.2 |
| SEm± | 1.44 | 1.0 | 0.18 | 2.9 | 1.3 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.10 | 0.72 | 0.02 | 0.004 | 0.7 | 0.17 |
| CD (P=0.05) | 4.13 | 2.9 | 0.53 | 8.2 | 3.9 | 0.12 | 0.19 | 0.12 | 0.19 | 0.15 | 0.29 | 2.06 | 0.06 | 0.010 | NS | 0.48 |

*in wheat, ** in maize, *CGR, Crop growth rate from 30–60 days after sowing (g/m/day)

left on top of soil which might have enhanced soil microbial biomass, consequently organic carbon as well as available N and P status of soil (Saha *et al.*, 2010).

On the basis of results it is inferred that in comparison to continuous conventional tillage in wheat and maize, adoption of zero tillage in wheat and conventional tillage in maize did not alter major weed dynamics and resulted equal yields of wheat, maize, system production in terms of wheat-equivalent grain and straw yield and proved economically beneficial. Use of isoproturon 0.75 kg/ha at 32 days after sowing in wheat and pre-emergence application of atrazine 0.75 kg/ha followed by 1 hoeing at 25 DAS in maize recorded significantly higher wheat-equivalent grain and straw yields over 2 hand-weedings and weedy check. Practicing rotated ZT-CT in wheat–maize sequence and weedy check also improved organic carbon of soil.

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