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AQUACULTURE WASTE WATER – AN IRRIGATION SOURCE

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ABSTRACT

Fresh water becomes a scarce resource therefore; its multiple uses become a need of the hour. Aquaculture option within the irrigation system is one of such attempts. An experiment was conducted at Indian Institute of Technology (IIT) Kharagpur, during the rabi season (2005-06) to study the response of crop growth using fish pond waste water, enriched in nutrients. Tomato (*Lycopesicum esculentum* L.) Var. MHTM-256 was grown at a planting geometry of 60 cm × 75 cm. Three lined ponds were stocked with fish at stocking densities of 1.5, 2.5 and 3.5 numbers per square meter. Fishes were being fed daily @ 5% of their body weight for the first month of their culture and subsequently reduced to 2% of their body weight. The pond water quality was measured at a regular interval to determine the level of NO_3^-, NO_2^- , NH_3 and PO_4^{3-} pollution. Nitrogen at the rate of 30% of the recommended dose and full doses of phosphate and potash fertilizers were applied to all the eight experimental plots as basal dose. Remaining amount of the nitrogen was applied in three splits of 30%, 20% and 20% to the two control plots. Whereas, only two split doses of 30% and 20% were applied to the six treatment plots. The nutrient value of the pond water varied between 1.85 to 2.25 ppm of N; 0.5 ppm of P. The yield obtained from the three treatments varied between 66-72 tons/ha, whereas, the yield from the control plot was 72 tons/ha. The average value of water application efficiency, water storage efficiency, and water use efficiency were 79%, 74% and 20.84 q /ha/cm respectively. The moisture content of the soil computed by CROPWAT model was compared with the observed values. The model efficiency was 0.95.

KEY WORDS: Pond waste water, stocking density, pond water quality, irrigation efficiencies, CROPWAT

INTRODUCTION

Increases in overall productivity in relation to water use are desirable in the context of rising pressure to utilize water more efficiently. Integrated agri–aquaculture systems (IAAS) involving various crop, livestock and aquaculture subsystems help to provide income whilst rehabilitating the soil through better on-farm nutrient recycling (O'Donnell et al., 1994). Several agronomical experiments conducted in China, Vietnam and other countries in Asia revealed that integrated systems have evolved from subsistence level to agro industrial scale. It also helps to minimise pollution and eutrophication, as well as to optimise the use of valuable natural resources. Nutrients are added in organic form to the water before irrigation, which may subsequently reduce the need for additional inorganic fertilizer (Edwards, 1993; Luo and Han, 1990; Marten, 1986). Jamu and Piedrahita, (1995) developed a computer model to analyse and predict nitrogen and organic matter outputs from aquaculture ponds. The developed model was linked with an agriculture crop model and an integrated model, which could simulate the flow of organic matter and nitrogen through combined aquaculture and conventional agriculture practices was developed. Fishpond waste water is a viable source to supplement irrigation water to the crop as well as bridge the gap of chemical fertilizer requirement, especially nitrogen to a marginal amount (Ray et al., 2006).

Study Area

Field experiment was carried out at the aquaculture farm of Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, India. The farm is located on a gently sloping drainage basin situated at an altitude of 48 m above mean sea level and is intersected by 22°19' N latitude and 87°19' E longitude. The climatic condition of the experimental site is humid subtropical with an average annual rainfall of 1500 mm with a large percent concentrated during the months of June to October. The mean annual maximum relative humidity varies from 76 percent in March to 96 percent in October, while the mean minimum relative humidity varies between 11 percent in March to 64 percent in July. The first field experiment was undertaken during the winter season of 2005 beginning in October and continued till April 2006. During this period, the temperature varied from 20 to 35°C, which is ideal for growing of tomato. Soil at the experimental site is lateritic with sandy loam texture, which is taxonomically grouped under the order ALFISOL (Oxyaquic haplustalf).

METHODS AND MATERIALS

Layout of experimental site

Three dugout ponds were constructed with about 2 meter depth in the experimental farm and were lined with 250-micron polyethylene sheets to check seepage. Below the lining material, 30 cm thickness of sand cushioning was provided to avoid rupture. Over the lining, loamy soils were provided to a depth of 30-45 cm to provide suitable environment for the growth of zooplankton and phytoplankton to be used by the fish as feed. Lined ponds were filled with tubewell water to culture three different species of Indian major carps. Adjacent to the ponds, eight experimental plots of 5 m × 6 m size each were laid out.

Culture of fish

Intensively managed aquaculture was practiced by using three different stocking densities of 1.5, 2.5 and 3.5 No / m^2 in ponds 1, 2 and 3 respectively. Indian major carp namely Catla (*Catla catla* L.), Rohu (*Labeo rohita* L.) and Mrigal (*Cirrhinus mrigala* L.) were released in the three ponds with stocking ratio of 3:4:3 respectively.

Crop

Tomato Var. MTHM-256, (*Lycopersicon esculentum* L.) was selected for the trial with a planting geometry of 0.6 m x 0.75 m. The schedules of fertilizer applications to tomato crop were based on local trials. The recommended dose of fertilizer (N-P-K) for tomato crop is 80-40-40 kg/ha. The nitrogen in the form of urea (45.45 %), phosphorous in the form of single super phosphate (16%) and potassium in the form of murate of potash (60.24%) were applied. Nitrogen at the rate of 30% of the recommended dose and full doses of phosphate and potassium fertilizers were applied to all the eight experimental plots as basal doses, whereas, only two split doses of 30% and 20% were applied to the six treatment plots as some amount of Nitrogen was expected to be available from the pond water.

Nutrient from pond water

Fishes were being fed daily @ 5% of their body weight for the first month of their cultivation and subsequently reduced to 2%. Fish produces ammonia as a waste product and other ammonia sources are fish waste, decomposed fish food and various organic matters like algae. Water quality parameters of the pond were monitored at 2 days interval to obtain the variation of nutrients at different levels of stocking density.

Soil Nutrients

To estimate the nutrient accumulation in the root zone at two different depths of 15 cm and 30 cm, soil samples were collected before and after each irrigation from the plots in a random manner and mixed thoroughly. This mixture was dried in shade for 24 hours and then ground to sieve it through a 2 mm sieve.

Irrigation scheduling using CROPWAT

The irrigation scheduling of tomato crop was based on maximum allowable depletion (MAD) of available soil water (ASW). The irrigation scheduling that would give minimum yield reduction with minimum possible application of irrigation water was followed. Irrigation scheduling was based on the simulation results of CROPWAT, a computer program for irrigation planning and management, developed by the Land and Water Development Division of FAO (FAO 1998). Using the soil moisture content and evapotranspiration rates, the soil water balance was computed on a daily basis using the model. The input parameters used to estimate irrigation requirements were climatic data including rainfall, crop data, soil data, and irrigation criteria. The climatic data required are reference evapotranspiration (monthly) and rainfall (monthly). Reference evapotranspiration was calculated using FAO Penman-Monteith method (FAO, 1998) in which data inputs were mean monthly maximum and minimum temperature (^{o}C), relative humidity (%), sunshine duration (hours), wind speed at 2 m high (m/s) and monthly rainfall in mm.

INPUT PARAMETERS

Crop data

The crop parameters used for the estimation of the crop evapotranspiration, water-balance calculations, and yield reductions are based on crop coefficient (K_c), length of the growing season, critical depletion level (p), percentage area covered by the crop and yield response factor (K_y). The program includes standard data for main crops and adjusts them to meet the actual conditions. The effect of water stress on yield is quantified by relating the relative yield reduction to the relative evapotranspiration deficit using the following empirically derived yield response factor (K_y).

$$1 - \frac{Y_a}{Y_{\max}} = K_y \left(1 - \frac{ET_a}{ET_m} \right) \qquad ......(1)$$

where, $1-Y_a/Y_{max}$ = the fractional yield reduction as a result of the decrease in evapotranspiration rate ($1 - ET_a/ET_m$),

Y_a = actual crop yield,
Y_m = maximum crop yield,
ET_a = actual evapotranspiration rate, and
ET_m = maximum evapotranspiration rate.

Soil data

The soil data include information regarding total available soil moisture content and the maximum infiltration rate for the estimation of losses. In addition, the initial soil water content at the start of the season, type of soil and root zone depth of crop are also needed as soil parameters.

OUTPUT PARAMETERS

The model assumes the irrigation efficiency as 80%. The model computed soil moisture content is compared with the observed soil moisture content to compute the performance of the model. The performance of the model is estimated by using Nash Sutcliffe index (E_{ns}) given by the following relationship.

$$E_{ns} = 1 - \frac{\sum (M_o - M_s)^2}{\sum (M_o - M_{oav})^2} \qquad ......(2)$$

where, E_{ns} = Nash Sutcliffe Index,
M_o = observed moisture content (mm),
M_s = simulated moisture content (mm) and
M_{oav} = average of the observed soil moisture content (mm)

Through estimates of effective rainfall, crop irrigation requirements are calculated assuming optimal water supply. Inputs on the cropping pattern will allow estimates of scheme irrigation requirements. With inputs on soil water retention and infiltration characteristics and estimates of rooting depth, a daily soil water balance was calculated for predicting water content in the rooted soil by means of a water balance equation.

Available nutrients

The total available major nutrients were analyzed using standard procedures APHA (1998).

Irrigation efficiencies

Different irrigation efficiencies were computed using the method suggested by Michael (1999). The efficiencies include application efficiency, storage efficiency and water use efficiency.

RESULTS AND DISCUSSION

Pond water quality measurement

The water samples collected from different ponds with different stocking densities were tested to determine the concentration of different nutrients which play critical role in aquatic ecosystem. The measured values of temporal variation of amoniacal nitrogen (NH_3-N), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N) , phosphate (PO_4-P), total suspended solids, pH and dissolved oxygen in three ponds P-I, P-II and P-III are presented in Fig.1 to Fig.7.

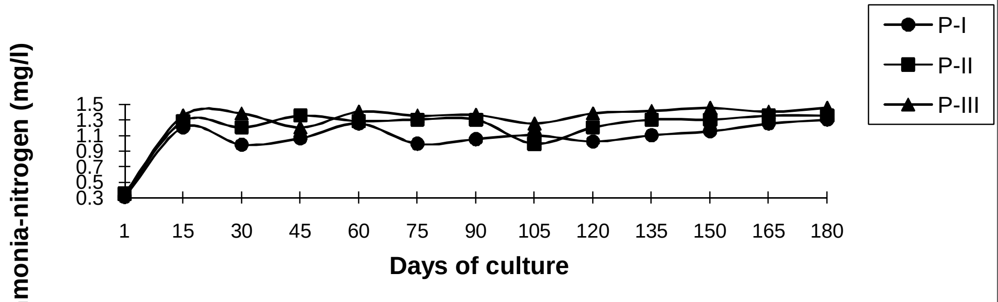

Fig.1: Variation in ammonia-nitrogen in ponds with different stocking density

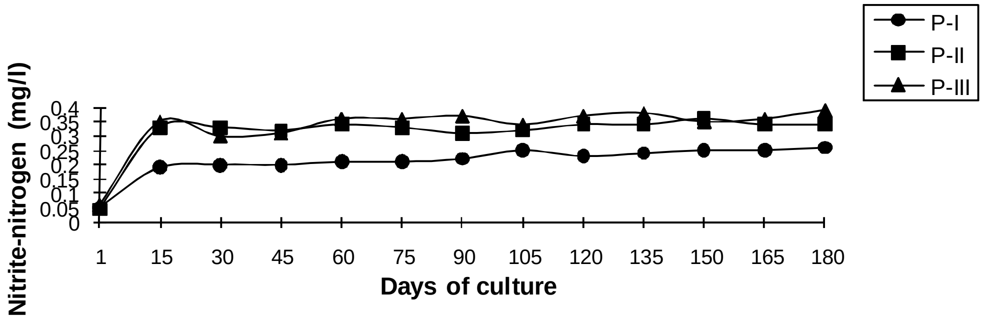

Fig.2: Variation in nitrite-nitrogen concentration in ponds with different stocking density

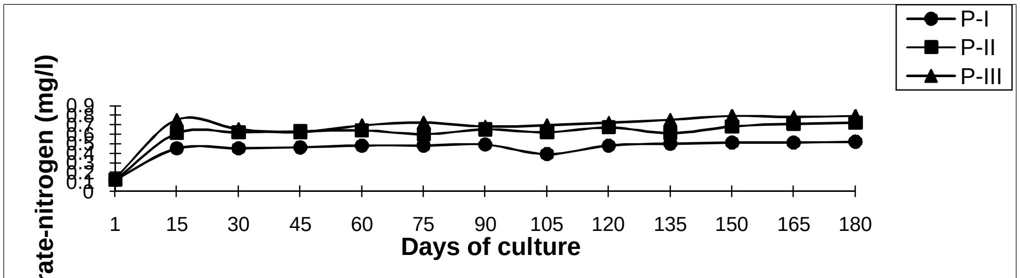

Fig.3: Variation in nitrate-nitrogen concentration in ponds with different stocking density

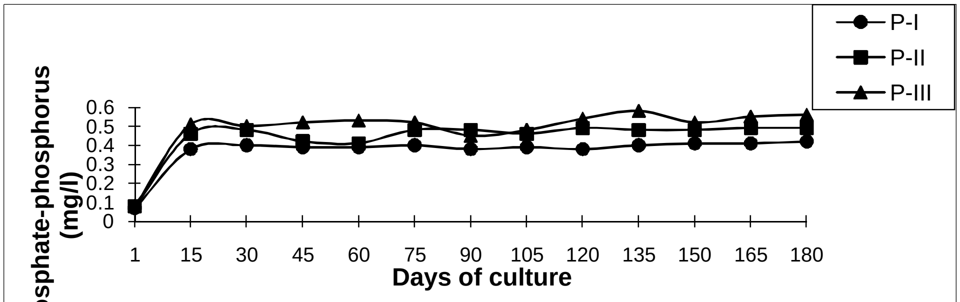

Fig.4: Variation in phosphate-phosphorus in ponds with different stocking density

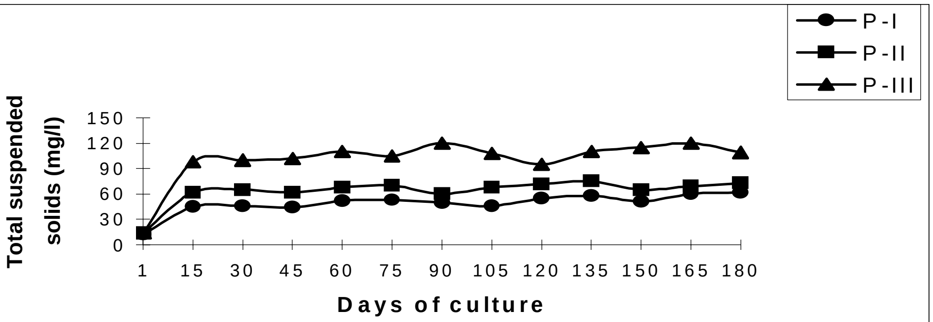

Fig.5: Variation in total suspended solids in ponds with different stocking density

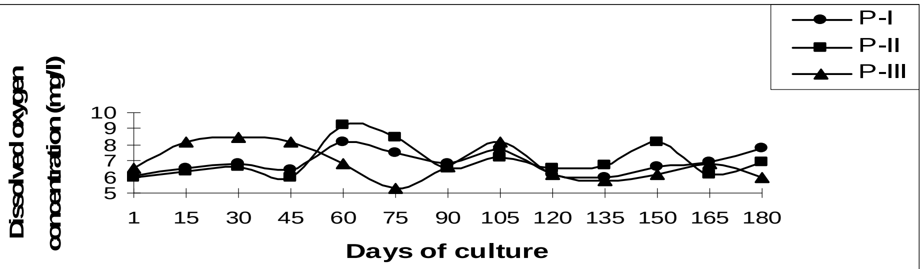

Fig.6: Variation in dissolved oxygen concentration in ponds with different stocking density

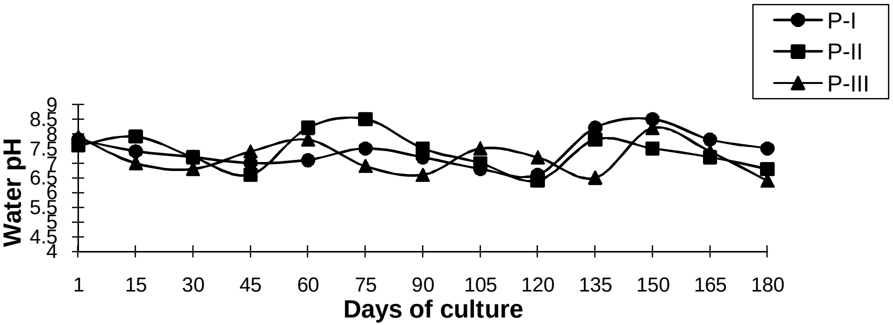

Fig.7: Variation in water pH in ponds with different stocking density

Nutrients

Nutrients initially increased with time until the water was exchanged. The exchange of water from the pond was carried out when nutrient concentrations exceeded critical values. Generally, the concentrations reached the critical limits 15 days after the exchange of water. It is seen from figures-1 to 7 that in pond III with stocking density of 35000/ha, the pollution level is higher than that of pond I and II with stocking densities of 15000/ha and 25000/ha respectively.

Other parameters

The other water quality parameters are total suspended solids, dissolved oxygen, pH and temperature. The dissolved oxygen is found to be more in P-I and less in P-III (Fig.6). This is due to less stocking density in pond-I than that of P-III. As can be seen from Fig-7, the pH often dropped below 7.0 in all the ponds which made the water acidic hampering the growth of the fishes. Hence lime was added into the water at the rate of 200 kg per hectare per month to neutralize the acidity. After addition of lime, the pH again increased to a favourable level. The variation of temperature for the whole growth period ranged from 15^0C to 28^0C.

SOIL NUTRIENT CONTENT ESTIMATION

Nitrogen

The total available nitrogen was measured at 15 cm and 30 cm depths before and after each irrigation. The average variation of total available nitrogen in two replications of each treatment including control plot at the above two depths with days after planting are presented in Fig.8.The high peak during initial period of time is due to application of 30% nitrogen as basal dose. Thereafter, the rise of concentration of nitrogen in the soil after 35 days and 50 days of planting is because of the application of two splits of nitrogen at the rate of 30% and 20% of the total dose (Fig 8a to 8d). After each irrigation the concentration was found to increase by a marginal amount in treatment plots due to application of nutrient rich pond water. In control, distinct peaks were found due to application of full doses of nitrogen as splits of 30%, 30%, 20% and 20 %.

Phosphorus

The total available phosphorous was measured at 15 cm and 30 cm depths before and after irrigation. The average variation of available phosphorus in two replications for each treatment including control plot at above two depths with days after planting is presented in Fig.9. Subsequent peaks are due to marginal amount of phosphorus obtained from enriched pond water through irrigation. After irrigation the drop of phosphorus concentration was not so high due to immobile behavior of phosphorus.

Potassium

The available potassium was also measured at 15 cm and 30 cm depths before and after irrigation in both the replications of each treatment including control plot (Fig-10). The high peaks during initial period of time is due to application of recommended dose of 40 kg/ha murate of potash as basal dose. The concentration decreased afterwards as irrigation water from pond has negligible amount of potash.

Plant parameters

The plant parameters viz. plant height, number of leaves, number of fruits, number of branches and leaf area index were measured at regular intervals after planting. Plant height, number of leaves and LAI are plotted against days after planting whereas, the number of fruits per plant is plotted against number of branch per plant (Fig.11 to 14). The plant height continued to increase with time since the date of planting up to about 80 days and then remained constant. The plant height was highest in control plant because of timely application of full doses of all the fertilizers. Plant height increased at a faster rate starting from flowering stage to late maturity stage (Fig.11). The same trend is marked in the variation of leaves with days (Fig.12). There is no significant difference between the yields obtained from the three treatments but the yield obtained from the control plot is highest (71.56 t/ha) whereas, this value varies from 66.68 to 69.8 t/ha for the three treatment

Irrigation scheduling

As per the model simulation results, a total of six irrigations were applied to satisfy the total water requirement of 34 cm. The minimum possible yield reduction for 34 cm of irrigation water requirement with zero loss is simulated as 2.5%. The simulated soil moisture status is compared with the observed soil moisture values at corresponding times. The Nash Sutcliffe Index criterion is used to determine the modeling efficiency. The comparison of the simulated and observed soil moisture values before and after irrigation is shown in Fig-15.

Irrigation efficiencies

Using the values of observed soil moisture contents during irrigation, three different efficiencies were computed such as application efficiency, storage efficiency and water use efficiency. The application efficiency of the irrigation system was computed by taking the average values of three application efficiencies obtained at three irrigation periods. The average application efficiency is found to be 79%. The storage efficiencies were computed by calculating depth of water stored in the root zone before and after irrigation. The average of the three storage efficiencies obtained for three different irrigations was found to be 79%. Water use efficiency was also calculated from the total yield of tomato and was found to be 20.84 q/ ha-cm.

CONCLUSION

It can be concluded that the fishpond waste water is a viable source to supplement irrigation water to the crop as well as bridge the gap of chemical fertilizer requirement, especially nitrogen to a marginal amount. Farmers owning irrigation source, fish pond and crop land can supply the water to the pond and pond water to the crop land for irrigation to increase the stocking density of fish, to supplement the nitrogen fertilizer to the crop and thereby increase the income.

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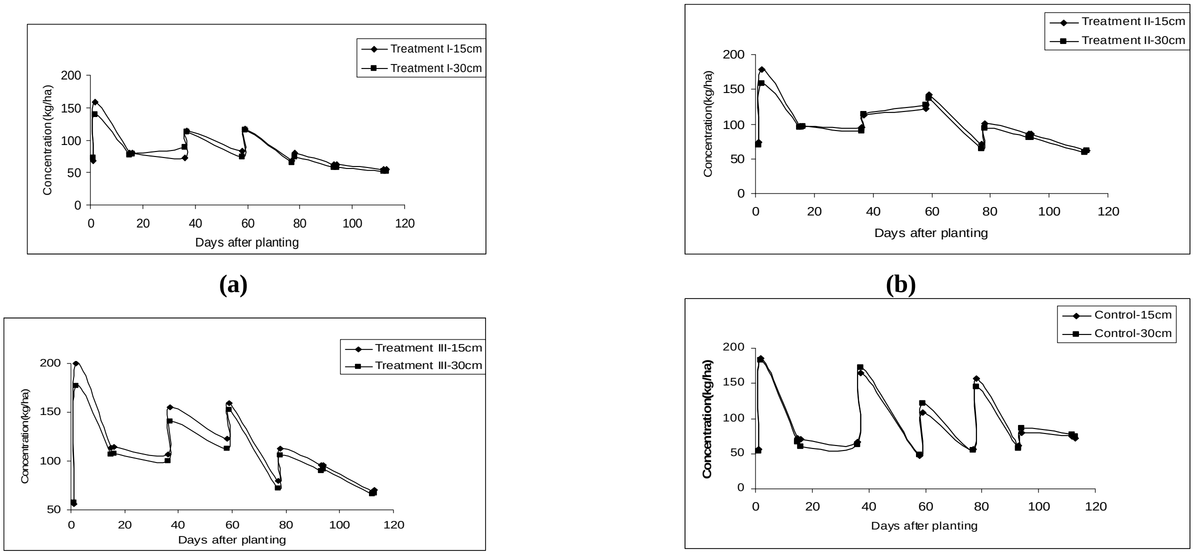
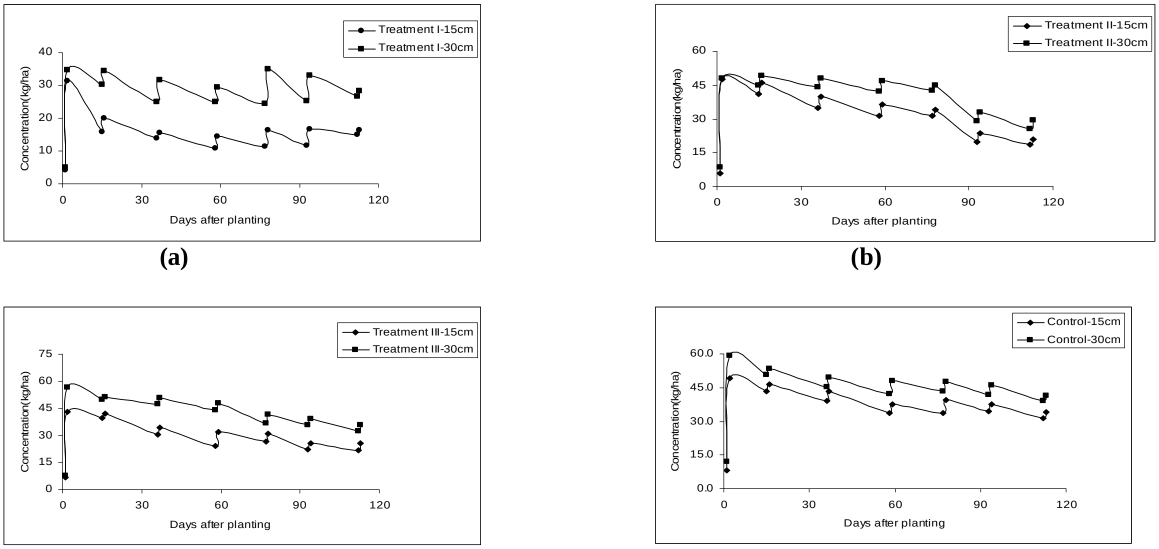


(a) **(b)**

(c) **(d)**

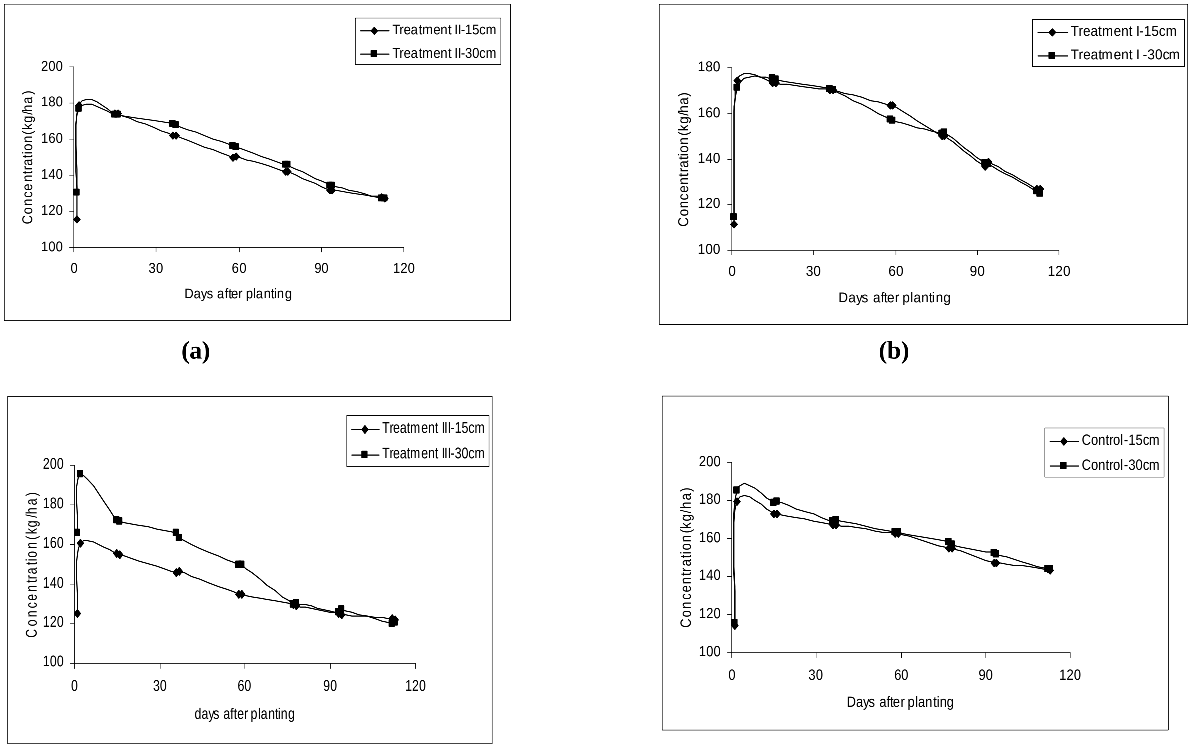
Fig.8.(a),(b),(c)and(d) variation of total available nitrogen at 15cm and 30 cm depths for different treatments



(a) **(b)**

(c) **(d)**

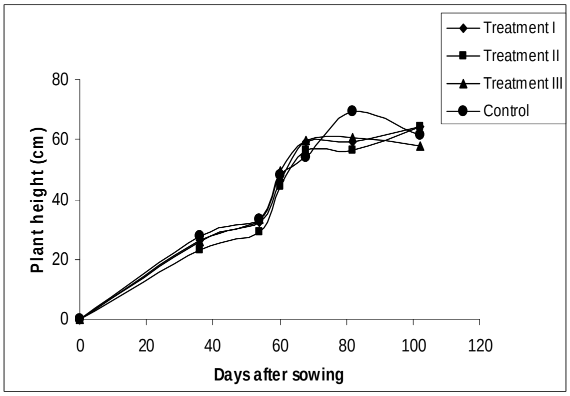
Fig.9. (a), (b), (c) and (d) Variation of available Phosphorus at 15cm and 30 cm depths for different treatments



(a) (b)

(c) (d)

Fig.10. (a), (b), (c) and (d) Variation of available Potassium at 15cm and 30 cm depths for different treatments



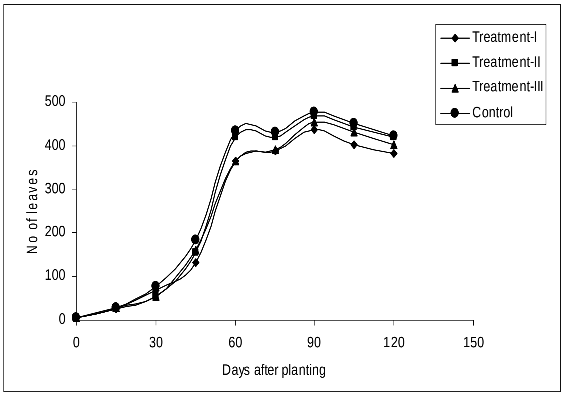
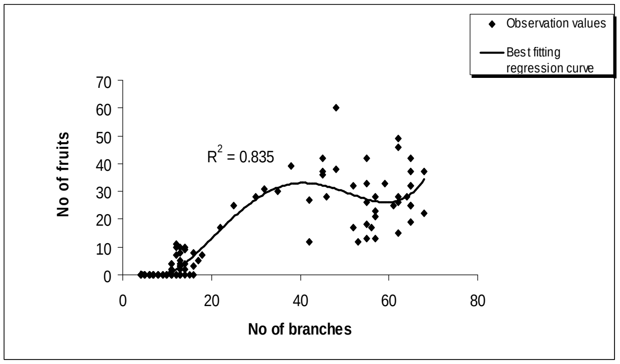


Fig.11. Variation of plant height with days after sowing

Fig.12. Variation of No. of leaves with days after sowing



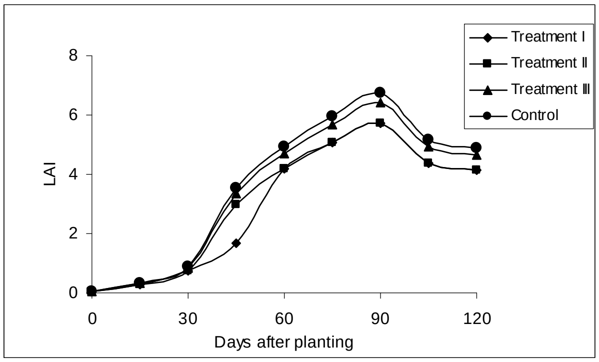


Fig.13. Var. of No. of branches with number of fruits

Fig.14.Variation of LAI with days

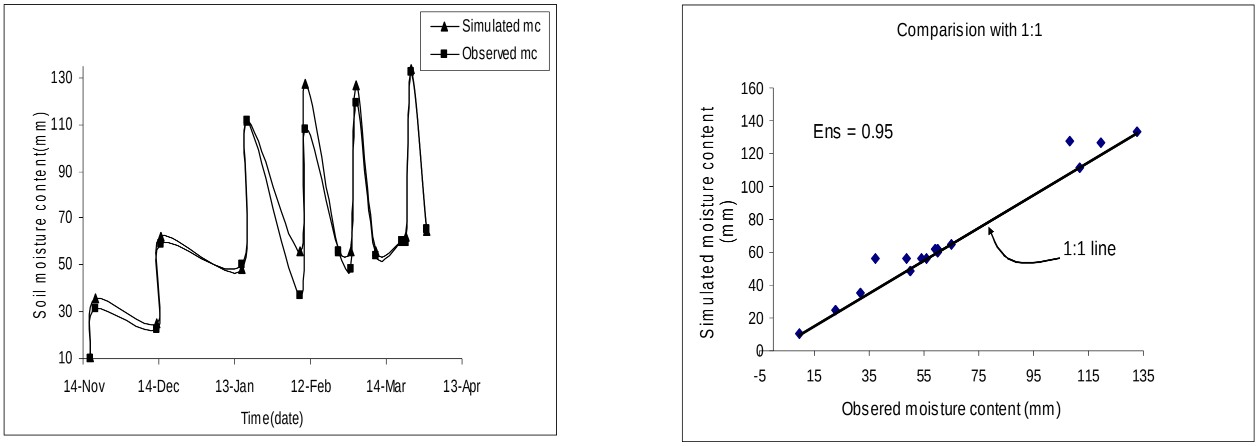


Fig.15. Comparison of the model computed moisture contents with observed soil moisture contents.

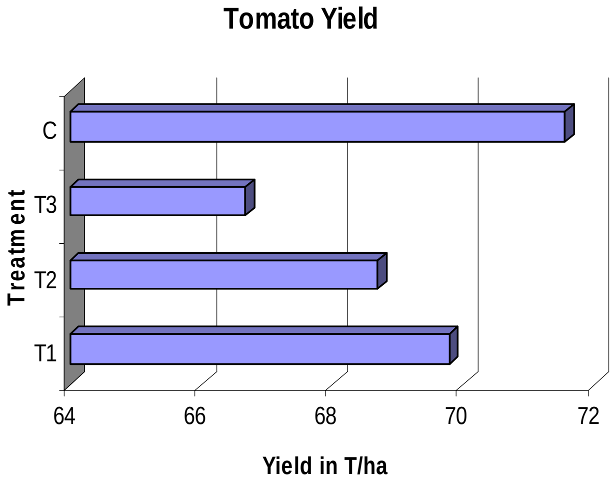


Fig.16. Comparison of yield obtained from three treatment and control plots in ton/ha.