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# Impact of irrigation and crop residue management on maize (*Zea mays*)–chickpea (*Cicer arietinum*) sequence under no tillage conditions

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ABSTRACT

A field experiment was conducted during 2007-08 and 2010-11 at Belvatagi, Karnataka to study the effect of irrigation and crop residue mulching on water use efficiency and yield of maize (*Zea mays* L.) - chickpea (*Cicer arietinum* L.) sequence under no tillage condition. In this experiment, three irrigation levels (0.8, 0.6 and 0.4 IW/CPE ratio) were combined with or without crop residue in no tillage situation in split plot design and compared with tillage control. Maize and chickpea grain yields were significantly influenced by irrigation. Application of crop residue did not affect the maize and chickpea but affected the maize - chickpea sequence as a whole. No till maize grain yield was higher with 0.6 IW/CPE ratio with residues (8.68 tonnes/ha) and was on par with tilled maize (8.69 tonnes/ha). This treatment also recorded higher water use efficiency (18.43 kg/ha-mm). No tillage significantly reduced the chickpea grain yield in comparison to normal tillage; but improved the water use efficiency. No tilled maize - chickpea sequence required irrigation at 0.6 IW/CPE ratio with crop residue application @ 5 tonnes/ha for maize and 0.4 IW/CPE with residue for chickpea was found better for higher yield and water use efficiency.

**Key words :** Chickpea, Irrigation, Maize, No tillage

Maize (*Zea mays* L.) - chickpea (*Cicer arietinum* L.) is one of the ideal and most productive cropping sequence suitable for the irrigated ecosystem in Northern Karnataka under Vertisols (Rajkumara *et al.* 2009). Irrigating maize at 0.7 IW/CPE ratio and chickpea at 0.6 IW/CPE ratio was found to be suitable under normal tilled conditions (Annual Report 2000). Uncertainty in the release of canal command water for irrigation purpose in *kharif* often leads to delay in the planting time of maize (Rajkumara *et al.* 2009). This often leads to delay in the harvesting of maize which further delays sowing of chickpea. Though maize yields are not affected due to photo insensitive nature, the chickpea yields are greatly affected by delayed sowing. Delay in sowing of chickpea from middle of November to middle of December reduces the yields from 2.0 to 1.5 tonnes/ha. Apart from this, it also increased amount of water required for irrigation thus lesser water use efficiency. Planting of chickpea in the standing stubbles of maize without any land preparation is a very popular practice. However, farmers practice deep ploughing, harrowing before planting of maize in *kharif*. Though tillage is a critical practice in crop production, often it is not required in crops like maize for getting optimum crop yield (Carter *et al.* 2002). Thus, conservation tillage practices, viz. minimum tillage or no tillage system are gaining importance in recent years and challenging the need of tillage operation in maize. In general, reduced tillage systems required lower operation costs and gave greater economic returns compared with conventional tillage (Smart and Bradford 1999). Application of crop residues either on the surface or incorporation into the field has been proved to be beneficial in many of the cropping systems including maize – chickpea (Veer Singh *et al.* 2011). Apart from improving the physical and chemical fertility of the soil, requirement of irrigation water was also reduced. In view of the above, the present investigation was aimed to determine the optimum irrigation levels in combination with mulch application on soil physical properties, yield and economics and also to compare with normal tillage maize and chickpea.

## MATERIALS AND METHODS

A field experiment was conducted at Water Management Research Centre, Belvatagi of University of Agricultural Sciences, Dharwad during 2007-08, 2008-09, 2009-10 and 2010-11 under irrigated conditions. The centre is situated at 15° 61'' N latitude and 75° 23'' E longitude at an elevation of 579 m above mean sea level. The soil was clay (24.5%

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sand, 14.6% silt and 60.9% clay) in texture having pH: 8.2, EC: 0.33 dS/m, organic carbon: 0.55%, available P (12.7 kg/ha) and available K (473 kg/ha). The soil was high in moisture retention capacity with 38.0% at - 0.03 MPa and 21.3% at - 1.5 MPa. Rainfall primarily occurs from June to September followed by cool to warm periods from October to March. During the experimental period the average rainfall recorded in *kharif* season (June – October) during 2007, 2008, 2009 and 2010 was 641 mm, 386.2 mm, 735 mm and 535.2 mm, respectively and in *rabi* (November – March) season during 2007-08, 2008-09, 2009-10 and 2010-11, it was 10.2 mm, 146.2 mm, 118.2 mm and 101 mm respectively, was recorded.

The experiment consisted of three irrigation levels as main treatments (0.8 IW/CPE, 0.6 IW/CPE and 0.4 IW/CPE) and two residue levels as sub treatments (crop residues @ 5 tonnes/ha and without crop residues) were laid out in a split plot design with five replications. All these treatments were laid out in no tillage conditions for both maize and chickpea crops. Along with these treatments a control treatment with one ploughing and two harrowing was included as conventional tillage since farmers practice ploughing before planting of maize in summer followed by harrowing during the cropping period of both maize and chickpea. The dimensions of individual plots were 5 m × 4.8 m. A recommended fertilizer dose of 150 – 75 – 37.5 kg N, $P_2O_5$, $K_2O$/ha was applied to maize during *kharif*. Entire dose of phosphorus and potassium was applied at the time of planting, while N was applied in three splits (1/3$^{rd}$ at sowing, 1/3$^{rd}$ at knee height stage and 1/3$^{rd}$ at silking stage). Cargill 900 M hybrid was planted with 60 cm × 20 cm spacing in *kharif* followed by A – 1 chickpea with 30 cm × 10 cm spacing in *rabi*. Planting was done by hand dibbling in both the crops. Fertilizer dose of 25 – 50 – 0 $NP_2O_5K_2O$ kg/ha was applied to chickpea as a single application at the time of planting. Maize and chickpea seeds were treated with captan @ 2 g/kg of seeds before planting. The weed control for maize was accomplished by pre emergent application of atrazine @ 1.0 kg a.i./ha followed by post emergent application of gramaxone @ 1.0 kg a.i./ha at 30 days after planting. While spraying the post emergent herbicide plastic hood cover was used to avoid the spray drift to the maize crop. In chickpea, pre emergence application of pendimethalin @ 1.0 kg a.i./ha was done to control the weeds. Scheduling of irrigation was done based on IW/CPE approach with a irrigation water depth of 60 mm. USWB Pan Evaporimeter was used to measure daily evaporation and cumulative pan evaporation was computed. In control treatment, irrigation was scheduled at 0.8 IW/CPE in maize while, 0.6 IW/CPE in chickpea. Maize crop residue was applied @ 5 tonnes/ha in crop residue treatment since it was commonly available residue in the Malaprabha Irrigation Command. Irrigation and residue treatments were statistically analyzed using split plot design, while; control treatment (conventional tillage) was compared by using randomized block design. The treatment means of irrigation, residues and interactions and comparison with control was done by using Duncan's multiple range tests at 5% level of significance. The soil samples from each treatment were analyzed for organic matter (Walkley and Black); available nitrogen (alkaline permanganate method); available $P_2O_5$ (Olsen's method) and available $K_2O$ (1 N ammonium acetate) as per the procedure outlined by Jackson (1973). Soil physical properties, i.e. bulk density, maximum water holding capacity, percent aggregate stability were analyzed as per the procedure described by Black (1965). Water use efficiency was worked out by the formula:

$$\text{WUE (kg/ha-mm)} = \frac{\text{Grain yield in kg}}{\text{Water used in mm}}$$

The water used by the crop in the season was computed by the summation of soil moisture contribution, effective rainfall and irrigation water applied.

## RESULTS AND DISCUSSION

*Maize yield and water use efficiency*

Grain yield of maize was significantly affected by different irrigation treatments in one out of four years (Table 1). In 2008, maize grain yield was significantly higher in 0.6 IW/CPE (10.67 tonnes/ha) compared to 0.8 IW/CPE (9.36 tonnes/ha) and 0.4 IW/CPE (8.50 tonnes/ha). On pooled basis, under no tilled conditions maize grain yield was significantly higher with 0.6 IW/CPE (8.55 tonnes/ha) compared to 0.4 IW/CPE (7.77 tonnes/ha) while it was on par with 0.8 IW/CPE ratio (8.21 tonnes/ha). This response to irrigation in 2008 was probably due to very low rainfall (386.2 mm). In rest of the years, rainfall received was sufficient to meet the moisture requirement of maize since the requirement of maize in northern dry zone of Karnataka is 500 – 600 mm (AICRP 2009). Application of crop residues @ 5 tonnes/ha under no tilled conditions significantly increased the maize grain yield over no crop residues in 2008. While; in remaining years it was not significant. On pooled basis, no significant beneficial effect of crop residue application was found. This might be due to low amount of rainfall received during 2008 (386.2 mm). On the contrary good rainfall received in remaining years might have nullified any of the positive effects of residue application. Similar response to residue application was noticed by Veer Singh *et al.* (2011) in maize both in *kharif* and *rabi*. However, numerically higher maize grain yield was noticed with crop residue application (8.30 tonnes/ha) over no residue application (8.05 tonnes/ha).

Interaction between irrigation and residue application was significant for maize grain yield in two out of four years. Irrigating maize crop at 0.6 IW/CPE ratio along with 5 tonnes/ha of residue application recorded significantly higher maize grain yield (11.32 tonnes/ha) in 2008, while 0.6 IW/CPE without residue (9.68 tonnes/ha) in 2007. In 2009 and

Table 1 Effect of irrigation and crop residues on maize yield and water use efficiency (2007-08 to 2010-11 and pooled)

| Treatment | Grain yield (tonnes/ha) | | | | | WUE (kg/ha-mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2009 | 2010 | Pooled | 2007 | 2008 | 2009 | 2010 | Pooled |
| *Irrigation levels (IW/CPE)* | | | | | | | | | | |
| I1 = 0.8 | 9.05 | 9.36 b | 7.84 | 6.92 | 8.21 a | 18.23 | 16.01 c | 14.74 | 17.01 | 17.40 b |
| I2 = 0.6 | 9.36 | 10.67 a | 7.4 | 6.89 | 8.55 a | 19.26 | 20.39 a | 14.48 | 17.46 | 18.81 a |
| I3 = 0.4 | 9.38 | 8.50 b | 7.34 | 6.81 | 7.77 b | 19.8 | 18.15 b | 15.57 | 18.23 | 18.65 a |
| SEM ± | 0.22 | 0.33 | 0.24 | 0.2 | 0.15 | 0.45 | 0.64 | 0.45 | 0.58 | 0.511 |
| CD (*P*=0.05) | NS | 1.03 | NS | NS | 0.41 | NS | 1.98 | NS | NS | 0.854 |
| *Residue* | | | | | | | | | | |
| T1= NT+ CR5t/ha | 9.24 | 9.94 a | 7.45 | 6.94 | 8.3 | 19.21 | 19.02 | 14.79 | 17.66 | 18.43 |
| T2= NT+ NR | 9.15 | 9.08 b | 7.6 | 6.82 | 8.05 | 18.99 | 17.35 | 15.07 | 17.48 | 18.15 |
| SEm ± | 0.29 | 0.32 | 0.18 | 0.15 | 0.12 | 0.42 | 0.62 | 0.34 | 0.36 | 0.24 |
| CD (*P*=0.05) | NS | 0.85 | NS | NS | NS | NS | NS | NS | NS | NS |
| *Interaction* | | | | | | | | | | |
| I1 T1 | 9.21 ab | 9.34 bc | 7.62 | 6.91 | 8.21 ab | 18.56 | 15.98 c | 14.33 | 16.8 | 17.12 c |
| I1 T2 | 8.49 b | 9.38 bc | 8.06 | 6.94 | 8.22 ab | 17.9 | 16.05 c | 15.16 | 17.23 | 17.69 bc |
| I2 T1 | 9.03 ab | 11.32 a | 7.4 | 6.94 | 8.68 a | 19.04 | 21.63 a | 14.48 | 17.59 | 19.20 a |
| I2 T2 | 9.68 a | 10.03 ab | 7.41 | 6.86 | 8.41 ab | 19.49 | 19.16 ab | 14.48 | 17.32 | 18.43 ab |
| I3 T1 | 9.49 ab | 9.17 bc | 7.34 | 6.98 | 8.00 bc | 20.02 | 19.46 ab | 15.56 | 18.57 | 18.98 a |
| I3 T2 | 9.28 ab | 7.83 c | 7.34 | 6.65 | 7.54 c | 19.59 | 16.83 bc | 15.58 | 17.88 | 18.33 ab |
| SEm ± | 0.31 | 0.47 | 0.31 | 0.26 | 0.21 | 0.64 | 0.9 | 0.59 | 0.62 | 0.425 |
| CD (*P*=0.05) | 1.12 | 1.46 | NS | NS | 0.59 | NS | 2.81 | NS | NS | 1.208 |
| Control (Conventional tillage with 0.8 IW/CPE irrigation) | 8.76 | 9.79 | 9.43 | 7.07 | 8.69 | 17.69 | 16.75 | 17.71 | 17.2 | 18.41 |
| Control v/s interactions | | | | | | | | | | |
| SEm ± | 0.55 | 0.66 | 0.43 | 0.27 | 0.26 | 1.31 | 1.32 | 0.84 | 0.67 | 0.58 |
| CD (*P*=0.05) | NS | 1.87 | 1.27 | NS | 0.73 | NS | 3.76 | 2.46 | NS | 1.62 |

2010 interaction effects were not significant for grain yield. Four years average maize grain yield was significant for interaction. Irrigating at 0.6 IW/CPE ratio with residue application recorded significantly higher maize grain yield (8.68 tonnes/ha) compared to 0.4 IW/CPE ratio with or without residues. There was no significant difference between tilled maize and no till maize in two out of four years. In the second year 0.4 IW/CPE without residue treatment under no tillage yielded significantly lower maize grain yield than conventional tilled maize. Similar trend was also noticed on pooled basis. Higher irrigation frequencies with or without residue application improved the grain yield under no tilled condition and yielded on par with conventional tillage maize. This confirms the earlier findings where no till maize yields as good as tilled maize (Mariela *et al.* 2009).

Water use efficiency was significant for maize in the second year out of four years. Irrigating at 0.6 IW/CPE (18.81 kg/ha mm) ratios was significantly higher over 0.8 (17.4 kg/ha mm) and was on par with 0.4 IW/CPE (18.65 kg/ha mm) ratio. Application of crop residues did not influence the water use efficiency in any of the years or on pooled basis. This may be due to shading effect of maize crop over the soil surface throughout the season. However, crop residue application had slightly higher yield over non-application. Interaction effects were significant for the second year only. Irrigating at 0.6 IW/CPE with residue application under no tillage was significantly higher than 0.8 IW/CPE ratio with or without residues and also with 0.4 IW/CPE without residues. Significant interactions observed in second year only probably due to low rains (386.2 mm) received during the maize period. 0.8 IW/CPE with or without residues and 0.4 IW/CPE with residue was better than conventional tillage maize for WUE. In the years of low rains, effect of no tillage appears to be more prominent than conventional tillage.

*Chickpea yield and water use efficiency*

Irrigating chickpea at 0.8 IW/CPE ratio significantly increased the grain yield to 2.259 tonnes/ha compared to 0.6 and 0.4 IW/CPE ratio under no tillage conditions in 2010-11 *rabi* (Table 2). In 2007-08 chickpea crop was vitiated due to high rainfall at the time of harvest in March. In 2008-09 chickpea crop was not sown due to delayed sowing and harvest

Table 2 Effect of irrigation and crop residues on chickpea yield and water use efficiency (2009-10, 2010- 11 and pooled)

| Treatment | Yield (tonnes/ha) | | | WUE (kg/ha-mm) | | |
|---|---|---|---|---|---|---|
| | 2009 | 2010 | Pooled | 2009 | 2010 | Pooled |
| *Irrigation levels (IW/CPE)* | | | | | | |
| I1 = 0.8 | 1.280 b | 2.259 a | 1.769 a | 5.662 b | 7.529 c | 6.576 b |
| I2 = 0.6 | 1.054 c | 2.015 b | 1.533 b | 4.651 c | 8.396 b | 6.524 b |
| I3 = 0.4 | 1.588 a | 1.947 b | 1.767 a | 9.559 a | 10.814 a | 10.187 a |
| SEm + | 0.05 | 0.05 | 0.038 | 0.26 | 0.2326 | 0.1755 |
| CD (P=0.05) | 0.16 | 0.15 | 0.114 | 0.81 | 0.7167 | 0.5122 |
| *Residue* | | | | | | |
| T1= No Till + CR @ 5t/ha | 1.245 | 2.234 a | 1.739 | 6.317 | 9.61 | 7.964 |
| T2= No Till + No residue | 1.37 | 1.913 b | 1.64 | 6.931 | 8.217 | 7.574 |
| SEm + | 0.076 | 0.0438 | 0.03 | 0.215 | 0.19 | 0.149 |
| CD (P=0.05) | NS | 0.135 | NS | NS | 0.585 | NS |
| *Interaction* | | | | | | |
| I1 T1 | 1.214 cd | 2.398 a | 1.806 a | 5.376 bc | 7.993 c | 6.683 b |
| I1 T2 | 1.346 bc | 2.120 b | 1.732 ab | 5.948 b | 7.066 c | 6.506 b |
| I2 T1 | 1.000 d | 2.214 ab | 1.606 bc | 4.414 c | 9.227 b | 6.820 b |
| I2 T2 | 1.108 cd | 1.816 c | 1.460 c | 4.888 bc | 7.566 c | 6.227 b |
| I3 T1 | 1.520 ab | 2.090 b | 1.805 a | 9.160 a | 11.611 a | 10.385 a |
| I3 T2 | 1.656 a | 1.803 c | 1.728 ab | 9.958 a | 10.018 b | 9.990 a |
| SEm + | 0.07 | 0.07 | 0.05 | 0.37 | 0.3289 | 0.2482 |
| CD (P=0.05) | 0.23 | 0.23 | 0.15 | 1.145 | 1.014 | 0.7244 |
| Control (Conventional tillage with 0.6 IW/CPE irrigation) | 1.632 | 2.613 | 2.123 | 7.214 | 10.888 | 9.051 |
| Control v/s interactions | | | | | | |
| SEm + | 0.117 | 0.142 | 0.094 | 0.575 | 0.557 | 0.41 |
| CD (P=0.05) | 0.34 | 0.415 | 0.275 | 1.678 | 1.626 | 1.196 |

Chickpea crop in 2007 was vitiated due to high rains at harvest and in 2008 was not sown due to delayed sowing and harvest of maize in *kharif*

of maize. This was due to delayed onset of monsoon rains. In 2009 and pooled basis, 0.4 IW/CPE recorded higher chickpea grain yield. This variation in response to irrigation in both the years may be due to variation in the amount of rainfall received. In 2009-10, the rainfall was high in maize which might have fulfilled the partial water requirement. Hence, high yields were noticed in 0.4 IW/CPE. On the contrary, rainfall was low in 2010-11 for maize as well as chickpea in comparison to remaining years which led to higher response to 0.8 IW/CPE. Application of crop residues of maize @ 5 tonnes/ha significantly increased the chickpea yield (2.234 tonnes/ha) in comparison to without residues in second year only. Interaction effects were significant with 0.6 IW/CPE ratio with residue (2.214 tonnes/ha). On pooled basis 0.4 IW/CPE with residues was better. Water use efficiency (10.814 kg/ha mm) was significantly higher with 0.4 IW/CPE ratio due to higher chickpea grain yield in 2010-11. This performance was consistent and similar to the 2009-10. Pool of two years also indicated that irrigation at 0.4 IW/CPE ratio resulted in significantly higher water use efficiency (10.187 kg/ ha mm) compared to 0.6 and 0.8 IW/CPE ratio. Application of crop residues @ 5 tonnes/ha did not influence the chickpea yield and water use efficiency in 2009-10. In the second year (2010-11), higher WUE due to crop residue application (9.61 kg/ha mm) was observed over without residues (8.217 kg/ha mm). Pooled results did not show benefit of residue application. Irrigation and residue interaction effects were significant for chickpea grain yield and water use efficiency. Chickpea grain yield (1.805 tonnes/ha) and water use efficiency (10.385 kg/ha mm) were significantly high with 0.4 IW/CPE ratio in combination with residue application and this was on par with 0.4 IW/CPE ratio without residue.

Significant differences were observed between control (conventional tillage) and no tillage treatments. IW/CPE ratio of 0.6 with residue (2.214 tonnes/ha) or 0.8 IW/CPE ratio with residue (2.398 tonnes/ha) were on par and comparable with control treatment of normal tillage with 0.6 IW/CPE (2.613 tonnes/ha). Pooled results indicated that chickpea yields were reduced significantly with no tillage. Water use efficiency was significantly higher in 0.4 IW/CPE

Table 3 Soil physical properties of maize – chickpea sequence as influenced by irrigation and residue (after 4 years)

| Treatment | *p*H | Electrical conductivity (dS/m) | Organic carbon (%) | Bulk density ($Mg/m^3$) | Particle density ($Mg/m^3$) | % pore space | Percent stable aggregates | Mean weight diameter (mm) | Maximum water holding capacity (%) |
|---|---|---|---|---|---|---|---|---|---|
| 0.8 IW/CPE Residue @ 5 t/ha | 8.12 | 0.28 | 0.64 | 1.32 | 2.65 | 50.2 | 56.9 | 0.38 | 69.8 |
| 0.8 IW/CPE without Residue | 8.14 | 0.25 | 0.59 | 1.32 | 2.65 | 50.2 | 50.0 | 0.36 | 68.8 |
| 0.8 IW/CPE Residue @ 5 t/ha | 8.13 | 0.34 | 0.67 | 1.31 | 2.65 | 50.6 | 58.4 | 0.40 | 70.0 |
| 0.8 IW/CPE without Residue | 8.15 | 0.36 | 0.55 | 1.35 | 2.65 | 49.1 | 48.8 | 0.34 | 68.2 |
| 0.8 IW/CPE Residue @ 5 t/ha | 8.10 | 0.32 | 0.68 | 1.30 | 2.65 | 50.9 | 57.6 | 0.40 | 71.0 |
| 0.8 IW/CPE without Residue | 8.12 | 0.36 | 0.63 | 1.34 | 2.65 | 49.4 | 55.0 | 0.38 | 69.4 |
| Control (Conventional tillage with 0.8 IW/CPE for maize and 0.6 IW/CPE for chickpea irrigation) | 8.22 | 0.32 | 0.54 | 1.36 | 2.65 | 48.6 | 47.0 | 0.35 | 68.0 |

Initial status of composite sample – *p*H-8.2, EC-0.33 dS/m, OC-0.55%, BD-1.35 $Mg/m^3$, PD-2.65 $Mg/m^3$, pore space-48.7%, MWD-0.36 mm and MWHC-68.1%

Table 4 Effect of irrigation and crop residues on maize – chickpea sequence for equivalent yield, water use efficiency, gross returns, net returns and BC ratio (2009-10 and 2010-11)

| Treatment | Maize equivalent yield (tonnes/ha) | WUE (kg/ha-mm) | Gross returns (000's ₹) | Net returns (000's ₹) | BC ratio |
|---|---|---|---|---|---|
| *Irrigation levels (IW/CPE):* | | | | | |
| I1 = 0.8 13.51 | 24.6 | 116.44 | 64.57 | 3.43 | |
| I2 = 0.6 12.44 | 24.71 | 107.27 | 60.49 | 3.19 | |
| I3 = 0.4 13.26 | 29.25 | 114.04 | 59.03 | 3.41 | |
| SEm + | 0.475 | 0.877 | 4.083 | 2.59 | 0.121 |
| CD (P=0.05) | NS | 2.86 | NS | NS | NS |
| *Residue* | | | | | |
| T1= No Till + CR @ 5t/ha | 13.21 | 26.32 | 113.83 | 63.91 | 3.37 |
| T2= No Till + No residue | 12.94 | 26.05 | 111.34 | 58.81 | 3.32 |
| SEm + | 0.191 | 0.353 | 1.64 | 1.033 | 0.049 |
| CD (P=0.05) | NS | NS | NS | 3.183 | NS |
| *Interaction* | | | | | |
| I1 T1 | 13.48 | 24.33 | 116.29 | 66.28 | 3.41 |
| I1 T2 | 13.54 | 24.87 | 116.59 | 61.87 | 3.44 |
| I2 T1 | 12.71 | 25.07 | 109.67 | 63.71 | 3.25 |
| I2 T2 | 12.17 | 24.34 | 104.87 | 57.26 | 3.13 |
| I3 T1 | 13.42 | 29.55 | 115.53 | 61.76 | 3.45 |
| I3 T2 | 13.1 | 28.95 | 112.55 | 56.31 | 3.38 |
| SEm + | 0.529 | 0.978 | 4.551 | 2.882 | 0.135 |
| CD (P=0.05) | NS | NS | NS | NS | NS |
| Control (Conventional tillage with 0.8 IW/CPE for maize and 0.6 IW/CPE for chickpea irrigation) | 15.68 | 29.23 | 134.89 | 70.23 | 3.98 |
| Control v/s interactions | | | | | |
| SEm + | 0.462 | 0.843 | 3.976 | 2.577 | 0.118 |
| CD (P=0.05) | 1.348 | 2.46 | 11.605 | 7.522 | 0.344 |

Maize price: ₹ 8 400 per tonne (2009-10) and ₹ 8 800 per tonne (2010-11); chickpea ₹ 30 000 per tonne

ratio with residue (11.611 kg/ha mm) and without residue (10.018 kg/ha mm) and comparable with control (10.888 kg/ha mm) in 2010-11. Similar trend was observed for pooled basis. This indicated the beneficial effect no tillage in improving the WUE in chickpea though it did not improve the grain yields.

*Soil physical and chemical properties*

Tillage and crop residues had significant effect on the soil physical properties like electrical conductivity and pH at the end of fourth year in comparison to conventional tillage and initial year (Table 3). Under no tillage conditions, application of crop residues in all the irrigation treatments improved the organic matter content. Similar conservation agriculture practices like zero tillage and residue application increased the soil organic carbon in maize and wheat (Mariela *et al.* 2009). The control plot with ploughing and harrowing showed significantly lower organic carbon over no tillage treatments with residue application. There was no difference between initial status and conventional tillage treatment after four years. On the contrary the bulk density was lower in no tilled treatments compared to conventionally tilled treatment. Similar reduction in the bulk density in a wheat experiment was confirmed earlier by Gupta *et al.* (2011). Percent stable aggregates were also higher with no tillage conditions compared to conventional tillage treatment. Application of crop residues had favourable effect over without residue application at all the levels of irrigation. Similar trend was observed with mean weight diameter (mm) and maximum water holding capacity. Peeyush, *et al.* (2011) confirmed similar improvement in soil physical properties under no tilled condition over conventional tillage in a maize – wheat rotation system.

*Economics*

The maize – chickpea sequence was assessed in terms of maize equivalent yield (Table 4). Irrigation, residue application and interactions did not influence the maize equivalent yield. Higher maize equivalent yield was obtained with 0.8 IW/CPE ratio (13.51 tonnes/ha). Residue application was beneficial (13.21 tonnes/ha) over no residues (12.94 tonnes/ha) in improving the maize equivalent yield. Significantly higher MEY was obtained with conventional tillage control (15.68 tonnes/ha) over irrigation and residue interactions indicating the negative effect of no tillage over a period of time. However, no tillage improved the WUE. Irrigation at 0.4 IW/CPE ratio recorded 29.25 kg/ha-mm. Crop residue application and interactions were not significant. Irrigation at 0.4 IW/CPE with or without residues recorded on par WUE indicating the possibility of cultivating no tillage maize and chickpea under water deficient situations.

Economics like gross returns, net returns and B:C ratio were not influenced by irrigation for the maize – chickpea sequence (Table 4). This was probably due to no effect of irrigation on the maize equivalent yield. However, higher net returns (₹ 64570/ha) and B:C ratio (3.43) was noticed with 0.8 IW/CPE ratio. Irrigation at lower frequency resulted in lower net returns and B:C ratio. Residue application was significantly better in terms of net returns over without residue. This was due to higher maize equivalent yield obtained in residue applied treatment over no residue treatment. Normal tillage practices significantly improved the gross returns, net returns and B:C ratio. Residue application significantly improved the yields of various crops under no tillage systems and thereby improved the economics. Irrigation at 0.8 IW/CPE or 0.6 IW/CPE with residues increased the net returns to the normal tillage level.

From the four years data it can be concluded that no till maize was comparable with tilled maize for yield and water use efficiency while it reduced the chickpea yield. Residue application had a favourable effect on yield and soil properties. No tilled maize – chickpea sequence required irrigation at 0.6 IW/CPE ratio with crop residue application @ 5 tonnes/ha for maize and 0.4 IW/CPE with residue for chickpea was found better for higher yield and water use efficiency.

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