International Journal of Tropical Agriculture, Vol. 25 No. 1-2, (January-June, 2007)

Soil-water-plant Relationship in Wint r Maize as Affected by Different Tillage M hods and Irrigation in N rth Bihar

Sanjeev Kumar, Shivani**, V.P Singh** & Manil husban****

The field experiments were conducted from 2002-04 in winter season at Rajendra Agricultural Universi Pusa, Samastipur, Bihar comprising of sixteen treatment combination of different tillage methods (4) and irrigation fr ency (4). Rotavator tilled maize reported superior overall other tillage practices in respect of bulk density (1.33 an 30 mg m^{-3}), soil strength (2.10 and 2.05 MPa), infiltration rate (0.420 and 0.432 cm hr^{-1}) and porosity (49. nd 50.94%) in both the years, respectively. Plant height, root volume, LAI, relative leaf water content were d significantly higher over zero-tilled maize with 5 to 6 irrigations while water saturation deficit had shown revers d being maximum in zero–tilled maize (6.91%) and minimum in rotavator tilled maize (4.62%) while WS as recorded to its minimum level in the crop receiving 5 to 6 irrigations. Rotavator tilled maize showed consumptive use of water (49.38cm) but significantly higher water use efficiency (119.39 Kg/ ha-cm) over er tillage practices, while it was found minimum at the highest level of irrigation (95.28 kg/ ha-cm). Rota d maize with 5 to 6 irrigations fetched maximum grain yield (67.20 and 67.29 q/ ha^{-1}). Maximum ne Rs. 16,833 ha^{-1}) was recorded with rotavator tilled maize with 5 irrigations (Rs. 14,815 ha^{-1}).

Key words: *Winter maize, Tillage, Irrigation, Yield, Plant-water status, and Economics*

Introduction

Among various factors responsible for low productivity, soil moisture availability rega s the most limiting factor because crops are very much sensitive to soil-moisture stress, partic rly at their critical stages. Strategies to minimize crop water stress include-irrigation, increased zone and conservation of soil moisture by increased infiltration, reduced evaporation and aximum exploitation of available soil water. Whereas, impact of tillage is routed through by provi g good soil tilth conducive to better crop growth and development. Actually tillage alters rh osphere environment by modifying most of the physical properties due to formation, destr ion and rearrangement of soil particles and aggregates and alternation in clod size distribution.

Adequate soil moisture is required for normal development of maize crop at a stages of growth. However under limited availability of water, scheduling of irrigation at the st critical stages increases crop productivity and water use efficiency as deleterious effec of water deficit is not equally pronounced over all the growth stages of crop. Only quantity of water is n important for getting higher yield but time of application to the crop is considered as deciding f or for yield of any crop. The excessive use of these vital inputs viz. tillage and irrigation to g higher and

* Scientist (SS), Agronomy, ICAR-RCER, ICAR Parisar, Patna-800 014
** Professor & Head Agronomy RAU, Pusa, Bihar.
*** Scientist(SS), Computer Application in Agriculture, ICAR-RCER, ICAR Parisar, Patna-800 014

higher yield to meet the growing need of escalating population not only diminishes the profitability by increasing the cost of cultivation but also degrades our natural endowments viz., soil and water. In North Bihar, winter maize has become a well adopted crop with high yield potentials (50-60 q/ha) and area under the crop has increased tremendously. In spite of established yield and other advantages of tillage and irrigation, their adoption at farmer's level on a scientific pattern need to be developed.

Thus, keeping the above facts in view the present investigation was planned and conducted with an objective to study the response of winter maize to different soil- tilth and irrigation frequencies and to evaluate the impact of interacting factors on soil, water and plant.

MATERIALS AND METHODS

The field experiments were conducted during winter (*Rabi*) season of 2002-03 and 2003-04 at Tirhut College of Agriculture Farm, Dholi (Muzaffarpur), a campus of Rajendra Agricultural University, Pusa (Samastipur), Bihar in Split Plot Design with three replications. The soil of the experimental plot was sandy loam in texture with pH value of 8.25, organic carbon 0.46%, available N,P and K (Kg/ha): 212.1, 20.5 and 125.2, respectively. The bulk density of the experimental soil was 1.47g/cc. and evaporation during the experimental seasons were 23.7 and 19.5 mm. with a total rainfall of 134.0 and 138.5 cm, respectively. The treatments comprises of four tillage practices (Main plot) : 1 disc ploughing+ 2 harrowing+ planking (conventional tillage) as T_1, 2 cultivator+ Planking (T_2), Rotavator once (T_3) and zero-till planter (T_4) and four irrigation frequencies on different physiological stages stages (Sub plot) : Pre- knee height (30 DAS) + Knee height(Kn) + Silking (Total 3 irrigations) as I_1, Pre- knee height (30 DAS) + Knee height(Kn) + Silking + Milking (Total 4 irrigations) as I_2, Pre- knee height (30 DAS) + Knee height(Kn) + Tasseling + Milking + Grain filling (Total 5 irrigations) as I_3 and Pre- knee height (30 DAS) + Knee height(Kn) + Tassel initiation stage + Silking + Milking + Grain filling (Total 6 irrigations) as I_4. The Composite maize variety (Deoki) was sown on 18 th October in both the years. Row to row spacing was maintained at 60 cm with a common fertilizer dose ($N:P_2O_5:K_2O$) of 120 : 75 : 50 (Kg/ha). All P and K fertilizers were applied as basal while, N was applied in three equal splits (1/3 as basal + 1/3 at Knee stage and 1/3 at tassel initiation stage). In each irrigation 6 cm. water was applied as per treatment. All soil, plant and irrigation observations were taken by following standard procedures and calculations while, yield was calculated on the basis of net plot area. Relative leaf water content and water saturation deficit were calculated by using the formula:

$$WSD = \frac{\text{Saturated weight} - \text{Fresh Weight}}{\text{Saturated weight} - \text{Dry weight}} \times 100$$

Results and discussion

Soil Studies

Bulk density tended to decrease as soil-tilth get finer due to different tillage operations. The lowest bulk density was recorded with rotavator tilled plots and the highest in zero-tilled plots during both the years of investigation. Reduction in bulk density may be attributed to increased soil volume by loosening the soil due to different tillage practices (Wahyuni,2001). As soil tilth get finer due to different tillage practices ,it tend to decrease the average soil strength of the tilled plots. The decrease in rotavator tilled plots was 17.6% (Table 1).

Table 1

Effect of Tillage on Physical Properties of Surface Soil (0-60 cm) after Harvest of Maize

Treatments	*Years*	
	2002-03	*2003-04*
	(a) Bulk density (mg m^{-3})	
Conventional tillage	1.36	1.33
2 cultivator + Planking	1.41	1.40
Rotavator once	1.33	1.30
Zero-till planter	1.43	1.40
	(b) Soil strength (MPa)	
Conventional tillage	2.28	2.24
2 cultivator + Planking	2.35	2.31
Rotavator once	2.10	2.05
Zero-till planter	2.56	2.39
	(c) Infiltration rate (cm hr^{-1})	
Conventional tillage	0.331	0.337
2 cultivator + Planking	0.328	0.325
Rotavator once	0.420	0.432
Zero-till planter	0.316	0.335
	(d) Porosity (%)	
Conventional tillage	48.68	49.81
2 cultivator + Planking	46.79	47.17
Rotavator once	49.81	50.94
Zero-till planter	46.02	47.17

Rotavator tilled plots had maximum infiltration rate (0.420 and 0.432 cm hr^{-1}) during both the years of experimentation but minimum average infiltration rate did not follow the same trend in both the years. In the first year, zero-tilled plots showed minimum average infiltration rate (0.316 cm hr^{-1}) while, in the 2nd year cultivator tilled plots resulted in lowest average infiltration rate (0.325 cm hr^{-1}). The increase in infiltration rate attributed to the maximum reduction in bulk density and had pronounced effect as total porosity and macro porosity both increased, may be correlated with the findings of Bhusan and sharma, 1997. Porosity tended to change with different tillage practices. As the soil tilth get finer, porosity increases (Table 1). Here, maximum average porosity was observed in rotavator tilled maize 49.81 and 50.94 per cent in both the years, respectively while, the minimum porosity was recorded in by zero-tilled maize in the first year but in the 2nd year of experimentation cultivator tilled maize and zero-tilled maize showed equal porosity of 47.17 per cent.

Plant Studies

Tillage and irrigation significantly affected plant height of winter maize at maturity (Table 2). Significantly higher plant height was recorded in rotavator tilled maize (189.70 cm) over zero-tilled maize which was followed by conventional tillage and cultivator tilled maize. Crop receiving 5 and 6 irrigations recorded highest plant height 192.82 and 189.62 cm at maturity over 3 or 4 irrigations.

Maximum root volume was recorded with rotavator tilled maize at 120 DAS (47.63 cc) over zero tillage (37.05 cc). Root volume was significantly higher with the crop receiving 6 no. of irrigations (46.54 cc) over 3 and 4 irrigations but was found at par with crop received 5 no. of irrigation.

Table 2
Effect of Tillage and Irrigation on Growth, Plant–water Status (120 DAS), Irrigation, Yield and Economic Studies at Harvest
(Polled data of year 2002-03 and 2003-04)

Treatments	*Plant height (cm)*	*Root volume (cc)*	*Leaf area index*	*Water saturation deficit (%)*	*Relative leaf water content(%)*	*Grain yield (Kg/ha)*	*WUE (Kg/ha-cm)*	*CUW cm*	*Net return (Rs./ha)*	*B:C ratio*
Tillage										
Conventional tillage (T_1)	183.81	42.61	2.53	4.97	91.53	5100	102.39	49.80	12,642	1.83
2 cultivator+Planking (T_2)	182.48	40.59	2.49	5.97	89.89	5015	99.84	50.23	12,663	1.85
Rotavator once (T_3)	189.70	47.63	2.70	4.62	93.98	5895	119.39	49.38	16,833	2.12
Zero-till planter (T_4)	175.13	37.05	2.35	6.91	86.05	3673	71.51	51.36	5,997	1.42
CD (P=0.05)	9.31	3.56	0.10	0.43	3.10	478	11.21	-	982	0.09
Irrigation										
30 DAS+Kn+S (I_1)	168.86	34.29	2.41	6.62	86.46	4085	97.66	41.82	8,670	1.61
30 DAS+Kn+S+M (I_2)	179.82	40.7[illegible]	2.47	6.40	88.27	4479	94.45	47.42	10,110	1.58
30 DAS+Kn+T+M+G.F. (I_3)	189.62	46.26	2.58	4.86	92.99	5545	110.19	50.32	14,815	1.96
30 DAS+Kn+TI+S+M+G.F. (I_4)	192.82	46.51	2.61	4.59	93.51	5575	95.28	58.51	14,514	1.92
CD (P=0.05)	8.82	4.46	0.08	0.57	3.45	452	3.12	-	810	0.08

Note: Kn = Knee height, S= Silking, M= Milking, T= Tasseling, TI= Tassel initiation, G.F= Grain filling.

Increasing level of tillage increased leaf area index (LAI) significantly, resulting maximum under rotavator tilled plots (2.70) over all other tillage treatments but leaf area index of maize in the plots under conventional tillage and cultivator tilled were found statistically at par with each other. Further, LAI index was recorded maximum with crop receiving 6 number of irrigations (2.61) at 120 DAS but was found at par with crop receiving 5 number of irrigations at the same growth stages over the crop receiving 3 and 4 number of irrigations (Table 2). This indicates that when crop gets proper nourishment and favourable soil physical condition at optimum moisture level, tended to increase in vegetative growth of the plants. Singh, 2001 also reported that optimum moisture at good soil physical condition at critical stages of corn increases dry weight, LAI, CGR of plants by increasing net assimilation rate of the crop which enables more production of photosynthates.

Plant–Water Status

Water saturation deficit decreased significantly in rotavator tilled plots (4.62%) and followed by conventional tillage (4.97%) at 120 DAS while it was recorded maximum in zero-tilled maize (6.91%). Similarly, water saturation deficit decreased significantly with increase in the level of irrigation. Water saturation deficit was recorded to its minimum value to the crop receiving 6 irrigations (4.59%) which was found at par with crop receiving 5 irrigations (4.86%) over 3 irrigations and 4 irrigations. (Table 2).

The crop grown under rotavator tilled plots exhibited maximum relative leaf water content (RLWC) 93.98 per cent, and was significantly superior over zero tillage 86.05 per cent at 120 DAS. RLWC was significantly higher in crop receiving 6 irrigations (93.51%) which was found at par with crop receiving 5 irrigations (92.99%) over crop receiving 3 and 4 irrigations (Table 2). The maximum value of RLWC and minimum value of WSD with rotavator tilled maize and 5 to 6 irrigations may be attributed to better soil-tilth, paralleled by increased water and nutrient absorption at critical growth stages due to greater root- soil contact than other tillage treatments. This is in close agreement with the findings of Sharma and Acharya, 1996.

Irrigation Studies

Zero tilled maize consumed maximum water (51.36 cm) which was 2.24, 3.13 and 4.08 per cent more than the water used by cultivator tilled, conventional tilled and rotavator tilled maize. Rotavator tilled maize consumed minimum water than maize grown under other tillage practices (Table 2). Crop receiving six irrigations had higher CUW than crop receiving two, three and four irrigations. Consumptive water use increased with increasing frequency of irrigation. Camp *et al* (2002) also obtained higher CUW with increasing soil moisture regime due to better soil moisture availability and higher plant canopy cover which led to more evaporation under higher frequency of irrigation.

Significantly higher WUE was reported under rotavator tilled maize (119.39 kg $ha^{-1}cm$) and was followed by conventional tillage (102.39 kg $ha^{-1}cm$) and cultivator tilled maize (99.84 kg $ha^{-1}cm$) over zero tilled maize (71.51 kg $ha^{-1}cm$) which was 41.4 per cent more in rotavator tilled maize. Likewise, significantly higher WUE was reported under crop receiving 5 irrigations (110.19 kg $ha^{-1}cm$) over other irrigation frequencies (Table 2). This may be due to the fact that tillage operations had made better root contact with the soil and that is why more water expense efficiency was observed. Camp *et al.*, 2002 concluded from their experiment that there is more ET demand at tasseling, silking and therefore, WUE will be also high and resulted in maximum yield. ET value that occurs maximum WUE equals the arithmetic square root of the ratio of the intercept of the function to the coefficient and function quadratic term.

Yield Studies

The yield of maize (Table 2) indicates that there was significant difference due to different tillage practices and frequency of irrigation. Significantly higher grain yield was recorded with rotavator tilled maize (5895 kg ha^{-1}) which was followed by conventional tillage (5100 kg ha^{-1}) and cultivator tilled maize (5015 kg ha^{-1}). Rotavator tilled maize reported an increase in grain yield (61.8%) over zero tilled maize. Similarly, grain yield was recorded significantly higher with crop receiving 6 irrigations (5575 kg ha^{-1}) over 3 irrigations (4085 kg ha^{-1}) and 4 irrigations (4479 kg ha^{-1}) but was found at par with crop receiving 5 irrigations (5545 kg ha^{-1}). There was increase of 35.4 per cent grain yield in crop receiving 5 irrigations over crop receiving 3 irrigations.

The interaction between tillage and irrigation exerted significant influence on grain yield in both the years (Table 3). Grain yield was significantly higher in rotavator tilled maize over other tillage practices at same level of irrigation. Grain yield of conventional tilled maize and cultivator tilled maize was statistically at par with each other but significantly superior over zero tilled maize at the same level of irrigation. Crop with 5 and 6 irrigations produced significantly higher grain yield than 3 and 4 irrigations in combination with different tillage practices. The maximum grain yield obtained in rotavator tilled maize may be due to superiority in physical environment by maintaining lowest soil hardiness, more infiltration rate and lesser bulk density over all other tillage practices, which resulted in more root volume, LAI and favoured yield attributes in positive manner. Lesser water saturation deficit and more relative leaf water content and increased WEE also helped yield attributes in positive manner. These all interlinked factors in association resulted in increased grain yield. The results are in conformity with the findings of and Nyakatowa *et al.*, 2002.

Table 3
Interaction Effect of Tillage and Irrigation on Grain Yield (kg/ha)
(Pooled Data of Year 2002-03 and 2003-04)

Irrigation	*Tillage*			
	T_1	T_2	T_3	T_4
I_1	4,309	4,263	4,850	2,917
I_2	4,702	4,686	5,280	3,250
I_3	5,686	5,535	6,720	4,237
I_4	5,704	5,576	6,729	4,290
CD (P=0.05)	586			

Economics

Data on net return as affected by tillage and irrigation were presented in table 2 denote that rotavator tilled maize had the maximum (Rs. 16,833 ha^{-1}) net return which was significantly superior to conventional tillage by fetching 27.84 and 22.53 per cent more net return.. All the tillage practices were found significantly superior over zero tilled maize (Rs. 5,997 ha^{-1}) in respect of net return. Similarly, crop receiving 5 irrigations resulted in significantly higher net return (Rs. 14,815 ha^{-1}) over 3 and 4 irrigations. Significantly higher B:C ratio was found with rotavator tilled maize (2.12) over

all other tillage practices in both the years, respectively. However, B:C ratio was found statistically at par with conventional tillage and cultivator tilled maize. Similarly, crop receiving 6 irrigations fetched significantly higher B:C ratio (1.92) over crop receiving 3 irrigations (1.61) and 4 irrigations (1.58).

The economic superiority of rotavator tilled maize in comparison with other tillage practices and irrigation over precessive levels were due to the fact that rotavator tilled maize had lower cost of cultivation than other tillage practices except zero-tilled maize. Though, there was increase in grain yield with six no. of irrigations but yield advantage was not much over crop receiving five irrigations on expense incurred in one more irrigation and thus crop receiving five irrigations resulted into higher B:C ratio.

References

Bhusan L. and Sharma Pradeep K. (1997), Effect of Soil Water Regime and Nutrient Supplies on Root Growth and Yield of Wheat in a Sub-surface Compacted soil. *Journal of Indian Society of Soil Science* 45 (2): 213-219.

Camp C. R. Jr, saddler E. J. (2002), Irrigation, Deep tillage and Nitrogen Management for a corn- Soybean System. *Transactions of the ASAE* 45 (3): 601-608.

Kumar Manish, Tripathi R. S., Shrivastava G. K., Kumar M. (2002), Quality and Yield of Winter Maize as Affected by Varying Genotypes, Nitrogen Levels and Irrigation Schedules. *Madras Agricultural Journal* 88 (10-12): 693-696.

*Nyakatawa E. Z, Reddy K. C. and Santen Evan (2002), Conservation Tillage and Poultry Litter effects on Cotton and Corn Yields. Proceedings of 25th annual Southern Conservation Tillage *Conference for Sustainable Agriculture, Auburn (USA)*, June 24-26, 2002, pp. 142-147.

Sharma J. C. and Acharya C. L. (1996), Effect of Nitrogen and Tillage on Soil Water Dynamics during Wheat Growth. *Indian Journal of Soil Conservation* 24 (3): 200-206.

Singh S. D. S. (2001), Effect of Irrigation Regimes and Nitrogen Levels on Growth, Yield and Quality of baby corn. *Madras Agril. J.* 88 (7-9): 367-370.

*Wahyuni E. D. (2001), Changes in Soil Porosity as a Result of Various Tillage and Cropping Systems and Maize and Soybean Cultivation. Perubahan pori tanah pada berbagai sistem olah tanah dan per tanaman jagung adan kedelai, *Agrivita* 17 (2): 88.