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**Research Paper**

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

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## ABSTRACT

A field experiment was conducted during 2013–14 and 2014–15 at Sher-e-Kashmir University of Agriculture Science and Technology of Jammu, to study the effect of tillage and weed-management practices on weed dynamics and productivity in maize (*Zea mays* L.)–wheat {*Triticum aestivum* (L.) emend. Fiori & Paol.] cropping sequence. Weed density, weed biomass, grain and stover yields of maize were found statistically at par in continuous conventional tillage and rotational conventional tillage in maize and zero tillage in wheat under maize. However, in wheat the density and biomass of grassy weeds were found significantly lowest under continuous zero tillage preceded by zero tillage or conventional tillage in maize. The different tillage treatments had non-significant effect on density and biomass of broad-leaf weeds and yields (grain and straw) of wheat. Amongst the weed-management practices, 2 hand-weedings 15 and 30 days after sowing (DAS) in maize and application of metribuzin (200 g/ha) at 30 DAS in wheat significantly reduced weed density, biomass and recorded significantly higher yields of maize and wheat respectively, over weedy check in both maize and wheat. Among the tillage treatments, adoption of zero tillage in maize and conventional tillage in wheat also proved economically beneficial with the highest benefit: cost ratio and the lowest cost of cultivation in maize–wheat system followed by continuous zero tillage in both the crop. However, in weed management, application of atrazine 1 kg/ha in maize and metribuzin (200 g/ha) in wheat resulted the highest benefit: cost ratio and net returns followed by 2 hand-weedings. At the end of the maize–wheat cropping cycles, both tillage and weed-management practices did not influence on status of bulk density of the soil.

***Key words*** **:** Maize–wheat sequence, Nutrient uptake, Tillage, Weed management, Yields

Of the 30 major cropping systems identified in India (Yadav and Prasad, 1998), maize-based cropping system is predominant out of which maize–wheat is the dominant cropping system. Maize and wheat are the two important staple food crops of India and the contribution of this cropping system to total foodgrain production of the country is considerably large (GoI, 2012). These crops are grown in almost all the pockets of the country either in irrigated or rainfed conditions, but the productivity is higher in irrigated ecosystems which are mainly situated in Indo-gangetic plains.

Traditionally, maize and wheat are grown by broadcast seeding or with seed drill after 2–3 tillage operations. The traditional practice of growing these crops is laborious, costly and time consuming. Traditional tillage practices also contribute to the energy and labour cost in crop production system resulting in lower economic returns (Kumar *et al.*, 2013). Repeated conventional tillage coupled with other faulty land-utilization practices have caused large-scale degradation of our soils over the past 50–60 years, and most of the soils have lost up to one-half of their native organic matter content and fauna (Malik *et al.,* 2006). Hence, zero tillage is one of the better options that reduces the problems associated with faulty land-utilization practices to certain extent. However, a combination of zero and conventional options in sequence needs to be standardized for each cropping, soil and microclimatic conditions in order to enhance the sustainability of systems and resource-use efficiency. Zero tillage improves physico-chemical and biological properties of soil and reduces the cost of production (Bisen and Singh, 2008; Jha *et al.,* 2011). Decline in population of a notorious weed

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under zero tillage like *Phalaris minor* set cases of acceptance of this technology in north India (Mahajan *et al*., 2002). Keeping these facts in view, the present investigation was carried out the effect of tillage and weed-management practices on weed dynamics, productivity and soil health in maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping sequence.

## MATERIALS AND METHODS

A field experiment was conducted during the rainy season (*kharif*) and winter season (*rabi*) of 2013–14 and 2014–15 at Jammu (32°–40' N and 74°–58' E, 332 m above mean sea level). The soil was sandy clay-loam in texture, having initial *p*H 7.87, organic carbon 0.52%, available nitrogen 247.60 kg/ha, phosphorus 12.32 kg/ha and potassium 148.4 kg/ha. The well-distributed rainfall of 1,016.5 and 893 mm was recorded during *kharif* 2013 and 2014. The treatments, combination of 4 tillage systems, viz. continuous conventional tillage in maize–wheat (CT-CT), continuous zero tillage in maize–wheat (ZT-ZT), zero tillage in maize–conventional tillage in wheat (ZT-CT), conventional tillage in maize–zero tillage in wheat (CT-ZT) and 3 weed-management practices, viz. 2 hand-weedings at 15 and 30 days after sowing (DAS), weedy check, atrazine 1 kg/ha as pre-emergence application in maize and metribuzin 200 g/ha as post-emergence application at 30 DAS, 2 hand-weedings at 30 and 60 DAS and weedy check in wheat were tested with 3 replications in split-plot design, keeping tillage treatments in main plots and weed-management treatments in subplots on a fixed site. Maize var. ‘Kanchan 517’ and wheat var. ‘RSP 561’ were sown at row- to -row spacing of 60 cm and plant- to -plant spacing of 20 cm for maize, and row- to -row spacing of 20 cm in wheat. During both the years, maize and wheat were sown in the first fortnight of June and November using 20 and 100 kg seed/ha, respectively. In each plot, grasses, broad leaves and sedges were counted from 2 randomly selected places in each plot 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 the selected areas were dried at 65°C to obtain constant weight and the weight was expressed in g/m$^2$. Benefit: cost ratio was calculated on the basis of prevailing market prices of inputs and produce. Bulk density of soil was analysed using Core method. Soil samples to study weed seed bank were taken with the tube auger from top 0–15 cm soil layer from each experimental plots at 4 places before sowing of maize and wheat during 2014. Number of weed seeds showing germination from 100 g of dry soil of representative soil samples obtained by mixing soil of four samples per experimental unit were recorded after putting soil in plastic tray which was kept at room temperature in the laboratory.

## RESULTS AND DISCUSSION

### *Weed flora*

The important weeds of the experimental site in the rainy season were *Cynodon dactylon, Echinocloa grus-galli* and *Setaria glauca* as grassy weeds*; Amaranthus viridis, Celosia argentea* as broad-leaf weeds and sedges, viz. *Cyperus rotundus*. While in the winter (*rabi*) season, important weeds noticed were grassy weeds*, Phalaris minor, Poa annua,* and broad-leaf weeds, viz. *Medicago denticulata, Anagallis arvensis, Cirsium arvense* and *Chenopodium album*.

### *Weed density*

Adopting ZT in both the crops significantly increased the weed population in maize, being statistically at par with ZT-CT in maize–wheat cropping, and both of these practices enhanced sedges population significantly as compared to continuous conventional tillage (CT-CT) and CT-ZT in maize–wheat system (Table 1). These results confirm the findings of Ramesh *et al.* (2014). Whereas in wheat, adoption of ZT in maize and CT in wheat significantly reduced the density of grassy weeds which was at par with continuous zero tillage (ZT-ZT) in maize–wheat cropping system (Table 1). The improvement in density of grassy weeds under continuous zero tillage in maize–wheat 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 lower grassy weed density 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 (Mahajan *et al*., 2002).

In both the crops, the minimum density of weeds was observed under application of recommended herbicides and 2 hand-weedings which were significantly lower than weedy check. On the contrary, little higher weed density under atrazine treatment in maize could be due to its application as pre-emergence, later on wide spacing of crop encourage weeds at later stages of crop growth.

### *Weed biomass*

In maize, the highest biomass of grassy, broad-leaf weeds and sedges were recorded under zero tillage (ZT-ZT) which was statistically at par with (ZT-CT) in maize–wheat cropping systems (Table 1). Whereas in wheat the lowest biomass of grassy weeds was recorded under continuous zero tillage (ZT-ZT) and the highest was recorded in continuous (CT-CT) in maize–wheat cropping systems

(Table 1). On the contrary, the biomass of broad-leaf weeds did not show any significant difference among the treatments.

The maximum reduction in biomass of weeds was recorded under 2 hand-weedings treatment which was at par with atrazine 1 kg/ha in maize. However, in wheat the minimum weed biomass was recorded under metribuzin 200 g/ha treatment which was at par with 2 hand-weedings. The biomass being a function of weed density followed the same trend in both the crops (Jain *et al*., 2007).

### *Crop-growth parameters*

In maize, the highest plant height and dry-matter accumulation at harvesting and crop growth rate at 30–60 DAS were recorded in continuous conventional tillage and which were at par with rotated CT-ZT in maize–wheat system but significantly higher than the rest of tillage systems (Table 1). In general, overall improvement in 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, there by resulting in higher photosynthesis and finally growth parameters (Bisen and Singh, 2008). However, in wheat different tillage systems did not significantly affect the plant height, dry matter and crop-growth rate.

Among weed-management treatments, the highest plant height, dry-matter accumulation and crop-growth rate in maize were recorded with 2 hand-weedings and which was at par with atrazine 1 kg/ha and both proved significantly superior to the weedy check. However, in wheat the highest plant height, dry-matter accumulation and crop-growth rate were recorded with the application of metribuzin 200 g/ha which was at par with 2 hand-weedings. The better growth parameters were owing to significant reduction in weed density and dry-matter accumulation under treatments of hand-weeding and recommended herbicides in both crops. Singh *et al*., (2010) also reported similar results.

### *Yield attributes and yields*

The highest number of grains/cob, 1,000-seed weight (Table 2) and grain yield (Table 3) of maize were recorded under continuous conventional tillage (CT-CT), which were at par with CT-ZT in maize–wheat cropping system but significantly higher than the rest of tillage systems. The possible reason for better yield attributes and grain yield in CT-CT maize could be owing to favourable soil physical conditions for growth and development as well as lesser crop-weed competition. Susha *et al.* (2014) and Sarma *et al.* (2010) reported similar results. In wheat, till-

**Table 1**. Effect of different tillage and weed management on weed density and weed biomass in maize–wheat cropping sequence (pooled data of 2 years)

| Treatment | Weed density at 60 DAS (No./m$^2$) | | | | | Weed biomass at 60 DAS (g/m$^2$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Maize | | | Wheat | | Maize | | | Wheat | |
| | Grassy | Broad leaf | Sedges | Grassy | Broad leaf | Grassy | Broad leaf | Sedges | Grassy | Broad leaf |
| *Tillage system* | | | | | | | | | | |
| ZT-ZT | 3.85 (14.74) | 3.54 (12.03) | 6.56 (43.78) | 4.46 (12.42) | 4.11 (18.24) | 3.96 (16.07) | 5(25.61) | 5.72 (35.28) | 5.04 (16.56) | 4.75 (24.51) |
| ZT-CT | 3.73 (13.84) | 3.44 (11.42) | 6.40 (41.95) | 4.32 (11.64) | 4.01 (17.83) | 3.85 (15.28) | 4.84(24.06) | 5.63 (34.39) | 5.13 (17.20) | 4.71 (24.11) |
| CT-ZT | 3.52 (12.22) | 3.27 (10.39) | 5.96 (37) | 4.69 (14.03) | 4.09 (17.24) | 3.57 (13.28) | 4.57(21.81) | 5.32 (31.5) | 5.39 (19.05) | 4.61 (23.12) |
| CT-CT | 3.44 (11.61) | 3.22 (10.00) | 5.89 (36.23) | 4.62 (13.83) | 3.95 (16.78) | 3.44 (12.37) | 4.48(20.70) | 5.25 (30.89) | 5.43 (19.59) | 4.52 (22.49) |
| SEm± | 0.07 | 0.07 | 0.07 | 0.09 | 0.08 | 0.05 | 0.05 | 0.05 | 0.10 | 0.11 |
| CD (P=0.05) | 0.22 | 0.22 | 0.23 | 0.33 | NS | 0.19 | 0.20 | 0.15 | 0.33 | NS |
| *Weed management* | | | | | | | | | | |
| 2 hand-weedings | 3.03 (8.36) | 2.79 (6.90) | 5.09 (25.00) | 4.01 (9.50) | 3.33 (10.69) | 2.90 (7.79) | 3.76 (13.25) | 4.04 (15.38) | 4.62 (13.06) | 3.83 (14.42) |
| Atrazine (1 kg/ha)*/ Metribuzin (200 g/ha)** | 3.12 (8.94) | 2.90 (7.48) | 5.22 (26.42) | 3.72 (8.03) | 3.12 (9.34) | 2.99 (8.35) | 3.89 (14.23) | 4.12 (16.04) | 4.22 (10.65) | 3.52 (12.28) |
| Weedy check | 4.76 (22.00) | 4.41 (18.50) | 8.29 (67.79) | 5.84 (21.42) | 5.65 (32.41) | 5.23 (26.61) | 6.52 (41.65) | 8.29 (67.63) | 6.92 (30.58) | 6.59 (43.98) |
| SEm± | 0.07 | 0.07 | 0.05 | 0.09 | 0.07 | 0.06 | 0.05 | 0.05 | 0.14 | 0.13 |
| CD (P=0.05) | 0.22 | 0.20 | 0.15 | 0.26 | 0.21 | 0.17 | 0.15 | 0.15 | 0.40 | 0.40 |

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

Details of treatments are given under Materials and Methods age systems failed to show any significant variation in grains/ear, test weight (g) and finally grain yield in maize–wheat cropping system.

Weed-management treatments improved all the yield attributes of maize as compared to those observed in weedy check. 2 hand-weedings recorded significantly higher number of grains/cob, 1,000-grain weight and grain yield of maize which was found to be statistically at par with atrazine 1 kg/ha. However, in wheat metribuzin 200 g/ha resulted in significantly higher number of grains/ears, 1,000-grain weight and grain yield of wheat which was statistically at par with 2 hand-weedings. This improvement in yield-attributing characters of maize might have happened owing to significant reduction in weed biomass and density and consequent reduction in crop-weed competition (Singh *et al.,* 2012).

**Table 2**. Effect of different tillage and weed management on growth character of maize and wheat crop in maize–wheat cropping sequence (pooled data of 2 years)

| Treatment | Growth and yield attributes of maize | | | | | Growth and yield attributes of wheat | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Plant height^ (cm) | Dry matter^ ^ (g/m$^2$) | CGR* | Grains/cob | 1,000-weight (g) | Plant height^ (cm) | Dry matter^ ^ (g/m$^2$) | CGR* | Grains/head | 1,000-weight (g) |
| *Tillage system* | | | | | | | | | | |
| ZT-ZT | 186.45 | 110.89 | 1.29 | 210.95 | 163.11 | 98.89 | 920.33 | 2.63 | 32.23 | 35.95 |
| ZT-CT | 187.00 | 113.72 | 1.33 | 212.00 | 164.28 | 99.67 | 923.78 | 2.64 | 32.56 | 36.06 |
| CT-ZT | 189.39 | 123.56 | 1.50 | 215.23 | 167.28 | 104.61 | 938.67 | 2.67 | 33.67 | 37.17 |
| CT-CT | 190.23 | 125.78 | 1.52 | 216.12 | 168.39 | 106.45 | 941.39 | 2.68 | 34.11 | 37.61 |
| SEm± | 0.70 | 0.64 | 0.03 | 0.38 | 0.54 | 1.87 | 5.41 | 0.05 | 0.60 | 0.63 |
| CD (P=0.05) | 2.38 | 2.21 | 0.09 | 1.32 | 1.88 | NS | NS | NS | NS | NS |
| *Weed management* | | | | | | | | | | |
| 2 hand-weedings | 190.92 | 123.54 | 1.48 | 217.62 | 169.62 | 102.83 | 941.71 | 2.74 | 34.59 | 40.09 |
| Atrazine (1 kg/ha)*/ Metribuzin (200 g/ha)** | 189.96 | 120.92 | 1.46 | 217.16 | 168.20 | 105.21 | 946.00 | 2.76 | 35.17 | 40.67 |
| Weedy check | 183.92 | 111.00 | 1.29 | 182.42 | 159.96 | 99.17 | 905.42 | 2.46 | 29.67 | 29.34 |
| SEm± | 0.50 | 1.12 | 0.02 | 0.45 | 0.61 | 1.29 | 3.80 | 0.10 | 0.26 | 0.28 |
| CD (P=0.05) | 1.49 | 3.35 | 0.07 | 1.34 | 1.83 | 3.86 | 11.37 | NS | 0.77 | 0.83 |

*in maize; **in wheat; *CGR, crop growth rate from 30–60 days after sowing (g/plant/day); ^ Plant height; dry-matters^ ^ at harvesting
Details of treatments are given under Materials and Methods

**Table 3.** Effect of different tillage and weed management on yield of maize–wheat cropping system (pooled data of 2 years)

| Treatment | Yield (t/ha) | | | | | |
|---|---|---|---|---|---|---|
| | Maize | | Wheat | | Maize equivalent | |
| | Grain | Stover | Grain | Straw | Grain | Straw |
| *Tillage system* | | | | | | |
| ZT-ZT | 2.86 | 8.19 | 3.16 | 5.82 | 6.39 | 22.7 |
| ZT-CT | 2.97 | 8.43 | 3.17 | 5.83 | 6.52 | 23.0 |
| CT-ZT | 3.31 | 9.11 | 3.34 | 6.01 | 7.05 | 24.1 |
| CT-CT | 3.49 | 9.48 | 3.36 | 6.03 | 7.24 | 24.5 |
| SEm± | 0.06 | 0.14 | 0.06 | 0.14 | - | - |
| CD (P=0.05) | 0.21 | 0.48 | NS | NS | - | - |
| *Weed management* | | | | | | |
| 2 hand-weedings | 3.63 | 9.79 | 3.88 | 6.63 | 7.96 | 26.4 |
| Atrazine (1 kg/ha)*/Metribuzin (200 g/ha)** | 3.47 | 9.49 | 3.98 | 6.72 | 7.92 | 26.3 |
| Weedy check | 2.38 | 7.12 | 1.91 | 4.40 | 4.51 | 18.1 |
| SEm± | 0.09 | 0.22 | 0.07 | 0.15 | - | - |
| CD P=0.05) | 0.26 | 0.65 | 0.21 | 0.47 | - | - |

**in wheat, *in maize
Details of treatments are given under Materials and Methods

**Table 4.** Effect of different tillage and weed-management practices on system economics, bulk density and seed bank of maize–wheat cropping system (pooled data of 2 years)

| Treatment | System | | | Seeds of weeds/kg of dry soil (2014) | | | Bulk density (g/cm$^3$) |
|---|---|---|---|---|---|---|---|
| | Cost of cultivation (×₹10$^3$/ha) | Net returns (×₹10$^3$/ha) | Benefit: cost ratio | *Medicago denticulata* | *Phalaris minor* | *Chinopodium album* | |
| *Tillage system* | | | | | | | |
| ZT-ZT | 41.5 | 77.5 | 1.87 | 62 | 9 | 11 | 1.43 |
| ZT-CT | 41.5 | 79.5 | 1.92 | 59 | 10 | 12 | 1.44 |
| CT-ZT | 50.8 | 79.0 | 1.56 | 51 | 12 | 14 | 1.45 |
| CT-CT | 50.8 | 82.2 | 1.62 | 48 | 13 | 15 | 1.46 |
| SEm± | - | - | - | 2.13 | 1.13 | 1.41 | 0.01 |
| CD (P=0.05) | - | - | - | 6.39 | 3.39 | NS | NS |
| *Weed management* | | | | | | | |
| 2 hand-weedings | 56.3 | 89.1 | 1.58 | 33 | 6 | 9 | 1.44 |
| Atrazine (1 kg/ha)*/Metribuzin (200 g/ha)** | 41.9 | 102.7 | 2.45 | 28 | 5 | 7 | 1.45 |
| Weedy check | 40.3 | 46.9 | 1.17 | 104 | 22 | 26 | 1.45 |
| SEm± | - | - | - | 4.21 | 1.46 | 1.52 | 0.01 |
| CD (P=0.05) | - | - | - | 12.65 | 4.38 | 4.59 | NS |

*in maize, **in wheat

Details of treatments are given under Materials and Methods

### *Economics*

Rotated ZT-CT in maize–wheat system fetched the highest benefit: cost ratio and low cost of cultivation, which was followed by continuous ZT-ZT, proved better than rest of the tillage systems in maize–wheat cropping systems (Table 4). Application of recommended herbicides for both the crop recorded the highest benefit: cost ratio, which was higher over 2 hand-weedings and the weedy check. But highest benefit: cost ratio in zero tillage was owing to less cost of cultivation in zero tillage system. Shekhar *et al.* (2014) also reported similar finding.

### *Soil weed seed bank*

Soil weed seed bank studies were conducted after second year of maize–wheat cropping system. The major weed species found in soil *Medicago denticulata, Phalaris minor* and *Chenopodium album*. Maize–wheat cropping system sown with continuous zero tillage recorded significantly higher number of seeds of *Medicago denticulata* which was at par with ZT-CT and the lowest was record under continuous conventional tillage. In case of *Phalaris minor* and *Chinopodium album,* higher number of seeds was recorded in continuous conventional tillage which was at par with CT-ZT and lowest was found in continuous zero tillage (Table 4) (Sen *et al*., 2002). However, herbicide treated and hand-weeded (2 times) plots exhibited significantly less seeds of *Phalaris minor* and *Chinopodium album* as compared to weedy check treatment.

### *Soil properties*

Both tillage and weed-management treatments did not show any significant variation in bulk density. Being non-significant numerically, the highest value of 1.46 was recroded under continuous conventional tillage (CT-CT) in both crops (Table 4).

This study indicated that maize–wheat system productivity was found to be more economical with respect to benefit: cost ratio when the current crop was grown with zero tillage either preceded by zero or conventional tilled crop in combination with herbicidal weed management.

## REFERENCES

Bisen, P.K. and Singh, R. 2008. Effect of tillage and weed management practices on weed growth and yield of wheat (*Triticum aestivum*)–rice (*Oryza sativa*) system. *Indian Journal of Agricultural Science* **78**(4): 347–350.

GoI. 2012. *Agricultural Statistics at a Glance*. Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi (www.dacnet.nic.in).

Jain, N., Mishra, J.S., Kewat, M.L. and Jain, V. 2007. Effect of tillage and herbicides on grain yield and nutrient uptake by wheat (*Triticum aestivum*) and weeds. *Indian Journal of Agronomy* **52**(2): 131–134.

Jha, A.K, Kawat. M.L., Upadhyay, V.B. and Vishwakarma, S.K. 2011. Effect of tillage and sowing methods on productivity, economics and energetic of rice (*Oryza Sativa* L.)–wheat (*Triticum aestivum* L.) cropping system. *Indian Journal of Agronomy* **56**(1): 35–40.

Kumar, V., Saharawat, Y.S., Gathala, M.K., Jat, A.S., Singh, S.K., Chaudhary, N. and Jat, M.L. 2013. Effect of different tillage and seeding methods on energy use efficiency and productivity of wheat in Indo-Gangetic plains. *Field Crops Research* **142**: 1–8.

Mahajan, G., Brar, L.S. and Walia, U.S. 2002. *Phalaris minor* response in wheat in relation to planting dates, tillage and herbicides. *Indian Journal of Weed Science* **34**(1 and 2): 114–15.

Malik, R.K., Yadav, A. and Kamboj, B.R. 2006. Conservation tillage and crop establishment techniques. (In) *Abstract-Golden Jubilee National Symposium on Conservation Agriculture and Environment*, held during October 26–28, Banaras Hindu University, pp. 11–16.

Ramesh, Rana, S.S., Negi, S.C., Kumar, Suresh and Subehia, S.K. 2014. Effect of resource-conserving and planting techniques on productivity of maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **59**(1): 34–40.

Sarma, C.K. and Gautam, R.C. 2010. Weed growth, yield and nutrient uptake in maize (*Zea mays*) as influenced by tillage, seed rate and weed management method. *Indian Journal of Agronomy* **55**(4): 299–303.

Sen, A., S.N. Sharma, Singh R.K. and Pandey, M.D. 2002. Effect of different tillage systems on the performance of wheat. (In) *Proceedings of the International Workshop on Herbicide Resistance Management and Zero Tillage in Rice–Wheat Cropping System,* held at CCS Haryana Agricultural University, Hisar, India, 4–6 March, pp. 115–116.

Shekhar, C., Singh, D., Singh, A.K., Nepalia, V. and Choudhary, J. 2014. Weed dynamic, productivity and soil health under different tillage and weed-control practices in wheat (*Triticum aestivum*)–maize (*Zea mays*) cropping sequence. *Indian Journal of Agronomy* **59**(4): 561–567.

Singh, G., Singh, O.P., Singh, S. and Prasad, K. 2010. Weed management in late sown wheat (*Triticum aestivum*) after rice (*Oryza sativa*) in rice–wheat system in rainfed lowland. *Indian Journal of Agronomy* **55**(2): 83–88.

Singh, V.P., Guru, S.K., Singh, S.P., Pratap, T., Banga, A. and Kumar, A. 2012. Bio efficacy of tembotrione against mixed weed complex in maize. *Indian Journal of Weed Science* **44**(1): 1–5.

Susha, V.S., Das, T.K., Sharma, A.R. and Nath, C.P. 2014. Carryover effect of weed management practices of maize (*Zea mays*) on weed dynamics and productivity of succeeding zero and conventional till wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **59**(1): 41–47.

Yadav, R.L. and Prasad, K. 1998. (In) *Annual Report 1997–98*. Project Directorate for Cropping Systems Research, Modipuram, Uttar Pradesh, India, pp. 36–49.