EFFECT OF TILLAGE AND IRRIGATION ON SOIL-WATER-PLANT RELATIONSHIP AND PRODUCTIVITY OF WINTER MAIZE IN NORTH BIHAR

BY

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EFFECT OF TILLAGE AND IRRIGATION ON SOIL-WATER-PLANT RELATIONSHIP AND PRODUCTIVITY OF WINTER MAIZE IN NORTH BIHAR

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Regd. No. D/Agro./09/2002-2003 of R.A.U.

DEDICATED

TO

MY DADAJI

"Whose silent presence and perpetual affection, faith and sacrifice inspired me to attain higher values of life and academic achievements"

✍..SANJEEV KUMAR

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The results of the investigations reported in this thesis have not so far been submitted for any other degree or diploma. The assistance and help received during the course of these investigations and sources of literature have been duly acknowledged.

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ABSTRACT

Field experiment were conducted for two consecutive years from rabi 2002-03 to rabi 2003-04 on sub-tropical calcareous sandy loam soil of the experimental farm of TCA, Dholi (Muzaffarpur) under Rajendra Agril. University, Bihar, Pusa comprising of sixteen treatment combinations of different tillage and irrigation levels in split plot design with three replications.

There was reduction in soil hardiness (bulk density and soil-strength) with subsequent increase in infiltration rate due to different tillage practices. Rotavator tilled maize reported to be superior overall other tillage practices in respect of improvement in soil-physical properties. Plant height, no. of leaves, leaf length, LAI, CGR, RGR, root volume and dry matter production per plant (g) was found significantly higher in rotavator tilled maize at all the growth stages over zero tilled maize while, crop receiving 5 to 6 irrigations were found significantly superior over lower frequencies of irrigation in both the years.

Specific leaf weight and relative leaf water content (RLWC) was found significantly higher in rotavator tilled maize while water saturation deficit was significantly lower in rotavator tilled maize over zero tilled maize with 5 to 6 irrigation. The computed data on water expense efficiency and water use efficiency tended to

increase significantly with increasing fineness of soil. Rotavator tilled maize showed significant higher water use efficiency and water expense efficiency over all other tillage practices, while these parameters were found minimum at the highest level of irrigation (6 irrigations). Crop receiving 5 irrigations was found at par with those of crop receiving 6 irrigations in all respects at each stage.

Among sixteen treatment combinations of tillage and irrigation, rotavator with five irrigation fetched the maximum grain and stover yield to the extent of (5831 and 5960 kg ha^{-1}) and (8586 and 8808 kg ha^{-1}) in both the years, respectively. Nutrient uptake (N, P & K) was found significantly higher in rotavator tilled maize under 5 to 6 irrigation in both the years over zero-tilled maize. Rotavator tilled maize with 5 irrigations fetched significantly higher gross return, net return and net return per rupees of investment over zero tilled maize with all frequencies of irrigation in both the experimental years.

Significant positive correlation was observed in respect of all growth & yield parameters with yield except water saturation deficit, bulk density and soil-strength which were negatively correlated.

CHAPTER I

INTRODUCTION

INTRODUCTION

Zea mays L., popularly known as 'maize' or 'corn' is often called as the queen of cereals by virtue of its contribution of about one third of the latter's global production as well as in maintaining the highest productivity of about 1700 kg/ha among the various coarse cereals grown in India. Globally, maize is grown in more then 130 countries, for grains and fodder. It is the main crop of United States of America which accounts for as much as three fourth of the world corn imports. Maize is one of the most important crop in the world agricultural economy both as food for man and feed for animals. It is a miracle crop having very high yield potential, there is no cereal on the earth which has so immense potentiality.

Maize crop furnish huge quantities of green fodder for cattle along with grain. Several industries like starch, milling etc. are based on maize products and by products. In addition to big industries, several cottage industries are also flourishing on the by products of maize.

In the country, maize occupies an area of about 6.59 m ha with a production of 13.30 million tones and productivity of 2018 kg/ha. Bihar ranks fourth in terms of area in maize cultivation with an area of about 6.0 lakh ha and ranks 2nd in production of about 15.60 lakh tones with productivity of 2618 kg/ha. Out of this area in Bihar, North Bihar only occupies more than 60 per cent of area under maize cultivation. The average productivity is quite low and there is ample scope to increase the productivity for unit area with suitable agronomic practices. (Source: Agriculture statistics at a glance, Government of India, 2003). Tillage and irrigation are two most basic input of crop production. Despite endowment of good soil of alluvial tract, the highest percentage of land under cultivation, abundant sunshine, ample water and vast human resources, the crop productivity per unit area in our country and that too in Bihar is very low. This dismal situation is largely attributed to the poor and defective utilization of various resources (Yadav, 1986). Among various factors responsible for low productivity, soil moisture availability regards as the most limiting factor because crops are very much sensitive to soil moisture stress, particularly at their critical stages. Strategies to minimize crop water stress include irrigation, increased root zone and conservation of

soil moisture by increased infiltration, reduced evaporation and maximum exploitation of available soil water (Wagger and Cassel, 1993).

Evapo transpiration and nutritional demand of the crop are met by applying irrigation and fertilizer which impose direct affect on crop growth, whereas impact of tillage is routed through by providing good soil tilth conducive to better crop growth and development. Actually tillage alters rhizosphere environment by modifying most of the physical properties, viz., bulk density and soil strength (Prasad *et al.* 1994), hydraulic conductivity and aggregate stability (Mallick and Nagrajan, 1973), infiltration rate (Jaggi and Bishen, 1986) and porosity (Van Ouwerkerk and Ratts, 1986) due to formation, destruction and rearrangement of soil particles and aggregates and alternation in clod size distribution. However, the extent of the impact of tillage is variable depending upon inherent soil characteristics and climatic conditions. The advent of herbicide in agriculture, seems to reduce the importance of tillage to some extent as a primary measure for eradication of the weeds. But now a days there is growing objection towards use of these chemicals, owing to their high prices and creating environmental pollution. Thus, tillage has now once again increased the interest in weed control aspect of tillage (Hillel, 1980).

Tillage induced physical condition of soil has direct bearing on soil-water-plant relationship influence movement, retention and the use of water. The rate of entry of water into the soil, its movement, poor retention, reduced root proliferation, more nutrient loss etc. are well associated with the crop growth and yield. Thus, any practice that promotes deeper rooting, will help the crop to utilize more available soil water, nutrients and thus increased crop yield.

Irrigation is an additional application of water to the soil to supplement the water available from rainfall and contribution to the soil moisture from ground water for successful crop production. Consumptive use by crop is an important factor in estimating irrigation requirement. Most of the water used by plants comes from the water held between interstatices of soil matrix with different tenacity. Often an excess or deficit of water in the soil is limiting factor in plant growth and development. Therefore, proper soil-water management is foremost in profitable agriculture. The rate of entry of water into the soil and its retention, movement and availability to the plants are all physical phenomenon. Hence, the physical properties of soil inducing its ability

to store water are highly associated with the fraction of the total soil volume that is occupied by soil matrix and pore space, but moisture supplying capacity for plant growth and development is related to the fraction of pore space that is occupied by water and air i.e. relative saturation (Hanks and Ashcraft, 1980).

Water, a key component of crop production system governs realization of full potential of high yielding maize cultivars. Actually adequate soil moisture is required for normal development of maize crop at all stages of growth. However under limited availability of water, scheduling of irrigation at the most critical stages increases crop productivity and water use efficiency as deleterious effect of water deficit is not equally pronounced over all the growth stages of crop (Prihar, 2000).

Only quantity of water is not important for getting higher yield. Ample water availability, time of application of water to the crop and quality of water are well interlinked with each other and considered as deciding factor for yield of the crop. In other words, we can say that if water is available in ample quantity then when to irrigate and how much to irrigate is very much important for any crop production in any ecological zone.

The excessive use of these vital inputs viz., tillage and irrigation to get higher and 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 (40-60 q/ha) and the 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 is hindered. This is mainly because

(i) the farmers are unaware of crop compatibility parameters and resource allocation for maximizing the input use efficiency in terms of total productivity.

(ii) the farmers are unaware of benefit and losses due to excessive tillage and irrigation.

(iii) there is lack of awareness about the scientific management of soil and water to the maize crop. All these, thus warrant for sincere efforts for fine tuning of the agronomic management practices for yield advantages and maximum return from a single crop per unit area per unit time.

Thus, keeping the above facts in view the present investigation entitled "**Effect of tillage and irrigation on soil-water-plant relationship and productivity of winter maize in North Bihar**" was planned and conducted at Tirhut College of Agriculture Farm, Dholi (Muzaffarpur), Bihar during the winter season of 2002-03 and 2003-04 with the following objectives :

1. To study the response of winter maize to different soil-tilth for optimizing production.

2. To quantify the contribution of irrigation applied at different physiological stages of crop growth in the yield synthesis.

3. To evaluate the impact of interacting factors on soil physical condition, plant water status and crop productivity.

4. To quantify the economics of tillage and irrigation management in winter maize.

*****

CHAPTER II

REVIEW OF LITERATURES

REVIEW OF LITERATURE

Augmentation and stabilization of crop production at higher level from a single crop per unit area per unit time is need of the day to meet the growing requirements of escalating population, a stupendous task, though not very difficult with efficient use of various inputs and improved technologies. The wide gap between the crop yield obtained on the research farm and on the farmers' field at the national level reveals that whatever innovations and technologies developed, have not benefited the bulk of our farming community (Yadav,1986). Therefore, it is imperative to adopt resource management approach to increase the production at various levels of management factors, under prevailing condition of the farmers. The pertained literature related to the topic in question are described under the following heads:

2.1 Effect of tillage practices on physical condition of the soil

It has been well established that crop growth is primarily limited by the physical condition of the soil, rather than the nutrient status.

Among the physical constraints, are low permeability of heavy textured soil, high permeability of light textured soil, formation of soil crust and plough sole that hinders seedling emergence and restricts root penetration, respectively resulting in unsatisfactory growth of the plants (Gautam, 1982). Favourable crop responses under these conditions to the management practices have been observed by several investigators from time to time.

Before growth to be triggered, environment must provide specific sets of physical, chemical and biological condition optimal for any particular crop species. Among physical conditions required are an adequate supply of water, suitable temperature, composition of gases, illumination of certain seeds and absence of toxic and inhibitory substances (Singh, 1979).

Tillage, which may be defined as 'mechanical manipulation of the soil' alongwith three main objectives: *viz.*, control of weeds, incorporation of organic matter into the soil and improvement of structure which have direct bearing on planting,

germination, emergence, early establishment of seedlings, air, moisture and thermal regime as well as erosion by wind and water. But tillage method is quite different ranging from conventional tillage like mould board ploughing, discing, pulverizing, sub-soiling, chiseling to strip and zero tillage at moist and friable consistency, lies between lower plastic and shrinkage limit.

When soils are put under suitable tillage practices, such soils are happened to be loose, friable and easily workable. Water is absorbed rapidly at the surface and readily moves into the soil profile. Falling rain drops do not disperse the soil aggregates, therefore individual particles do not clog the soil pores. As a result, the physical condition of the soil is modified as such to provide good soil tilth, conducive to better plant growth. However, the extent of change in rhizosphere environment differs considerably, depending upon antecedent soil properties and climatic conditions, history of cultural management and extent and type of tillage (Blevins *et al.,* 1983). In addition to these factors wheel traffic compaction significantly alters structural properties (Lal and Van Doren, 1990), which may eliminate any differences between tillage treatment (Voorhees and Lindstorm, 1984). Thus tillage induced physical condition due to alteration of most of the physical properties of soil.

Several workers reported that tillage reduces bulk density through increased soil volume by loosening the soil and by disrupting dense restricted layer (Cassel, 1983). Among three tillage treatments *viz.* tine cultivation (12.5 cm), mould board plough (20 cm) and direct drilling on sandy loam soil, Sharma (1985) reported lower bulk density between 0-10 cm surface layer under mould board and tine cultivated plot as compared to direct drilled, whereas Kooistra *et al.* (1984) observed lower bulk density between 30-35 cm soil layer in disturbed than undisturbed plough pan in same type of soil. Reduction in bulk density by disruption of dense pan by tillage has also been reported by Sharma (1986) and Cassel and Nelson (1979).

Deep tillage (35-40 cm) by chiseling reduced the bulk density as compared to conventional tillage (10 cm) on sandy loam and loamy sand soil, as reported by Prasad *et al.* (1994). Chiseling decreased the bulk density from 1.62 to 1.54 Mgm^{-3} between 0-10 cm layer, from 1.60 to 1.51 Mgm^{-3} between 20-30 cm and from 1.60 to 1.50 Mgm^{-3} between 30-40 cm soil layer as pointed out by Chaudhary *et al.* (1985).

Several researchers concluded from their experiments on fine textured soil that bulk density is usually higher under no till than under conventional tillage (Lal *et al.*, 1989 and Herd *et al.*, 1988). The penetration resistance/mechanical impedance or cone index which is a function of bulk density and moisture content is influenced by tillage. As the soil gets loose by tillage, the cone index changes but the extent of change is based upon moisture content. At given moisture content bulk density and mechanical impedance are positively related. However, inverse relation exists between moisture content and soil strength and influence of moisture is more pronounced under high to moderate soil strength as compared to low strength (Nimlos *et al.*, 1990). No till plot usually shows higher bulk density and penetration resistance as compared to cultivated plot (Vyan and Raimbault, 1993).

Ide *et al.* (1984) observed that sub-soiling of silt loam to 60 cm depth reduced penetration resistance from 5 MPa to MPa. Decreased soil strength (Cone Index) was also reported by Prasad *et al.* (1994) under deep ploughing by chiseling to 40 cm depth than conventional tillage of sandy loam and loamy sand soil. In sandy loam soil penetrometer reading showed significantly higher resistance in the direct drilled plot down to a depth of 22.8 cm as compared to the ploughed and up to 15.2 cm as compared to that in tine cultivated plot (Sharma, 1985). The extent of soil strength from 1.5 to 2.5 MPa has been found root limiting as reported by Busscher *et al.* (1986).

Physical properties of soil have mainly two significant characteristics. First they are interrelated and never be independent of each other. Secondary under field condition, it is impossible to change one physical property without changing the other. From previous literature it is evident that tillage reduces bulk density through increased soil volume. Therefore, an inverse relation exists between bulk density and porosity.

Carter and Kunelius (1986) compared soil porosity, pore size distribution, pore continuity and aggregation between cultivated and direct drilled plot and concluded that whatever changes produced in these parameters by tillage treatments were within the range considered optimum for soil structure. Continuous chiseling of clay loam increased air porosity to 0.59 cm^3 near the soil surface, which varied with depth as observed by Bauder *et al.* (1981). Pore characteristics of silt loam and clay loam under direct drilled and ploughed plot were studied by Ball (1981) between 30-80 mm soil depth. He concluded that relative diffusivity and air permeability at –2 kPa were 6 to 15

times greater respectively under ploughed than direct drilled soil presumably due to larger volume of air filled large pores. However, clay loam showed greater value of these parameters than silt loam irrespective of tillage.

Deep digging of Fatehpur loamy sand increased the proportion of 18-600 μm diameter pores in 10-20 and 30-35 cm layer by soil loosening but pore size distribution was unaffected in the upper 0-10 cm layer in deep digging and in the control, as concluded by Chaudhary *et al.* (1985).

Sub-soiling has pronounced effect on light loam soil on total porosity and macroporosity (pores > 30 cm diameter) but the effect was short lived (Van Ouwerkerk and Raats, 1986).

Aggregate stability of sandy loam soil under four tillage treatments *viz.*, chiseling, discing, mould board and desi plough was evaluated by Mallick and Nagrajarao (1973). Chiseling showed decreased aggregation due to increased settling percentage at lower depth and it was concluded that planting of deep rooted crops alongwith deep placement of fertilizer were necessary to build up stable structure in sub-soil.

Djenni and Dexter (1979) observed larger aggregates and voids under continuous cropping of cereals with tine cultivation than the pasture or fallow. Poor growth in seed beds containing preponderance of large aggregate was attributed to reduce root-soil contact resulting in decreased absorption of water and nutrients (Donald *et al.*, 1987). Cultivation destroys macro-aggregates into micro-aggregates with concomitant reduction in soil organic carbon and nitrogen which may be ameliorated by reduced tillage management as suggested by Camberdella and Elliot (1993).

Franzen H. *et al.*, (1993) reported from their experiment that in zero tillage treatment the bulk density and penetration resistance were significantly greater on plots with high mechanization i.e. deep tillage treatments.

Tillage alongwith living root of different crops have adequate effect on structural stability. Reid and Goss (1981) pointed out that growing corn root had adverse effect on structural stability due to implicated chelation of Fe and Al involved in mineral-metal-organic matter linkage. Similar observation on other soil failed to

confirm the detrimental effect of crop species on structural stability (Pojasok and Kay, 1990). Wahyuni ED, 2001 reported that the tillage systems of minimum and conventional tillages decreased available water from 14.50 to 13.62 per cent, while rotavator tilled plots increased the available water from 8.5 to 16.3 per cent and increased the soil porosity analysed after harvest of the crop.

2.2 Effect of tillage and irrigation on water retention, soil-water-plant relationship

Often an excess or deficit of water in the soil is limiting factor in plant growth and development. Therefore, proper soil-water management is foremost in profitable agriculture. The rate of entry of water into the soil and its retention, movement and availability to the plants are all physical phenomenon hence, the physical properties of soil including its ability to store water are highly associated with the fraction of the total soil volume that is occupied by soil matrix and pore space (pore ratio), but moisture supplying capacity for plant growth and development in related to the fraction of pore space that is occupied by water and air i.e. relative saturation (Hanks and Ashcroft, 1980).

Therefore, the ability of soil to retain and transmit water is determined by its hydraulic properties, influenced by adopting suitable tillage practices which resulted significant changes in soil porosity, pore size distribution, pore-continuity, aggregation and soil strength in the range, considered optimum for soil structure (Carter and Kunelius, 1986). The soil moisture at 1/3 bar, 15 bar and available water were found to be positively correlated with organic matter, porosity, water stable aggregates (> 0.25 mm) in addition to clay + silt content and negatively correlated with bulk density and sand content (Mungare *et al.*, 1983). Inverse relationship between, initial moisture content of soil and penetration coefficient of water was reported by Malik *et al.* (1987) who observed decrease in cumulative infiltration at increasing initial moisture content but the effect was more pronounced in light textured than the fine textured soil. Hasan *et al.* (1984) found increased infiltration rate under deep tillage as compared to shallow tillage on sandy loam soil having plough pan below the soil surface.

Relationship between hydraulic conductivity and different tillage practices was evaluated for red sandy loam soil by Joshi *et al.* (1987). They reported higher hydraulic conductivity (48.9 cm/hr) under disking, followed by disking but partially compaction

(26.9 cm/hr) and minimum (18.2 cm/hr) where the soil was not tilled for several years. Unsaturated hydraulic conductivity of Alfisol was found lower in 10-20 cm soil layer under tilled plot than untilled treatments without affecting 20-40 cm soil layer, as reported by Opara and Lal (1987).

Soil water content, soil water movement and water uptake were less under conventional tillage without sub-soiling than other tillage treatments, *viz*., conventional tillage with sub-soiling, no tillage with sub-soiling and no tillage without sub-soiling in a soil with plough sole as pointed out by Weatherly and Dane (1979). While evaluating the long term effect of no tillage and conventional tillage with or without mulch, Opara and Lal (1987) reported the maximum available water storage capacity of an Alfisol for the surface 40 cm layer was 59 and 41 mm under no tillage and 44 and 33 mm under conventional tillage, with or without mulch respectively. Some investigators observed enhanced infiltration and soil water content under no till soil than cultivated Mengel *et al.*, 1982). Intensive cultivation showed conduction in hydraulic conductivity paralleled by an increase in bulk density and decrease in porosity, had been reported by Magaritz and Amiel (1981). During evaluating the long term effect of tillage treatments, the mean hydraulic conductivity was found 15 times more in no till plot due to significantly higher aggregate percentage and mean weight diameter, than mould board and chisel plough which resulted 24 and 23 per cent more mean available moisture content in no till treatment, as compared to mould board and chisel plough respectively (Mahboubi *et al.*, 1993). Increasing year of cultivation reduced water holding capacity and cation exchange capacity due to loss of fine materials and organic matter as reported by Bowman *et al.* (1990) and Zhang *et al.* (1995).

Compaction of soil surface, provision of impervious layer below the root zone and puddling by different implements had been found to influence percolation loss and water use efficiency but among puddling implements; power tiller with rotavator followed by tractor with cage wheel showed the most efficient in terms of percolation and water use efficiency than local plough, mould board plough and disk harrow on sandy loam soil (Tyagi *et al.*, 1975).

Prasad *et al.* (1994) observed 77 and 23 mm higher water use for winter maize in 1983 and 1984, respectively under deep than the conventional tillage on loamy sand while these values were 41 and 27 mm for sandy loam soil, respectively. Although no

significant relationship between tillage treatments and plant water status (leaf water potential, dry matter production and grain yield) in sandy loam soil was detected by Sharma (1985) but there was greater extraction of water from 20 cm depth of soil at 80 days after planting of barley as pointed out by him.

Winter wheat extracted up to 22 mm more water from uncultivated soil due to 10 per cent higher water storage capacity than mould board plough when winter was dry. Therefore, the effects of tillage or its avoidance are inadequately understood to explain the contrasting results under different conditions of soil and climate (Goss *et al.*, 1978).

Nozdrovicky L. *et al.* reported that the highest infiltration rate (0.34 mm/min) was recorded in the no till system with direct drilling of seeds rather than conventional tillage (0.08 mm/min), which is in contrast with the earlier findings.

Nyakatawe EZ *et al.* (2002) concluded from their experiments on different tillage practices that the adoption of conservation tillage in production of maize in Northern USA, has been hindered by poor emergence, reduced seedling growth, delayed maturity and reduced yield that have been attributed to conservation tillage as compared to deep tillage practices.

Liuwz *et al.* (2002) concluded from their expert that when ET is more, WUE will be also high and resulted into maximum yield. ET value that occurs at maximum WUE equals the arithmetic square root of the ratio of the intercept of the function to the coefficient of function quadratic term.

2.3 Effect of tillage on crop growth

Tillage modifies rhizosphere environment to provide good soil tilth for better plant growth and development, but the extent of impact varies depending upon soil and climatic conditions, due to lack of an universal system of tillage, that can be suited to everywhere.

Root growth and proliferation of maize were enhanced under deep tillage as compared to shallow tilled plot in loamy sand soil (Chaudhary *et al.,* 1985). Maize root

growth was affected by soil water and soil temperature. Tillage influenced the levels of these parameters during the growth, as reported by Barbar and Kovar (1988).

Delayed emergence, silking, maturity and reduced plant dry weight, final plant population and grain weight were observed under zero tillage than conventional tillage (Wall and Stobbe, 1983). Vogel (1994) recorded significantly higher yield of maize (6.6 t ha^{-1}) under ridging due to increased root volume and root length density than mould board plough (5.1 t ha^{-1}). The yield of soybean, barley, wheat and maize was highest with ploughing due to superiority of the soil structure over direct drilled as pointed out by Jitareanu *et al.* (1992). Differences in total root length, shoot dry weight and final leaf area of maize were related to aggregate size because a plot having preponderance of large aggregates showed poor growth of maize due to reduced water and nutrient absorption caused by decreased root soil contact (Donald *et al.*, 1987).

Evaluating the long term effect of five tillage system on crop response Vyan and Raimbault (1993) observed the highest bulk density, greatest penetration resistance and the lowest proportion of aggregates (< 5 mm) under no till, resulted lowest yield of maize than ploughed plot. Grain yield as well as dry matter production of corn was found significantly greater under deep tillage (Chisel and sub-soiling) on loamy sand soil due to better utilization of soil moisture below the disrupted plough pan than conventional tillage as pointed out by chancy and Kamprath (1982).

Chaudhary *et al.* (1985) recorded increase in plant height by 30-35 cm, stover yield and grain yield by 80-100 and 30-70 per cent, respectively due to deeper and greater rooting and enhanced water use under deep tillage by sub-soiling, digging and mould board ploughing than conventional tillage on loamy sand soil. Deep ripping to a depth of 40 cm increased maize yield by 30 per cent in fine sandy soil due to deeper rooting and high water use efficiency (Bennie and Botha, 1986).

Significant increase in grain yield of maize on sandy loam and loamy sand soil was recorded by Prasad *et al.* (1994) under deep tillage to enhanced nutrient and water use by deeper and denser rooting under deep than conventional tillage. Ike (1987), on the other hand did not get any significant difference of maize yield between no tillage and conventional tillage in ferruginous soil and suggested that additional cost of deep ploughing under conventional tillage could be saved without scarifying the yield. Under

tractor drawn cultivator (4 times), mould hand plough (1 time) + desi plough (2 times) and mould board (1 time) + bullock drawn cultivator (2 times) respectively. These difference in yield were attributed to increase sol-moisture, water stable aggregates and decreased bulk density in mould board plough having more depth and width than the other tillage treatments.

Ruegg WT *et al.* (1998) reported that on average, dry matter and nitrogen yields of maize were highest under plough and lowest under no-till system. These differences occurred as early s the 3rd leaf stage and remained until the end of the growing season.

Nyakatawa Ez *et al.* (2002) concluded from their five year experts on corn that due to deeper tillage practices continuously for three years soil porosity, infiltration rate and WUE increased and after three years no significant responses was observed but LAI and CGR and yield increased significantly continuously for five years due to deeper tillage over conservation tillage or minimum tillage practices.

2.4 Effect of irrigation on crop growth

Irrigation is an additional application of water to the soil to supplement the water available from rainfall and contribution to the soil moisture from ground water for successful crop production. Consumptive use of crop is an important factor in estimating irrigation requirement.

Corn is most sensitive to water stress specially during the teaseling to silking stage when evaporative demand exceeds rainfall (Wagger and Cassel, 1993). The application of excess water on relatively fixed area has generated new problems, *viz.*, rise of water table, build up of salt in soil profile and in some location water logging. For maximum plant productivity soil water within the root zone needs to be kept below the upper limit to ensure adequate oxygen supply to the plant root and above lower limit to ensure low soil strength and unsaturated hydraulic conductivity enough for water and nutrient uptake by crop (Phene, 1974).

Maximum root depth of maize, soybean and barley was found to be inversely related to available water within the limits, imposed by crop rooting habits and soil physical characteristics and maximum root density was found at physiological maturity as reported by Dwyer *et al.* (1988). A common notion among the farmers is that some

early season water stress encourages root growth and conditions the crop to better withstand stress occurring later in season. Therefore, the crops growing in relatively dry soil should have more extensive root system than the crop grown in moist soil. Tarbea *et al.* (1994) observed higher root density under mild hydric or physical stress due to better proliferation of root of maize than the control but another experiment in sandy clay loam, conducted by Ahmad *et al.* (1993) revealed that delay in first irrigation did not condition the corn plant for moisture stress but hindered root development, decreased plant water requirement and decreased yield Tanguilig *et al.* (1987) concluded that ability of maize and soybean to grown better than rice under water stress condition might be due to their ability to maintain turgor as a result of slow decline in leaf water potential brought about by low transpiration rate and continued uptake of potassium which must allowed osmotic adjustment to occur.

Water use efficiency of corn was fond from 2-3 times and 2 times greater than wheat and sunflower respectively under adequate and limiting moisture treatments (Green and Read, 1983). Evaluating the impact of weather variables on yield and yield attributes of *rabi* maize (*Zea mays* L.), Reddy *et al.* (1995) reported that grain yield was best related with after noon vapour pressure during silk emergence to dough stage and total biomass with temperature range during emergence to silk stage. Water deficit during pollination increased the frequency of zygotic abortion in maize and assimilate supply alone was unable to determine the sensitivity of kernel set at low water potential during pollination Zinselmeier *et al.* (1995 and Agarwal *et al.* (1997).

Estimating the maximum attainable yield by maize in rainfed area Galvis-S *et al.* (1993) concluded that water availability particularly around flowering period (50 days before and 30 days after anthesis) was the most critical for maize production. Strong relationship between corn yield and available water in the surface layer (0-15 cm) was also observed by Boyer *et al.* (1990) than any other soil or climatic characteristics. (Katerji *et al* (1994) suggested that change in daily maximum stem diameter should be used to characterize plant water status of maize, rather than daily stem contraction).

Mal and Mishra (1987) reported that alternate furrow or skip irrigation saved irrigation water by 30 per cent rather than irrigation in all furrow with marginal reduction in the grain yield of winter maize. Irrigation at IW/CPE ratio of 1 to 1.2

significantly increased yield and yield attributes (except girth of the cob) of winter maize than other IW/CPE ratio with 180, 90 and 60 kg ha^{-1}. N, P_2O_5 and K_2O respectively (Sridhar *et al.*, 1991).

Grain yield of winter maize at IW/CPE ratio of 0.9 and 23 per cent yield reduction at 0.5 IW/CPE ratio over 0.9 with 150, 90 and 60 kg ha^{-1} of N, P_2O_5 and K_2O respectively. Irrigation at five critical stages of maize fetched the maximum grain yield but water use efficiency decreased from lower to higher no of irrigation as reported by Singh *et al.* (1981).

Save and Serrano, 1986 reported that optimum moisture at different critical stages in corn increases dry wt., RGR, leaf water content and decreases water saturation deficit in maize leaves. LAI and sp. Leaf weight has been recorded to be highest when 5-6 irrigations were supplied at different critical stages to maize crop (Jayasanker and RamaKrishnayya, 1993). This may be due to high not assimilation rate of the crop which enables more production of photosynthates.

Srivastava (1991) reported that there is reduction in growth, foliage area and NAR and also decrease in leaf water content in sugarcane when plants have faced moisture stress at critical stages of growth.

Singh SDS (2001) reported that the no. of cobs/plant, young cob yield (5074 and 4855 kg/ha during summer & kharif) were highest with five no. irrigation in baby maize and similar trend was observed in the case of stover yield and crude protein. Leaf water potential, relative leaf water content, LAI, RGR, CGR was also found higher when maize crop was given 5-6 irrigation during the crop period.

Manish *et al.* (2002) reported that when irrigation is scheduled at tassel initiation stage and silking stage then N-concentration in leaves and grain protein content increased as compared to irrigation given at other stages of crop growth in maize.

2.6 Interaction effect of tillage and irrigation on crop growth & yield.

Tillage x Irrigation

The effect of tillage induced physical condition on soil water and plant relationship has already been reviewed in the beginning, however, Schinder and Mathers (1970) recorded maximum yield of sorghum with one irrigation under 80 cm deep tillage than 40 cm deep tillage with two irrigation. In sandy loam soil sub-soiling with two irrigation increased grain yield of maize by 35 per cent under early sown condition and 47 per cent under late sown condition at lower level of irrigation than conventional tillage (Chaudhary *et al.*, 1985).

Effect of tillage was found to be more pronounced where root development and water movement were restricted due to presence of compact or dense layer within soil profile as evident by the experiment of Chancy and Kamprath (1982). They obtained increased yield of maize with deep ploughing in loamy sand due to disruption of tillage pan, resulted better moisture availability during growth period. Box and Langdale (1984) observed improved corn yield with deep tillage due to favourable effect on infiltration and rooting volume. No difference was observed between tillage treatments under adequate moisture supply in sandy loam soil but under water stress condition a significant difference in grain yield was observed between shallow and chiseled soil (Reicosky *et al.*, 1976).

Ripping of soil to a depth of 40 cm increased maize yield and water use efficiency under irrigation by ameliorating compaction effect in sandy aeolian soil, as pointed out by Bennie and Botha (1986).

Wagger and Cassel (1993) observed similar water use efficiency for corn grain production, being 217 kg ha^{-1} cm^{-1} of applied irrigation water but for silage production WUE was higher under no tilled plot (381 kg ha^{-1} cm^{-1}) by reducing the number of irrigation than conventional tillage (277 kg ha^{-1} cm^{-1}). On the basis of their experiment they further concluded that irrigation regime was prime factor to influence all plant parameters, rather than tillage treatments.

The maximum soil water content of upper 100 cm of soil differed little between tillage treatments when winter rainfall was close to or greater than the long term average but under dry winter, direct drilled soil stored about 10 per cent more water

especially below 50 cm depth which resulted better growth of cereal crops due to 22 mm greater extraction of water from uncultivated soil than after ploughing as reported by Goss *et al.* (1978). They further added that the effect of cultivation or its avoidance was inadequately understood to explain the contrasting result under different conditions of soil and climate. The mean available water content in silt loam soil was 23 and 24 per cent more in no tilled than chiseled and mould board plot respectively due to increased hydraulic conductivity by 15 times in no tilled plot.

Sharma (1985) observed no significant effect of tillage on plant water status *viz.*, leaf water potential and above ground dry matter in sandy loam soil between ploughed and direct drilled plot whereas Prasad *et al.* (1994) reported higher extraction of water by maize crop under deep tillage than conventional tillage in loamy sand and sandy loam soil.

Ogola JBO *et al.* (2002) reported that irrigation scheduled at knee height, teaseling and grain filling stage resulted in higher leaf area, CGR and grain yield under deep tillage practices.

Camp CR Jr. and Sadler EJ (2002) reported from their 5 years experiments that irrigation increased maize yield all the year (8 to 135 %) while deep tillage increased the corn yield continuously for three years (4 to 68 %) and then get stabled and concluded that soil and weather conditions, irrigation increased maize and soybean yields more consistently than deep tillage.

2.7 Effect of tillage and irrigation on quality and nutrient uptake

Maximum yield of maize was recorded with deep tillage and minimum with reduced tillage treatment and the application of nitrogen increased the water use efficiency and yield (Masand *et al.*, 1993).

Deep ploughing minimized the chance of applied nitrogen loss with time because bulk of nitrogen applied was utilized by rainfed wheat in deep ploughed soil within 10 days as reported by Sharma *et al.* (1984).

Yield response to nitrogen application is influenced by level, time and method of application as well as availability of the moisture in the soil (Chaudhary *et al.*, 1982).

No or low rate of nitrogen produced higher corn yield under conventional than no tillage but at high rate of nitrogen application, no tillage yielded more due to improved nitrogen efficiency associated with high soil water content than conventional tillage (Frye, 1984).

The wide gap between actual and potential yield is largely attributed to the defective utilization of various resources and low use efficiency of the input like water and tillage (Yadav, 1986).

Dhillon *et al.* (1987) on the other hand did not get any significant change in the grain and stover yield of maize due to different tillage treatments but each increment in the dose of nitrogen up to 120 kg N ha^{-1} significantly increased the grain yield of maize and whet.

Significant increase in the yield of maize grain with deep tillage was obtained by Prasad *et al.* (1994) due to enhanced nutrient and water uptake than conventional tillage in sandy loam and loamy sand soil.

To visualize the two tillage method *viz.*, conventional shallow tillage (15 cm) and deep ploughing 930 cm) on silty clay loam soil, Sharma and Acharya (1996) observed that changes in water content, increase in hydraulic gradient and root water uptake was considerably more under the combination of 120 kg N ha^{-1} in deep poughing than conventional shallow tillage.

Fapohunda and Hossain (1990) obtained maximum yield of maize to the tune of 6.15 t ha^{-1} with 523 mm of water and 300 kg NPK and the highest dry matter production of 7.84 to ha^{-1} with 495 mm of water and 300 kg ha^{-1} NPK, indicated high correlation between water and fertilizer with R^2 of 0.95 and 0.96 for grain and dry matter production, respectively. They further added that water productivity increased by fertilizer application but the relationship was not as definite as soil moisture. Selvaraju (1992) observed increased stomatal conductance and transpiration rate from 25 to 50 days after sowing of maize which were associated with irrigation scheduling based on critical stages. Water use efficiency of sunflower increased with low irrigation efficiency and high level of tillage practices as reported by Bharambe *et al.* (1997).

Ojemiyi SO (1993) reported that effect of row tillage, zero tillage and hoe tillage of total land area on maize yield and nutrients availability was compared in order to evolve an efficient minimum tillage practice for tropical Alfisols. He concluded that availability of N, P & K in the soil and the leaf, cob weight and grain yield were increased by increased degree of tillage.

Fertilization of plant and yield of maize grain were much affected by water stress during flowering, resulted increased number of barren plant, intensified by higher dose of nitrogen (Maric *et al.*, 1994).

Significant interactions between and among sub-soil compaction and irrigation and nitrogen on grain yield of wheat were also reported by Bhusan and Sharma (1997).

Stewart's Linear yield model for grain yield and linear and exponential function for total dry matter yield were recommended by Kumar *et al.* (1996) for précised prediction of summer maize.

Mason SC and D-Croz mason NE (2002) reported that grain yield increase have resulted in lower protein content except when the yield increase resulted from nitrogen fertilizer application irrigation improves the biological value of protein, while higher nitrogen application rates alter amino-acid balance thereby reducing the nutritional value. Kernel breakage susceptibility and kernel density increase with higher N-fertilizer application are reduced by irrigation.

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CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The details of materials and methods followed during the course of investigation are described below:

3.1 Experimental site

The field experiments were conducted during winter (*Rabi*) season of 2002-03 and 2003-04 in plot no. 1 of Tirhut College of Agriculture Farm, Dholi (Muzaffarpur), a campus of RAU, Pusa (Samastipur), Bihar. The field with homogenous fertility and uniform textural make up was selected for the experiment.

3.2 Climatic and weather condition

Geographically, TCA, Dholi is situated on the southern bank of the river Burhi Gandak at 25° 39' N latitude and 85° 40'E longitude and at an altitude of 52.1 m above mSL. It enjoys semi-arid, sub-tropical climatic with moderate rainfall, hot dry summer and cold winter. Generally monsoon sets in third or fourth week of June and continues upto September. The av. rainfall is about 1493.34 mm, out of which nearly 1256.03 mm is received during the monsoon extending from the middle of June to middle of Oct. with an av. winter rainfall of about 145.29 mm only. The period between last week of December to first half of January receives occasional winter showers. January is the coldest month of the year with an av. winter maximum and minimum temp. of 23.2° and 7.9°C respectively. Normally temp. starts decreasing from the second fortnight of October and reaches the minimum in the end of December or early January. Again, it starts rising from the end of Feb., reaching the maximum in May-June. The meteorological parameters were recorded during the experimental years from the meteorological station of TCA, Dholi (Muzaffarpur) given in table –1 (Appendix) and fig. 1(a & b) .

3.3 Soil characteristics of the experimental plot

The soil of the experimental plot was alluvial and calcarious in nature. It is characterized by high content of free calcium carbonate varying from 20 to 40 per cent and distributed throughout the depth of the profile. The soil samples (0-30 cm) were analysed for its mechanical, chemical and physical composition and results have been presented in table –1.

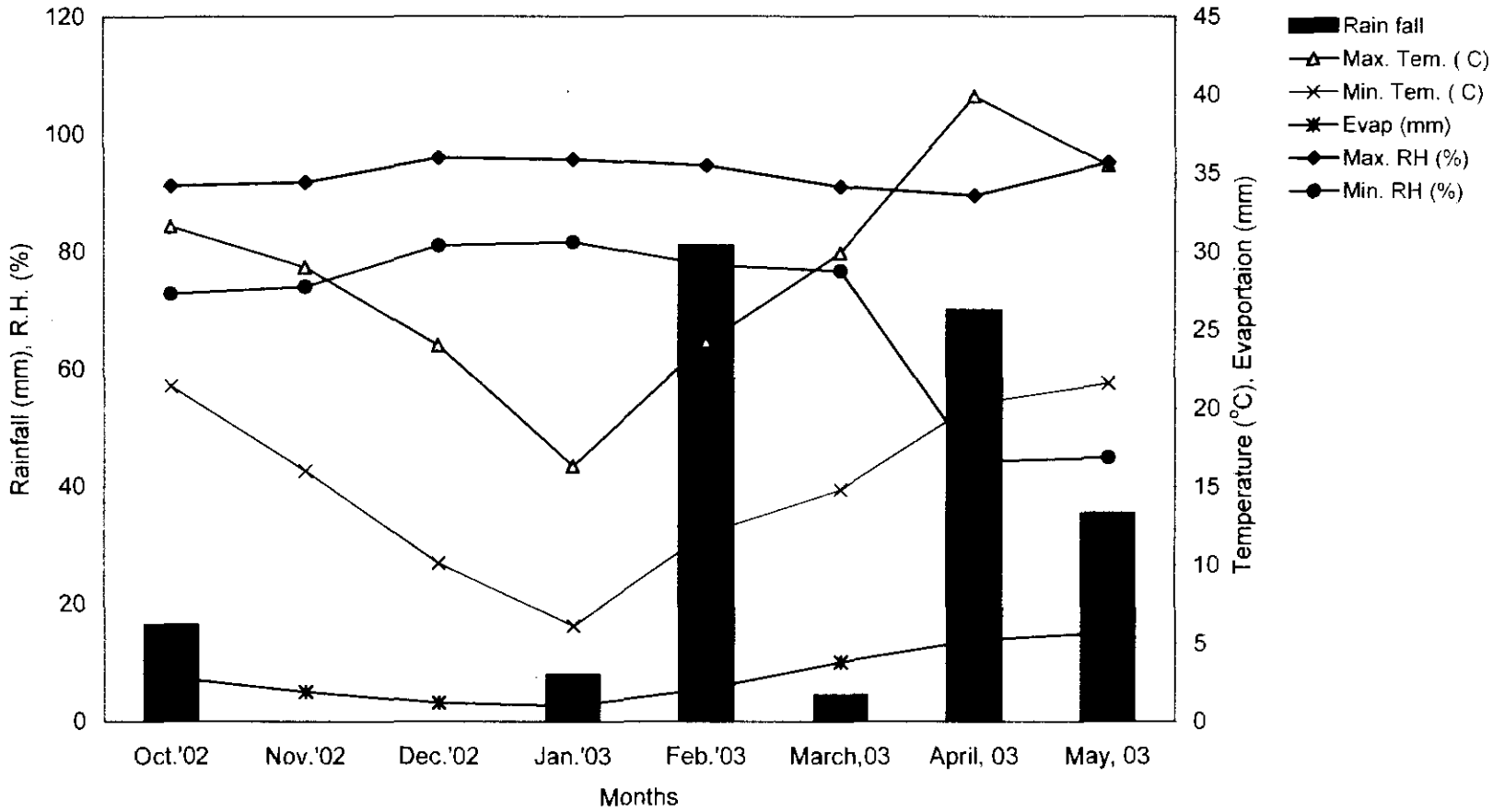

Fig. 1(a). Weather condition during 2002-03

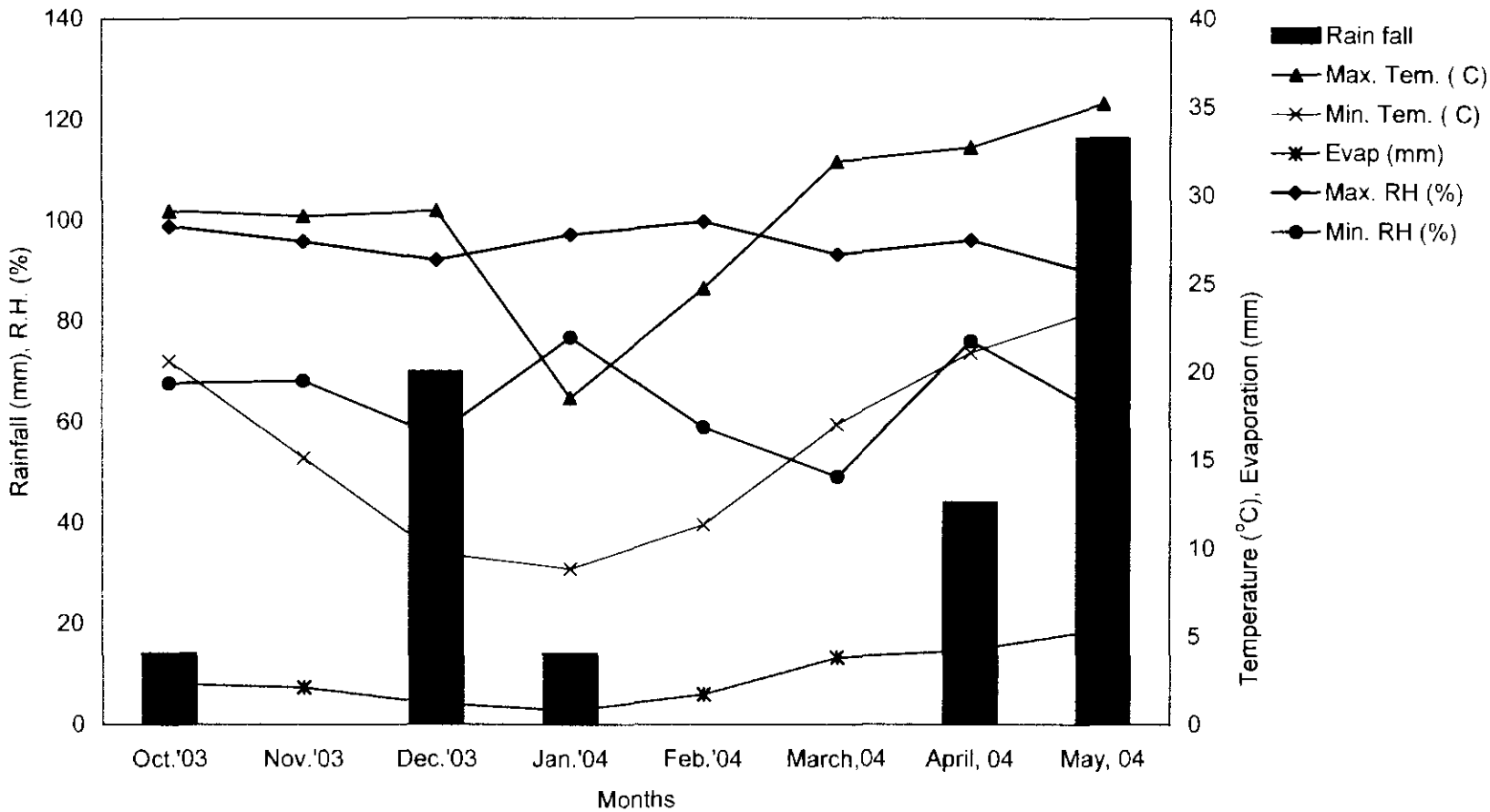

Fig. 1(b). Weather condition during 2003-04

Table –1. Physico-chemical properties of soil of the experimental plot :

Particulars	Pre-sowing value	Post-harvest value	Method applied
Coarse sand (%)	0.80		
Fine sand (%)	48.41		International Pipette method (Piper, 1950)
Silt (%)	42.10		
Clay (%)	8.79		
Texture	Sandy loam		
Porosity (%)	45.72		
pH (1:2.5)	8.5		Glass electrode pH meter (Jackson, 1978)
Organic carbon (%)	0.46		Walkley and Black's method (Jackson, 1978)
Available N (kg/ha)	212.12	180.21	Alkaline permanganate method (Subaiah and Asija, 1956)
Available P_2O_5 (kg/ha)	20.5	18.62	Olsen's method (Piper, 1966)
Available K_2O (kg/ha)	125.2	123.34	Flame photometer method (Piper, 1966)
EC (dsm^{-1})	0.6		Conductivity bridge (Jackson, 1978)
Free $CaCo_3$ (%)	27.60		Rapid titration method (Piper, 1950)
B.D. (g/cc)	1.47		Core sample (Piper, 1950)
Feed capacity (%)	21.00		Piper, 1950
WHC (%)	26.90		Piper, 1950
Steady infiltration rate (cm hr^{-1})	0.18		Double ring infiltrometer (Bertrand, 1965)
Soil strength (MPa)	0.190		Core penetrometer (Davidson, 1965)

From, the results of analysis presented in table 2, it is evident that soil of the experimental plot was sandy loam in texture, alkaline in reaction and low in nitrogen, phosphorus, potassium as well as organic carbon content.

3.4 Cropping history of the experimental plot

In order to have a general idea of the cropping pattern of the experimental plot, the cropping history of the previous years starting from 1999-2000 till the preceding years of investigation was recorded and presented in table 3.

Table –2. Sequence of crops grown on the experimental plot since 1999-2000.

Year	Season		Remarks
	Kharif	Rabi	
1999-2000	Paddy	Maize	
2000-2001	Paddy	Gram	
2001-2002	Paddy	Maize	
2002-2003	Paddy	Maize	First year of experiment
2003-2004	Paddy	Maize	Second year of experiment

3.5 Experimental details

A field experimental to find out the effect of tillage and irrigation on winter maize was conducted during 2002-03 and 2003-04 in split-plot design with three replications. Four levels each of tillage and irrigation were taken in main and sub plots respectively with a total of 16 treatment combinations in a replication. Lay out of the experiment has been presented in fig. 2. The details of the treatments are given below:

Treatments **Crop (Winter maize)**

A) Main plot (Tillage) - 4 levels

T_1 = 1 disc ploughing + 2 harrowing + planking

T_2 = 2 cultivator + planking

T_3 = Rotavator once

T_4 = Zero – till planter

B) Sub-plot (irrigation) – 4 levels

I_1 = Pre-knee height (30 DAS) + knee height (Kn) + Silking (3 irrigation)

I_2 = Pre-knee height (30 DAS) + knee height (Kn) + Silking + Milking (4 irrigation)

I_3 = Pre-knee height (30 DAS) + knee height (Kn) + Tasseling + Milking + Grain filling (G.F.) (5 irrigation).

I_4 = Pre-knee height (30 DAS) + knee height (Kn) + Tassel initiation stage + Silking + Milking + G.F. (6 irrigation).

C)	Variety	-	Deoki
D)	Spacing (in like)	-	60 x 25 cm
E)	Seed rate	-	20 kg/ha
F)	Seed depth	-	4-5 cm
G)	Fertilizer (N:P:K)	-	120:75:50 kg/ha

(N @ 1/3 as basal + 1/3 at Knee height + ½ at tassel initiation stage)

H) Treatment combinations

I_1I_1	I_2I_1	I_3I_1	I_4I_1
I_1I_2	I_2I_2	I_3I_2	I_4I_2
I_1I_3	I_2I_3	I_3I_3	I_4I_3
I_1I_4	I_2I_4	I_3I_4	I_4I_4

I) Experimental lay out

i)	Location – Tirhut College of Agriculture Farm, Dholi (Muzaffarpur)		
ii)	Design	–	Split-plot
iii)	No. of replications	–	3
iv)	No. of main plots	–	4
v)	No. of sub plots	–	16
vi)	Total no. of plots	–	48
vii)	Size of the plot	–	5.4 x 6 m^2 = 32.4 m^2
viii)	Net plot size	–	4.2 x 5 m^2 = 21.0 m^2
ix)	Net expt. area	–	1008 m^2
x)	Gross expt. area	–	1645.95 m^2 = 1646 m^2

3.6 Details about the variety (Deoki)

Deoki is a a composite variety evolved from progenies of IPTT-44 and was released during 1993-94 by Rajendra Agril. University, Bihar, Pusa. It is full season variety grown both the *rabi*, Summer as well as in *kharif* seasons. Its maturity period varies from 160-165 days in *rabi* crop. The grain is white in colour, bold, semident and flat type. It is resistant to leaf rust and leaf light.

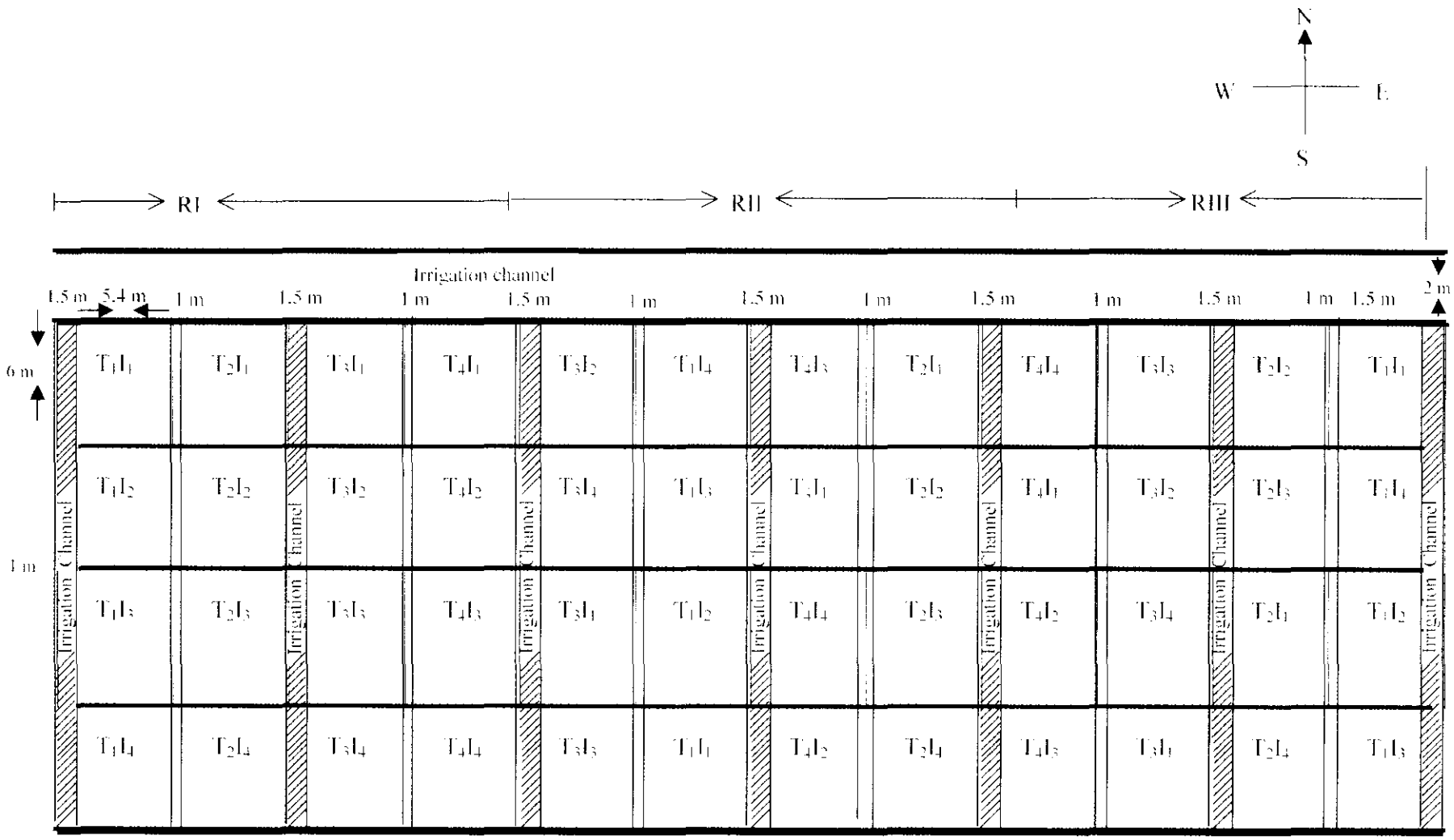

Fig.:-2. Lay out of the experiment

3.7 Cultural practices

The tillage practices followed in the experimental area as per treatments. Irrigations were given at different critical stages as per treatments with furrow method of irrigation. Full P and K were applied as basal while nitrogen was applied in three equal splits (1/3 N as basal + 1/3 N at knee height and 1/3 N at tassel initiation stage). All plant protection measurers were taken into consideration as per recommendation. Details of the field operations are given in (Table-4).

Table –3. Calendar of field operations.

Sl. No.	Operations	Year & date	
		2002-03	2003-03
1.	Lay out	13-10-02	13-10-03
2.	Tillage practices	15-10-02	15-10-03
3.	Fertilizer application (basal) & sowing	16-10-02	16-10-03
	(a) 1/3 N at knee height (top dressing)	28-12-02	26-12-03
	(b) 1/3 N at Tassel initiation stage (Top dressing)	18-01-03	16-01-04
4.	Herbicide application	20-10-02	19-10-03
5.	Thinning	08-11-02	08-11-03
6.	Irrigations (Stage wise)		
	- 30 DAS	25-11-02	25-11-03
	- Knee height	26-12-02	26-12-03
	Tassel initiation stage	14-01-03	11-01-04
	Tasseling	18-01-03	15-01-04
	Silking	28-01-03	27-01-04
	Milking	20-02-03	17-02-04
	G.F.	02-03-03	01-03-04
7.	Hand weeding	10-01-03	08-01-04
8.	Plant protection measures		
	1. Spraying of Diethene M-45		
	I	25-12-02	23-12-03
	II	02-02-03	02-02-04
9.	Harvesting	02-04-03	30-03-04

3.7.1 Seed & sowing

Seeds were treated with fungicide (Bavistin) @ 3 g/kg of seed before 4 hrs. of sowing and seeds were sown in line at 4 cm depth in shallow furrows in both the years.

3.7.2 Weeding

One hand weeding was also done at tasseling stage with the help of kudpi and 2 sprays of Diathane M-45 were done at 75 DAS and 100 DAS in all the plots in both the years.

3.7.3 Harvesting

The crops were harvested when the crop attained its maturity i.e. the cob sheath turned brownish, grains become hard and contain 18-20 per cent moisture. Cobs along with sheath from each net plot was harvested separately for each treatment and after proper labeling they were brought to the threshing floor for shelling. Stalks from each net plot were also harvested and left for few days in the respective plots for drying. After drying, these were tied into bundles and weight of the bundle was recorded.

Shelling was done manually. Moisture content of kernels were recorded by the moisture meter and the final grain yield was calculated at 15 per cent kernel moisture.

3.8 Observation recorded

The technique of representative sampling was adopted for recording of observation on various agronomic parameters/practices at different stages. Five plants of maize were tagged from each plot was randomly selected for recording the observations for the characters under study.

The methods/procedures, adopted for recording observation during the course of present investigation are enumerated as follows in tabular form :

Table – 4. Methods adopted for different observations.

A)	**Soil (Physiochemical properties)**	
1.	Mechanical analysis	- International pipette method (Piper, 1966)
2.	Bulk density	- Core sampler method (Biswas *et al.*, 1961)
3.	Porosity	- (Hillel, 1980)
4.	Soil-strength	- Core penetrometer (Davidson, 1965)
5.	Infiltration rate	- Double ring infiltrometer (Bertrand, 1965)
6.	Electrical conductivity	- Conductivity bridge (Jackson, 1978)
7.	Soil moisture content	- Soil moisture meter
8.	Soil reaction	- Glass electrode pH metre (Jackson, 1978)
9.	Organic carbon	- Walkley and Black method (1934), Jackson (1978)
10.	Available nitrogen	- Alkaline permanganate method (Subhiah and Asiya, 1956)
11.	Available phosphorus	- Olsen's method (Olsen *et al.* 1954)
12.	Available potassium	- Flame photometer (Jackson, 1978)
B)	**On plant**	
1.	Leaf area index	- Electronic leaf area meter
2.	Relative leaf water content, sp. Leaf wt. and water saturation deficit	- Proposed by Weatherley (1950)
3.	Moisture per cent in grain	- Universal moisture meter
4.	Root volume	- Displacement technique (Mishra and Ahmad, 1987)

In addition to these, plant height, no. of leaves, leaf length, yield parameters were also recorded.

3.8.1 Physical and chemical properties of surface soil

Most of the physical and chemical properties of soil were measured before sowing and after harvest of the crop. Moisture content in soil was also determined upto depth of 60 cm at the interval of 30 cm before sowing and after harvest of the crop.

3.8.2 Pre-harvest studies

3.8.2.1 Plant height, no. of leaves and leaf length

Plant height was measured at a regular interval of 30 days from sowing to till harvest. No. of leaves and leaf length were also recorded in the some manner. The height of five randomly selected and tagged plants were measured from base of the plant to the base of flag leaf, leaves were counted from base leaf to the fully opened leaf and length of the middle five leaves were measured in cm.

3.8.2.2 Dry matter production

Randomly selected five plants of maize from the border lines in each plot were uprooted and samples so obtained were sub-dried for 5 days and then oven-dried at 70°C for 72 hrs and then final dry weight was recorded at regular interval of 30 days from sowing to harvest of the crop.

3.8.2.3 Root volume

Randomly selected five plants of maize from the border lines in each plots were uprooted and roots were cut from the base of stem and then roots were cleaned with water and root volume was measured with the help of the technique (displacement technique) described by Mishra and Ahmad, 1987.

3.8.2.4 Weed dry wt.

Weeds were removed from 0.25 m^2 area from the places selected randomly in each plot. The weeds were cleaned, washed and air dried and placed in oven for 48 hrs at 70°C and constant weight was recorded. The dry matter accumulation of weeds were computed in g/m^2 at 120 DAS.

3.8.2.5 Germinatiou per cent

After 30 days of sowing of crops, the emerged plants were counted from each plot in $1m^2$ area and then computed in percent.

3.8.3 Physiological studies

3.8.3.1 Leaf area index (LAI)

For determining leaf area of the crop, three leaves (lower, middle and upper) from each of the five randomly selected plants in each plot were measured with the help of leaf area meter at 60 DAS and 120 DAS and thereafter, leaf area index were computed.

3.8.3.2 Crop grown rate (CGR)

It represents dry matter accumulation per unit area per unit time (Radford, 1967), compressed as $g/m^2/day$ CGR was calculated at 60 and 120 DAS by using the formula.

$$CGR = 1/a \times \frac{w_2 - w_1}{t_2 - t_1} \quad \text{-------(i)}$$

Where, G is the ground area, w_2 & w_1 are the dry weight at the time t_2 and t_1, respectively. One of the assumptions of this formula is that dry weight changes without discontinuity from w_1 to w_2 as the time changes from t_1 and t_2.

3.8.3.3 Relative growth rate (RGR)

It is an index of the amount of growing material per unit dry weight of plant per unit time (Ladford, 1967) and impressed in g/g/day. It was determined at 60 DAS and 120 DAS by using the formula:

$$RGR = 1/a \times \frac{\ln w_2 - \ln w_1}{t_2 - t_1} \quad \text{-------(ii)}$$

Where w_1 and w_2 are the dry weight at time t_1 and t_2 respectively. This is based on the assumption that the change in dry weight is discontinuous with change in time.

3.8.3.4 Specific leaf weight (SLW)

This was determined in the fully expanded leaves at 120 DAS by using the formula.

$$SLW = \frac{\text{Leaf dry wt. in mg}}{\text{Leaf area in } cm^2}$$

3.8.3.5 Water saturation deficit (WSD)

There topmost, fully expanded leaves were taken from each replicates of the respective treatments. The leaves after blotting of the surface moisture were weighed to obtain the fresh weight and the submerged fully in distilled water for 24 hrs. The leaves were removed and surface water was blotted off smoothly without putting any pressure on the leaves. Leaves were dried at 70°C for 48 hrs. and dry wt. of leaves were determined. The water saturation deficit was calculated at 60, 90 and 120 DAS by using the formula reported by Weatherley (1950) :

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

It is expressed in per cent.

3.8.3.6 Relative leaf water content (RLWC)

The relative leaf water content was determined for each treatment by the method described by Weatherley (1950). Fresh flag leaves were cut into pieces and weighed. The leaf pieces were floated in distilled water and kept for 6 hrs in dark. Excess water from the leaf pieces was removed by keeping them between the blotting sheets and pressing softy. The pieces were dried in oven at 85-90°C and dry weight was recorded and it was calculated by the formula :

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

3.8.4 Post harvest studies

3.8.4.1 Number of cobs/plant and cob length

The no. of cobs from five randomly selected plants were counted from the observational plants and length of each cob (from base of the cob upto its tip) were measured with the help of metre scale and then averaged.

3.8.4.2 Diameter/girth of the cob

Girth of each cob of five observational plants were measured in cm with the help of threads and scale. The measurements were taken at three places i.e. base, tip and middle. The mean of these three were regarded as the cob girth.

3.8.4.3 Number of grains/per cob

Number of grains of each cob of observational plants were counted after shelling the cobs with hand and then averaged.

3.8.4.4 Weight of grains per cob

After counting of grain number of the sampled cobs, the weight of grains were recorded and then averaged.

3.8.4.5 Test weight (100 grains)

One hundred representative kernels were counted from clean and dry produce of each plot and weight was recorded in g.

3.8.5 Yield studies

3.8.5.1 Grain yield per hectare

Grain yield for each net plot was recorded in kg after shelling the cobs when it was properly dried. Yield obtained from each net plot at 15 per cent moisture content of kernel was calculated into kg per hectare.

3.8.5.2 Stover yield per hectare

After the cobs of each plot was picked-up, the stover of each plot was also harvested and left for few days in the respective plots for sun drying. After complete drying of stover, the weight of the bundles were recorded in kg and then calculated into kg per hectare. The stover consisted all the plant parts except the cobs.

3.8.5.3 Stone yield per hectare

After shelling the cobs of each plot separately the stones were dried in the sun for 3-4 days and their weight was taken separately in kg and the yield was then calculated in kg per hectare.

3.8.5.4 Grain : Stover ratio

From the yield data of grain and stover per plot, grain : Stover ratio was obtained after dividing the weight of grains by the weight of stover.

3.8.5.5 Grain : Stone ratio

It was obtained by dividing the yield of grain by the yield of stones per plot.

3.8.5.6 Harvest index (H.I.)

Harvest index was calculated as the ratio of economic yield (grain) and total biological yield. Its value was expressed in per cent.

$$\text{H.I. (\%)} = \frac{\text{Grain yield (kg/ha)}}{\text{Grain (kg/ha) + stover yield (kg/ha) along with sheath and stone}}$$

3.8.6 Qualitative studies

3.8.6.1 Crude protein content

The crude protein content of grain was calculated by multiplying the nitrogen content in grains with a constant factor of 6.25 (assuming 16 per cent N in protein).

3.8.6.2 Total nitrogen

Total nitrogen in plant's sample after harvest was determined by digesting 0.2 g of grounded material 10 ml of Conc. H_2So_4 was added to samples and then left overnight. After that the content was heated to high temperature, adding H_2O_2 drop by drop till a clear and white solution was obtained. After making the volume to 50 ml, the aliquot was neutralized adjusting to neutral pH and then adding 2 ml of Nesseler reagent. The colour intensity was measured at 535 nm in photo electro colorimeter as suggested by Arthur and Herbert (1977).

3.8.6.3 Total phosphorus

It was determined in the extract by vanado molybdate yellow colour method (Jackson, 1973). The optical density was measured with photoelectric colorimeter at 470 nm. The content was estimated with calibration curve.

3.8.6.4 Total potassium

The potassium content was determined with the help of flame photometer (Jackson, 1973). The content was estimated with calibration curve.

3.8.7 Irrigation studies

3.8.7.1 Water use efficiency (WUE)

Soil moisture extracted from different layer (0-60 cm soil depth) at an interval of 30 cm was calculated before sowing of the crop and after harvest of the crop and expressed as per cent of total water by using the formula :

$$\text{Soil profile contribution} = \frac{\text{Initial moisture} - \text{Final moisture}}{100} \text{ X B.D. X soil-depth}$$

Thereafter, water use efficiency was calculated by the following formula :

$$\text{WUE} = \frac{\text{Grain yield (kg/ha)}}{\text{IW} + \text{ER} + \text{SW}}$$

Where,

IW = Quantity of irrigation water in cm.

ER = Quantity of rainfall received during the crop season, and

SW = Soil profile contribution in cm.

3.8.7.2 Water expense efficiency (WEE)

Water expense efficiency of maize was estimated by dividing the grain yield of corresponding crop water expense (Prihar *et al.*, 1976).

$$\text{WEE} = \frac{\text{Grain yield (kg/ha)}}{\text{IW} + \text{ER} + \text{SW} + \text{D}}$$

Where,

IW = Quantity of irrigation water in cm.

ER = Effective rainfall in cm during the crop season

SW = Soil profile contribution and

D = Water depleted beyond the root zone in cm.

3.8.8 Economics

Cost of cultivation, gross and net return, net return per rupee of investment, gross return per day, net return per day and net return per rupee of investment per day under various treatment combinations were worked out on the basis of the mean yield of grain and strew/stover/stone. Approved rates of grain straw and stone were used for calculating the economics.

3.8.9 Statistical analysis

The experimental data was subjected to statistical analysis to find out the differences among the treatments using methods described by Shedecor and Cochran (1967).

3.8.9.1 Correlation studies

The correlation coefficient was calculated by using the procedure described by Panse and Sukhatme (1967) as grain below:

$$r = \frac{Sxy}{\sqrt{Sxx.\ Syy}}$$

$$tc = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}, \text{ d.f. } (n-2)$$

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CHAPTER IV

EXPERIMENTAL FINDINGS

EXPERIMENTAL FINDINGS

The chapter deals with the effect of different tillage practices and frequency of irrigation on various crop growth parameters, plant-water status, yield, water use efficiency and economics of cultivation along with correlation studies of field experiments conducted during 2002-03 and 2003-04 on a sub-tropic sandy loam soil. The results obtained are presented under the following heads :-

4.1 Physical properties of soil

Physical properties of surface soil were determined after harvest of the crop during both the years and results in form of average values, thus obtained are presented in table-1 and fig.3 under the following sub-heads.

4.1.1 Bulk density

It is evident from the table-5(a) and fig.3(a) that bulk density tended to decrease as soil-tilth get finer due to different tillage practices. The lowest av. bulk density was recorded with rotavator tilled plots which was followed by conventional tillage and cultivator tilled plots. The maximum av. bulk density was recorded in zero-tilled plots during both the years of investigation.

4.1.2 Soil strength

As soil tilth get finer due to different tillage practices table-5(b) and fig.3(b), it tend to decrease the average soil strength of the tilled plots. The decrease in rotavator tilled plots were 8.20 and 17.6 per cent during 2002-03 and 2003-04, respectively. However, the magnitude of decrease from zero-tilled plots to rotavator was relatively higher than that of zero-tilled plots to conventional tillage in both the years of experimentation.

4.1.3 Infiltration rate

A cursory glance of the table-5(c) and fig. 3(c) revealed that rotavator tilled plots had maximum average 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

Table 5. Effect of tillage on physical properties of surface soil (0-30 cm) after harvest of maize.

Treatments	Years	
	2002-03	2003-04
	(a) Bulk density (mg m^{-3})	
T_1	1.36	1.33
T_2	1.41	1.40
T_3	1.33	1.30
T_4	1.43	1.40
	(b) Soil strength (MPa)	
T_1	2.28	2.24
T_2	2.35	2.31
T_3	2.10	2.05
T_4	2.56	2.39
	(c) Infiltration rate (cm ha^{-1})	
T_1	0.331	0.337
T_2	0.328	0.325
T_3	0.420	0.432
T_4	0.316	0.335
	(d) Porosity (%)	
T_1	48.68	49.81
T_2	46.79	47.17
T_3	49.81	50.94
T_4	46.02	47.17

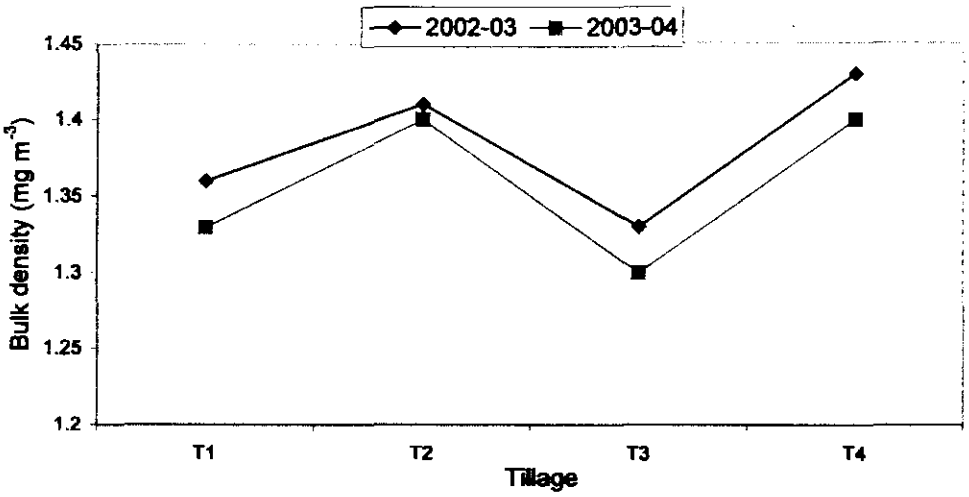

Fig. 3(a). Bulk density

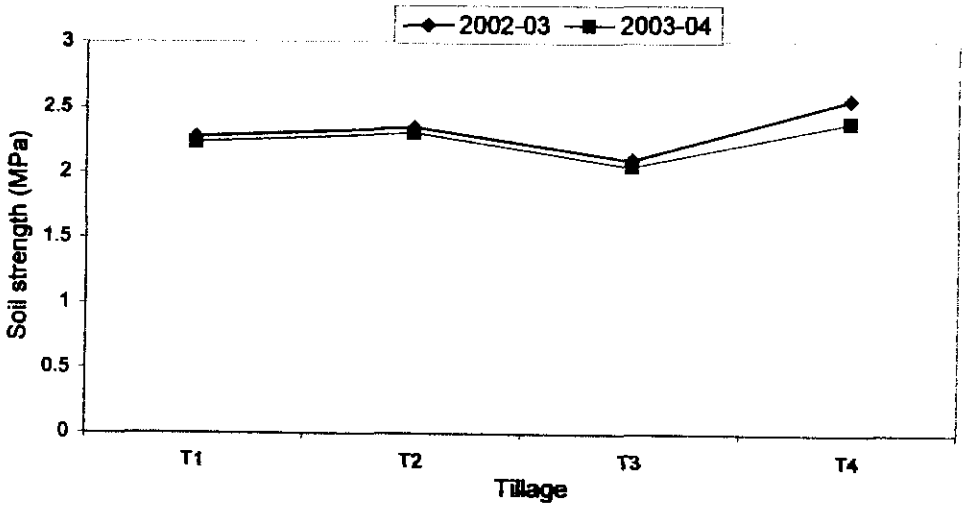

Fig. 3(b). Soil strength

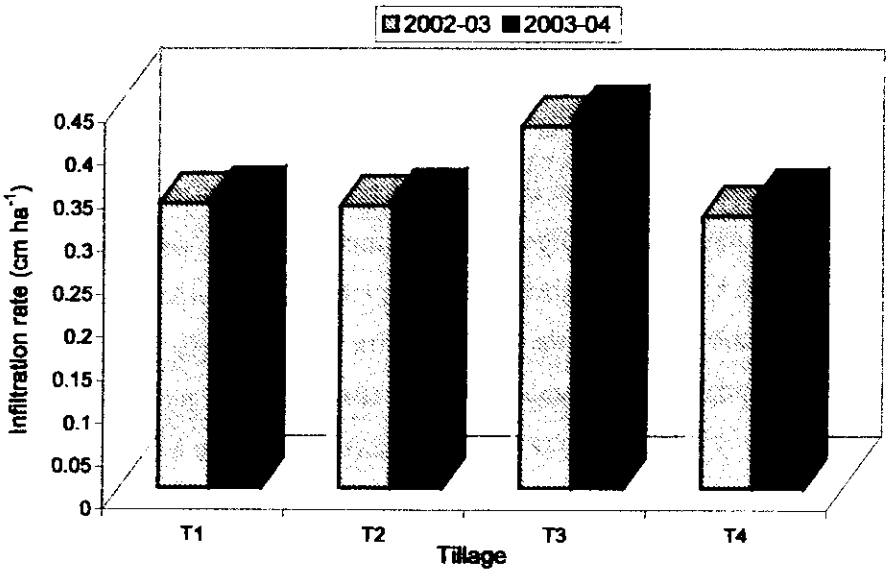

Fig. 3(c). Infiltration rate

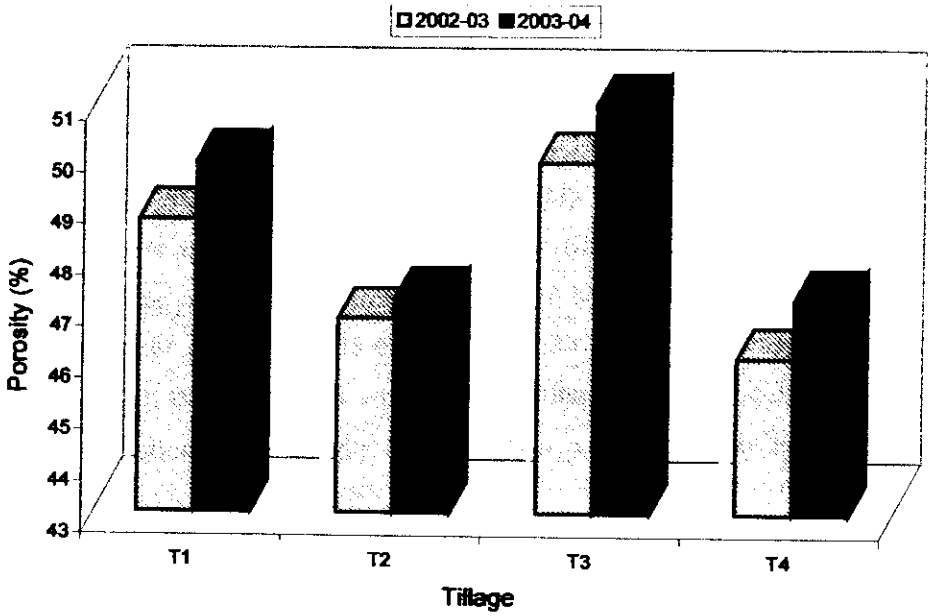

Fig. 3(d). Porosity

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}).

4.1.4 Porosity

It is evident from table-5(d) and fig.3(d) that porosity tended to increase with different tillage practices. As the soil tilth get finer, porosity increases. 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.

4.2 Vegetative studies

4.2.1 Germination percentage

Germination per cent was recorded significantly higher in all the tilled plots over zero-tilled plots but no significant differences were recorded due to differences in number of irrigations at different critical stages (Table-6).

4.2.2 Plant height

Tillage and irrigation significantly affected plant height of winter maize at 120 DAS and at maturity (Table-7). Rotavator tilled plots shown significantly higher plant height at 30 DAS (10.59 and 10.70 cm) in both the years respectively and the same trend was also observed at 60 DAS. Plant height was recorded significantly highest in rotavator tilled plots (88.58 and 88.25 cm) at 90 DAS, 166.42 and 167.28 cm at 120 DAS and 189.33 and 190.07 cm at maturity respectively over zero-tilled plots which was followed by conventional tillage and cultivator tilled plots at 120 DAS and maturity during both the years of experimentation. Plant height was recorded higher in rotavator tilled plots (166.42 and 167.28 cm) and (189.33 and 190.07 cm) at 120 DAS and at maturity over all the treatments while conventional tillage and cultivator tilled plots were found statistically at par with each other in respect of plant height during both the years at 120 DAS and at maturity.

Variation in frequency of irrigation also affected plant height significantly at 120 DAS and at maturity. Crop receiving 5 and 6 irrigations recorded highest plant height (154.50 and 154.72 cm) at 120 DAS over 3 irrigations and 194.25 and 191.39cm

Table 6. Effect of tillage and irrigation on germination percentage of maize at 30 DAS during 2002-03 and 2003-04.

Treatments	Germination percentages	
	2002-03	2003-04
Tillage		
Conventional (T_1)	92.17	91.67
Cultivator (T_2)	91.33	91.08
Rotavator (T_3)	93.33	92.00
Zero tillage (T_4)	88.42	86.25
SE. m. (±)	0.63	0.85
CD (P=0.05)	2.18	2.94
Irrigations		
30 DAS + Knee ht + Silk (I_1)	90.75	89.83
30 DAS + Kn ht + S + M (I_2)	90.92	90.58
30 DAS + Kn + TI + GF (I_3)	91.75	90.33
30 DAS + Kn + IT + S + M + GF (I_4)	91.83	90.25
SE. m. (±)	1.13	0.98
CD (P=0.05)	NS	(NS)

Table-7. Effect of tillage and irrigation on plant height (cm.) at 30, 60, 90, 120 DAS and maturity during 2002-03 and 2003-04.

Treatments	Plant height (cm)									
	2002-03					2003-04				
	30 DAS	60 DAS	90 DAS	120 DAS	Maturity	30 DAS	60 DAS	90 DAS	120 DAS	Maturity
Tillage										
T_1	10.28	35.92	80.17	145.75	183.33	10.67	35.25	81.75	145.50	184.30
T_2	10.16	35.00	79.33	144.92	183.17	10.67	35.02	79.50	144.52	181.79
T_3	10.59	45.50	88.58	166.42	189.33	10.70	35.45	88.25	167.28	190.07
T_4	10.15	34.33	76.33	130.42	176.67	10.65	35.00	75.17	130.91	173.60
SE. m. (±)	0.09	0.78	1.56	2.67	2.37	0.012	0.09	1.82	2.66	2.32
CD (P=0.05)	0.31	2.69	5.41	9.25	8.22	0.04	0.31	6.29	9.20	8.02
Irrigation										
I_1	10.12	36.92	77.67	138.75	169.25	10.67	35.00	77.82	138.32	168.47
I_2	10.27	37.33	78.92	144.83	179.42	10.66	35.00	79.72	141.50	180.22
I_3	10.36	37.83	83.50	149.42	189.58	10.68	35.22	83.28	153.66	189.67
I_4	10.43	38.67	84.33	154.50	194.25	10.69	35.50	83.85	154.72	191.39
SE. m. (±)	0.16	1.33	2.43	3.41	2.78	.093	0.12	2.40	3.38	2.74
CD (P=0.05)	NS	NS	NS	9.97	8.11	NS	NS	NS	9.86	8.00

at maturity over 3 or 4 irrigations during both the years, respectively. No significant differences were recorded with frequency of irrigation at 30 DAS, 60 DAS at 90 DAS during both the years. Crop receiving 5 and 6 irrigations was found statistically at par in both the years Table-6).

No significant interaction was recorded in respect of plant height at any stage of crop growth.

4.2.3 Number of leaves per plant

Number of leaves per plant was significantly affected by different tillage and irrigation treatments. Number of leaves per plant was found non-significant at 30 DAS due to different tillage practices but was found significantly higher at later growth stages over zero-tilled plots. Number of leaves per plant was higher in rotavator, tilled plots over all other tillage practices. Conventional tilled plots, cultivator tilled plots and rotavator tilled plots were found significantly superior over zero-tilled plots in respect of number of leaves per plant at 60, 90, 120 DAS and at maturity during both the years. A significant difference was also recorded in respect of number of leaves per plant in rotavator tilled plots (12.92 and 12.40cm) over conventional tillage (11.43 and 11.87cm) at 90 DAS respectively but was found at par at later growth stages till maturity during both the years (Table-8).

Frequency of irrigation also affected number of leaves per plant significantly at later growth stages. Number of leaves per plant was recorded significantly higher in crop receiving 5 to 6 irrigation over 3 or 4 irrigations. No significant difference in number of leaves per plant was recorded at 30 and 60 DAS but number of leaves per plant was found significantly higher in crop receiving 6 irrigations at 90, 120 DAS and at maturity over 3 and 4 number of irrigations at different growth stages during both the years which was found at par with crop receiving 5 irrigations (Table-7).

4.2.4 Leaf length

Leaf length of winter maize was affected by different tillage practices and frequency of irrigation.

Leaf length was recorded significantly higher in rotavator tilled plots (68.55, 77.54 and 80.08 cm) during 2002-03 and 63.07, 74.37 and 80.12 cm during 2003-04 at 90, 120 DAS and at maturity respectively over zero-tillage maize. Rotavator tilled

Table-8. Effect of tillage and irrigation on number of leaves per plant at 30, 60, 90, 120 DAS at maturity during 2002-03 and 2003-04.

Treatments	Number of leaves/plant									
	2002-03					2003-04				
	30 DAS	60 DAS	90 DAS	120 DAS	Maturity	30 DAS	60 DAS	90 DAS	120 DAS	Maturity
Tillage										
T_1	4.44	8.92	11.43	14.64	15.90	4.52	9.40	11.87	13.79	16.56
T_2	4.40	8.83	10.93	14.01	15.42	4.50	8.80	11.00	13.12	15.63
T_3	4.67	10.33	12.92	14.75	16.43	4.56	10.09	12.40	14.31	17.12
T_4	4.33	7.92	10.55	13.55	15.00	4.50	8.03	10.74	12.80	15.33
SE m (±)	0.14	0.12	0.24	0.28	0.22	0.18	0.18	0.26	0.24	0.20
CD (P=0.05)	NS	0.42	0.84	0.99	0.76	NS	0.62	0.89	0.83	0.69
Irrigation										
I_1	4.33	8.75	10.92	13.42	14.86	4.45	8.47	10.46	12.63	15.38
I_2	4.33	9.00	11.08	13.78	15.47	4.52	8.92	11.04	13.22	15.84
I_3	4.50	9.08	11.83	14.72	16.20	4.55	9.45	12.16	14.02	16.70
I_4	4.67	9.16	12.00	14.83	16.22	4.57	9.50	12.35	14.15	16.73
SE m (±)	0.16	0.32	0.21	0.29	0.22	0.15	0.36	0.22	0.25	0.21
CD (P=0.05)	NS	NS	0.61	0.84	0.65	NS	NS	0.64	0.73	0.61

Table-9. **Effect** of tillage and irrigation on leaf length at 30, 60, 90, 120 DAS and at maturity during 2002-03 and 2003-04.

Treatments	Leaf length (cm)									
	2002-03					2003-04				
	30 DAS	60 DAS	90 DAS	120 DAS	Maturity	30 DAS	60 DAS	90 DAS	120 DAS	Maturity
Tillage										
T_1	15.02	35.16	58.54	71.50	76.93	15.03	34.30	58.97	71.12	78.25
T_2	14.85	31.32	57.37	71.71	76.82	14.97	33.29	58.32	70.55	77.10
T_3	15.63	38.32	68.55	77.54	80.08	15.06	35.22	63.07	74.37	80.12
T_4	14.51	27.77	53.22	66.26	77.75	14.87	32.05	53.70	67.85	74.72
SE. m. (±)	0.11	0.66	1.47	1.41	0.60	0.12	0.58	1.42	1.20	0.58
CD (P=0.05)	0.39	2.41	5.09	4.87	2.08	0.41	2.00	4.91	4.15	2.00
Irrigation										
I_1	14.82	32.42	54.51	67.82	71.12	14.92	31.69	54.20	67.77	72.92
I_2	14.84	32.79	57.42	68.95	74.54	14.97	33.37	56.15	67.87	75.62
I_3	15.08	33.44	62.42	74.48	80.78	15.00	34.40	61.25	73.95	79.97
I_4	15.27	33.89	63.33	75.15	82.14	15.04	35.40	62.37	74.30	80.67
SE. m. (±)	0.21	1.32	1.45	1.84	1.77	0.22	1.35	1.43	1.62	1.70
CD (P=0.05)	NS	NS	4.25	5.37	5.17	NS	NS	4.17	4.72	4.96

maize also recorded significantly higher leaf length over all other tillage practices applied here at maturity in both the years (Table-9).

No significant difference in respect of leaf length was recorded at 30 and 60 DAS with frequency of irrigation in both the years but significantly more leaf length was recorded in the crop receiving 5 to 6 irrigations over 3 and 4 irrigations in both the years. Leaf length was found at par in crop receiving 5 or 6 irrigations in both the years.

No significant interaction was observed in leaf length at any growth stages.

4.2.5 Dry matter production per plant

Tillage significantly influenced dry mater production per plant throughout the crop growth period (Table- 10 & 11) and fig. 4 & 5. Total plant dry matter production gradually increased with crop age and attained maximum at maturity. Dry matter production per plant was significantly higher in rotavator tilled plots at 30 DAS (1.27 and 1.30 g) and 60 DAS (7.48 and 7.08 g) over cultivator tilled and zero tilled plots during both the years but was at par with the dry matter produced through conventional tillage. Further, at 90 DAS and onwards rotavator tilled plots produced significantly higher dry matter per plant over all other tillage practices during both the years i.e. 37.42 and 37.61 g at 90 DAS, 101.52 and 108.25 g at 120 DAS and 369.77 and 392.78 g at maturity stage in 2002-03 and 2003-04 respectively.

However, no significantly difference was found in dry matter production per plant between conventional tillage and cultivator tilled plots at 90 and 120 DAS and at maturity during both the years of experimentation. Dry matter production of zero tilled plots were significantly lower over all other tillage practices throughout the crop growth period.

Irrigation frequency significantly affected the production of dry matter per plant at later growth stages of maize. During 30 DAS and 60 DAS dry matter production/plant did not differ significantly. Crop receiving 5 or 6 irrigations being at par with each other produced significantly higher dry matter per plant over 3 or 4 irrigations at 90 DAS and 120 DAS during both the years. Likewise, at maturity crop receiving 6 irrigations produced highest dry matter per plant (357.85 and 382.02 g) over all other irrigation treatments which was at par with that of 5 irrigations and significantly superior over 4 irrigations (302.98 and 314.21 g) and 3 irrigations (291.08 and 301.50 g) during 2002-03 and 2003-04 respectively (Table- 10 & 11). Dry matter

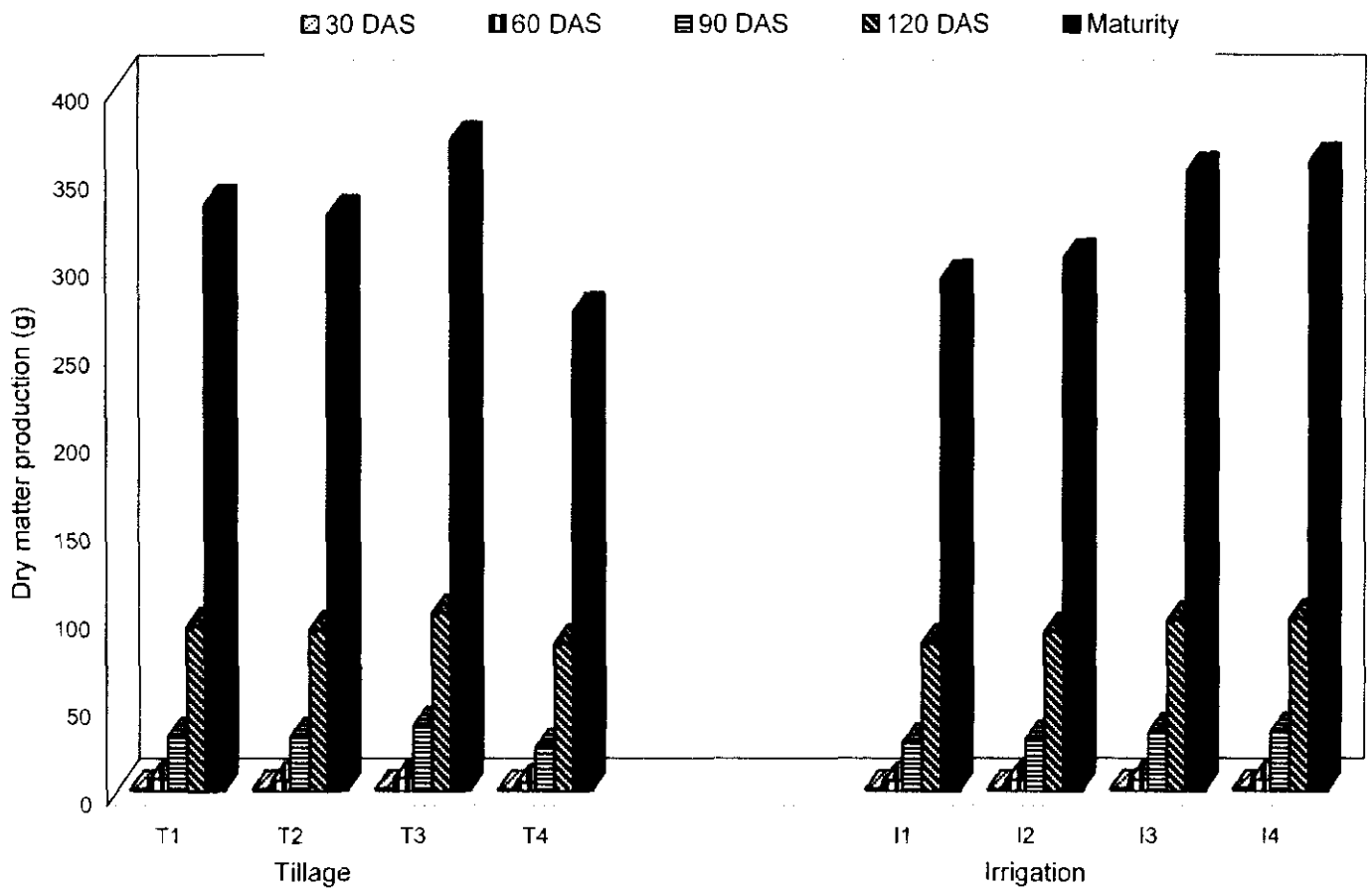

Fig. 4. Effect of tillage and irrigation on dry matter production per plant at different growth stages (2002-03)

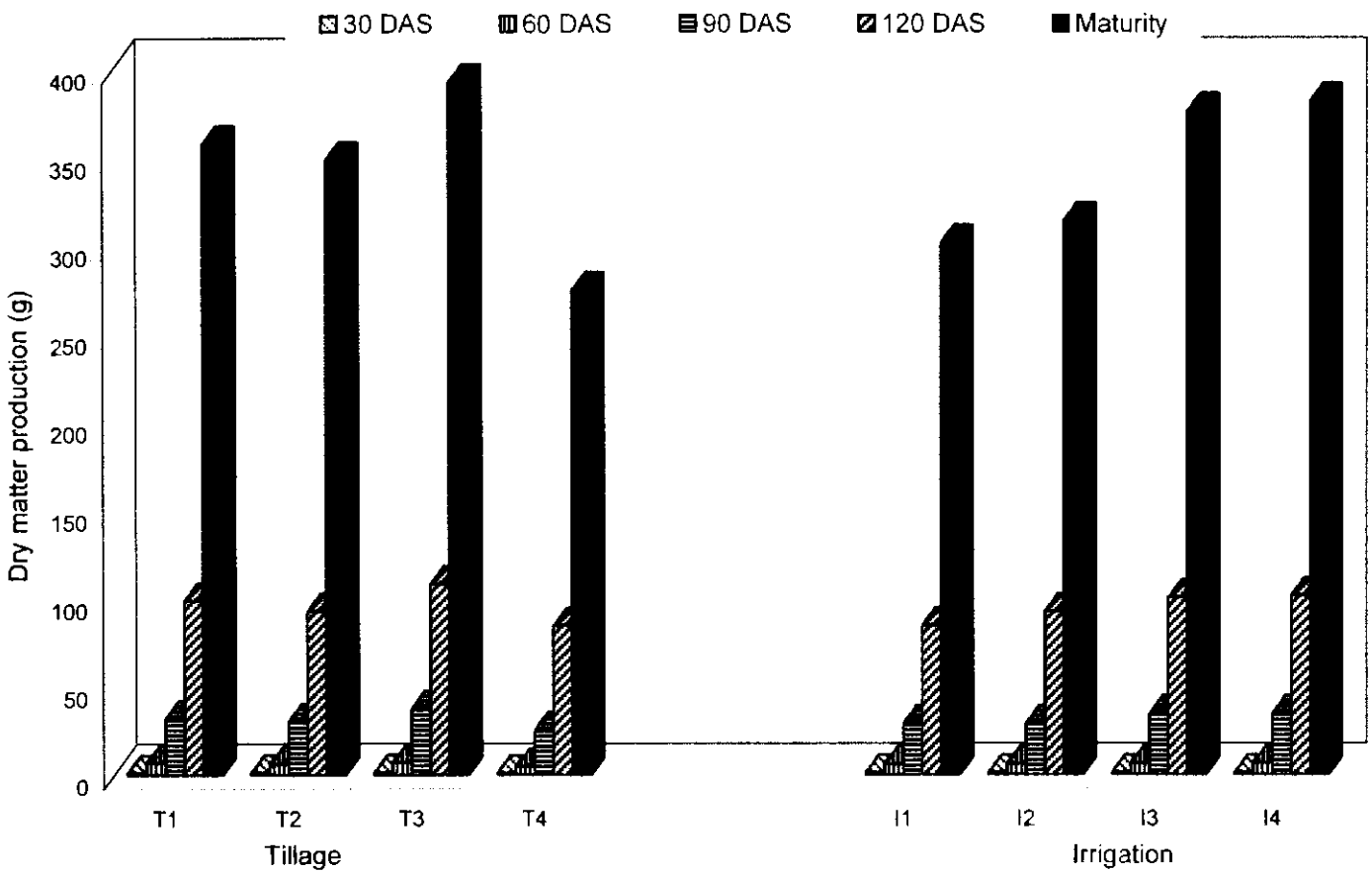

Fig. 5. Effect of tillage and irrigation on dry matter production per plant at different growth stages (2003-04)

Table 11. Effect of tillage and irrigation on dry matter production per plant (g) at 30, 60, 90, 120 DAS and at maturity during 2003-04.

Treatments	Dry matter production/plant (g)				
	30 DAS	60 DAS	90 DAS	120 DAS	Maturity
Tillage					
T_1	1.261	6.95	32.03	98.80	357.81
T_2	1.140	5.92	30.38	92.64	348.45
T_3	1.300	7.08	37.61	108.25	392.78
T_4	1.027	4.83	25.67	84.30	274.82
SE. m. (±)	0.016	0.27	1.56	2.32	9.92
CD (P=0.05)	0.055	0.93	5.39	8.02	34.82
Irrigation					
I_1	1.125	5.88	28.98	84.49	301.50
I_2	1.151	6.00	29.27	92.48	314.21
I_3	1.218	6.41	34.60	100.34	376.13
I_4	1.222	6.50	34.84	101.69	382.02
SE. m. (±)	0.039	0.25	1.22	1.45	6.82
CD (P=0.05)	NS	NS	3.56	4.23	19.90

Table 10. Effect of tillage and irrigation on dry matter production per plant (g) at 30, 60, 90, 120 DAS and at maturity during 2002-03.

Treatments	Dry matter production/plant (g)				
	30 DAS	60 DAS	90 DAS	120 DAS	Maturity
Tillage					
T_1	1.258	6.900	31.408	93.808	333.958
T_2	1.161	5.850	31.317	91.792	327.975
T_3	1.273	7.483	37.417	101.517	369.767
T_4	0.942	4.767	25.008	84.006	272.642
SE. m. (±)	0.017	0.293	1.632	2.029	8.303
CD (P=0.05)	0.059	1.013	5.647	7.022	28.733
Irrigation					
I_1	1.095	5.933	27.867	84.242	291.075
I_2	1.133	6.092	29.558	90.737	302.983
I_3	1.195	6.433	33.600	97.393	352.433
I_4	1.210	6.542	34.125	98.750	357.850
SE. m. (±)	0.037	0.233	1.260	1.343	6.265
CD (P=0.05)	NS	NS	3.678	3.921	18.287

production per plant with 3 and 4 irrigations was at par with each other during 90 DAS, 120 DAS and at maturity.

No significant interaction was observed in respect of dry matter production per plant at any growth stages.

4.2.6 Root volume

There was significant increase in root volume due to each increasing level of tillage and irrigation at 90 DAS and 120 DAS (Table-12), resulting in maximum root volume with rotavator tilled plot (43.40 and 46.98 cc) in the first year and (45.28 and 48.29 cc) during 2nd year of experimentation over all other tillage treatments. Root volume was found significantly higher over zero tillage in all other tillage treatments and was recorded at par with cultivator tilled plots and conventional tilled plots.

Root volume was found significantly higher with frequency of irrigation. Crop receiving 6 irrigations recorded maximum root volume (41.47 and 46.27 cc) and (41.58 and 46.82 cc) respectively at 90 DAS and 120 DAS over 3 and 4 irrigations (32.01 and 34.30 cc) and (34.70 and 34.28 cc) during both the years but was found at par with crop receiving 5 irrigations at different growth stages.

No significant interaction was observed in respect of root volume at any growth stages.

4.2.7 Weed dry weight

Data on weed growth as influenced by various tillage treatments and irrigation level (Table-13) exhibited that plots tilled with rotavator (T_3) registered minimum weed dry weight per plot (3.898 and 3.980 g) followed by conventional tillage (T_1) (4.772 and 5.125 g) and maximum under zero tilled plot (T_4) (6.833 and 7.533 g), respectively at 120 DAS during both the years.

In general, there was significant increase in weed dry weight due to increasing level of irrigation. Crop receiving 6 irrigations recorded maximum weed dry weight (6.045 and 6.442 g) at 120 DAS during both the years over crop receiving 3 and 4 irrigations (4.192 and 4.352 g) and (4.728 and 4.995 g) respectively. However, the crop receiving 3 and 4 irrigations did not exhibit significant difference in weed dry weight per plot.

No significant interaction was observed in respect of weed dry weight at 120 DAS.

Table 12. Effect of tillage and irrigation on root volume (cc.) at 90 and 120 DAS.

Treatments	Root volume (cc.)			
	2002-03		2003-04	
	90 DAS	120 DAS	90 DAS	120 DAS
Tillage				
T_1	38.12	42.71	37.77	42.52
T_2	37.32	40.04	37.47	40.97
T_3	43.40	46.98	45.28	48.29
T_4	32.65	36.69	33.22	37.41
SE. m. (±)	0.86	1.02	0.42	1.09
CD (P=0.05)	2.06	3.52	1.45	3.77
Irrigation				
I_1	32.01	34.30	34.70	34.28
I_2	36.69	39.74	37.42	41.68
I_3	41.37	46.12	40.03	46.40
I_4	41.41	46.27	41.58	46.82
SE. m. (±)	1.67	1.58	0.42	1.51
CD (P=0.05)	4.67	4.60	1.23	4.41

Table 13. Effect of tillage and irrigation on weed dry weight (kg/plot) at 120 DAS during 2002-03 and 2003-04.

Treatments	Weed dry weight (kg/plot)	
	2002-03	2003-04
	120 DAS	120 DAS
Tillage		
T_1	4.772	5.125
T_2	4.975	5.217
T_3	3.898	3.980
T_4	6.833	7.533
SE. m. (±)	0.121	0.132
CD (P=0.05)	0.418	0.456
Irrigation		
I_1	4.192	4.352
I_2	4.728	4.995
I_3	5.514	6.065
I_4	6.045	6.442
SE. m. (±)	0.216	0.285
CD (P=0.05)	0.630	0.831

4.3 Physiological studies

4.3.1 Leaf area index (LAI)

It is obvious from the data (Table-14) that different levels of tillage and irrigation significantly affected leaf area index of maize recorded at 60, 90 and 120 DAS during both the experimental years.

Increasing level of tillage increased leaf area index (LAI) significantly, resulting maximum under rotavator tilled plots (0.374, 1.315 and 2.673) and (0.373, 1.330 and 2.728) at 60, 90 and 120 DAS respectively during both the years 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 during both the years at each stages of crop growth.

Further, frequency of irrigation also affected the LAI of maize crop in both the years. LAI index was recorded maximum with crop receiving 6 number of irrigations (1.307 and 2.519) and (1.314 and 2.700) respectively at 90 and 120 DAS during both the years 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-14). Level of irrigation did not have any significant difference in respect of LAI at 60 DAS during both the years.

No significant interaction was observed in respect of LAI at any crop growth stages.

4.3.2 Crop growth rate (CGR)

Crop growth rate was significantly affected by different tillage practices and level of irrigation during both the years (Table-15).

Crop growth rate of rotavator tilled plots (1.973 and 1.780 $g/m^2/day$) was significantly superior over all other tillage practices during first and second year respectively. Conventional tillage recorded significantly higher crop growth rate (1.855 and 1.668 $g/m^2/day$) than cultivator tilled and zero tilled plots during both the years respectively. Zero tilled plots showed minimum crop growth rate which was similar to that of cultivator tilled plots during both the years of experimentation.

Crop growth rate increased with each increasing level of irrigation up to five irrigations during both the years. Maximum crop growth rate (1.97 and 1.623 $g/m^2/day$) was maintained by the crop receiving 6 irrigations which was significantly superior

Table 14. Effect of tillage and irrigation on leaf area index at 60, 90 and 120 DAS during 2002-003 and 2003-04.

Treatment	Leaf area index (LAI)					
	2002-03			2003-04		
	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
Tillage						
T_1	0.348	1.251	2.441	0.349	1.255	2.615
T_2	0.335	1.239	2.429	0.337	1.241	2.552
T_3	0.374	1.315	2.673	0.373	1.330	2.728
T_4	0.304	1.166	2.300	0.298	1.162	2.405
SE. m. (±)	0.005	0.018	0.025	0.004	0.020	0.028
CD (P=0.05)	0.016	0.062	0.086	0.014	0.069	0.097
Irrigation						
I_1	0.330	1.181	2.377	0.332	1.165	2.445
I_2	0.333	1.198	2.438	0.338	1.212	2.505
I_3	0.336	1.285	2.514	0.349	1.297	2.650
I_4	0.342	1.307	2.519	0.344	1.314	2.700
SE. m. (±)	0.013	0.030	0.020	0.11	0.027	0.023
CD (P=0.05)	NS	0.063	0.058	NS	0.079	0.067

Table 15. Effect of tillage and irrigation on growth rate ($g/m^2/day$) and relative growth rate (g/g/day) during 60 to 120 DAS.

Treatments	Crop growth rate (CGR)		Relative growth rate (RGR)	
	2002-03	2003-04	2002-03	2003-04
	60-120 DAS	60-120 DAS	60-120 DAS	60-120 DAS
Tillage				
T_1	1.855	1.668	0.027	.026
T_2	1.317	1.306	0.027	.025
T_3	1.973	1.780	0.030	.032
T_4	1.229	1.235	0.020	.022
SE. m. (±)	0.030	0.028	.0008	.0007
CD (P=0.05)	0.102	0.096	.0028	.0024
Irrigation				
I_1	1.323	1.313	.020	.021
I_2	1.507	1.450	.021	.022
I_3	1.747	1.603	.030	.030
I_4	1.797	1.623	.030	.032
SE. m. (±)	0.036	0.046	.0007	.0009
CD (P=0.05)	0.106	0.136	.0020	.0026

Table 16. Interaction effect of tillage and irrigation on crop growth rate ($g/m^2/day$) during 60-120 DAS in 2002-03.

Irrigation	Tillage			
	T_1	T_2	T_3	T_4
I_1	1.433	1.197	1.500	1.163
I_2	1.753	1.257	1.827	1.190
I_3	2.113	1.353	2.270	1.253
I_4	2.120	1.460	2.297	1.310
SE. m. (±)	0.073			
CD (P=0.05)	0.213			

Table 17. Interaction effect of tillage and irrigation on crop growth rate ($g/m^2/day$) during 60-120 DAS in 2003-04.

Irrigation	Tillage			
	T_1	T_2	T_3	T_4
I_1	1.440	1.133	1.540	1.140
I_2	1.590	1.260	1.740	1.210
I_3	1.810	1.410	1.910	1.280
I_4	1.830	1.420	1.930	1.310
SE. m. (±)	0.093			
CD (P=0.05)	0.271			

over crop growth rate of 3 or 4 irrigations but was at par with that of 5 irrigations during first and second year respectively. Further, crop receiving 4 number of irrigations recorded significantly higher crop growth rate than that of 3 number of irrigations applied to maize crop.

Interaction between different tillage practices and levels of irrigation was significant during both experimental years (Table-16 and 17). Crop growth rate of rotavator tilled plots with 6 irrigations was significantly higher over all other treatments but did not differ significantly from crop receiving 5 irrigations under same tillage practice. CGR was also similar with 5 and 6 irrigations under conventional tillage during both the years. Crop growth rate of zero tilled maize with six irrigations was statistically at par to that of conventional tillage and rotavator tilled plots with three irrigations during both the year of experimentation.

4.3.3 Relative growth rate (RGR)

Different tillage practices and levels of irrigation showed its pronounced affected on relative growth rate (RGR) during both the years of experimentation at 120 DAS (Tble-15).

Relative growth rate was recorded significantly higher with rotavator tilled plots (.030 and .032 gg^{-1} day^{-1}) over all other tillage treatments during both the years of experimentation. RGR was recorded significantly lower in zero-tilled plots in both the years where as cultivator tilled plots and conventional tillage did not exhibit any significant difference with each other during both the years.

Frequency of irrigation shown its pronounced effect on relative growth rate in both the years. However, no significant difference was observed with the crop receiving 3 and 4 irrigations but maximum relative growth rate was recorded in the crop receiving 6 irrigation (0.030 and 0.032 gg^{-1} day^{-1}) at different crop growth stages and was recorded at par with the crop receiving 5 irrigations (.030 and .030 gg^{-1} day^{-1}) over 3 and 4 irrigations (.020 and .021 gg^{-1} day^{-1}) and (.021 and .022 gg^{-1} day^{-1}) respectively during both the years (Table-16) of experimentation.

Relative growth rate did not exhibit any significant interaction due to different tillage and irrigation levels.

4.4 Plant water status

4.4.1 Specific leaf weight (SLW)

Tillage and frequency of irrigation exhibited its effect on specific leaf weight (SLW) at 120 DAS during both the years (Table-18).

Specific leaf weight was recorded significantly maximum with rotavator tilled plots (59.04 and 62.05 mg/cm^2) respectively at 120 DAS during both the years and was followed by conventional tillage and cultivator tilled plots over zero tillage (44.88 and 47.77 mg/cm^2).

Frequency of irrigation also exhibited significant effect on specific leaf weight in winter maize (Table 18). Specific leaf weight was found significantly higher in crop receiving 6 irrigations (59.42 and 61.35 mg/cm^2) and was found statistically at par with crop receiving 5 irrigations at different crop growth stages during both the years of experimentation over crop receiving 3 irrigations (46.90 and 47.50 kg/ha) and 4 irrigations (47.92 and 50.29 mg/cm^2), respectively.

4.4.2 Water saturation deficit (WSD)

Different tillage and frequency of irrigation affected water saturation deficit at different growth stages (Table-15).

Water saturation deficit decreased significantly in rotavator tilled plots (9.68, 8.10 and 4.57 per cent) and followed by conventional tillage (9.62, 7.98 and 4.67 per cent) at 60, 90 and 120 DAS. Water saturation deficit was recorded maximum in zero-tilled maize at each stages of growth and was at par with cultivator tilled maize at 60 and 90 DAS but differed significantly at 120 DAS in both the years.

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 (8.29 and 4.78 per cent) and (8.28 and 4.40 per cent) at 90 and 120 DAS during both the years which was found at par with crop receiving 5 irrigations over 3 irrigations (9.53 and 6.65 per cent) and (9.50 and 6.60 per cent) and 4 irrigations (9.17 and 6.48 per cent) and (9.27 and 6.32 per cent), respectively. However, no significant difference was recorded in respect of water saturation deficit with frequency of irrigation at 60 DAS during both the years (Table-19).

No significant interaction was observed in respect of water saturation deficit at any stage of crop growth in both the years.

Table 18. Effect of tillage and irrigation on specific leaf weight (mg/cm^2) at 120 DAS during 2002-03 and 2003-04.

Treatments	Specific leaf weight (mg/cm^2)	
	2002-03	2003-04
	120 DAS	120 DAS
Tillage		
T_1	58.04	60.07
T_2	49.18	49.87
T_3	59.04	62.05
T_4	46.88	47.77
SE. m. (±)	3.12	3.21
CD (P=0.05)	10.80	11.11
Irrigation		
I_1	46.90	47.50
I_2	47.92	50.29
I_3	58.92	60.62
I_4	59.42	61.35
SE. m. (±)	2.14	2.37
CD (P=0.05)	6.26	6.92

Table 19. Effect of tillage and irrigation on water saturation deficit (%) at 60, 90 and 120 DAS during 2002-03 and 2003-04.

Treatment	Water saturation deficit (%)					
	2002-03			2003-04		
	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
Tillage						
T_1	9.75	8.27	4.67	10.00	8.22	5.27
T_2	11.30	9.28	6.43	10.77	9.22	5.52
T_3	9.68	8.10	4.57	9.62	7.98	4.67
T_4	11.35	9.65	7.22	11.47	10.07	6.60
SE. m. (±)	0.34	0.34	0.09	0.36	0.28	0.12
CD (P=0.05)	1.18	1.18	0.30	1.24	0.97	0.43
Irrigation						
I_1	11.38	9.53	6.65	11.67	9.50	6.60
I_2	11.28	9.17	6.48	10.82	9.27	6.32
I_3	9.78	8.31	4.97	9.77	8.45	4.75
I_4	9.63	8.29	4.78	9.60	8.28	4.40
SE. m. (±)	0.67	0.29	0.20	0.73	0.23	0.12
CD (P=0.05)	NS	0.85	0.60	NS	0.67	0.43

4.4.3 Relative leaf water content (RLWC)

The affect of different tillage practices and frequency of irrigation on relative leaf water content (RLWC) of winter maize was estimated at 60, 90 and 120 DAS. A perusal of data presented in table 20 showed that different tillage practices and levels of irrigations affected RLWC significantly in both the experimental years.

The crop grown under rotavator tilled plots exhibited maximum RLWC (87.98, 89.57 and 94.67 per cent) and (80.92, 89.66 and 93.36 per cent), which was statistically at par with conventional tillage (85.49, 87.28 and 90.58 per cent) and (86.69, 88.29 and 92.49 per cent) but was significantly superior to zero tillage (85.49, 87.28 and 90.58 per cent) and (86.69, 88.29 and 92.49 per cent) at 60, 90 and 120 DAS during both the years of expeimentation, respectively. However, RLWC in cultivator tilled maize which was statistically at par with zero tillage at 60 and 90 DAS, showed its superiority over zero tillage at 120 DAS in both the years.

Relative leaf water content was significantly higher in crop receiving 6 irrigations (88.93 and 92.90 per cent) and (89.34 and 94.58 per cent) which was found at par with crop receiving 5 irrigations (88.33 and 91.87 per cent) and (88.87 and 94.12 per cent) at 90 DAS and 120 DAS over crop receiving 3 irrigations (83.57 and 86.63 per cent) and (84.41 and 86.29 per cent) and 4 irrigations (86.32 and 87.78 per cent) and (86.27 and 88.76 per cent) during both the years of investigation. However, no significant difference was observed at 60 DAS in both the years due to frequency of irrigation (Table-20).

No significantly interaction was observed in respect of relative leaf water content (RLWC) at any stages of crop growth during the years of investigation.

4.5 Post harvest studies

4.5.1 Number of cobs per plant

Different tillage practices and frequency of irrigation did not shown any significant difference among treatments in respect of number of cobs per plant in winter maize during both the years of investigation (Table-21 & 22).

4.5.2 Length of cob

Different tillage practices i.e. conventional tillage, cultivator tilled and rotavator tilled maize shown significant difference in respect of length of cob in both the years

Table 20. Effect of tillage and irrigation on relative water content (%) at 60, 90 and 120 DAS during 2002-03 and 2003-04.

Treatment	Relative leaf water content (%)					
	2002-03			2003-04		
	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
Tillage						
T_1	85.49	87.28	90.58	86.69	88.29	92.49
T_2	84.04	86.30	88.46	84.87	86.87	91.33
T_3	87.98	89.57	94.61	86.92	89.66	93.36
T_4	80.46	84.00	85.52	80.00	84.07	86.58
SE. m. (±)	1.50	0.94	0.84	1.47	0.83	0.85
CD (P=0.05)	3.99	3.25	2.92	5.09	2.87	2.94
Irrigation						
I_1	83.14	83.57	86.63	83.17	84.41	86.29
I_2	83.46	86.32	87.78	83.92	86.27	88.76
I_3	85.62	88.33	91.87	85.44	88.87	94.12
I_4	85.75	88.93	92.90	85.96	89.34	94.58
SE. m. (±)	1.20	1.19	1.03	1.22	1.17	1.06
CD (P=0.05)	NS	3.49	3.01	NS	3.41	3.09

(Table-17 & 18) rotavator tilled maize exhibited significantly more cob length (17.21 and 17.67 cm) over zero tilled maize (12.72 and 13.27 cm) and followed by conventional tillage (15.42 and 16.90 cm) during both the years of investigation.

Frequency of irrigation exhibited its effect on length of cob in winter maize. Cob length was recorded significantly more in crop receiving 6 irrigations (16.23 and 17.07 cm) but was at par with crop receiving 5 irrigations (16.08 and 16.70 cm) over 3 and 4 irrigations (14.70 and 15.27 cm) during both the years of experimentation (Table-21 & 22).

No significant interaction was observed in respect of cob length in both the years.

4.5.3 Diameter of cob/cob girth

Rotavator tilled plots shown its superiority over all other tillage practices in respect of diameter of cob (16.00 and 15.73 cm), which was also found superior over conventional tillage (14.12 and 14.25 cm) during both the years of experimentation, respectively.

Crop receiving 6 irrigations recorded maximum diameter (14.87 and 14.98 cm) but was fund at par with crop receiving 5 irrigations (14.81 and 14.90 cm) during both the years over 3 and 4 irrigation (13.25 and 13.29 cm) respectively (Table- 21 & 22).

4.5.4 Number of grains per cob

Tillage and frequency of irrigation affected number of grains per cob significantly (Table-21 & 22) in both the years.

Rotavator tilled maize recorded maximum number of grains per cob (405.02 and 425.08) over all other tillage practices applied during the experimental years.

Crop receiving 6 irrigations recorded significantly more number of grains per cob (397.42 and 393.67) and was at par with crop receiving 5 irrigations (370.56 and 390.17) over 3 and 4 irrigations (316.24 and 342.08) during both the years, respectively.

No significant interaction was observed in respect of number of grains per cob during the investigation years.

4.5.5 Weight of grains per cob

Different tillage practices and irrigation level affected the grain weight per cob also during both the years (Table-21 & 22).

Grain weight per cob was reported significantly higher in rotavator tilled maize (125.73 and 143.75 g) over all other tillage practices which was followed by conventional tillage (110.95 and 125.05 g) in both the experimental years. However, grain weight per cob was found at par in zero tilled maize (96.35 g) and cultivator tilled maize (108.02 g) during 2002-03 but again tillage practices shown its superiority over zero tillage in 2003-04.

Similarly, grain wt. per cob was reported significantly higher with the crop receiving 6 irrigations (119.45 and 132.05 g) but was found at par with crop receiving 5 irrigations (116.74 and 132.05 g) during both the years over 3 irrigations (99.10 and 107.67 g) and 4 irrigations (103.76 and 116.30 g), respectively. Crop receiving 4 irrigations failed to show its superiority over crop receiving 3 irrigations in both the years.

Interaction between tillage and irrigation frequency led to significant differences in the weight of grain per cob during both the years (Table-23). Weight of grains per cob increased with each successive increase in the number of irrigation in all tillage practices. Among different tillage practices irrespective of irrigation level weight of grains per cob in rotavator tilled plots was higher over conventional, cultivator and zero tilled plots. Maize grown in rotavator tilled plots with 3 irrigation was at par with that of grown in zero tilled plots with six irrigation. Weight of grain per cob in rotavator tilled plots with 4 irrigations (126.27 and 140.1 g in 2002-03 and 2003-04, respectively) was significantly superior over grain weight per cob in zero tilled plots with six irrigations as well as conventional and cultivator tilled plots with 4 irrigations.

4.5.6 Test weight (100 grains)

A perusal of data on test weight of maize as influenced by different tillage practices and frequency of irrigation are presented in table (21 and 22), which revealed that rotavator tilled maize had maximum (34.95 and 36.00 g) and minimum under zero tillage (30.55 and 29.95 g), respectively during both the years. Test weight under conventional tillage (T_1) (32.47 and 33.15 g) which was found at par with rotavator

Table 21. Effect of tillage and irrigation on yield attributing characters during 2002-03.

Treatment	No. of cobs per plant	Length of cob (cm)	Diameter of cob (cm)	No. of grains/cob	Weight of grains/cob (g)	100-grain weight (g)
Tillage						
T_1	2.08	15.42	14.12	341.65	110.95	32.47
T_2	2.08	15.15	13.66	330.62	108.02	32.35
T_3	2.13	17.79	16.00	405.02	125.73	34.95
T_4	1.95	12.72	11.75	299.19	96.35	30.55
SE. m. (±)	0.11	0.66	0.42	15.88	3.89	0.91
CD (P=0.05)	NS	2.28	1.45	54.95	13.46	3.15
Irrigation						
I_1	1.92	14.06	12.60	312.26	99.10	30.78
I_2	2.06	14.70	13.25	336.24	103.76	31.87
I_3	2.10	16.08	14.81	350.56	116.74	33.82
I_4	2.17	16.23	14.87	377.42	119.45	33.83
SE. m. (±)	0.15	0.41	0.53	15.02	2.71	0.58
CD (P=0.05)	NS	1.20	1.55	43.84	7.9	1.69

Table 22. Effect of tillage and irrigation on yield attributing characters during 2003-04.

Treatment	No. of cobs per plant	Length of cob (cm)	Diameter/ Girth of cob (cm)	No. of grains/cob	Weight of grain/cob (g)	100-grain weight (g)
Tillage						
T_1	2.25	16.10	14.25	372.67	125.05	33.15
T_2	2.08	15.52	14.02	350.92	120.47	32.05
T_3	2.32	18.62	15.73	432.08	143.75	36.00
T_4	2.02	13.27	11.90	290.67	97.82	29.95
SE. m. (±)	0.11	0.72	0.39	16.23	5.21	0.72
CD (P=0.05)	NS	2.49	1.35	56.15	18.03	2.49
Irrigation						
I_1	2.08	14.37	12.73	320.42	107.67	30.40
I_2	2.15	15.27	13.29	342.08	116.30	32.12
I_3	2.19	16.70	14.90	390.17	131.57	34.20
I_4	2.25	17.07	14.98	393.67	132.05	34.42
SE. m. (±)	0.12	0.48	0.51	15.47	3.12	0.42
CD (P=0.05)	NS	1.40	1.49	45.14	9.20	1.22

Table 23. Interaction effect of tillage and irrigation on weight of grains/cob (g) during 2002-03 and 2003-04.

Irrigation	Tillage							
	2002-03				2003-04			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
I_1	100.87	97.80	115.47	84.27	114.2	108.5	124.2	83.8
I_2	103.93	100.83	126.27	88.03	119.8	113.2	140.1	92.1
I_3	117.20	115.40	130.27	106.10	133.0	131.0	155.1	107.2
I_4	121.80	118.07	130.92	107.00	133.2	131.2	155.6	108.2
SE. m. (±)	5.42				6.24			
CD (P=0.05)	15.80				18.2			

tilled maize in the first year was significantly lower than rotavator tilled maize during the second year of experimentation.

Similar to tillage, crop receiving 6 irrigations exhibited maximum test weight (33.83 and 34.42 g) and minimum at crop receiving 3 irrigations (30.78 and 30.40 g) in 2002-03 and 2003-04, respectively. The test weight of crop receiving 4 irrigations (31.87 and 32.12 g) were statistically at par with crop receiving 3 irrigations but was significantly lower than crop receiving 5 and 6 irrigation in both the experimental years.

No significant interaction was observed in respect of test weight in both the years of experimentation.

4.6 Yield studies

4.6.1 Kernel/grain yield

The yield of maize (Table-24) 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 (5831 and 5560 kg ha^{-1}) which was followed by conventional tillage (4974 and 5226 kg ha^{-1}) and cultivator tilled maize (4892 and 5138 kg ha^{-1}) during both the years of experimentation. However, conventional tillage did not show any significant increase in yield level over cultivator tilled maize in both the years. Rotavator tilled maize reported an increase in grain yield (60.7 and 63.8 per cent) over zero tilled maize in both the years, respectively.

Similarly, grain yield was recorded significantly higher with crop receiving 6 irrigations (5478 and 5673 kg ha^{-1}) over 3 irrigations (4051 and 4119 kg ha^{-1}) and 4 irrigations (4259 and 4700 kg ha^{-1}) in both the years but was fund at par with crop receiving 5 irrigations (5452 and 5638 kg ha^{-1}) at different stages of crop growth. Crop receiving 3 and 4 irrigations did not differ significantly i.e. at par with each other during both the years of investigation. There was increase of 34.6 per cent grain yield in crop receiving 5 irrigations over crop receiving 3 irrigations in the first year and 36.9 per cent during 2nd year of experimentation.

The interaction between tillage and irrigation frequency exerted significant influence on grain yield in both the years (Table-25). 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

Table 24. Effect of tillage and irrigation on grain yield, stover yield and stone yield during 2002-03 and 2003-04.

Treatment	Grain yield (kg/ha)		Stover yield (kg/ha)		Stone yield (kg/ha)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Tillage						
T_1	4974	5226	7769	8096	1203	1303
T_2	4892	5138	7711	7990	1206	1281
T_3	5831	5960	8586	8808	1342	1373
T_4	3542	3805	6075	6528	1194	1252
SE. m. (±)	88.00	101	164	181	53	46
CD (P=0.05)	304.48	349	568	626	184	159
Irrigation						
I_1	4051	4119	6936	7321	1108	1201
I_2	4259	4700	7221	7631	1187	1282
I_3	5452	5638	7917	8190	1319	1350
I_4	5478	5673	8068	8280	1330	1378
SE. m. (±)	112	86	163	166	26	21
CD (P=0.05)	327	251	476	484	77	61

Table 25. Interaction effect of tillage and irrigation on grains yield (kg/ha) during 2002-03 and 2003-04.

Irrigation	Tillage							
	2002-03				2003-04			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
I_1	4261	4242	4951	2752	4358	4284	4750	3083
I_2	4479	4469	5186	2903	4925	4904	5374	3598
I_3	5572	5428	6590	4215	5800	5642	6850	4259
I_4	5587	5430	6598	4299	5822	5722	6868	4281
SE. m. (±)	224				172			
CD (P=0.05)	654				502			

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 was registered at T_3I_4 to the extent of 6598 and 6868 kg ha^{-1} in first and second year, respectively which was significantly higher than all other treatment combination of tillage and irrigation except T_3I_3 (6590 kg ha^{-1} and 6850 kg ha^{-1} in first and second year, respectively). During second year of experimentation each level of irrigation resulted significant increase in grain yield except with six irrigations in combination with all tillage practices.

4.6.2 Stover yield

As evident from the data table (24) signified that tillage and irrigation significantly affected the stover yield of maize during both the years of experimentation.

A significant higher stover yield was obtained under rotavator tilled maize which was 7769 and 8096 kg ha^{-1} and lowest under zero-tilled maize which was 6075 and 6428 kg ha^{-1} during 2002-03 and 2003-04, respectively. The variation was found significant with all other tillage practices over zero tillage. Conventional tillage and cultivator tilled maize did not exhibited any significant difference in stover yield in both the years.

Similarly, the crop receiving 6 irrigations resulted in significantly higher stover yield (8068 and 8280 kg ha^{-1}) over all other frequencies of irrigation applied here in the experiment except crop receiving 5 irrigations (7917 and 8190 kg ha^{-1}) during both the years. Crop receiving 3 irrigations and 4 irrigations again did not exhibited any significant difference with each other in both the years of experimentation.

Interaction between tillage and irrigation was noticed significant in both the years of experimentation (Table-26). Irrespective of tillage practices, stover yield increased with increasing level of irrigation. Maximum stover yield was recorded at T_3I_4 (9400 and 9458 kg ha^{-1} in 2002-03 and 2003-04 respectively), which was again significantly superior over all other treatment combinations but statistically at par with T_3I_3. Stover yield of rotavator, conventional and cultivator tilled maize was significantly superior than grain yield of zero tilled maize at all levels of irrigation. Stover yield of rotavator tilled maize was statistically at par with conventional and

cultivator tilled maize upto four irrigations but at 5 and 6 irrigations level stover yield of rotavator tilled maize was significantly higher over that of all other tillage practices applied here during both the years of experimentation.

4.6.3 Stone yield

It is obvious from the table (24) that stone yield of maize was significantly affected by irrigation treatments.

Stone yield, having the maximum under rotavator tilled maize (1342 and 1373 kg ha^{-1}) was reported highest and minimum under zero - tilled maize (1194 and 1252 kg ha^{-1}) during both the years but all the tillage treatments were found at par with each other.

Crop receiving 6 irrigations fetched maximum stone yield (1330 and 1376 kg ha^{-1}) which were significantly superior to 3 irrigations (1108 and 1201 kg ha^{-1}) and 4 irrigations (1187 and 1282 kg ha^{-1}) during both the years, respectively but were found at par with crop receiving 5 irrigations (1319 and 1350 kg ha^{-1}) in both the years, respectively.

4.6.4 Grain : Stover ratio

Significant higher grain : Stover ratio was observed in rotavator tilled maize (0.67) in both the years over all other tillage practices (Table-27). Conventional tillage (0.64 and 0.64) and cultivator tilled maize (0.63 and 0.64) were found at par with each other but shown their superiority over zero-tilled maize (0.59 and 0.58) in both the years, respectively.

Similarly, crop receiving 6 irrigations recorded significantly higher grain : stover ratio (0.68 and 0.69) over 3 irrigations (0.58 and 0.56) and 4 irrigations (0.59 and 0.61) in both the experimental years. Crop receiving 4 irrigations did not exhibited any significant difference to crop receiving 3 irrigations in the first year but showed its significant superiority over 3 irrigations in the 2nd year of experimentation.

No significant interaction was observed in respect of grain : stover ratio in both the years.

4.6.5 Grain : Stone ratio

It is obvious from the data table (27) that different tillage practices exhibited their effect on grain : stone ratio in winter maize. Rotavator tilled maize achieved highest grain : stone ratio (4.35 and 4.34) over zero-tilled maize (2.95 and 3.04) and was followed by conventional tillage (4.14 and 4.01) and cultivator tilled maize (4.07 and 4.01) in both the years, respectively. All the tillage treatments were significantly superior over zero-tillage in both the years of investigation.

Similarly, crop receiving 5 and 6 irrigations recorded significantly higher grain : stone ratio (4.13 and 4.12) in the first year and (4.17 and 4.11) in the 2nd year over 3 irrigations (3.65 and 3.42) in both the years, crop receiving 4 irrigations (3.66) showed its superiority over 3 irrigations (3.42) in the 2nd year of experimentation which was at par during the 1st year of experimentation.

No significant interaction was observed in respect of grain : stone ratio during the course of investigation.

4.6.6 Harvest index

As evident from the data given in table 27 signified that different tillage treatments and frequency of irrigation significantly affected the harvest index during both the years of experimentation.

Significantly higher harvest index was recorded in rotavator tilled maize (37.00 and 36.92 per cent) over all other tillage treatments in both the years. Conventional tillage (35.66 and 35.73 per cent) also exhibited significant increase in harvest index over cultivator tilled maize (35.44 and 35.65 per cent) in both the years. All the tillage treatments were significantly superior over zero-tillage maize (32.74 and 32.84 per cent) in both the years, respectively.

Similarly, crop receiving 5 and 6 irrigations being at par with each other (37.11 and 37.00 per cent) and (37.10 and 37.00 per cent) during first and second year, of experimentation shown its superiority over 3 irrigations (33.49 and 32.58 per cent) and 4 irrigations (33.62 and 34.52 per cent) in both the years respectively. Harvest index was recorded statistically at par with crop receiving 3 and 4 irrigations in first year of experiment but crop receiving 4 irrigations shown its superiority over 3 irrigations in 2nd year of investigation.

Table 26. Interaction effect of tillage and irrigation on stover yield (kg/ha) during 2002-03 and 2003-04.

Irrigation	Tillage							
	2002-03				2003-04			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
I_1	7743	7639	7824	6077	7255	7253	7576	5658
I_2	7900	7796	8498	6331	7608	7388	8041	5847
I_3	8330	8224	9454	6754	8088	8083	9327	6168
I_4	8411	8301	9458	6952	8124	8120	9400	6626
SE. m. (±)	333				326			
CD (P=0.05)	972				951			

Table 27. Effect of tillage and irrigation on grain : stover, grain : stone and harvest index during 2002-03 and 2003-04.

Treatment	Grain : Stover		Grain : Stone		H.I. (%)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Tillage						
T_1	0.64	0.64	4.14	4.01	35.66	35.73
T_2	0.63	0.64	4.07	4.01	35.44	35.66
T_3	0.67	0.67	4.35	4.34	37.00	36.92
T_4	0.59	0.58	2.95	3.04	32.74	32.88
SE. m. (±)	0.01	0.01	0.20	0.17	0.32	0.18
CD (P=0.05)	0.03	0.03	0.71	0.59	1.10	0.65
Irrigation						
I_1	0.58	0.56	3.65	3.42	33.49	32.58
I_2	0.59	0.61	3.58	3.66	33.62	34.52
I_3	0.68	0.69	4.13	4.17	37.11	37.10
I_4	0.68	0.69	4.12	4.11	37.00	37.00
SE. m. (±)	0.01	0.01	0.05	0.07	0.36	0.17
CD (P=0.05)	0.03	0.03	0.11	0.20	1.05	0.50

The interaction between tillage and irrigation was significant during 2003-04 only when harvest index of all tillage treatments increased significantly with each increasing level of irrigation except 6 irrigations which was at par with harvest index of crop receiving 5 irrigations. Rotavator tilled maize with 5 irrigations (T_3I_4) recorded maximum harvest index (38.81 per cent) which was significantly superior over all treatment combinations except T_3I_4 (38.78 per cent). Harvest index of rotavator tilled maize with 3 irrigations (35.48 per cent) was found significantly higher than that of zero tilled maize with 6 irrigations (34.37 per cent). Rotavator tilled maize exhibited in significantly higher harvest index than other tillage practices at each level of irrigation except T_1I_2 and T_2I_2 (Table-28).

4.7 Irrigation studies

4.7.1 Water expense efficiency (WEE)

A perusal of the table (29) and fig. (6) on water expense efficiency (WEE), indicated that there was significant effect on WEE due to different tillage practices. Maximum WEE was reported under rotavator tilled maize (114.10 and 124.68 kg ha^{-1} cm^{-1}) which was found significantly superior over all other tillage practices. The minimum WEE was reported under zero tillage maize (82.50 and 90.74 kg ha^{-1} cm^{-1}) in both the years of experimentation, respectively. The magnitude of increase of WEE over zero tillage to rotavator tilled maize was (50.27 and 37.35 per cent) and to conventional tillage (39.8 and 27.8 per cent), respectively in both the years.

Water expense efficiency was reported highest under crop receiving 5 irrigations and was found significantly superior (91.32 and 100.58 kg $ha^{-1}cm^{-1}$) over all other higher frequencies of irrigation in both the years except crop receiving 3 irrigations which was found at par with each other (88.44 and 97.56 kg $ha^{-1}cm^{-1}$), respectively.

No significant interaction was observed in respect of water expense efficiency in both the years of experimentation.

4.7.2 Water use efficiency (WUE)

Likewise, water use efficiency was also affected due to different tillage practices and frequency of irrigations (Table-29) and fig. (7).

Significantly higher WUE was reported under rotavator tilled maize (114.10 and 124.68 kg $ha^{-1}cm^{-1}$) and was followed by conventional tillage (96.58 and 108.20 kg

Table 28. Interaction effect of tillage and irrigation on harvest index (%) during 2003-04.

Irrigation	Tillage			
	T_1	T_2	T_3	T_4
I_1	32.86	32.83	34.58	30.04
I_2	35.15	35.13	35.48	32.34
I_3	37.47	37.33	38.81	34.77
I_4	37.47	37.36	38.78	34.37
SE. m. (±)	0.34			
CD (P=0.05)	0.99			

Table 29. Effect of tillage and irrigation on water use efficiency (WUE) and water expense efficiency (WEE) in winter maize during 2002-03 and 2003-04.

Treatments	WUE (kg/ha-cm^{-1})		WEE (kg/ha-cm^{-1})	
	2002-03	2003-04	2002-03	2003-04
Tillage				
T_1	96.58	108.20	88.66	99.50
T_2	94.08	105.61	86.74	97.55
T_3	114.10	124.68	107.40	114.61
T_4	66.83	76.40	53.34	71.80
SE. m. (±)	2.83	3.20	1.70	2.12
CD (P=0.05)	9.79	11.07	5.88	7.33
Irrigation				
I_1	92.91	102.41	88.44	97.56
I_2	86.56	102.35	80.51	95.14
I_3	110.80	109.58	91.32	100.58
I_4	90.99	99.57	82.50	90.74
SE. m. (±)	1.68	2.95	1.31	1.76
CD (P=0.05)	4.90	7.44	3.82	5.13

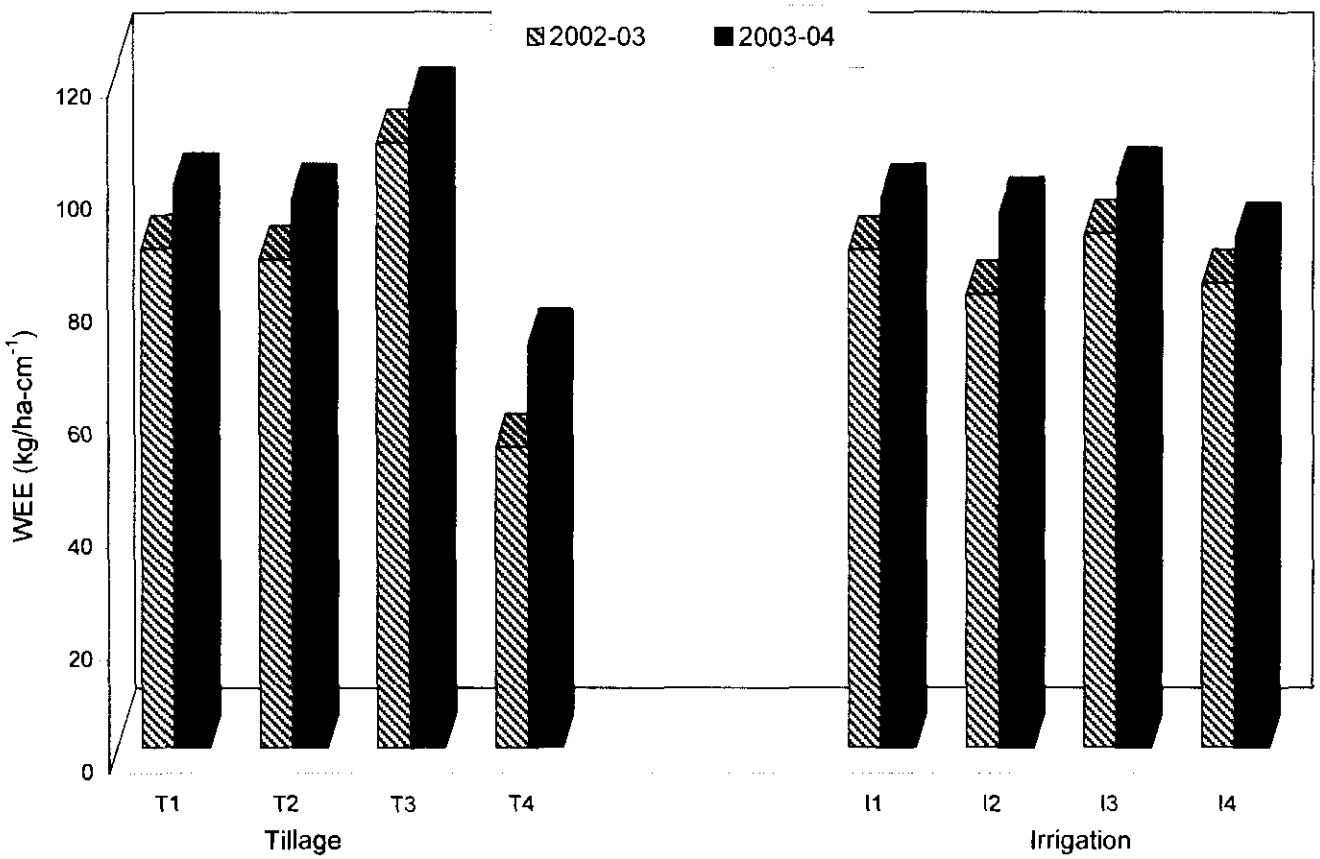

Fig. 6. Effect of tillage and irrigation on water expense efficiency of winter maie during 2002-03 and 2003-04

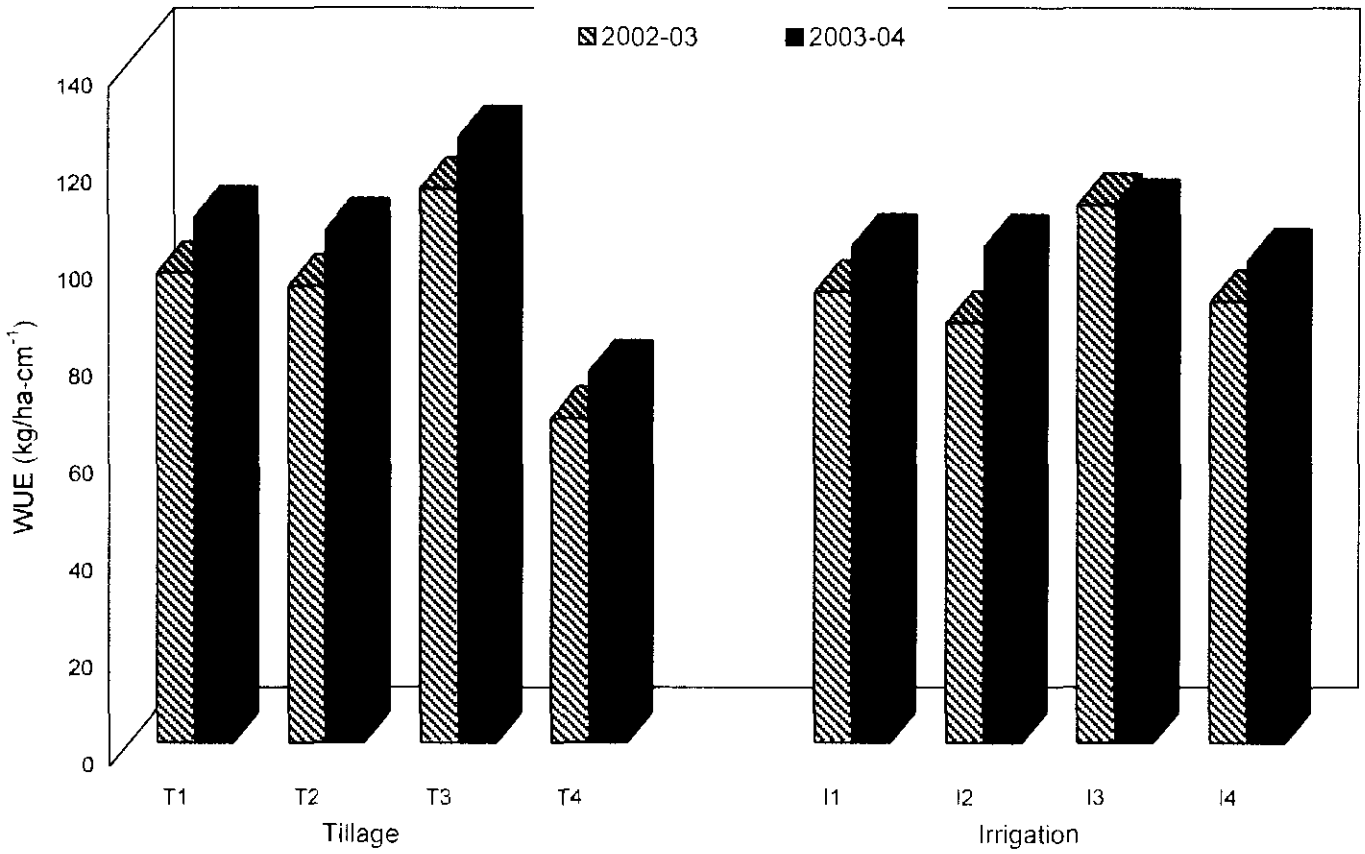

Fig. 7. Effect of tillage and irrigation on water use efficiency at harvest of winter maize during 2002-03 and 2003-04

$ha^{-1}cm^{-1}$) and cultivator tilled maize (94.08 and 105.61 kg $ha^{-1}cm^{-1}$) over zero tilled maize (66.03 and 76.40 kg $ha^{-1}cm^{-1}$) which was 41.4 and 38.72 per cent more in rotavator tilled maize during first and 2nd year of experimentations, respectively.

However, more number of irrigations to maize crop lead to significantly decrease in water use efficiency with successive increase in number of irrigations. Significantly highest WUE was reported under crop receiving 5 irrigations (110.80 and 109.58 kg $ha^{-1}cm^{-1}$), which was found at par with 3 irrigations (102.41 kg $ha^{-1}cm^{-1}$) in the 2nd year only and lowest under crop receiving 6 irrigations (90.99 and 44.57 kg ha^{-1} cm^{-1}) in both the years of experimentation, respectively.

However, no significant interaction was reported in both the year of investigation.

4.8 Qualitative studies

4.8.1 Protein content in grains

A perusal from the data table 30 & 31 no significant differences were observed among the tillage practices during both the years of investigation in respect of protein content in grains.

However, frequency of irrigation affected protein content in maize grains. Significant higher protein content was recorded under crop receiving 6 irrigations (8.58 and 8.69 per cent) which was found at par with crop receiving 5 irrigations (8.55 and 8.55 per cent) over 3 irrigations (7.27 and 7.23 per cent) and 4 irrigations (7.64 and 7.60 per cent) during both the years of experimentation, respectively.

No significant interaction was observed in respect of protein content in grains during the course of investigation.

4.8.2 Nitrogen uptake by plants

4.8.2.1 N-uptake by grains

A significant higher N-uptake by grain was recorded under rotavator tilled maize (69.38 and 71.52 kg ha^{-1}) which was followed by conventional tillage and cultivator tilled maize over zero tillage maize (38.96 and 41.47 kg ha^{-1}) in both the years, respectively (Table-30 & 31).

Similarly, N-uptake by grains was also found significantly higher in crop receiving 6 irrigations (68.47 and 69.78 kg ha^{-1}) and was found at par with crop

receiving 5 irrigations (65.42 and 65.40 kg ha^{-1}) over 3 and 4 irrigations, during both the years of experimentation, respectively.

4.8.2.2 N-uptake by stover

Maximum N-uptake by stover was reported under rotavator tilled plots (40.26 and 41.57 kg ha^{-1}) which was significantly higher over zero-tillage maize (26.73 and 29.24 kg ha^{-1}) in both the years, respectively. Conventional and cultivator tilled maize had followed rotavator tilled maize in both the years being at par with each other (Table-30 & 31).

With each successive level of irrigation (upto 5 irrigations) significantly increased the N-uptake in stover but was statistically at par with crop receiving 6 irrigations (37.83 and 38.91 kg ha^{-1}) during both the years of experimentation, respectively.

4.8.2.3 Total nitrogen uptake

Total nitrogen uptake by plants was affected by different tillage practices (Table 30 & 31). Significantly higher N-uptake by plants was recorded under rotavator tilled maize (109.58 and 113.09 kg ha^{-1}) over zero tillage maize (65.69 and 70.71 kg ha^{-1}) during both the years of experimentation, respectively. Different tillage practices except zero-tillage were found statistically at par with each other.

Similarly, crop receiving 6 irrigations (106.30 and 104.69 kg ha^{-1}) was found significantly superior over crop receiving 3 irrigations (73.74 and 76.68 kg ha^{-1}) and 4 irrigations (80.19 and 87.89 kg ha^{-1}) during both the years, but was found statistically at par with crop receiving 5 irrigations at different critical stages (101.99 and 103.48 kg ha^{-1}) of crop growth (Table 30 & 31).

No significant interaction was recorded in respect of total N-uptake by plants in both the years of investigation.

4.8.3 Phosphorus uptake by plants

4.8.3.1 P-uptake by grains

P-uptake in grain was found significantly higher in rotavator tilled maize (23.09 and 23.66 kg ha^{-1}) over all the tillage practices taken into consideration here, during both the years of experimentation (Table 30 & 31). Whereas, conventional tillage (19.05 and 20.66 kg ha^{-1}) and cultivator tilled maize (18.68 and 19.63 kg ha^{-1}) did not

exhibited any significant difference during both the years of experimentation, respectively i.e. at par with each other.

Likewise tillage, different irrigation frequencies also differed significantly in respect of P-uptake by grains (Table 30 & 31). Each level of irrigation showed its superiority over its lower level of irrigation. The crop receiving 6 irrigations (22.24 kg ha^{-1}) was found significantly superior over all other lower frequency of irrigation in the first year but during the 2nd year of experimentation crop receiving 6 irrigations (23.08 kg ha^{-1}) was found at par with crop receiving 5 irrigations (21.98 kg ha^{-1}), respectively.

No significant interaction was observed in respect of P-uptake by grains during the course of investigation.

4.8.3.2 P-uptake by stover

Different tillage practices and frequency of irrigation either in combination or individually did not differed significantly in respect of P-uptake by stover in both the years of experimentation (Table 30 & 31).

4.8.3.3 Total P-uptake

Total P-uptake by maize crop was significantly higher in rotavator tilled maize (40.94 and 42.15 kg ha^{-1}) which was again followed by conventional tillage (34.97 and 37.06 kg ha^{-1}) and cultivator tilled maize (34.49 and 35.92 kg ha^{-1}) over zero tilled maize (25.04 and 26.88 kg ha^{-1}) during both the years of experimentation, respectively (Table 30 & 31).

Similarly, higher total P-uptake by plants were recorded by crop receiving 6 irrigations (39.34 and 40.79 kg ha^{-1}) over all other lower frequencies of irrigation except crop receiving 5 irrigations (37.77 and 39.09 kg ha^{-1}) during both the years of experimentation, respectively. The crop receiving 3 and 4 irrigations were found statistically at par with each other (27.92 and 30.53 kg ha^{-1}) during first year of experimentation, respectively but crop receiving 4 irrigations showed its superiority (33.35 kg ha^{-1}) over crop receiving 3 irrigations (29.01 kg ha^{-1}) in the 2nd year of experimentation.

No significant interaction was observed in respect of total P-uptake by plants during both the years of experimentation.

Table-30. Effect of tillage and irrigation on nitrogen, phosphorus, potassium uptake and protein content in winter maize during 2002-03.

Treatments	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})			Protein content in grain (%)
	Grain N	Stover N	Total N	Grain P	Stover P	Total P	Grain K	Stover K	Total	
Tillage										
T_1	57.69	35.97	93.66	19.05	15.92	34.97	19.79	66.58	86.37	8.07
T_2	56.80	35.39	92.19	18.68	15.81	34.49	19.56	66.70	86.26	8.00
T_3	69.32	40.26	109.58	23.09	17.85	40.94	23.84	75.12	98.96	8.44
T_4	38.96	26.73	65.69	13.38	11.66	25.04	13.56	50.05	63.61	7.53
SE. m. (±)	3.72	1.52	5.05	0.41	1.85	1.95	1.56	2.85	3.68	0.29
CD (P=0.05)	12.87	5.25	17.47	1.42	NS	6.74	5.34	9.86	12.73	NS
Irrigation										
I_1	42.53	31.21	73.74	14.74	13.18	27.92	15.47	55.97	71.44	7.27
I_2	47.70	32.49	80.19	16.09	14.44	30.53	16.78	60.00	76.78	7.64
I_3	65.42	36.57	101.99	21.31	16.46	37.77	22.02	69.98	92.00	8.55
I_4	68.47	37.83	106.30	22.24	17.10	39.34	22.45	72.53	94.98	8.58
SE. m. (±)	1.70	0.38	2.60	0.15	1.62	1.21	0.52	1.92	1.61	0.29
CD (P=0.05)	4.96	1.10	7.58	0.44	NS	3.53	1.52	5.31	4.69	0.85

Table-31. Effect of tillage and irrigation on nitrogen, phosphorus, potassium uptake and protein content in winter maize during 2003-04.

Treatments	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})			Protein content in grain (%)
	Grain N	Stover N	Total N	Grain P	Stover P	Total P	Grain K	Stover K	Total	
Tillage										
T_1	61.66	37.80	99.46	20.06	17.00	37.06	20.85	70.03	90.88	8.12
T_2	59.08	36.91	95.55	19.63	16.30	35.92	20.34	68.95	89.29	8.02
T_3	71.57	41.57	113.09	23.66	18.49	42.15	24.43	77.42	101.85	8.42
T_4	41.47	29.24	70.71	14.45	12.73	26.88	14.69	54.12	68.81	7.51
SE. m. (±)	3.66	1.38	5.32	0.32	1.88	1.82	1.32	2.52	3.63	0.30
CD (P=0.05)	12.66	4.77	18.41	1.11	NS	6.29	4.56	8.71	12.55	NS
Irrigation										
I_1	43.66	33.02	76.68	15.11	13.90	29.01	15.73	59.30	75.03	7.23
I_2	52.64	35.25	87.89	17.86	15.44	33.35	18.56	63.56	82.12	7.60
I_3	65.40	38.08	103.48	21.98	17.11	39.02	22.89	72.72	95.61	8.55
I_4	69.78	38.91	104.69	23.08	17.71	40.79	23.31	74.93	98.24	8.69
SE. m. (±)	1.82	0.52	5.21	0.38	1.40	1.41	0.41	2.72	1.80	0.27
CD (P=0.05)	5.31	1.51	15.20	1.11	NS	4.11	1.20	7.93	5.25	0.79

4.8.4 Potassium uptake by plants

4.8.4.1 K-uptake by grains

Potassium uptake by grains were found significantly higher in rotavator tilled maize (23.84 and 24.43 kg ha^{-1}) which was followed by conventional tilled maize (19.79 and 20.85 kg ha^{-1}) and cultivator tilled maize (19.56 and 20.34 kg ha^{-1}) over zero tilled maize (13.56 and 14.69 kg ha^{-1}), respectively during both the years of experimentation.

Similarly, crop receiving 6 irrigations resulted in significantly higher K-uptake by grains (22.45 and 23.31 kg ha^{-1}) and were found at par with crop receiving 5 irrigations (22.02 and 22.89 kg ha^{-1}) over crop receiving 3 irrigations (15.47 and 15.73 kg ha^{-1}) and 4 irrigations (16.78 and 18.56 kg ha^{-1}) in both the years of experimentation, respectively. Crop receiving 3 irrigations and 4 irrigations were found statistically at par with each other during the first year of experimentation, but crop receiving 4 irrigations (18.56 kg ha^{-1}) showed its superiority over crop receiving 3 irrigations (15.73 kg ha^{-1}) in the second year of experimentation.

However, no significant interaction was observed in respect of K-uptake by grains during the both years of experimentation.

4.8.4.2 K-uptake by stover

On the basis of data presented in (Table 30 & 31) it is obvious that rotavator tilled maize recorded maximum K-uptake by stover (75.12 and 77.42 kg ha^{-1}) and was followed by conventional tilled maize (66.58 and 70.03 kg ha^{-1}) and cultivator tilled maize (66.70 and 68.95 kg ha^{-1}) which were found significantly superior over zero-tilled maize (50.05 and 54.42 kg ha^{-1}) in both the years of experimentation.

Likewise, crop receiving 6 irrigations exhibited in significantly higher K-uptake by stover (72.53 and 74.93 kg ha^{-1}) and was found statistically at par with crop receiving 5 irrigations (69.98 and 72.72 kg ha^{-1}) over 3 irrigations (55.97 and 59.30 kg ha^{-1}) and 4 irrigations (60.00 and 63.56 kg ha^{-1}) in both the years, respectively.

No significant interaction was recorded during course of investigation.

4.8.4.3 Total K-uptake

Significant higher K-uptake by plants, were recorded in rotavator tilled maize (98.96 and 101.95 kg ha^{-1}) over all other tillage treatments in both the years, respectively (Table 30 & 31).

Similarly, crop receiving 5 and 6 irrigations having at par with each other resulted in significantly higher K-uptake by plants (92.00 and 94.98 kg ha^{-1}) and (95.61 and 98.24 kg ha^{-1}) over 3 irrigations (71.44 and 75.03 kg ha^{-1}) and 4 irrigations (76.78 and 82.12 kg ha^{-1}) in both the years, respectively.

No significant interaction was observed during both the years of experimentation.

4.9 Economics

4.9.1 Gross return

It is evident from the table 32 & 33 that there was significant increase in gross return due to different tillage practices during both the years. As a result rotavator tilled maize fetched the maximum gross return (Rs.31.203 and 32.523 ha^{-1}) which were significantly superior to conventional tilled maize by 14.5 and 11.3 per cent, cultivator tilled maize by 15.20 and 12.6 per cent and zero tillage maize by 37.9 and 33.7 per cent in 2002-03 and 2003-04, respectively.

Similarly, crop receiving 6 irrigations had the maximum gross return (Rs. 29,340 and 30,934 ha^{-1}) and minimum with crop receiving 3 irrigations (Rs. 22,251 and 23,409 ha^{-1}) during first and 2nd year of experimentation, respectively which were found significantly higher over 3 irrigations and 4 irrigations too.

4.9.2 Net return

Data on net return as affected by tillage and irrigation were presented in table 32 & 33 denote that rotavator tilled maize had the maximum (Rs. 16,173 and 17,493 ha^{-1}) net return which was significantly superior to conventional tillage by fetching 27.84 and 22.53 per cent more net return, respectively in both the years. All the tillage practices were found significantly superior over zero tilled maize (Rs. 5,014 and 6,980 ha^{-1}) in respect of net return in both the years, respectively. Conventional tillage and cultivator tilled maize do not differ significantly in respect of net return during both the years.

Similarly, crop receiving 5 irrigations resulted in significantly higher net return (Rs. 13,717 and 15,311) over 3 irrigations (Rs. 8,091 and 9,249) and 4 irrigations (Rs. 8,722 and 11,559) during both the years of experimentation, respectively.

4.9.3 Net return per rupee investment (B:C ratio)

It is evident from the table (32 & 33) and fig. (8) that tillage and irrigation affected the B:C ratio in both the years. B:C ratio of rotavator tilled maize was found significantly higher (2.08 and 2.17) over all other tilled practices during both the years, respectively. However, B:C ratio was found statistically at par with conventional tillage and cultivator tilled maize in both the years.

Similarly, crop receiving 6 irrigations fetched significantly higher B:C ratio (1.88 and 1.96) over crop receiving 3 irrigations (1.57 and 1.66) and 4 irrigations (1.60 and 1.78) during both the years of experimentation. Crop receiving 3 and 4 irrigations do not differ significantly with each other. Crop receiving 5 and 6 irrigations were also found statistically at par with each other during both the years of experimentation, respectively.

4.9.4 Gross return per day

Gross return per day was found significantly higher in rotavator tilled maize (Rs. 184 and 197 ha^{-1}) over zero tillage (Rs. 124 and 134.62 ha^{-1}), during both the years respectively.

Similarly crop receiving 5 and 6 irrigations were found significantly superior over 3 and 4 irrigations and followed the same trend as in case of gross return during both the years of experimentation (Table 32 & 33) in respect of gross return per day.

4.9.5 Net return per day

Likewise, net return per day also followed the same trend in respect of tillage practices and irrigation frequencies as in case of net return during both the years of experimentation. Data is presented in table 32 & 33.

4.9.6 Net return per rupee of investment per day

Net return per rupee of investment per day was significantly higher in rotavator tilled maize over all other tillage practices in 2003-04 but were found at par with each other in 2002-03 except zero-tillage maize (Table 32 & 33).

Similarly, crop receiving 5 irrigations showed significantly increase in return per rupee of investment per day over all other irrigation frequencies which were found statistically at par with each other during 2002-03 but in the year 2003-04 successive increase in frequency of irrigation resulted in significantly higher net return per rupee

Table 32. Effect of tillage and irrigation on gross income, gross income per day, net return, net return per day, net return per rupee of investment, net return per rupee of investment per day during 2002-03.

Treatment	Gross income (Rs.)	Gross income/day (Rs.)	Net return (Rs.)	Net return/day (Rs.)	Net return per rupee of investment / B:C ratio	Net return per rupee of investment/day (Rs.)
Tillage						
T_1	28869	158	11669	68.64	1.77	0.010
T_2	26472	156	11696	68.80	1.79	0.010
T_3	31203	184	16173	95.13	2.08	0.012
T_4	19573	124	5014	30.95	1.37	0.008
SE. m. (±)	457	5.21	251	2.23	0.02	0.001
CD (P=0.05)	1582	18.03	868	7.71	0.07	0.003
Irrigation						
I_1	22251	131	8091	47.59	1.57	0.009
I_2	23369	137	8722	51.30	1.39	0.008
I_3	29751	171	14017	82.45	1.93	0.011
I_4	29340	172	13717	80.68	1.88	0.011
SE. m. (±)	425	5.83	237	3.21	0.02	0.001
CD (P=0.05)	1240	17.01	692	9.36	0.06	0.003

Table 33. Effect of tillage and irrigation on gross income, gross income per day, net return, net return per day, net return per rupee of investment, net return per rupee of investment per day during 2003-04.

Treatment	Gross income (Rs.)	Gross income/day (Rs.)	Net return (Rs.)	Net return/day (Rs.)	Net return per rupee of investment (Rs.)	Net return per rupee of investment/day (Rs.)
Tillage						
T_1	28816	174.64	13615	82.51	1.89	0.011
T_2	28406	172.16	13630	82.10	1.91	0.011
T_3	32523	197.10	17493	106.50	2.17	0.013
T_4	21539	134.62	6980	43.20	1.47	0.009
SE. m. (±)	492	5.22	298	1.65	0.02	0.001
CD (P=0.05)	1702	18.06	1031	5.71	0.07	0.003
Irrigation						
I_1	23409	141.87	9249	56.55	1.66	0.010
I_2	26206	158.82	11559	70.00	1.78	0.011
I_3	30741	186.30	15613	94.58	2.03	0.012
I_4	30934	187.48	15311	91.88	1.96	0.012
SE. m. (±)	456	6.21	248	5.219	0.02	0.001
CD (P=0.05)	1331	18.12	724	15.20	0.06	0.003

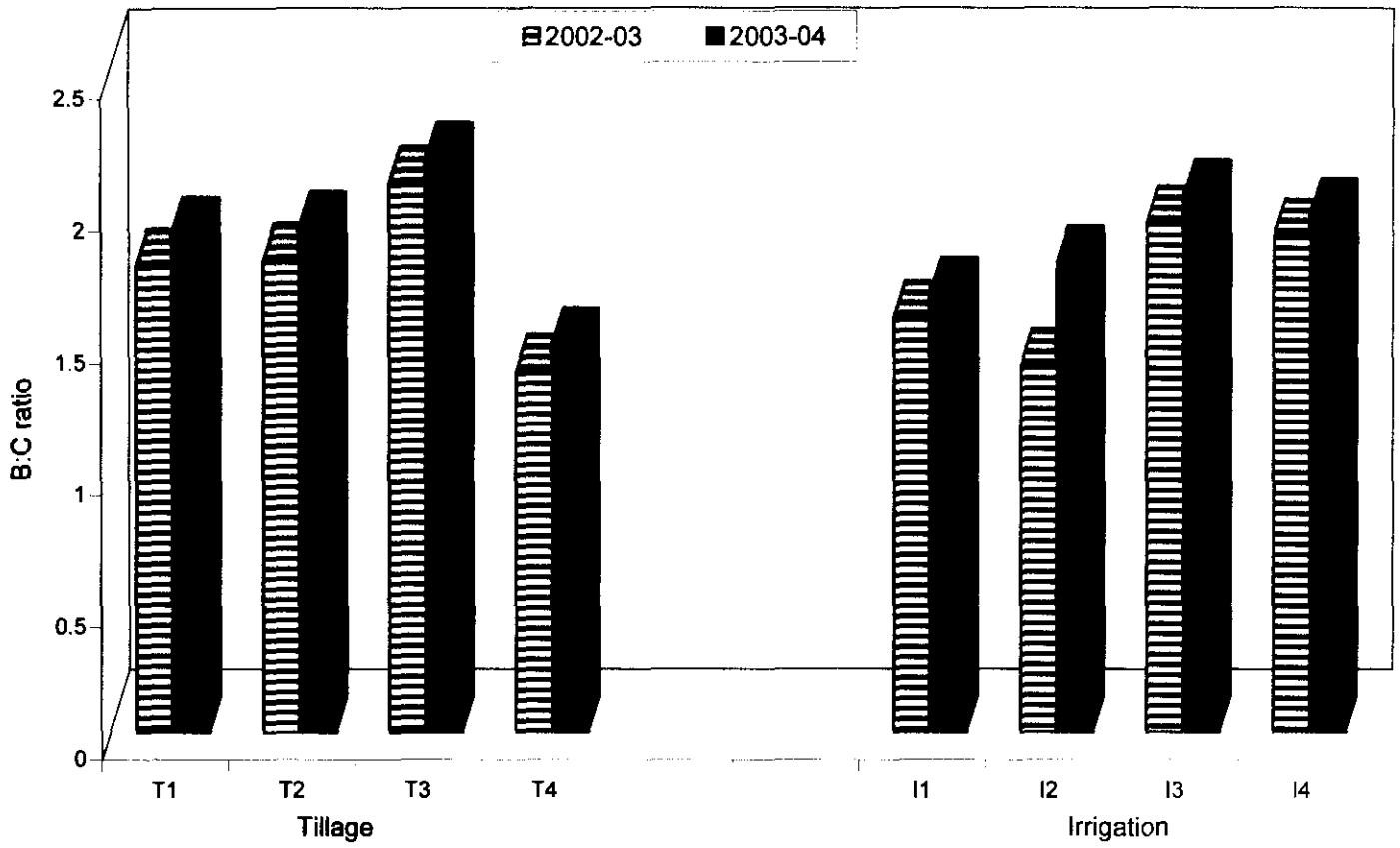

Fig. 8. Effect of tillage and irrigation on Benifit:Cost ratio (2002-03 & 2003-04)

of investment per day upto 5 irrigations, whereas, crop receiving 5 irrigations and 6 irrigations were found at par with each other.

4.10 Correlation studies

A perusal of data (34 & 35) indicates that the grain yield of maize was significantly correlated with soil physical properties, like bulk density (BD), porosity and infiltration rate (IR), plant factors : viz. dry matter accumulation (DM), crop growth rate (CGR), leaf area index (LAI), root volume (RV) and test weight (TW) and plant water status : viz., relative leaf water content (RLWC), water saturation deficit (WSD) and water use efficiency (WUE) during both the years of experimentation.

A cursory glance of correlation table (34 and 35) reveals that yield of maize was significantly but negatively correlated with bulk density and water saturation deficit, while the rest of the parameters taken in study here, showed positive and significant correlation during both the years with few exceptions. The existence of non-significantly correlation bulk density with dry matter accumulation, crop growth rate, leaf area index and relative leaf water content, infiltration rate with LAI and WSD, CGR with RLWC and LAI with RLWC and WSD, RLWC with root volume and WSD with WUE indicated their insignificant role in combination with respective factors during both the years. The coefficient of correlation among all soil and plant characters were significant during the year of study with few exceptions.

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Table 34. Correlation coefficient of different soil and plant characters of winter maize with yield during 2002-03.

Characters	B.D.	Porosity	IR	D.M.	CGR	LAI	RLWC	WSD	RV	WUE	TW
Yield	-.575*	.787**	.792**	.672*	.581*	.589*	.612*	-.612*	.909**	.628*	.928**
Bulk density (B.D.)		-.789*	-.727**	-.580*	-.282	-.442	-.382	.484	-.612*	-.628*	-.579*
Porosity			.815**	.857**	.628*	.629*	.480	.285	.712**	.808**	.844**
Infiltration rate (IR)				.672*	.777**	.619*	.772*	.592*	.618*	.712**	.684*
Dry matter accumulation (DM)					.725**	.413	.372	-.614*	.620*	.580*	.682*
Crop growth rate (CGR)						.685*	.412	-.385	.618*	.684*	.592*
Leaf area index (LAI)							.609*	-.412	.289	.654*	.720*
Relative leaf water content (RLWC)								-.792**	.624*	.582*	.682*
Water saturation deficit (WSD)									-.612*	.342	-.749**
Root volume (RV)										.685*	.787**
Water use efficiency (WUE)											.919**
Test weight (TW)											

Table 35. Correlation coefficient of different soil and plant characters of winter maize with yield during 2003-04.

Characters	B.D.	Porosity	IR	D.M.	CGR	LAI	RLWC	WSD	RV	WUE	TW
Yield	-.612*	.792**	.820**	.692*	.592*	.612*	.702*	-.623*	.912**	.678*	.748**
Bulk density (B.D.)		-.812**	-.747**	-.610*	-384	-.512	-.396	.485	.675*	-.642*	-.592*
Porosity			.853**	.872**	.672*	.652*	.515	.384	.787**	.901**	.873**
Infiltration rate (IR)				.842**	.877**	.688*	.672*	.510	.312	.742**	.648*
Dry matter accumulation (DM)					.751**	.435	.412	.685*	.687*	.613*	.697*
Crop growth rate (CGR)						.697*	.451	.387	.627*	.696*	.597*
Leaf area index (LAI)							.621*	-.512	.318	.678*	.756**
Relative leaf water content (RLWC)								-.808**	.724*	.593*	.697*
Water saturation deficit (WSD)									-.684*	.415	-.752**
Root volume (RV)										.712**	.813**
Water use efficiency (WUE)											.957**
Test weight (TW)											

CHAPTER V

DISCUSSION

DISCUSSION

Winter maize is popular in the calcareous belt of North Bihar, especially among marginal and small farmers due to its higher yield potential. Winter maize, particularly in rice-based cropping system has to face very still competition with tobacco and wheat. Owing to the variations in the maturity of low land rice sowing period of winter maize is generally delayed. Irrigation is a costly affair and mostly ground water is being utilized through diesel operated pump. Tillage operations also consumed a lot of diesel. Therefore, it is imperative to optimize tillage practices and choosing such tillage machinery which is lighter and consume less fuel for economizing irrigation and to increase the efficiency of nutrient uptake by plants without any deleterious impact on soil physical conditions. The findings of the present field experiment conducted during 2002-2003 to 2003-2004 on the same piece of land in *rabi* season have been discussed as follows under various sub-heads :

5.1 Physical conditions of surface soil in relation to tillage treatments

Deterioration in physical condition of soil due to rice cultivation under puddled conditions has been reported by several investigators. Here, tillage practices were performed under moist condition of soil as per tillage treatments. Improvement in soil physical conditions was noted as evidenced (fig.- 9 a & b) by increase in infiltration rate followed by decrease in soil strength and bulk density due to adoption of different tillage practices (Mehta *et al.*, 1992).

5.1.1 Bulk density

Bulk density which is a function of porosity alone was found maximum under zero tillage and minimum under rotavator tilled plots. Conventional tillage had intermediate bulk density dung both the years of experimentation at harvest of maize. Reduction in bulk densities may be attributed to increased soil volume by loosening the soil due to different tillage practices. The result is in agreement with those of Prasad *et al.* (1994) and Wahyuni (2001), who observed that optimum depth of tillage and tillage practices done with light machineries lower bulk densities by increasing porosity in sandy loam and loamy sand soils.

5.1.2 Soil strength

Resistance to penetration is a function of bulk density and moisture content, tended to decrease significantly with increasing frequency of tillage and depth of tillage which resulted minimum under rotavator tilled plots and maximum under zero tillage. Conventional tillage stands at medium position in respect of soil-strength. Though, deeper tillage in comparison to rotavator was done under conventional tillage but due to wheel traffic compaction rotavator tilled plots resulted in significantly lower soil strength in comparison to conventional tillage and cultivator tilled plots. The above finding is in conformity with those of Choudhary *et al.* (1985) and Lal and Van Doren, 1990, who reported that with increase in porosity bulk density decrease and thus soil strength also decreased. In addition to these factors wheel traffic compaction significantly alters structural properties which may eliminate differences between different tillage practices.

5.1.3 Infiltration rate

Infiltration rate is associated with porosity, pore size distribution, and continuity of pore space in the system. Rotavator tilled plots exhibited more infiltration rate followed by conventional tillage (1 disc ploughing + 2 harrowing + planking) and cultivated tilled plots and variation among tillage treatments were observed during both the years of investigation. The increase in infiltration rate attributed to the maximum reduction in bulk density and had pronounced effect as total porosity and macro porosity both, may be correlated with the finding of Bhusan and Sharma (1997) and Nozdrovicky *et al.* (1998). In the 2nd year zero tillage recorded more infiltration rate than that of cultivator tilled plots. This may be due to that zero tillage has deeper root system to absorb moisture from the lower horizon of the soil and thus deeper mining of the roots.

5.2 Growth

Growth parameters of the plants are manifested in plant height, no. of leaves per plant, leaf length, dry matter accumulation, leaf area index, crop growth rate, relative crop growth rate and other vegetative parts which collectively determine the size of photosynthetic structure.

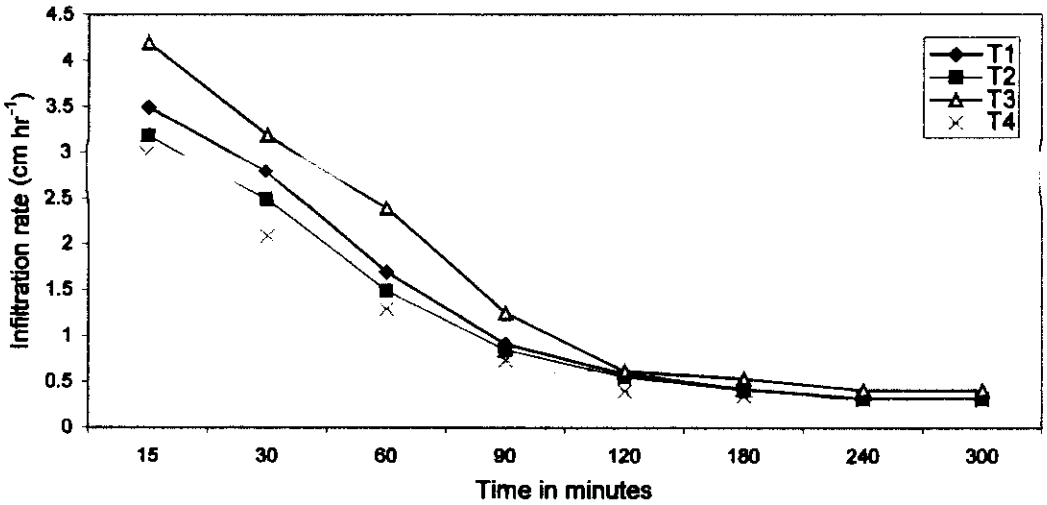

Fig. 9(a). Effect of tillage on infiltration rate with respect to time after harvest of maize (2002-03)

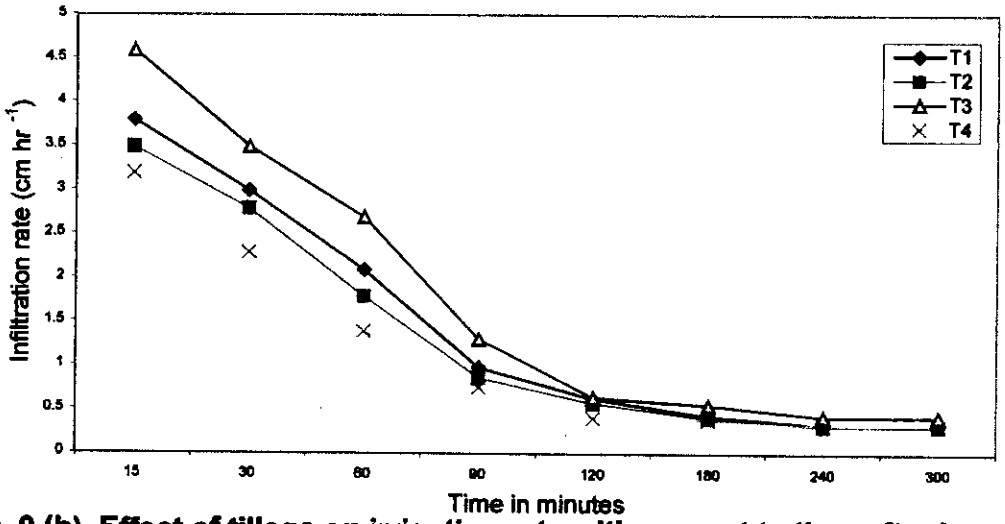

Fig. 9 (b). Effect of tillage on irrigation rate with respect to time after harvest of maize (2003-04)

5.2.1 Plant height, no. of leaves per plant and leaf length

Plant height No. of leaves and leaf length at initial stages 30, 60 and 90 DAS did not differ significantly with increase in frequency of irrigation but at later stages significant differences were recorded. At initial stages all the plots received three equal irrigations and so did not differ significantly but on later stages due to difference in irrigation frequency and time of irrigation significant differences was observed. Maximum vegetative growth was recorded under crop receiving 5 and 6 irrigations. While, tillage has significant effect on vegetative growth in winter maize during both the years due to different tillage practices. Maximum vegetative growth was recorded under rotavator tilled plots. Vegetative growth of maize was affected by soil-water and soil-temperature. Tillage influenced the levels of these parameters during the growth as reported by Barbar and Kovar (1988) and Franzen *et al.* (1993). Corn is most sensitive to water stress specially during the tasseling to silking stage when evaporative demand exceeds rainfall or soil moisture (Wragger and Cassel, 1993).

5.2.2 Dry matter accumulation per plant

Dry matter accumulation per plant is associated with vegetative and reproductive growth of the individual plants. Maximum dry matter accumulation was observed under rotavator tilled plots with 5 to 6 irrigations at critical growth stages. This may be due to the fact that rotavator tilled maize received maximum nutrients from the soil due to better root growth and density of roots with sufficient moisture at each stage of growth. The results are in conformity with the findings of Tarbea *et al.* (1994) and Ruegg *et al.* (1998).

5.2.3 Leaf area index, crop growth rate and relative growth rate

Maximum leaf area index, crop growth and relative growth rate was found in rotavator tilled maize with 5 to 6 number of irrigations at 90 DAS, 60-120 DAS and 60-120 DAS, respectively in both the years. This indicates that when crop get proper nourishment and favourable soil physical condition at optimum moisture level, tended to more vegetative growth of the plants. Srivastava (1991), Save and Sirreno (1986) and Singh SDS (2001) also reported that optimum moisture at good soil physical condition at critical stages of corn increases dry weight, LAI, CGR and RGR of plants by increasing net assimilation rate of the crop which enables more production of photosynthates.

5.2.4 Root volume

Maximum root volume in corn was reported under rotavator tilled maize with 5 and 6 irrigations at different critical stages of crop growth (Table-12). This may be due to the fact that tillage modifies rhizosphere environment to provide good soil tilth for better plant growth and root development at optimum moisture level. This is in conformity with the finding of Choudhary *et al.* (1985), Barber and Kovar (1988), Vogel (1994) and Dwyer *et al.* (1988).

5.2.5 Weed dry weight

Weed dry weight per plot at 120 DAS in winter maize (Table-13) exhibited inverse relation with increasing depth of tillage. Variation in weed dry weight due to frequency of irrigations was also significant. Maximum weed dry weight was reported in plots receiving 5 to 6 irrigations. This may be due to the fact that irrigation also favoured the weed plants with crop in respect of better growth and development. The minimum dry weight of weeds was observed under rotavator tilled plots due to inversion and churning actions of blades which disturbed the soil to a great extent and damage the weed seeds and rhizomes as compared to remaining tillage treatments and may be corroborated with the findings of Mahto and Sinha (1980) and Singh (1987).

5.3 Plant-water status

Crop growth is directly controlled by plant water deficit rather than soil-water. Even under adequate soil-moisture, plant may feel water stress when evaporative demand is higher than rate of ascent of sap. Relative leaf water content (RLWC) and water saturation deficit (WSD), which are inversely related to each other, denote the actual water status of the plants recorded at 60, 90 and 120 DAS in winter maize at 1.30 PM. Although plant-water status differed significantly due to tillage and irrigation (Table 19 & 20) treatments but values of both the parameters (RLWC and WSD) were found maximum and minimum in rotavator tilled maize with 5 to 6 irrigations in both the years, respectively. The maximum value of RLWC with rotavator tilled maize may be attributed to better soil tilth, paralleled by increased water and nutrient absorption due to greater root-soil contact than other tillage treatment, irrigation frequencies under study, while vice-versa is also true for water saturation deficit, where rotavator tilled maize exhibited in lower water saturation deficit and at crop receiving 5 to 6 irrigations. Specific leaf weight of maize also follow the same trend as the pattern followed by

relative leaf water content. This is close agreement to the findings of Danold *et al.* (1987), Sharma and Acharya (1996) and Jayasanker and Ramakrishnyya (1993) who observed higher uptake of water and nutrients under such circumstances.

5.4 Yield and yield attributes

The ultimate growth potential of the cop is the net result of coordinated inter-play of different factors of production under the limits of the genetic potential of the variety. There was significant increase in kernel yield, stover yield and stone yield of winter maize (Table 24) due to different tillage practices and frequency of irrigation.

The maximum grain yield, stover yield, stone yield and harvest index were reported under 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 the maximum root volume, leaf area index, crop growth rate, lesser water saturation deficit and more relative leaf water content, yield attributing characters like number of cobs per plant, length of cob, diameter of cob, number of grains per cob, weight of grains per cob, test weight and finally grain, stover and stone yield in both the years of experimentation. These results are in conformity with Chancy and Comprath (1982), Chaudhary *et al.* (1985), Vogel (1994), Nyakatowa *et al.* (2002).

Like tillage treatments, the maximum grain, stover, stone yield and harvest index were registered under 5 and 6 irrigations (5 irrigations at 30 dAS + knee height + tasseling + Milking + Grain filling stage and 6 irrigation at 30 DAS + knee height and tassel initiation stage + silking + milking + grain filling stage) due to better availability of soil-water and higher uptake of nutrients in association which resulted in higher crop growth parameters, yield attributes and plant-water status as compared to crop receiving 3 and 4 irrigations, which may be corroborated with the finding of Sridhar *et al.* (1991), Reddy and Kuladaivelu (1992), Singh SDS (2001) who also experienced the same findings from their experiments.

The maximum grain yield, stover yield and harvest index was registered at T_3I_4 (rotavator tilled maize with 6 irrigations) to the extent of (6595 and 6868 kg ha^{-1}) and (9400 and 9458 kg ha^{-1}) which were significantly higher than all other treatment combinations of tillage and irrigation except T_3I_3 (rotavator tilled maize with 5 irrigations (6950 and 6850 kg ha^{-1}) and (9327 and 9454 kg ha^{-1}) in both the years,

respectively. On the basis of above interaction results between tillage practices and frequency of irrigation it may be concluded that the number of irrigation may be reduced either by increasing the level of tillage and better soil tilth or by using suitable tillage machineries because yield of maize at T_3I_1 was at per with the next supeior combination T_1I_2 J(conventional tillage with 4 irrigations), thus saving water and energy both at the same time. These findings may be corroborated with the findings that of Wager and Cassel (1993), Prasad *et al.* (1994), Ogola *et al.* (2002) and Camp and Sadler (2002).

5.5 Qualitative studies

5.5.1 Protein content in grains

One of the objective of the conducted field experiment was to improve the quality of the produce by manipulating agronomic practices and by proper management of the natural resources like soil and water on the basis of the result presented in table (30 & 31) it is imperative to say that different tillage practices did not alter protein content in grains significantly in both the years of experimentation, while frequency of irrigation showed reasonable difference among the irrigation treatments. Crop receiving 5 to 6 irrigations (at 30 DAS + Knee height + Teaseling + Milking + Grain filling stage) resulted in higher protein content in grains over all the irrigation frequencies in both the years of experimentation. It may be due to the fact that better soil-moisture at critical period and contact of moist roots to the soil favours the higher uptake of nitrogen in grains which ultimately results in the higher protein content in grains. Manish *et al.* (2002) also reported that when irrigation is scheduled at tasseling and grain filling stage, then N-concentration in leaves and grain protein content increased as compared to irrigation scheduled at other stages of crop growth. In conformity of the result, Mason *et al.* (2002) also reported that irrigation improves the biological value of protein, while higher nitrogen application rates alter amino-acid balance thereby reducing the nutritional value. Kernel breakage susceptibility and kernel density also increase with higher nitrogen fertilizer application and are reduced by irrigation.

5.5.2 Nutrients uptake by plants

Different tillage practices and irrigation frequencies significantly affected the nutrient uptake (N, P & K) in plants and plant parts (Table 30 and 31).

Higher nitrogen uptake (109.64 kg ha^{-1} and 113.09 kg ha^{-1}), phosphorus uptake (40.94 and 42.15 kg ha^{-1}) and potassium uptake (98.96 and 101.85 kg ha^{-1}) was observed during both the years in rotavator tilled maize over zero-tilled maize, respectively. N-uptake in grains exhibited more difference than N-uptake in stover of maize crop during both the years, while more K-uptake was reported in stover than grain K-uptake. Phosphorus uptake by stover did not exhibit any significant differences among the tillage treatments. This may be due to the fact that deeper tillage minimized the chance of applied nitrogen loss with time because bulk of nitrogen applied was utilized by crop in deeper ploughed soil within a short span of time due to better root contact with soil. N, P & K exhibited synergistic effect upon each other, so increase in uptake of one nutrient also improves the rate of uptake of other nutrients at the same time. Ojeniyi (1993) also compared effect of nutrient uptake with minimum tillage to increased tillage and concluded that availability of N, P and K in the soil and the leaf, cob weight and grain yield were increased by increased degree of tillage. The results obtained here may be corroborated with the finding of Prasad *et al.* (1994), Kumar *et al.* (1996) and Mason *et al.* (2002).

Like wise, tillage irrigation frequencies also affected the nutrient uptake by plants and plant parts. Higher N, P & K uptake was reported by crop receiving 5 to 6 irrigations over 3 to 4 irrigations in both the years of experimentation. This may be due to the fact that more nutrient and water uptake at critical stages when there was requirement of nutrients to the plants especially at tasseling and silking stages. Moist roots and better contact of roots favoured higher rate of nutrient uptake in plants and resulted in higher yield and quality. Selvaraju (1992) observed increased stomatal conductance and transpiration rate from 50 to 100 days after sowing of maize which were associated with irrigation scheduling based on critical stages. Significant increase in nutrient uptake with sub-soil compaction and irrigation was also reported by Bhusan and Sharma (1997). The result obtained here, confirms the reality of findings of Manish *et al.* (2002).

5.6 Irrigation studies

Water expense efficiency (WEE) and water use efficiency differed significantly in positive manner due to in different tillage practices but reverse trend was noted with irrigation frequencies.

The higher water expense efficiency (WEE) and water use efficiency (WUE) at 5 stages of irrigation revealed that increase in yield of maize was lesser as compared to increase in water applicants and (6 stages of irrigation), while as the soil tilth get finer due to tillage practices WUE and WEE also increased in the same trend. This may be due to the fact that tillage operations had make better root contact with the soil and that is why more WUE and WEE was observed during both years. Liu W J *et al.* (2002) concluded from their experiment that there is more ET demand at tasseling, silking and grain filling stage and when ET is more and moisture is available in sufficient quantity 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 of function quadratic term. The results obtained from different researchers an WUE and WEE due to tillage and irrigation treatments by Prasad *et al.* (1994) Bherambe *et al.* (1997), Camp *et al.* (2002) and Nyakatawa *et al.* (2002) also confirms the trend of findings reported here.

5.7 Economics

In present investigation, the economic superiority of the highest level of tillage and irrigation over their precessive levels were noted during the years of experimentation. As a result, gross return, net return, net return per rupee of investment, gross return per day, net return per day and net return per rupee of investment per day of winter maize were found to be maximum under rotavator tilled maize than rest of the tillage treatments. Similar to tillage, irrigation at 5 and 6 physiological stages fetched the maximum gross return, net return, B:C ratio, gross return per day, net return per day and net return per rupee of investment per day as compared to crop receiving 3 and 4 irrigations at different physiological stages during the both years of study due to maximum grain and stover yield under rotavator tilled maize under crop receiving 5 to 6 irrigations. Though, there was increase in grain and stover yield with 6 irrigations but yield advantage was not much over crop receiving 5 irrigations on expense incurred in one more irrigation and thus crop receiving 5 irrigations resulted into higher B:C ratio

in both the years of investigation, and so, net return was also higher in crop receiving 5 irrigation over all other irrigation frequencies.

5.8 Correlation and regression

A cursory glance of correlation table 34 and 35 implies positive and highly significant correlation of yield of maize with all the plant factors under study except water saturation deficit which was found negatively correlated among plant factors during both the years of experimentation because all parameters are related to yield. Among soil factors, infiltration rate was positively and significantly correlated with yield due to the fact that infiltration rate is well related with plant growth in positive manner on the other hand higher values of bulk density was noticed as undesirable character of soil in relation to crop growth and development. Therefore, negative correlation with yield of maize were quite expected. Since these physical properties of soil are characteristically interrelated among themselves, therefore either positive or negative correlation existed between them. Similarly, positive correlation between all the plant factor was noted to be higher significant except water saturation deficit in maize leaves. Water saturation deficit did not exhibit any correlation with infiltration rate of the soil there, during the both the years of experiment. Singh (1998) also noticed the same trend from their experiment in maize crop.

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CHAPTER VI

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

Field experiments were conducted for two consecutive years from *rabi* 2002-03 to *rabi* 2003-04 on sub-tropical calcarious sandy loam soil of the experimental farm of Tirhut College of Agriculture, Dholi (Muzaffarpur) under Rajendra Agricultural University, Pusa, Bihar in plot No.1 comprising sixteen treatment combinations of different tillage practices and irrigation frequencies in split-plot design. Tillage was in main plot while, irrigation in sub plots, respectively with their three replications. Each treatment has four level *viz.*, Conventional tillage : 1 disc plough + 2 harrowing + planking (T_1), 2 cultivator + planking (T_2), Rotavator once (T_3) and Zero-tillage (T_4) under tillage treatments and 3 irrigations at pre-knee height (30 DAS) + knee height (kn) + silking stage (I_1), 4 irrigations at 30 DAS + knee height + silking + milking stage (I_2), five irrigations at 30 DAS + knee height + teaseling + milking + grain filling stage (I_3) and 6 irrigations at 30 DAS + knee height + tassel initiation + silking + milking + grain filling stages. The maize variety selected for the experiment was Deoki (composite). The important results of the investigation are summarized as follows :

(i) There was reduction in soil-hardiness (bulk density and soil-strength) with subsequent increase in infiltration rate due to different tillage practices. However, all the tillage practices followed the similar trend in both the years except zero tillage in which infiltration rate was found quite closer to cultivator tilled plots in the 2nd year of experimentation. Rotavator tilled plots was found superior over all other tillage practices in respect of improvement in soil-physical properties under study.

(ii) Plant height, no. of leaves and leaf length were found significantly higher in rotavator tilled plots over zero-tillage practices, while crop receiving 5 to 6 irrigations were found significantly superior over low frequency of irrigation after 60 DAS in both the years.

(iii) Dry matter production per plant (g) was found significantly higher in rotavator tilled plots at all the growth stages over zero tillage and cultivator tilled plots while crop receiving 5 to 6 irrigations showed their superiority

over low frequency of irrigation in respect of dry matter accumulation per plant in both the years.

(iv) Root volume at 90 and 120 DAS was found to be affected significantly in positive manner with finer soil-tilth, here rotavator exhibited best result over all other tillage practices while, crop receiving 5 to 6 irrigations exhibited significantly higher root volume.

(v) Weed dry weight recorded at 120 DAS showed significant reduction as soil-tilth gets finer. Rotavator tilled plots resulted in significantly lower weed dry weight over all other tillage treatments while weed dry weight significantly increased with successive increase in irrigation frequency in both the years.

(vi) Leaf area index (LAI), crop growth rate (CGR) and relative growth rate (RGR) were found significantly higher in rotavator tilled plots and crop receiving 5 to 6 irrigations. CGR also exhibited significant interaction between tillage and irrigation treatments.

(vii) Plant-water status (specific leaf weight (SLW), water saturation deficit (WSD) and relative leaf water content (RLWC) content) at 13.30 hrs. differed significantly. SLW and RLWC was found higher in rotavator tilled plots while WSD was found significantly lower in rotavator tilled plots over zero-tillage.

(viii) All the yield attributing character were found significantly superior in rotavator tilled plots over all other tillage treatments except no. of cobs per plant. Crop receiving 5 to 6 irrigations also favoured the yield attributes towards higher yield significantly over lower frequency of irrigation.

(ix) Test weight (100 grains) was also found significantly higher in rotavator tilled plots over zero tillage and cultivator tilled plots but was at par with conventional tillage, while crop receiving higher frequency of irrigation resulted in higher test weight over lower irrigation frequency in both the years.

(x) Among 16 treatment combinations of tillage and irrigation T_3I_3 fetched the maximum grain and stover yield to the extent of (5831 and 5960 kg ha^{-1}) and (8586 and 8808 kg ha^{-1}) during both the years of experimentation, respectively. Grain yield & stover yield also differed significantly due to increasing frequency of irrigation along with their interactions in both the years of experimentation.

(xi) Grain : Stover and harvest index also exhibited in significantly higher values in case of rotavator tilled plots over all other tillage treatments while, Grain : stone was found significantly higher over zero tilled maize only in both the years. Like wise tillage, grain : stover, grain : stone and harvest index also different significantly in positive manner with each increment in irrigation but 5 and 6 irrigation were found at par with each other statistically. Harvest index also showed significantly interaction between T x I during 2nd year of experimentation.

(xii) The computed data on water expense efficiency (WEE) and water use efficiency (WUE), tended to increase significantly with increasing fineness of the soil. Rotavator tilled maize showed significantly higher WEE and WUE over all other tillage treatments, while these parameters were found minimum at the highest level of irrigation (6 irrigations) but statistically at per with 5 irrigations and 3 irrigations during the years of study.

(xiii) Nutrient uptake (N, P & K) was found significantly higher in rotavator tilled maize over zero-tilled maize and the same was reported to be significantly higher in crops receiving 5 to 6 irrigations during the years of investigation.

(xiv) Protein content in maize grains was found significantly higher in crop receiving higher frequency of irrigation over lower frequency of irrigation (3 to 4) but no significant differences were observed with different tillage practices during both the years of experimentation.

(xv) Different tillage practices and irrigation frequency also proved their economic superiority over their precessive level by fetching significantly higher gross return, net return, net return per rupees of investment of maize cultivation.

(xvi) All plant parameters like dry matter accumulation, crop growth rate, leaf area index and root volume, plant-water status parameters *viz.*, relative leaf water content and water saturation deficit and irrigation parameter like water use efficiency showed their positive and almost significant correlation with grain yield except water saturation deficit among plant factor which was negatively correlated while, soil-physical parameters like bulk density was also negatively correlated with grain yield and infiltration rate was positively correlated under study.

Conclusion

On the basis of the present field experiment, it is imperative to say that under prevailing environmental and soil condition, the practice of tillage with rotavator once and irrigation at five physiological stages is the best combination among the rest of the treatment combinations of tillage and irrigation under study for better soil tilth and soil-water-plant relationship by maintaining higher plant-water status and water use efficiency which have been ultimately reflected in higher yield and profitability of maize cultivation. As there was progressive response of tillage practices towards finer tilth with different tillage machineries and irrigation frequency in the present investigation, it is clear that in future, some trials should be conducted with other tillage equipments at different depths and irrigation frequencies or different levels of irrigation along with higher levels of input for yield maximization and in turn profitability.

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Note : *Original not seen

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APPENDICES

Appendix - 1

Meteorological observation during the crop seasons.

Month	Temp. (°C)				R.H. (%)				R.F. (mm)		Evap (mm.)
	Max.	Normal	Min.	Normal	At 2 PM	Normal	At 7 AM	Normal	Actual	Normal	
						2002-2003					
Oct.'02	31.6	32.0	21.4	20.7	72.8	62	91.2	88.0	16.5	74.7	2.8
Nov.'02	29.0	29.0	16.0	13.5	74.0	49	91.8	87.0	-	12.7	1.9
Dec.'02	24.0	24.6	10.1	10.3	81.0	53	96.0	88.0	-	7.0	1.2
Jan.'03	16.3	22.8	6.1	7.7	81.6	68	95.7	90.0	8.0	10.7	1.0
Feb.'03	24.2	25.6	12.0	9.8	77.7	46	94.6	89.0	81.0	13.4	2.1
Mar.'03	29.9	31.3	14.8	14.4	76.7	44	91.0	84.0	4.5	5.5	3.8
Apr.'03	39.9	36.0	20.3	20.3	44.2	54	89.5	77.0	70.0	15.8	5.2
May, 03	35.5	36.6	21.6	23.0	45.0	49	95.2	82.0	35.5	108.0	5.7
						2003-2004					
Oct.'03	29.1		20.6		67.7		98.8		14.14		2.3
Nov.'03	28.8		15.1		68.13		95.8		-		2.1
Dec.'03	29.1		9.7		57.32		92.06		70.0		1.2
Jan.'04	18.5		8.8		76.74		97.12		14.0		0.8
Feb.'04	24.7		11.3		58.89		99.65		-		1.7
Mar.'04	31.9		17.0		49.12		93.25		-		3.8
Apr.'04	32.7		21.06		76.03		96.03		44.04		4.2
May, 04	35.19		23.61		61.4		88.9		116.3		5.4

Appendix - II

Cost of cultivation (Rs/ha) of maize cultivation.

	Particulars	Total Cost (Rs.)
1.	**Seed-bed preparation**	
(a)	5 man days for by out and leveling of field @ Rs. 60/day)	1,840.00
(b)	Tillage operations	
(i)	1 Disc ploughing + 2 harrowing + planking alongwith then power	960.00
(ii)	Cultivator twice + planking + 1 man power	560.00
(iii)	Rotavator once + 1 man power	860.00
(iv)	Zero-till planter + 1 man power	360.00
2.	**Seed and sowing**	
(a)	Seed @ 20 kg/ha (Rs. 20/kg)	400.00
(b)	20 man days for sowing of seeds	1,200.00
3.	Preparation of bunds and irrigation channels (10 man days)	600.00
4.	Earthing up (10 man days)	600.00
5.	Irrigation @ Rs. 400 per irrigation + 1 man day	460.00
(i)	3 irrigations	1,300.00
(ii)	4 irrigations	1,840.00
(iii)	5 irrigations	2,300.00
(iv)	6 irrigations	2,760.00
6. (a)	Cost of fertilizers (120:75:50 kg/ha)	
	Urea = 155 kg @ 260/50 kg	806.00
	DAP = 163 kg @ 510/50 kg	1,662.00
	MOP = 84 kg @ 260/50 kg	440.00
	Total :	**2,908.00**
(b)	6 man days for fertilizer application twice @ Rs. 60/day	360.00
7.	10 man days for manual weeding	600.00
8.	Plant protection measures	
(a)	Heptachlore (soil in corporation @ 25 kg/ha) @ Rs. 10/kg.	250.00
(b)	Spray twice with Diathane-M-45 including price and cost of application	600.00
(c)	Bavistin for seed treatment @ 3 g/kg of seeds	300.00
9.	Harvesting (25 man days)	1,500.00
10.	20 man days for shelling of cobs, winnowing and cleaning	1,200.00
11.	Land revenue for six month @ Rs. 500/ha	500.00
	General cost excluding cost of tillage practice and irrigation	11,310.00
12.	Interest on working capital @ 12 % for six month	Given in table

Contd.....

Treatment wise cost of cultivation

Treatments	General cost (Rs.)	Cost incurred in tillage practice (Rs.)	Cost incurred in irrigation (Rs.)	Interest on working capital @ 12% (six monthly) (Rs.)	Total cost of cultivation (Rs.)
	(1)	(2)	(3)	(4)	(5)
T_1I_1		12,270	1,380	819	14,469
T_1I_2		12,270	1,840	846	14,956
T_1I_3		12,270	2,300	874	15,444
T_1I_4		12,270	2,760	902	15,932
T_2I_1		11,870	1,380	794	14,044
T_2I_2		11,870	1,840	822	14,532
T_2I_3		11,870	2,300	850	15,020
T_2I_4	11,310	11,870	2,760	877	15,507
T_3I_1		12,110	1,380	809	14,299
T_3I_2		12,110	1,840	836	14,786
T_3I_3		12,110	2,300	864	15,274
T_3I_4		12,110	2,760	892	15,762
T_4I_1		11,670	1,380	779	13,829
T_4I_2		11,670	1,840	806	14,316
T_4I_3		11,670	2,300	833	14,803
T_4I_4		11,670	2,760	860	15,290

Note:- Selling price of maize grain @ Rs. 450/qt.
Selling price of maize straw and stone @ Rs. 50/qt.

Appendix - III

Total water expense under winter maize cultivation during 2002-03 and 2003-04

Treatments	2002-03					2003-04				
	Av. Rainfall cm	Depth of Irrigation water (cm)	Profile water depletion (cm)	Leached water beyond root zone (cm)	Total water expense (cm)	Av. Rainfall cm	Depth of Irrigation water (cm)	Profile water depletion (cm)	Leached water beyond root zone (cm)	Total water expense (cm)
T_1I_1		18	7.0	2.6	45.9		18	7.6	2.5	42.1
T_1I_2		24	6.5	4.0	52.8		24	7.3	3.8	49.3
T_1I_3		30	5.8	5.3	59.4		30	7.0	4.8	56.0
T_1I_4		36	5.5	6.5	66.3		36	6.5	6.0	62.7
T_2I_1		18	7.4	2.2	45.9		18	8.0	2.0	42.2
T_2I_2		24	7.0	3.8	53.1		24	7.8	3.5	49.5
T_2I_3		30	6.5	5.2	60.0		30	7.2	4.8	56.2
T_2I_4	18.3	36	6.0	6.2	66.5	14.2	36	6.8	5.8	62.8
T_3I_1		18	6.5	2.5	45.3		18	7.4	2.3	41.9
T_3I_2		24	6.2	4.0	52.5		24	7.0	3.8	49.0
T_3I_3		30	5.4	5.2	58.9		30	6.4	5.0	55.6
T_3I_4		36	5.1	6.5	65.9		36	5.8	5.5	61.5
T_4I_1		18	8.2	1.8	46.3		18	9.0	1.5	42.7
T_4I_2		24	7.8	3.0	53.1		24	8.8	2.8	49.8
T_4I_3		30	7.6	4.5	60.4		30	8.4	3.8	56.4
T_4I_4		36	7.2	5.5	67.0		36	8.1	4.8	63.1

Appendix - IV

Nitrogen, phosphorus and potassium content (%) in maize grain and stover (2002-03)

Treatments	Grain			Stover		
	N-content (%)	P-content (%)	K-content (%)	N-content (%)	P-content (%)	K-content (%)
T_1I_1	1.10	0.320	0.390	0.452	0.192	0.810
T_1I_2	1.12	0.375	0.397	0.462	0.205	0.832
T_1I_3	1.20	0.381	0.400	0.468	0.210	0.888
T_1I_4	1.23	0.408	0.408	0.472	0.215	0.900
T_2I_1	1.08	0.365	0.392	0.450	0.190	0.818
T_2I_2	1.12	0.372	0.396	0.458	0.205	0.840
T_2I_3	1.22	0.388	0.404	0.461	0.212	0.892
T_2I_4	1.25	0.405	0.410	0.468	0.214	0.910
T_3I_1	1.12	0.381	0.398	0.460	0.198	0.820
T_3I_2	1.18	0.389	0.402	0.468	0.208	0.842
T_3I_3	1.23	0.405	0.415	0.472	0.212	0.918
T_3I_4	0.25	0.410	0.420	0.478	0.216	0.920
T_4I_1	0.90	0.342	0.350	0.439	0.180	0.780
T_4I_2	1.05	0.378	0.382	0.444	0.185	0.810
T_4I_3	1.16	0.392	0.398	0.449	0.198	0.840
T_4I_4	1.28	0.401	0.405	0.458	0.205	0.867

Appendix - V

Nitrogen, phosphorus and potassium content (%) in maize grain and stover (2003-04)

Treatments	Grain			Stover		
	N-content (%)	P-content (%)	K-content (%)	N-content (%)	P-content (%)	K-content (%)
T_1I_1	1.12	0.372	0.390	0.456	0.195	0.818
T_1I_2	1.14	0.378	0.396	0.468	0.208	0.835
T_1I_3	1.21	0.380	0.402	0.470	0.212	0.845
T_1I_4	1.25	0.408	0.410	0.475	0.216	0.914
T_2I_1	1.06	0.368	0.390	0.452	0.188	0.814
T_2I_2	1.10	0.374	0.393	0.462	0.205	0.835
T_2I_3	1.20	0.385	0.403	0.464	0.210	0.842
T_2I_4	1.24	0.404	0.400	0.469	0.214	0.910
T_3I_1	1.14	0.384	0.396	0.462	0.195	0.822
T_3I_2	1.16	0.392	0.405	0.471	0.210	0.848
T_3I_3	1.25	0.403	0.418	0.476	0.214	0.922
T_3I_4	1.26	0.412	0.421	0.481	0.219	0.926
T_4I_1	0.92	0.346	0.352	0.435	0.182	0.786
T_4I_2	1.08	0.376	0.386	0.448	0.189	0.816
T_4I_3	1.18	0.395	0.400	0.452	0.201	0.845
T_4I_4	1.20	0.404	0.407	0.458	0.210	0.870

Appendix - VI

Analysis of variance table (ANOVA)

Mean sum of squares

Plant height

Source		30 DAS	60 DAS	90 DAS	120 DAS	Harvest
Replication	I	10.28**	36.94**	85.27*	434.94**	322.75**
	II	16.50**	64.00**	148.85**	452.08**	402.08**
Factor A	I	0.511**	359.91**	330.85*	2631.42**	321.19**
	II	0.007*	11.47**	169.91**	2718.08**	329.67**
Error	I	0.093	7.243	29.35	85.69	67.69
	II	0.002	0.097	39.74	84.90	64.59
Factor B	I	0.211	26.799	131.07	539.14**	1486.97**
	II	0.002	0.340	112.24	387.81*	1262.02**
A B	I	0.40	11.576	1.41	15.58	111.56
	II	0.001	0.242	1.95	18.81	117.54
Error	I	0.307	21.36	70.64	139.89	92.87
	II	0.001	0.173	69.12	137.09	90.09

Number of leaves per plant

Source		30 DAS	60 DAS	90 DAS	120 DAS	Harvest
Replication	I	0.583	11.31**	31.90**	8.75**	0.90
	II	0.521	13.39**	36.26**	9.07**	1.02
Factor A	I	0.250	9.94**	12.14**	3.24**	4.24**
	II	0.076	07.39**	1.89*	3.63**	11.10**
Error	I	0.250	0.17	0.70	0.97	0.58
	II	0.388	0.42	0.81	0.69	0.48
Factor B	I	0.406	0.39	3.47**	4.30**	5.58**
	II	0.465	1.97	10.35**	8.10**	4.68**
A B	I	0.102	0.24	0.49	0.15	0.69
	II	0.039	0.17	0.27	0.35	0.73
Error	I	0.319	1.21	0.53	1.00	0.59
	II	0.271	1.62	0.58	0.75	0.53

Leaf length

Source		30 DAS	60 DAS	90 DAS	120 DAS	Harvest
Replication	I	160.23**	33.33**	264.44**	224.75**	192.04**
	II	135.49**	255.60**	385.18**	285.88**	180.82**
Factor A	I	2.47**	231.87**	472.22**	114.10**	108.73**
	II	2.01**	89.69**	195.37**	222.51**	112.99**
Error	I	0.15	5.80	25.99	23.74	4.31
	II	0.19	4.06	24.19	17.28	4.03
Factor B	I	0.84	35.11	177.79**	199.09**	211.69**
	II	1.10	31.17	209.96**	92.22**	188.37**
A B	I	0.11	14.02	37.00	21.12	101.29
	II	0.20	14.08	21.65	25.22	105.93
Error	I	0.53	20.90	25.40	40.57	37.62
	II	0.58	21.87	24.52	31.49	34.68

Dry matter production per plant

Source		30 DAS	60 DAS	90 DAS	120 DAS	Harvest
Replication	I	0.114**	0.96	17.34	167.86*	1087.13
	II	0.160**	2.16*	14.14	164.00*	2895.15*
Factor A	I	0.280**	23.42**	144.51**	786.60**	23005.89**
	II	0.352**	21.14**	149.32**	797.48**	26645.27**
Error	I	0.003	1.03	31.95	49.41	827.27
	II	0.003	0.87	29.20	64.59	1180.87
Factor B	I	0.030	1.22	112.36**	535.99**	13850.58**
	II	0.028	1.43	110.52**	889.53**	20682.86**
A B	I	0.009	0.21	25.30	30.22	502.86
	II	0.007	0.42	23.32	36.77	574.70
Error	I	0.016	0.63	19.06	21.65	471.07
	II	0.018	0.75	17.86	25.23	558.14

Source		Root volume		Leaf area index		
		90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
Replication	I	32.49*	119.93**	0.001**	0.103**	0.053**
	II	46.08**	452.08**	0.002**	0.159**	0.160**
Factor A	I	232.89**	213.49**	0.014**	0.015**	0.290**
	II	301.61**	246.43**	0.012**	0.026**	0.183**
Error	I	8.76	12.44	0.0002	0.004	0.008
	II	2.08	14.26	0.0002	0.005	0.009
Factor B	I	109.78**	105.07**	0.001	0.047**	0.099**
	II	109.57**	113.96**	0.002	0.057**	0.215**
A B	I	42.38	30.611	0.000	0.000	0.003
	II	03.39	34.61	0.000	0.001	0.012
Error	I	30.72	29.86	0.002	0.006	0.005
	II	2.08	27.36	0.001	0.009	0.006

Source		Relative leaf water content			Water saturation deficit		
		60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
Replication	I	70.21**	70.99**	132.79**	54.92**	22.62**	8.26**
	II	64.22*	161.66**	144.00**	64.22**	63.80**	16.18**
Factor A	I	39.51*	53.12**	129.70**	10.36**	6.91**	20.75**
	II	68.97*	27.21*	109.74**	5.51**	9.12**	7.76**
Error	I	15.87	10.52	8.53	1.39	1.36	0.09
	II	25.93	08.27	8.67	1.55	0.94	0.18
Factor B	I	32.77	45.42*	111.90**	10.63	4.69**	11.57**
	II	20.14	63.90**	198.75**	12.91	4.32**	16.39**
A B	I	0.83	12.79	16.94	0.91	0.38	0.30
	II	0.18	14.85	18.06	1.06	0.34	0.76
Error	I	17.40	17.66	12.73	5.40	1.00	0.50
	II	17.86	16.42	13.48	6.39	0.63	0.19

Source		Sp. Leaf wt.	CGR	Weed dry weight
		120 DAS	60-120 DAS	120 DAS
Replication	I	106.86	0.083**	10.785**
	II	116.08	0.170**	16.23**
Factor A	I	454.28*	1.674**	18.279**
	II	607.44**	0.164**	26.63**
Error	I	117.15	0.011	0.233
	II	123.65	0.009	0.209
Factor B	I	555.60**	0.577**	8.10**
	II	288.71**	0.197**	11.10**
A B	I	101.94	0.034*	0.311
	II	54.32	0.041*	0.26
Error	I	55.22	0.016	0.561
	II	67.40	0.019	0.974

Source		No. of cobs per plant	Cob length	Cob dia	Grain no per cob	Grain wt. per cob	Test wt.
Replication	I	0.063	11.240	4.83	5523.68	164.00	32.91**
	II	0.333*	16.14*	3.38*	2418.58	362.25	76.75**
Factor A	I	0.288	43.29**	31.80**	8607.59*	1523.55**	39.21*
	II	0.256	44.56**	29.97**	7604.17*	1667.62**	42.99**
Error	I	0.146	5.31	2.08	3025.86	181.52	9.91
	II	0.139	6.22	1.82	3160.95	325.72	6.22
Factor B	I	0.332	13.53**	10.36**	6992.57**	937.23**	27.38**
	II	0.356	16.31**	11.72**	6815.17*	1219.62**	43.26**
A B	I	0.413	3.77	0.20	554.71	17.53*	5.24
	II	0.303	2.02	0.24	307.00	6.14*	6.04
Error	I	0.264	2.02	3.41	2705.81	88.13	4.04
	II	0.188	2.76	3.12	2871.85	206.67	2.15

Source		Grain yield	Stover yield	Stone yield	Grain: Stone	Grain: Stover	H.I.
Replication	I	246233.89*	471837.52	59959.021	0.102	.001	2.654*
	II	622257.25**	522292.21	60252.88	0.045	.026**	2.981**
Factor A	I	5015130.46**	12364315.19**	95179.85**	1.476*	.007**	3.191*
	II	521138.50**	12975821.19**	166917.50**	0.832*	.004**	2.698**
Error	I	92928.41	322752.20	33708.00	0.528	.001	1.228
	II	122412.00	393132.45	25392.21	0.347	.001	0.388
Factor B	I	1604676.24**	1963696.41**	20436.69**	0.252**	.013**	3.311*
	II	1528281.00**	2260965.69**	39717.50**	0.114**	.003*	4.015**
A B	I	361820.41*	785828.56*	13643.35	0.056	.001	1.504
	II	178121.17*	772073.02*	10015.33	0.107	.000	0.331*
Error	I	150528.21	318828.20	8112.24	0.030	.001	1.555
	II	88752.13	330672.15	5292.62	0.058	.001	0.347

Source		WUE	WEE	N-uptake	P uptake	K-uptake	Protein content
Replication	I	270.39*	345.81**	1533.21	848.27**	1605.00**	08.21**
	II	425.23*	1601.00**	352.08	147.02**	1599.50**	02.24**
Factor A	I	2337.94**	1768.61**	4722.49**	354.66**	2185.83**	2.00
	II	3173.82**	2296.31**	2711.93**	353.56**	2286.63**	2.15
Error	I	96.10	34.68	306.03	45.63	162.57	1.01
	II	122.88	53.93	339.62	39.75	158.12	1.08
Factor B	I	953.47**	1389.64**	1115.96**	175.37**	1162.61**	23.14*
	II	1210.28**	1799.43**	1556.77**	566.18**	1111.18**	25.24**
A B	I	43.15	37.43	118.311	30.030	43.28	0.66
	II	36.09	31.49	128.57	45.21	43.13	1.85
Error	I	33.86	20.59	81.12	17.57	31.10	8.67
	II	78.03	37.17	325.73	23.86	38.88	7.48

Source		Gross return	Net return	Net return per rupee of investment
Replication	I	4393458.81	4849012.33**	0.032**
	II	3741323.06	5149425.58**	0.040**
Factor A	I	133506255.18**	118021122.66**	0.478**
	II	143980674.08**	130523049.92**	0.522**
Error	I	2506188.10	756012.87	0.005
	II	2904768.25	1065648.22	0.005
Factor B	I	987826.52*	1495458.80*	0.023**
	II	42466868.18**	1530962.28*	0.030**
A B	I	4371669.98	211349.54	0.010
	II	4048169.39	242155.99	0.010
Error	I	2169540.50	674028.18	0.005
	II	2495232.23	738048.73	0.005

VITA

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