ISSN 0972-1665

# Journal of Agrometeorology

Volume 15 Special Issue - I March 2013

Editors
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Association of Agrometeorologists
Anand - 388 110, India

# *Journal of Agrometeorology*

Volume 15 | Special Issue - I | March 2013

**Association of Agrometeorologists, Anand Agricultural University,**
**Anand - 388 110, Gujarat, India**

Volume 15 Special Issue - I March 2013

# Journal of Agrometeorology

## CONTENTS

***Short Communication***

*Journal of Agrometeorology 15 (Special Issue-I) : 131-137 (March 2013)*

# Management of tillage and crop residue under maize for enhancing soil resilience to climate change

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## ABSTRACT

Development of appropriate coping strategies to adapt to the adverse impacts of climate variability should be a part of research activity in dryland agriculture. Therefore, a field study was established in semi-arid Alfisols to study the effect of conservation tillage practices, which influences the soil - water - plant ecosystem, thereby affecting crop yield. Surface residue cover, soil moisture, bulk density and penetration resistance were measured at different depths in the study composed of three tillage practices in combination with *in-situ* residue recycling. Tillage methods in combination with residue management significantly influenced biomass and grain yield with maize stalk slashing and spreading + tillage twice with offset disc harrow giving highest average stover and grain yield of 3726 and 2402 kg ha$^{-1}$ respectively. Reduced till or No till slightly recorded more soil moisture than that of conventional tillage. Differences in soil bulk density between tillage practices were temporally dependent and were largest at the depth of 0-100 mm immediately after tillage events. In crop stubbles + No till practice plots, bulk density mean yearly values were highest, 1.53 and 1.6 g cm$^{-3}$ at 0-100 mm and 100-200 mm depths. The penetration resistance was higher in No-till practice than that under conventional tillage at 0 - 25 cm depth. It is concluded that, under semi-arid Alfisols, reduced tillage, even in combination with in-situ crop residue management, gives small yield benefits in the short run. Crop residue mulching helped significantly to conserve soil and water from off-season rainfall events. If adopted on long term basis, the practice could favourably improve other soil physical properties also. Therefore, reduced till and zero tillage practices in conjunction with biomass recycling could be of high significance in making the soil resilient towards climate variability.

***Key words:*** Climate variability, conservation agriculture, tillage practices, soil resilience, soil moisture, penetration resistance, maize yield

Agriculture provides livelihood for 60 per cent of rural population of India and contributes to 35 per cent of country's Gross National Product (GNP). In recent past, it has been observed that extreme weather factors like more intense rainfall events, prolonged dry spells, rise in temperatures, early withdrawal and late on-set of monsoon patterns are recurring due to climate change and variability. The climate change impacts are predicted to have more pronounced influence on rainfed crop yields than irrigated due to limited water supply, poor fertility status of rainfed soils and poor resource base of the farmers. In order to increase food security, minimize or overcome the adverse impacts of climate change on agriculture, adaptive and mitigation strategies such as conserving soil moisture through appropriate tillage practices, sowing on ridge - furrow or bed and furrow system rather than flat land, improving soil physical conditions by recycling crop residue and cover cropping need to be advocated more vigorously than ever before (Gwambene and Majule, 2010).

In face with the modernization and to meet the growing population food supply requirements, hybrid seeds and chemical fertilizers have been introduced to increase the crop yields. Since, the chemical fertilizers are handy and easy to apply; the farmers slowly neglected the crop residue recycling and importance of its application to soil from three to four decades. Adoption and spread of commercial crops, dwindling individual and community grazing lands, agricultural mechanization and increased agricultural labour wages further restricted crop residue recycling to composting and soil application. The discontinuity of addition of crop residue directly or indirectly through composting have severely affected the soil fertility status and properties in rainfed agriculture. However, in rainfed areas, the farmers are resorting to throw away the residues of crops like maize, castor, sunflower and cotton stalk on farm bunds or even burning in many instances. Instead of resorting to such practices, if the crop residue is managed to recycle *in-situ* in conservation agricultural practice mode using appropriate machinery and tillage practices, it simultaneously conserve soil by reducing surface run-off and improves ground water resources (Lipiec *et al.,* 2005), reduces farm energy and leads to positive changes in the soil physical properties besides increase or stabilize crop production (Bescansa *et al.,* 2006). In arid and semi-arid zones of India, conservation agricultural practices of *in-situ* crop residue recycling besides reduced tillage and direct planting will minimize rainwater run-off loss, promotes timely planting and make use of scarce rainfall. Earlier studies revealed that conservation agriculture (CA) comprising of tillage and residue management has the potential to improve adaptation to climate change mainly due to enhanced water balance in CA managed fields and to climate change mitigation through possible C sequestration and reduced emission of $CO_2$ to the atmosphere. No tillage (NT) or Zero tillage (ZT) is also seen as an important soil management practice in the context of global climate change as it may increase C sequestration in soil due to improved crop residue management (Batjes and Sombroek, 1997; Lal, 1997). The $CO_2$ emission from the conventionally managed soils is due to ploughing, mixing crop residues and other biomass into the soil surface and burning of biomass (FAO, 2001). In rainfed agriculture, conservation agriculture practices such as reduced tillage or No tillage in combination with residue retention on soil surface on long term basis can play significant role in mitigating the ill effects of climate change by way of improving soil physical properties and thus influencing water infiltration and storage, reducing bulk density and compaction. Hence, such studies are needed in a more systematic manner on long term basis. Therefore, the present study was conducted with the specific objective of studying the influence of tillage and crop residue management on crop yield and crucial soil physical properties which enhance soil resilience towards climate variability.

## MATERIALS AND METHODS

The present experimental work was carried out at Central Research Institute for Dryland Agriculture, Hayatnagar Research Farm, Hyderabad (17° 20'N latitude, 78° 35'E longitude, and an elevation of 515 m above mean sea level). Farm situation represents semi-arid tropical environment and the soil in the experimental field is light textured shallow depth red soil representing Alfisol with a gentle slope of 3% .The basic characteristics of the soil at the experimental site are presented in Table 1. The field was under castor and pigeonpea crop rotation system for 5 years with conventional tillage practice using tractor operated heavy duty tillage implements before the experiment was started in 2008. The mean annual rainfall of the region is 750 mm and accounts for approximately 42% of the annual potential evapotranspiration.

The treatments consisted of four practices: Conventional Tillage (CT) - Crop stalk removal and tillage operations using tractor operated light duty cultivator and offset disc harrow twice each, Residue with Reduced tillage (RRT) – Maize stalk slashing and spreading + Tillage twice with offset disc harrow, RNT- Maize stalk slashing and spreading + No Till and SNT- Maize stubbles up to 50 cm height + No till. The experiment layout was in strip plot design; each plot is 8x35 m in size. During early season of 2008, shredded maize residue @ 4 tonnes $ha^{-1}$ was spread uniformly in three treatments except CT. In rest of three seasons, the stalk produced in the plots was utilized to impose treatments using tractor operated slasher and followed by tillage operations. Planting was carried out using a double disc furrow openers 6 row horizontal plate planter at 45 cm x 20 cm row to row and plant to plant spacing in the month of June, and cobs were harvested in the last week of October in all four years. Pre-emergence herbicide was applied immediately after planting for early growth stages weed control and later in the season weeds were removed manually.

The plant residue cover after imposition of treatments and after planting was estimated as for the Line-Transect method suggested by Anonymous (2000). Soil moisture measurements were monitored few weeks after maize planting to until the grain filling stage for a soil profile depth of 0.8 m, at four increments through the soil profile: 0-20, 20-40, 40-60 and 60-80 cm soil depth using neutron probe. We got few occasions where soil surface moisture could be monitored using Theta probe when the crop residue was present in considerable quantity on soil surface in all the treatments. Intact cylindrical soil cores were collected at two depths (0-10 and 10-20 cm) for each treatment plot on fixed intervals to estimate soil bulk density by determining mass of oven dried soil $volume^{-1}$ of core. The soil bulk density measurements were made during all important crop growth stages and monthly means were estimated which comprised of three to four sampling dates. Soil penetration resistance (PR) as a cone index was measured within few days after planting and after cobs harvest by pushing a hand – held

**Table 1:** Characteristics of the soil at the experimental site

| Depth cm | Sand % w/w | Silt % w/w | Clay % w/w | Water holding capacity % v / v | | Organic carbon % w/w | Available nutrients ( kg $ha^{-1}$) | | | Soil $p^H$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FC | WP | | N | P | K | |
| 0 - 10 | 82.2 | 6.5 | 11.9 | 16.08 | 7.4 | 0.38 | 250.46 | 6.9 | 115.4 | 6.9 |
| 10 - 20 | 80.3 | 6.1 | 13.3 | 17.5 | 8.3 | 0.45 | 260.50 | 6.3 | 120.6 | 6.6 |

digital cone tipped penetrometer at three locations within 50 cm radius at each plot where soil cores for bulk density were extracted. Soil PR readings were recorded in 2.5 cm increments up to a depth of 25 cm. The penetrometer used a 30° cone with a base 1.27 cm in diameter. Insertion points for each measurement were taken in-row. PR measurements were avoided during crop growth period because of the sensitivity of the penetrometer's sensor to vegetative parts of maize. The data were statistically analyzed to determine the significance of the treatments on the measured parameters.

## RESULTS AND DISCUSSION

### *Seasonal rainfall*

The cropping seasons during the experimentation period were characterized for different rainfall patterns. Total crop growth seasonal rainfall for 2011and 2009 was deficit *ie* around 54 and 67%, respectively of the normal rainfall and 29% excess in 2010 (Table 2). The planting operation was delayed by three weeks in 2011 cropping season because of insufficient moisture in the soil. In 2008, 2009 and 2011, the crop experienced short duration dry spells in early crop growth period.

### *Crop yield*

Maize grain and biomass yield were significantly affected by the tillage practices. In the first year, where the rainfall was normal, both the grain and biomass yields were weakly influenced by treatments. During first year (2008), tillage and residue treatment didn't show any significant effect on maize grain yield. However, during the subsequent years viz. 2009, 2010 and 2011, tillage and residue treatments significantly influenced the maize grain and biomass yield. During the low rainfall cropping seasons in 2009 and 2011, the highest grain and biomass yields were achieved in RRT (residue + disc harrow twice tillage treatment) plot. The average yield levels were 921 and 1389 kg ha$^{-1}$ and 3341 and 3894 kg ha$^{-1}$ respectively. Overall, maize crop planting under RRT produced

**Table 2 :** Effective rainfall and number of rainy days during the crop growth period

| Year | Rainfall / rainy days | June | July | August | September | October | November | Total |
|---|---|---|---|---|---|---|---|---|
| 2008 | No.of rainy days | 2 | 12 | 14 | 11 | 6 | 0 | 45 |
| | Rainfall , mm | 28.0 | 89.8 | 400 | 158 | 61.1 | 0 | 736.9 |
| 2009 | No.of rainy days | 4 | 8 | 16 | 12 | 6 | 0 | 46 |
| | Rainfall , mm | 60 | 62 | 163 | 102 | 106 | 0 | 493.0 |
| 2010 | No.of rainy days | 8 | 19 | 16 | 15 | 7 | 0 | 65 |
| | Rainfall , mm | 171.5 | 277.2 | 272 | 121 | 111 | 0 | 952.7 |
| 2011 | No.of rainy days | 0 | 5 | 15 | 8 | 4 | 1 | 33 |
| | Rainfall , mm | 0 | 91 | 218 | 60.1 | 22.4 | 6.4 | 397.9 |

**Table 3 :** Results of treatment mean for maize grain and biomass yields

| Treatment | Year | | | | |
|---|---|---|---|---|---|
| | 2008 | 2009 | 2010 | 2011 | Mean |
| | | | Grain yield, kg ha$^{-1}$ | | |
| CT | 2449.8 | 500.9 | 3931.7 | 1213.5 | 2023.9 |
| RRT | 2499.2 | 921.3 | 4797.3 | 1389.8 | 2401.9 |
| SNT | 2540.0 | 550.0 | 3905.0 | 972.5 | 1991.8 |
| RNT | 2305.0 | 798.9 | 4054.3 | 1059.2 | 2054.3 |
| SEm (±) | NS | 59.09* | 149.4** | 107.5* | |
| LSD | | 365.8 | 553.8 | 263.1 | |
| Dry stover yield, kg ha$^{-1}$ | | | | | |
| CT | 2929.3 | 1755.5 | 4016.6 | 2987.1 | 2922.1 |
| RRT | 2716.8 | 3341.0 | 4954.3 | 3893.9 | 3726.5 |
| SNT | 3179.8 | 1732.6 | 4101.0 | 2265.5 | 2819.7 |
| RNT | 2895.0 | 2481.0 | 3930.0 | 2529.3 | 2958.8 |
| SEm (±) | 37.4* | 46.3** | 51.1** | 229.0** | |
| LSD | 120.5 | 652.4 | 189.4 | 848.9 | |

more total grain and biomass compared to other tillage and residue management treatments across the four seasons. Poor distribution of rainfall during 2009 and 2011 seasons negatively impacted maize growth irrespective of the treatments. Soil moisture measurements showed that RRT had over all marginally higher soil water, which might have contributed to more biomass and grain yields (Table 3).

***Soil moisture***

Improvement in soil moisture is one of the important aspect in adoptive strategies for climate variability through conservation tillage practices in the soil environment. The analysis of data indicates that, the soil moisture among different treatments was significantly different at pre-emergence and tasseling stages in 2008 and pre-emergence and pre-harvest stages in 2011. Soil moisture profiles under CT, RRT, RNT and SNT for the experimental plots show that post emergence and pre-harvest soil moisture content were higher beyond 30 cm soil depth in both the years. The soil moisture in the top 20 cm profile little bit varied among the treatments *i.e* it was higher in reduced and no till, beyond that the variation narrowed down in all the treatments in both the years. The soil moisture in reduced till or no till was slightly greater compared to conventional tillage at all soil profile depths in both the years (Fig.1)**.**

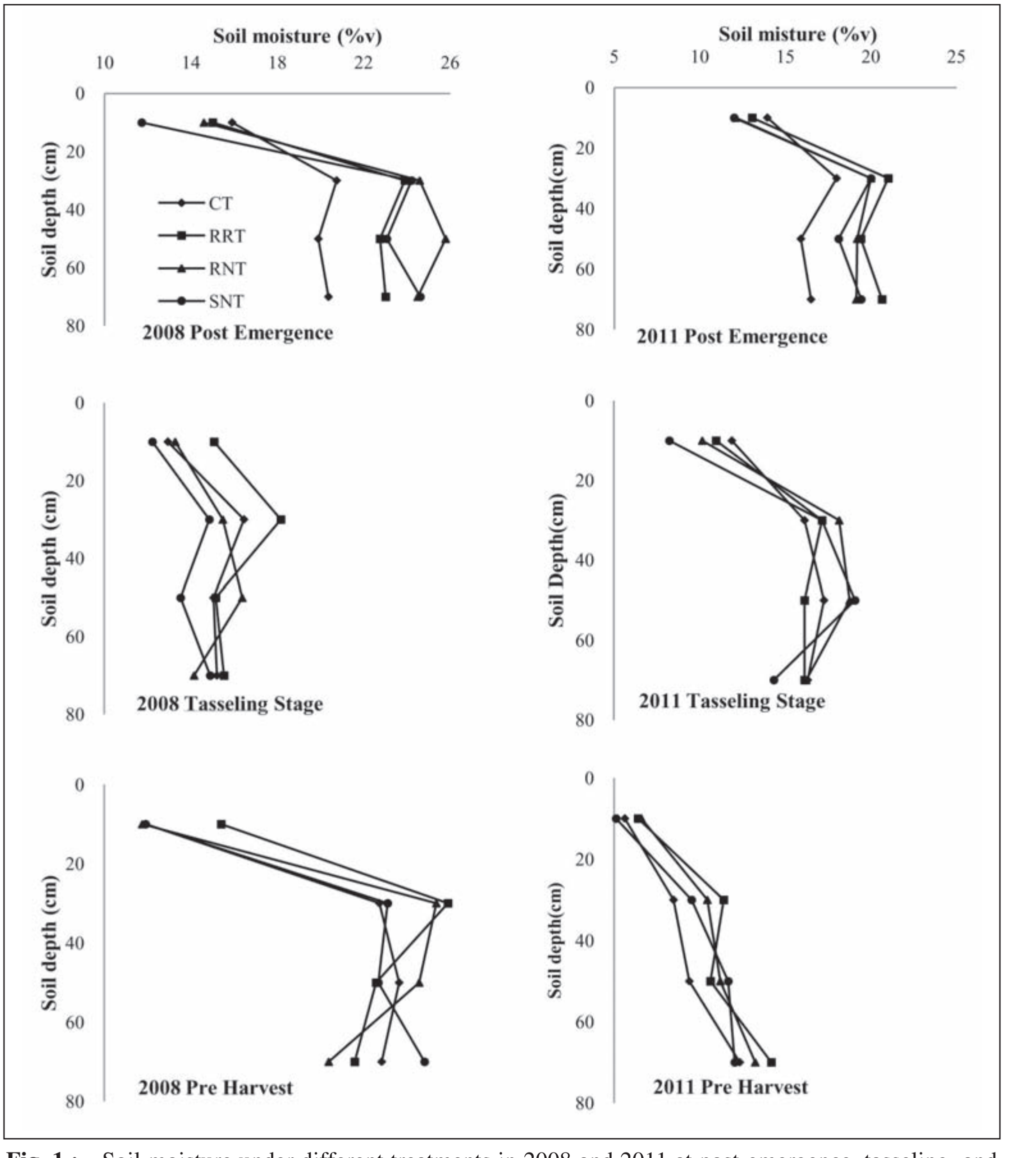


**Fig. 1 :** Soil moisture under different treatments in 2008 and 2011 at post-emergence, tasseling and preharvest stages

If both growing seasons are compared, the soil moisture recorded in 2011 was low at all profile depths, because the effective rainfall received was lower *i.e* 398 mm against 737 mm in 2008. As these results were obtained only after three year of study, though the effects on soil moisture conservation are slightly meager, nevertheless indicate the potential of these practices in conserving moisture, if adopted on long term basis. These results are in conformity to the findings of Karlen *et al.,* (1994), which concluded that no-tillage is desired to have higher soil moisture content than cultivator/disc plowing in the top 5 cm soil depth. In four years of experimentation, we had only one opportunity in October 2010, to examine the full effect of crop residue cover on surface soil moisture in the 0 - 15 cm profile, in off-season immediately after imposition of treatments. The soil moisture content increased with increase in mulch cover under the treatments and remained significantly higher in Residue + No till practice (15.03%) and lowest (10%) in conventional tillage practice (Fig. 2)**.** Jat *et al.,* (2012) reported that CA improves water availability and soil quality, besides other advantages, it is likely CA may emerge as an important climate change adaptation strategy.

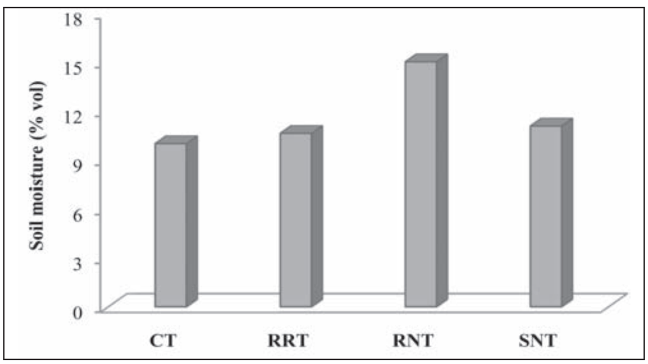


**Fig. 2 :** Soil moisture with residue under different treatments (0-15 cm depth)

### *Bulk density*

Regardless of tillage practices, the soil bulk density increased with depth. The bulk density after harvest was higher than at sowing (Fig. 3). The difference in these values may be due to the influence of rainfall after tillage. Tillage methods significantly influenced soil bulk density at sowing and after harvesting period at 5% significant level. At the depth of 0 - 100 mm, the conventional tillage treatment had least value of bulk density 1.1 g $cm^{-3}$. The SNT treatment showed the highest bulk density of 1.69 g $cm^{-3}$. Mean yearly values were 1.33, 1.38, 1.53 g $cm^{-3}$ and 1.48, 1.47 and 1.6 g $cm^{-3}$ under CT, RRT and SNT treatments at 0-100 mm and 100-200 mm depth, respectively. Differences in mean yearly soil BD between different treatment regimes were significant at two depths. Differences in soil bulk density between tillage practices were temporally dependent. Differences were largest at the depth 0 - 100 mm immediately after tillage events, but quickly returned to levels closer to NT owing to the process of soil densification. Immediately after imposing the treatments, as expected, the bulk density in conventional was slightly lower than other treatments. However, at later stage as the season progressed, the bulk density values were almost close to that of No or reduced tillage. Probably, the beneficial effect of reducing the bulk density in No or reduced tillage can be accrued by maintaining adequate crop residue throughout the season on long term basis.

### *Penetration resistance*

Resistance of the soil for penetration also can be an indicator that can be used to evaluate the tillage effects on soil physical properties. Penetration resistance values for all treatments to a depth of 25 cm soil profile were presented in Fig. 4. The values of PR under RNT and SNT were considerably higher than that under CT from 0 - 25 cm, which might be affected by the tillage. Lower PR with CT at different depths was mainly as a result of soil loosening

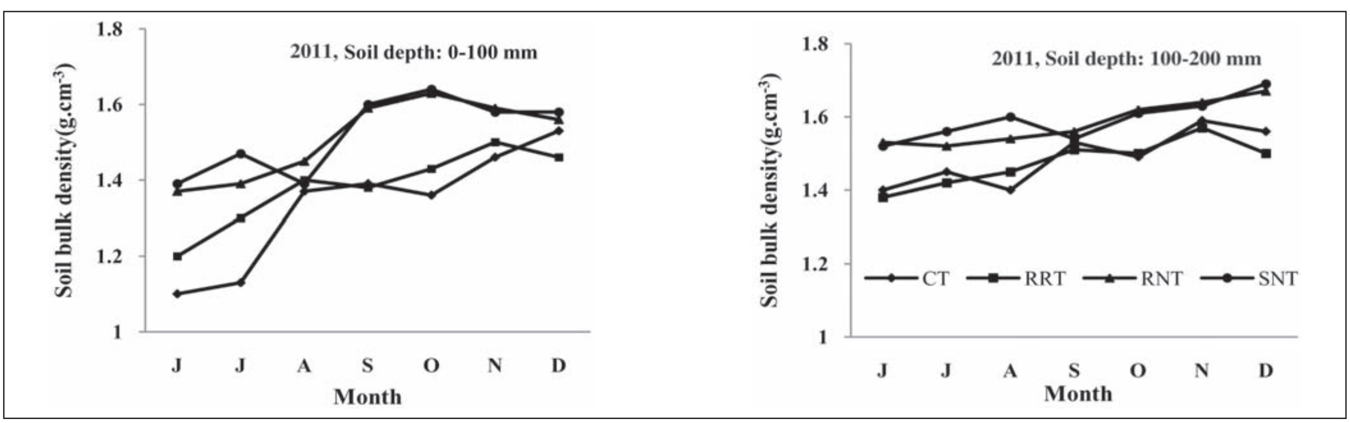


**Fig. 3 :** Mean monthly soil bulk density as effected by tillage and soil depth

and mechanical manipulation by tillage implements. Soil PR in CT, RRT and No – till plots (RNT and SNT) averaged 0.9, 1.08 and 1.24 MPa, respectively across the 0 – 25 cm depth range at post-emergence. The lower PR with CT was likely the results of tillage induced soil loosening caused by penetration of tillage tool. Similar results were reported in PR with respect to soil depth in tilled soil by Etana *et al.,* (1999). However, in post harvest stage, all treatments showed greater penetration resistance at all depths when compared with post-emergence, mean values ranging from 1.45 to 1.72 MPa. In general, the results showed high variability in penetration resistance across the depths, among different tillage treatments and it was more pronounced later in the season. The PR values can be lowered in reduced or No tillage, only if adequate amount of residue is retained on long term basis. Low PR could be the manifestation of less compaction, more receptivity of soil towards water infiltration and low runoff, which in turn can help in improving the resilience of soil towards climate variability and more specifically towards short term droughts. There are several reports to indicate that CA practices help to adapt climate change induced water stress through increased water infiltration (Pikul and Aase, 1995; Cassel *et al.,* 1995; McGarry *et al.,* 2000) and reduced evaporation of stored soil moisture (Nurbekov, 2008; Gupta *et al.,* 2010).

### *Effect of residue cover with time*

The treatments used in this experiment influenced the residue cover on soil surface in each year and the difference was highly significant at 0.01 probability level (on imposition of treatment and as well as after maize crop planting) (Fig. 5).The treatment and year interaction effect was also significant. The residue cover on imposition of treatments in different years varied depending upon stalk / biomass yield. Highest residue cover after imposition of treatments was achieved in all treatments during the fourth year (2011), because the biomass produced during this year was also high. The residue cover under RNT was significantly greater in quantity when compared with other two treatments in all the years and in both the situations. Disc harrow operation reduced the surface residue to the tune of 10% in RRT when compared with RNT. In SNT, in all years, residue was lowest, since rest of the biomass leaving crop stalk to a height of 50

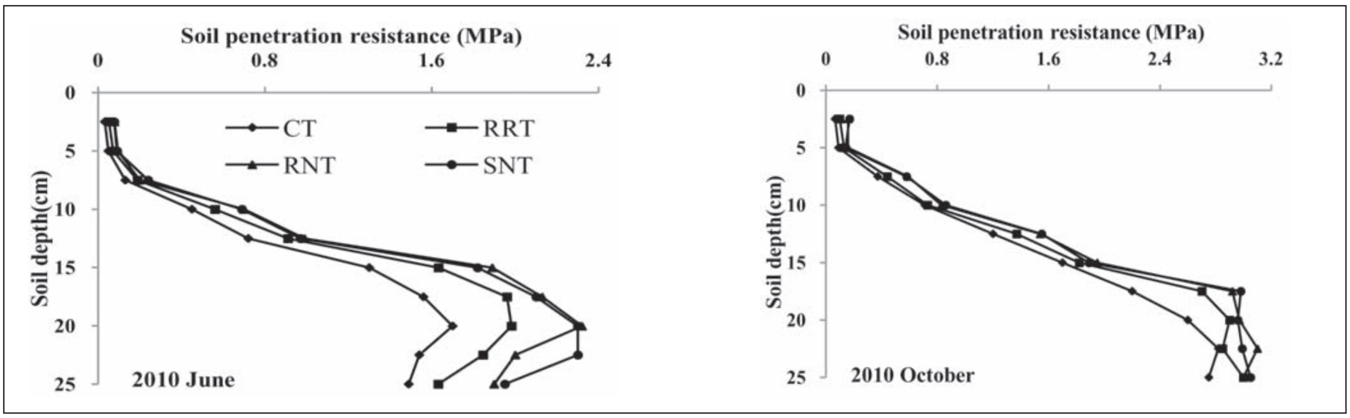


**Fig. 4**: Soil penetration resistance for the soil profile under different treatments

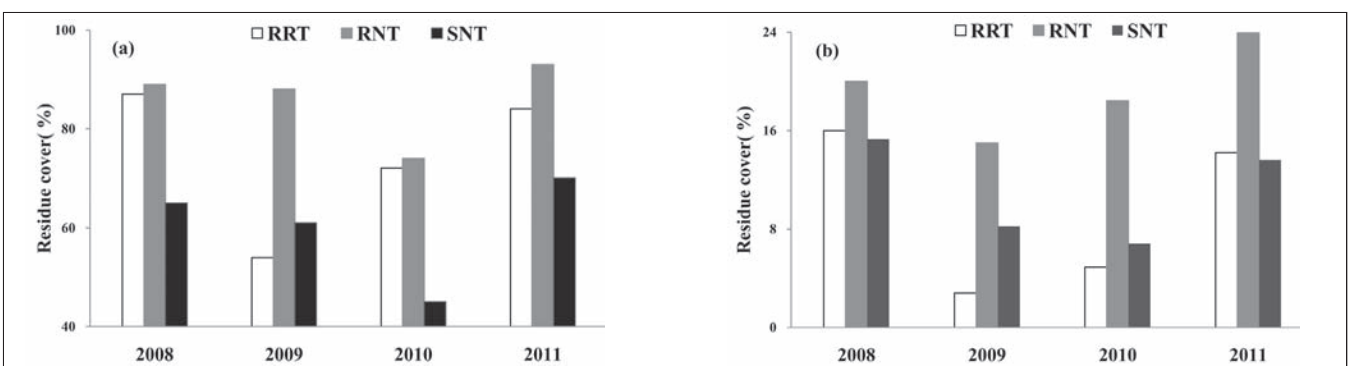


**Fig. 5**: Residue cover on soil surface (a) after imposition of treatments (b) after planting maize

cm was removed. Though, the surface residue cover was in considerable amount on imposition of treatments, thereafter, residue cover gradually reduced in dry periods. This reduction was more rapid whenever some rainfall occurred intermittently leading to termite activity. As a consequence, the residue remained after planting was got declined to meager percent. The experimental results in many of the conservation agricultural studies showed that, surface crop residue cover of about 30% or more can significantly influence the productivity of crops and increases grain yield. However, in semi arid Alfisols, where the soils are subjected to one or two off- season intense rainfall, the erosion reducing benefits of crop residue cover can be exploited by selection of an appropriate combination of tillage operations. Though in the present study, we have not measured soil temperature and $CO_2$ fluxes, but the earlier studies revealed that besides the above benefits, adequate crop residue cover during hot months helps in keeping the soil temperature low and in turn reduces $CO_2$ fluxes (Licht and Al-Kaisi, 2005).

Hence, in the present study, conservation agriculture practices comprising of reduced or zero tillage coupled with surface residue retention, helped in improving crop yield and enhancing moisture in soil. There are scopes that, these practices if adopted on long term basis could also favorably impact other soil physical properties such as improving soil structure, reducing bulk density, decreasing penetration resistance significantly. Therefore, these practices could be of high significance in making the soil more resilient towards climate variability.

## REFERENCES

Anonymuos. (2000**).** Estimating crop residue cover for soil erosion control - *Soil Fact sheet*. Ministry of Agriculture and Food. British Columbia.

Batjes, N. H. and Sombroek, W. G. (1997). Possibilities for carbon sequestration in tropical and subtropical soils. *Global Change Biol.,* 3: 161-173.

Bescansa, P., Imaz, M. J., Virto, I., Enrique, A. and Hoogmoed, W. B. (2006). Soil water retention as affected by tillage and residue management in semi-arid Spain. *Soil and Tillage Res*., 87: 19- 27.

Cassel, D. K., Raczkowski, C. W. and Denton, H. P. (1995). Tillage effects on corn production and soil physical conditions. *Soil Sci. Soc. Am. J.,* 59: 1436—1443.

Etana, A., Hakansson, I., Zagal, E. and Bucas, S. (1999). Effects of tillage depth on organic content and physical properties in five Swedish soils. *Soil and Tillage Res*., 52: 129-139.

FAO. (2001). Conservation agriculture case studies in Latin America and Africa. Introduction. FAO Soils Bulletin *No. 78. Rome: FAO.*

Gupta, R., Gopal, R., Jat, M. L., Jat, R. K., Sidhu, H. S., Minhas, P.S. and Malik, R.K. (2010). Wheat productivity in Indo-Gangetic Plains of India during 2010: Terminal heat stress and mitigating strategies. *Conservation agriculture newsletter*, Getting agriculture to work for people and the environment, PACA, 1st floor, NASC complex, DPS Marg, Pusa, New Delhi- 110 012, India.

Gwambene, B. and Majule, A. E. (2010). Contribution of tillage practices on adaptation to climate change and variability on agricultural production in semi-arid areas of Central Tanzania. In: *Proceeding of 9th European IFSA Symposium on climate change: Agriculture, food security and human health.* 1300 -1309.

Jat, R. A., Wani, S. P., and Sahrawat, K. L. (2012). Conservation agriculture in the semi-arid tropics: prospects and problems. In D. L. Sparks (Ed.). *Advances in Agronomy,*117: 191-273.

Karlen, D. L., Wollenhaupt, N. C., Erbach, D. C., Berry., E. C., Swan, J. B., Eash, N. S., Jordahl, J. L. (1994). Long term tillage effects on soil quality. *Soil and Tillage Res.,* 32: 313-327.

Lal, R. (1997). Residue management, conservation tillage and soil restoration for mitigating greenhouse effect by $CO_2$ - enrichment. *Soil and Tillage Res.,* 43: 81-107.

Licht, M. A. and Al-Kaisi, M. (2005). Strip-tillage effect on seedbed soil temperature and other soil physical properties. *Soil and Tillage Res.,* 80**:** 233-249.

Lipiec, J., Kus, J., Slowinska, J. A. and Nosalewicz, A. (2005). Soil porosity and water infiltration as influenced by tillage methods. *Soil and Tillage Res.,* 89**:** 210-220.

McGarry, D., Bridge, B. J. and Radford, B. J. (2000). Contrasting soil physical properties after zero and traditional tillage of an alluvial soil in the semi-arid subtropics. *Soil and Tillage Res.,* 53: 105-115.

Nurbekov, A. (2008). Manual on conservation agriculture practices in Uzbekistan. Tashkent, Uzbekistan, p. 40.

Pikul, J. L. and Aase, J. K. (1995**).** Infiltration and soil properties as affected by annual cropping in the northern Great-Plains. *Agron. J.,* 87: 656-662.