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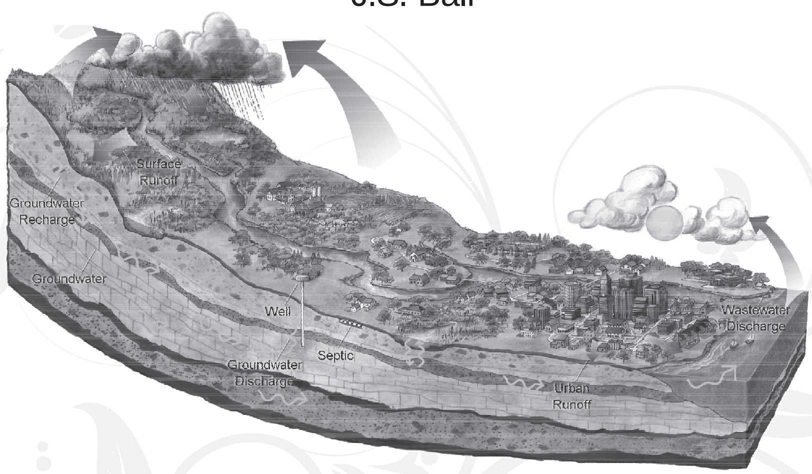
Contents

Pledge

J.S. Bali



I pledge to conserve Soil,
that sustains me.
I pledge to conserve Water,
that is vital for life.
I care for Plants and Animals and the Wildlife,
which sustain me.
I pledge to work for adaptation to,
and mitigation of Global Warming.
I pledge to remain devoted,
to the management of all Natural Resources,
With harmony between Ecology and Economics.

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Soil water and nitrate dynamics under drip irrigated cabbage

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ABSTRACT

Design and management of a drip irrigation and fertigation system depends upon the understanding of water and nutrient distribution in the soil. A field experiment was conducted on Indo-American Hybrid var. Ramakrishna of cabbage crop during the winter season of 2010-2011 in loamy soil of Indian Agricultural Research Institute, New Delhi. The performance of the inline drip systems having (i) pressure compensating (PC) and (ii) non-pressure compensating (NPC) drippers revealed that the emission uniformity (EU) values were 92.68 and 92.12%, respectively. It was observed that with the increasing discharge of drippers both the wetted soil width and depth increased but increase in wetted soil depth was more than the increase in wetted width of the soil. In 3 h operation of the drip system, maximum wetting width 23 and 25.5 cm were observed in cases of PC and NPC drippers, respectively. Largest wetting depths of 24 and 26 cm were observed in PC and NPC drippers, respectively. Analysis of soil samples indicated the significant influence of fertigation frequency on nitrate-nitrogen (NO_3-N) distribution in soil profile. NO_3-N in lower soil profile (45-60 cm soil depth), was marginally affected in biweekly and weekly fertigation. However, NO_3-N concentration in 0-15 cm, 15-30 cm, 30-45 cm soil depths varied significantly in fortnightly fertigation frequency. The concentration of soil NO_3-N at the end of mid season of crop showed that more NO_3-N leached beyond root zone depth of crop in fortnightly fertigation as compared to biweekly and weekly fertigation frequencies.

Key words: Cabbage; drip system performance; soil water distribution; nitrate dynamics

INTRODUCTION

Sustainability of any agricultural production systems require optimal use of input resources such as water, fertilizer and soil etc., without causing detrimental effect to the environment. There are different inputs in agriculture such as water, energy, nutrients and seeds. Out of which water and nutrients are key inputs. In order to optimize the use of water and nutrients drip irrigation is one of the best methods which is all about irrigating the plant not the soil. To understand the behavior of water and nutrient in soil we need to the study water and nutrient dynamics. Drip irrigation applies water slowly matching with the consumptive water use by the plant to keep the sufficient soil water for plant growth.

It is an appropriate irrigation method for cultivation of vegetable crops such as cabbage owing to its potential of precisely applying water and nutrients in the root zone of crop. It also helps in reducing the losses of water such as evaporation and deep percolation in comparison to conventional irrigation methods. Proper design and management of a drip irrigation and fertigation system requires an understanding of water distribution in the soil, which may be described either by predicting the solutions of the equations defining the flow of water through soil (Bristow *et al.*, 2000) or by detailed field experimentation.

Increasing needs of irrigation water for enhancing agricultural production indicate to attempt to increase adoption of water saving technologies, including drip irrigation systems. This system not only saves water but also improves yield of crops. It

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has high distribution uniformity and application efficiency. However, its evaluation in actual field situations is often overlooked. Techniques for identifying drip irrigation system performance ranges from simplistic field-based 'catch cans' method to use of satellite vegetation measurements for identifying changes in crop growth throughout the field. The key factors responsible for proper system performance are system design, water analysis, proper filtration, system monitoring, careful installation, maintenance and troubleshooting. Levin *et al.* (1979) and Mostaghimi *et al.* (1981) studied the effect of discharge rate and intermittent water application by a surface point source. Cote *et al.* (2003) studied the effect of intermittent water application on the wetting front advance in the subsurface drip irrigation.

Cabbage (cv. Ramakrishna) is a popular cultivar of the species *Brassica oleracea* of the family Brassicaceae. It is one of the most common cold climate crops, which thrives best in cool weather. Spring season crop usually has a growing period of 90 days, while autumn crop has an extended growth period of 200 days. Growing period of the selected cultivar is 120 days. It has a shallow root system. The majority of the roots are found in the top 40 to 50 cm depth of soil. During the vegetative period, the development of crop is slow and the water requirement is low. During formation and maturity stage the availability of soil water content is important.

Fertigation enables the application of soluble fertilizers and other water soluble chemicals along with irrigation water, uniformly and more efficiently. In recent years, the studies on water flow and nitrate movement are increasing because of the concern about the effect of injudicious use of water and fertilizer on environmental balance. Nitrate leaching occurs when there is an accumulation of NO_3-N in the soil profile that coincides with or is followed by a period of high drainage (Di and Cameron, 2002). The method of fertilizer application is very important in obtaining the optimal use of fertilizer. It is recommended that fertilizer should be applied regularly and timely in small amounts. This will increase the amount of fertilizer used by the plant and reduce the amount lost by leaching. Therefore, efforts were made to study the water and nitrate movement under various irrigation levels, irrigation systems and fertigation frequencies in drip irrigated cabbage crop. The main objective of this work was to develop a strategy for better nutrition and water management in cabbage crop.

MATERIALS AND METHODS

Location and soil of the experimental site

The experiment was conducted at the research farm of Water Technology Centre, Indian Agricultural Research Institute, New Delhi, India (Latitude $28^0$37'30''–$28^0$30'0'' N, Longitude $77^0$8'45''–77'10'24'' E and AMSL 228.61 m) during October-March, 2010-2011. The experiment was conducted on a field of size 35 m x 33 m. The field was divided into two equal parts each of 35 m x 16 m. A buffer strip of 1 m was maintained in between the two for separating the plots from one another. The experiment consisted of 18 treatments and 3 replications. The experimental design followed was the 'split plot design'. There were two types of inline drip systems (i) Pressure compensating (PC) and (ii) Non-pressure compensating (NPC). Three different irrigation levels of 60, 80 and 100% of the ET_c with three fertigation frequencies namely; biweekly, weekly and fortnightly were employed.

Soil samples were collected from the depth of 60 cm at 15 cm intervals. The physical and chemical properties of soil were determined. Hydrometer method was used to determine the sand, silt and clay percentage of soil. The soil of the experimental site was deep, well-drained loamy soil comprising of 48.28 % sand, 32.22 % silt and 19.5 % clay (Table 2). The bulk density of soil was 1.53 g cm^{-3}, field capacity 0.25 and saturated hydraulic conductivity 1.17 cm h^{-1}, respectively. The pH and EC of soil was 7.3 and 0.12 dS m^{-1} respectively (Table 3). The available N, P and K in the soil before the starting of field experiment were 108.5, 15.80 and 143.864 kg ha^{-1}. Fallowing treatments were used in the experimental study (Table 1).

Raising of seedling and transplanting

The cabbage (Indo-American Hybrid var. Ramakrishna) seeds were treated with Bavistin (2 g kg^{-1} of seed) and sown in a nursery bed in the first week of October. The seedlings were transplanted in the field on 16^{th} of November, 2010 at a plant to plant and row to row spacing of 30 cm x 60 cm, respectively.

Table 1. Treatment details

Pressure compensating dripper system		Non-Pressure compensating dripper system	
T1	100% of ET_c with biweekly fertigation	**T10**	100% of ET_c with biweekly fertigation
T2	80% of ET_c with biweekly fertigation	**T11**	80% of ET_c with biweekly fertigation
T3	60% of ET_c with biweekly fertigation	**T12**	60% of ET_c with biweekly fertigation
T4	100% of ET_c with weekly fertigation	**T13**	100% of ET_c with weekly fertigation
T5	80% of ET_c with weekly fertigation	**T14**	80% of ET_c with weekly fertigation
T6	60% of ET_c with weekly fertigation	**T15**	60% of ET_c with weekly fertigation
T7	100% of ET_c with fortnightly fertigation	**T16**	100% of ET_c with fortnightly fertigation
T8	80% of ET_c with fortnightly fertigation	**T17**	80% of ET_c with fortnightly fertigation
T9	60% of ET_c with fortnightly fertigation	**T18**	60% of ET_c with fortnightly fertigation

Table 2. Physical properties of soil

Depth (cm)	Particle size Distribution (%)			Textural Class	Hydraulic Conductivity (cm h^{-1})	Bulk Density (gm cm^{-3})	FC(%)	PWP(%)
	Sand	Silt	Clay					
0-15	7.28	24.72	18	sandy loam	1.65	1.61	17.42	7.78
15-30	47.28	34.72	18	loam	1.12	1.45	19.65	9.10
30-45	43.28	34.72	22	loam	1.06	1.45	18.16	10.36
45-60	45.28	34.72	20	loam	1.55	1.60	18.22	10.71
Avg.	48.28	32.22	19.5	loamy	1.345	1.52	18.36	9.49

Table 3. Chemical properties of soil

Depth (cm)	pH	EC(dS m^{-1})	Available nutrients		
			N(Kg ha^{-1})	P(Kg ha^{-1})	K(Kg ha^{-1})
0-15	7.2	0.14	95.2	20.12	254.24
15-30	7.3	0.12	81.2	18.44	140.22
30-45	7.3	0.11	100.8	12.52	89.37
45-60	7.3	0.11	156.8	12.15	91.61
Average	7.3	0.12	108.5	15.80	143.86

Design of the drip irrigation system

Drip irrigation system was designed for cabbage crop and was installed in the loamy soil using standard procedures. The two types of inline dripper systems namely (i) pressure compensating (PC) and (ii) non-pressure compensating (NPC) were installed in the field. The average discharge of water, under normal operating pressure, from PC and NPC drippers were observed to be 0.82 and 1.65 lph, respectively. Each lateral was used to irrigate only one row of plants which was about 15 m in length. Each lateral was provided with a flow control valve at the start of the line to regulate the supply of irrigation water.

Drip irrigation system performance

Performance of drip irrigation systems was evaluated using standard procedures. Discharge data from selected drippers was recorded. Catch cans were placed in zigzag manner such that each row of lateral contains one catch can (Fig.1). In each block 18 drippers were selected randomly from the head, the middle and tail portion of the field to collect the discharge from them. The total numbers of drippers selected were 108 out of 5400 drippers in the whole experimental field. Catch cans were kept under selected drippers to collect the water for a known duration. This data was used to calculate the uniformity coefficient, coefficient of variation and emission uniformity of water application. These parameters were separately calculated for PC and NPC drippers.

The Christiansen formula was used to calculate the uniformity coefficient (UC) and the same is given by the equation 1.

$$UC = 100\left[1.0 - \frac{\sum_{i=1}^{n}\left|(X_i - m)\right|}{\sum_{i=1}^{n} X_i}\right] \quad (1)$$

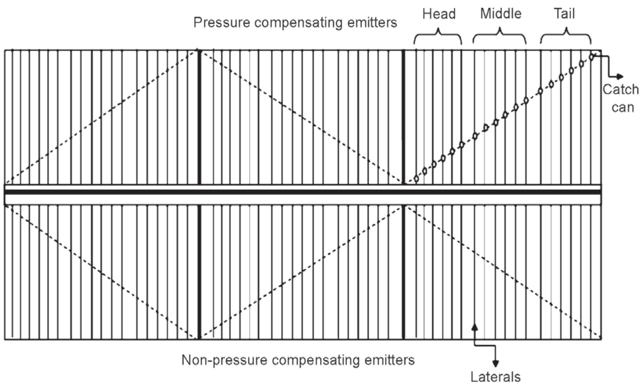

Fig. 1. Layout of the field for evaluating system performance

Where,

X_i = Individual catch can value (volume)

n = Number of the observation.

m = Average of all catch can volume

Coefficient of manufacturing variation (CV) was determined by using Equation 2

(Keller and Karmeli, 1974).

$$CV = \frac{S}{q_a} \quad (2)$$

Where,

CV = Coefficient of manufacture's variation, Fraction

S = Standard deviation

q_a = Average discharge of dripper, lph

Emission uniformity (EU) is the measure of the uniformity of drippers discharge from all the drippers of drip irrigation system and most important parameter for evaluating system performance by using Equation 3.

$$EU = \frac{q_n}{q_a} x100 \quad (3)$$

Where,

EU = Emission uniformity, %

q_n = Average of the dripper discharge of lowest quarter of the field, lph

q_a = Average of the dripper discharge of all field , lph

Soil wetting pattern

To determine the wetting front under drip irrigation, six laterals from pressure compensating system and six laterals from non-pressure compensating system were selected. First lateral, each of PC and NPC block were operated for 0.5 h at 1 kg cm^{-2} operating pressure. Second lateral of both the systems were operated for 1 h at 1 kg cm^{-2} and the remaining laterals were operated for 1.5, 2, 2.5 and 3 h, respectively for both the systems. Wetted soil widths from dripper position were measured after every 10 min interval at head, middle and tail position of lateral whereas the wetted soil depths were measured by digging holes at single representative dripper position from each lateral.

Irrigation and fertigation scheduling

Irrigation was scheduled according to the water requirement of crop. Water requirement of cabbage crop was calculated on the basis of reference evapotranspiration (ET_0) on daily basis by using Penman-Monteith's semi empirical formula (Smith, 1991). The necessary weather data were collected from an automatic weather station, located adjacent to the field site. The crop evapotranspiration (ET_c) was estimated by multiplying the reference crop evapotranspiration (ET_0) with crop coefficient (K_c) for different months based on crop growth stages (i.e. $ET_c = ET_0 \times K_c$). Crop coefficients adopted for cabbage crop for initial, development, mid-season and harvesting stage were 0.70, 0.88, 1.05 and 0.95, respectively (Allen *et al.*, 1998). Total water requirement of cabbage crop was estimated to be 36 cm for total growing period. Accordingly daily Irrigation was given to the field.

To meet the nutritional requirements of cabbage, 180 kg nitrogen (N) ha^{-1}, 100 kg phosphorous (P_2O_5) ha^{-1} and 150 kg potassium (K_2O) ha^{-1} rate were applied. The fertilizers used in the study included urea (46%), Phosphoric acid (85%) and Muriate of potash (60%) to ensure the requirement of N, P and K respectively. Fertigation was started 15 days after transplanting and was stopped 15 days before the harvesting i.e. the field was fertigated for 90 days. The requirements of nutrients for the experimental unit (according to recommended fertilizers dose) were 20.79 kg of nitrogen (45 kg of Urea), 11.55 kg of phosphorous (15 kg of Phosphoric acid) and 17.32 kg of potassium (30 kg of Muriate of potash). Fertilizer solutions were prepared in large plastic tanks for the entire crop season. The fertilizer solutions were applied in equal doses 26 times, 13 times and 6 times during the crop season under biweekly, weekly and fortnightly fertigation frequencies, respectively. Before starting the fertigation, the fertilizer solutions were filtered to remove the un-dissolved solids. A 0.95 cm (3/8 inch.)

venturi was used to inject the fertilizer solution into the main line of drip system.

Soil water and nitrate-nitrogen analysis

Frequency domain reflectometry (FDR) was used in this study to determine soil water content. Six access tubes were installed near the plant in each block up to a depth of 100 cm. These access tubes were used to measure the soil water content in the root zone of the cabbage crop with the help of FDR. Soil water content was measured in six treatments (T1, T2, T3, T10, T11 and T12) on weekly basis during November to March (2010-11) before the irrigations.

The soil sampling was done along as well as across the lateral pipe. Soil samples were collected from 0–15, 15–30, 30–45 and 45– 60 cm soil depths for nitrate-nitrogen (NO_3-N) determination. NO_3-N content in soil water extract was calculated assuming that NO_3-N form of nitrogen was dissolved in the water. Some soil samples were analyzed immediately after collecting from the field but storage was required beyond 24 h due to large number of samples. NO_3-N analysis was determined by Kjeldhal Apparatus in laboratory. Equation 4 was used to estimate the NO_3-N present in the soil sample.

$$NO_3 - N(mg/kgsoil) = \frac{V \times 0.02 \times 0.014 \times 100 \times 10^6}{20 \times 50} \quad (4)$$

Where,

V = Volume of 0.02N H_2SO_4 in ml
Normality of H_2SO_4 = 0.02N
Weight of soil taken = 20 gm
Volume of KCl added = 100 ml
Volume of extract taken in distillation flask = 50 ml

RESULTS AND DISCUSSION

System performance

The study revealed that, in general, dripper discharge was lesser than the rated discharge in both the systems, i.e. PC and NPC. The average discharges of the PC and NPC drippers were 0.82 lph and 1.65 lph, respectively, whereas, the rated dripper discharges (given by manufacturer) were 1 lph and 2.1 lph, respectively. The UC (Uniformity Coefficient) was found to be higher in PC system (96.0 %) as compared to NPC system (95.4 %). The UC value was higher in PC drippers owing mainly to its compensation of dripper discharge at varying pressures. CV (Coefficient of Variation) was found to be 0.048 and 0.058 for the systems with PC drippers and NPC drippers, respectively. The value of CV for PC and NPC system can be considered as ‘good’ and ‘average’, respectively (ASAE, 1985). The EU (Emission Uniformity) of the drip system with PC and NPC drippers was 92.7 and 92.1%, respectively.

Horizonal and vertical wetting front

It was observed that with the increase in duration of water application both the wetted soil width and depth increased but increase in wetted soil depth was more than the wetted width of soil. The maximum wetted soil depth and width was 26 cm and 25.5 cm respectively, under NPC drippers after 3h of water application. The drippers on the laterals behaved as independent point sources until 1.5 hours of operation of the both systems. After 1.5 h hours the adjacent wetted zones started merging with each other.

The effect of duration of water application on the depth and width of the wetted zone of soil in the drip system is illustrated in fig. 2 and 3. The figures indicate that for a given dripper discharge the wetted soil depth and width increased with duration of water application (Fig. 4 and 5). The relationship between the wetted soil depth and width with the duration of water application followed a power equation of the form Y= X**n. It may be noted that the greater application rate allows water to move farther both in vertical and horizontal directions. Li *et. al.* (2004) also reported the similar results and fitted similar power equations to predict wetting front movement.

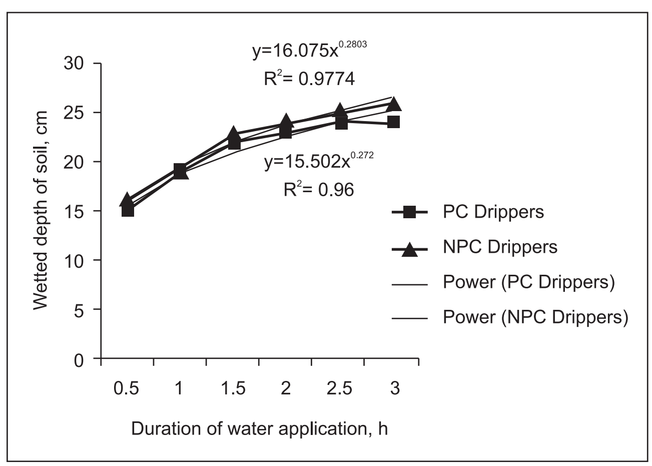

Fig. 2. Wetted depth soil under different dripper discharge

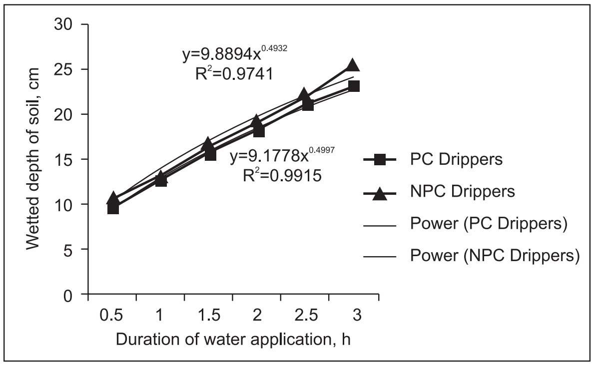

Fig. 3. Wetted width of soil under different dripper discharge

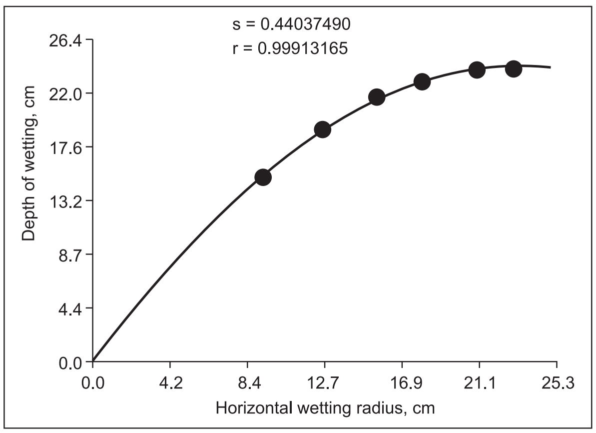

Fig. 4. Wetting front for PC drip irrigation system

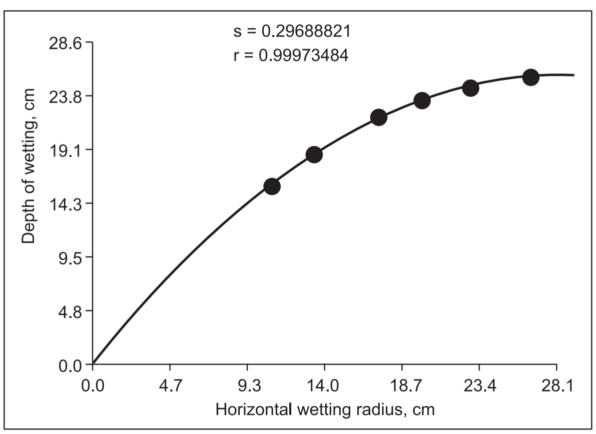

Fig. 5. Wetting front for NPC drip irrigation system

The lateral spacing for a given dripper discharge and dripper type (PC and NPC) may be decided by selecting the discharge rate. The relationship between wetted soil width and depth with the discharge rate and duration of operation may provide the critical information for designing of drip systems. The said relationship may also help in determining operation duration of a drip system having known rate of dripper discharge and lateral spacing to meet the requirement of a crop in terms of its root zone depth and water requirement.

Soil water distribution

Loam soil needs frequent irrigation with less amount of water per irrigation. Changes in volumetric water content with growth of cabbage in treatments (T1, T2, T3, T10, T11 and T12) were monitored weekly. It was found that fertigation frequency had no effect on water distribution. Soil water content just below the dripper was more throughout the crop season at field capacity (~ 30 % on volumetric basis). Desired wetting patterns of soil can be obtained by selecting the appropriate dripper discharge and duration of water application and by influencing the soil dripper interface. In drip irrigation, application of water, aimed directly at the root zone, moves by soil matric suction. Water distribution in the soil around a dripper mainly depends on soil texture, dripper discharge and root water uptake.

During the early initial growth stage, the soil up to the depth of 15-20 cm was kept wetted (Fig. 6 and 7). The downward movement of water was more than its lateral movement at all growth stages of crop. It was observed that in NPC system, soil moisture increased more at deeper soil depths and was not available for crop uptake because of less development of root system (Fig. 7). The more downward movement takes place because of more predominant role of the gravity. It was found that cabbage roots penetrate up to a depth of 60 cm but most were contained within 40 cm width and 50 cm depth.

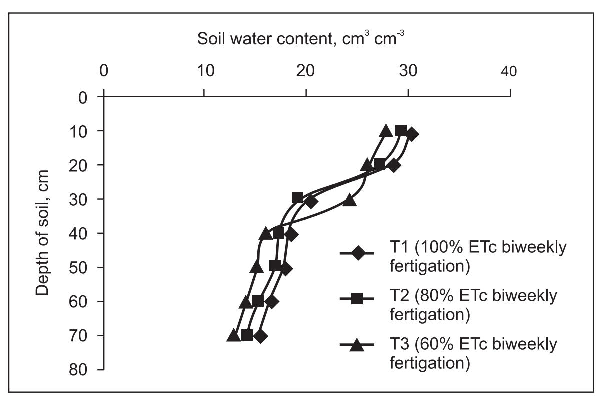

Fig. 6. Soil water distribution at initial stage of crop in PC dripper

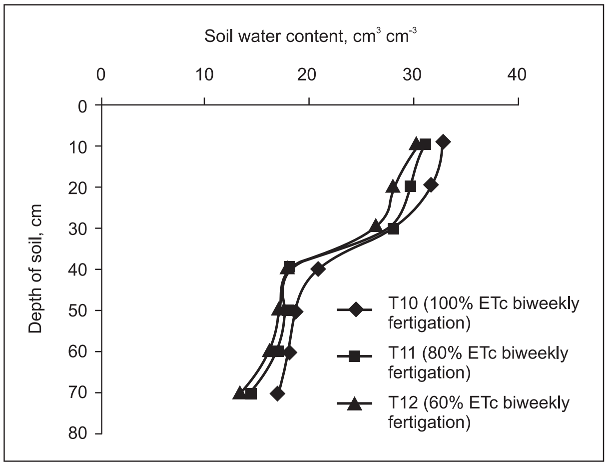

Fig. 7. Soil water distribution at initial stage of crop in NPC dripper

It was observed that water content of soil increases up to development stage of crop but then it starts decreasing at all soil depths (Figs. 8 and 9). Drip system having PC dripper was low discharge system and irrigation frequency was kept high therefore the soil around the dripper was almost at field capacity throughout the crop season.

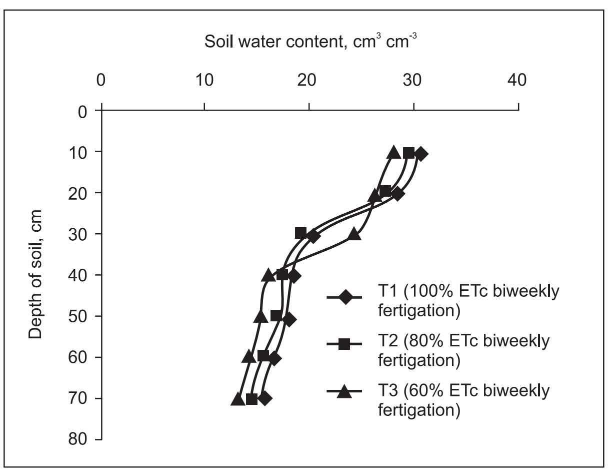

Fig. 8. Soil water distribution at development stage of crop in PC dripper

Uptake of soil water was more up to development stage. But after development stage the soil water content increased between 40 cm and 50 cm soil depth, with growth of crop (Figs. 10 and 11). One of the reasons could be the shallow root system of crop. With successive irrigation event, the water moves from upper profile to lower profile. Low discharge system is most appropriate for vegetables to enhance

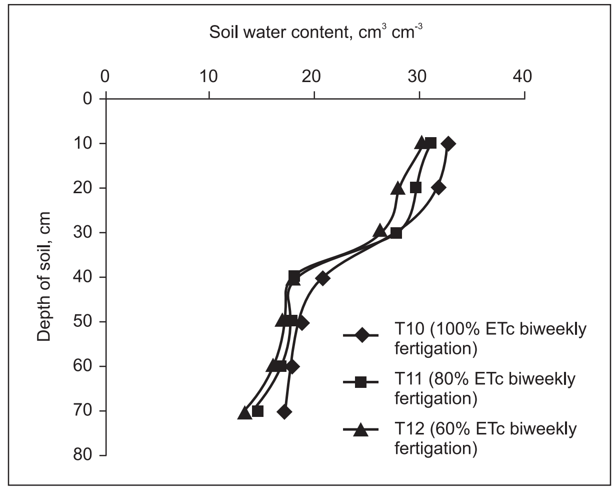

Fig. 9. Soil water distribution at development stage of crop in NPC dripper

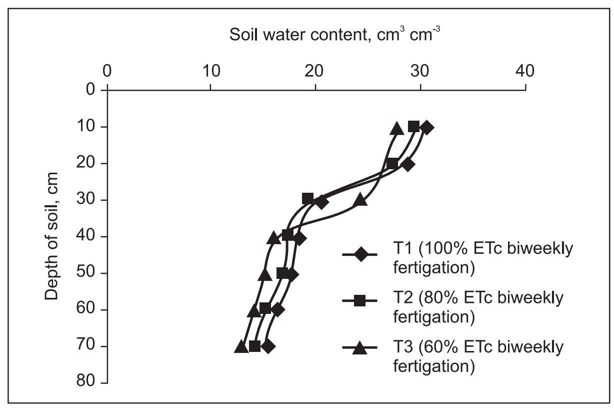

Fig. 10. Soil water distribution at mid-season stage of crop in PC dripper

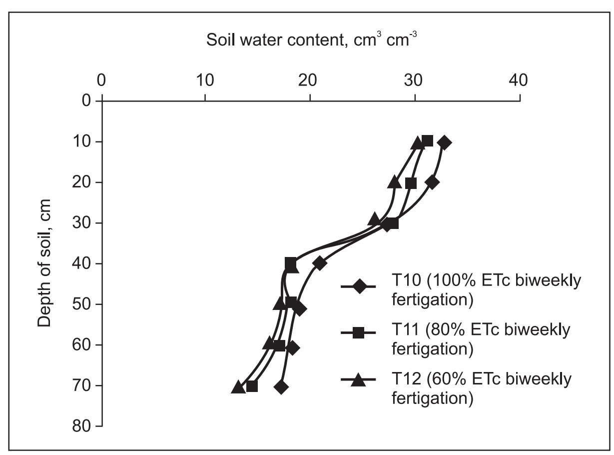

Fig. 11. Soil water distribution at mid-season stage of crop in NPC dripper

soil water level in the active root zone. Decrease in discharge will increase the operation duration of system but it will not allow the loss of water, through percolation, beyond root zone.

When PC drippers were used more soil water was found at a depth of 50 cm (Fig. 12). But in NPC, soil water content extended beyond 50 cm depth of soil at harvesting stage of crop (Fig. 13). It was observed that deficit of 20 and 40 % does not decrease water content up to 30 cm soil depth. This is very conducive for good growth up to development stage of crop in treatments T1, T2, T3, T10, T11 and T12. But beyond this depth it decreases significantly under 40 % water deficit treatment. Less availability of soil water at 40 and 50 cm depth decreases the yield at 60 % ET_c (40 % deficit).

In cabbage, the maximum roots were confined within the top 50 cm soil. Water moving beyond this depth was not available for plants at any stage of its growth. To increase the production and to achieve higher yield, adequate water content needs to be continuously maintained to create conditions conducive to good plant growth. This can be achieved by using a drip irrigation system having low discharge drippers operated at a high frequency. The high water content of the soil around the drippers maintains relatively high soil hydraulic conductivity and good replenishment of soil water taken up by plants.

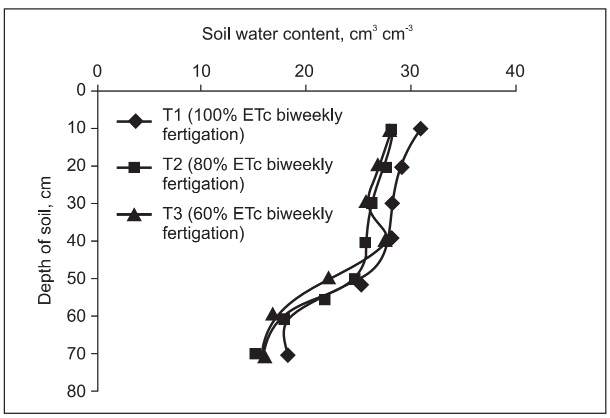

Fig. 12. Soil water distribution at harvesting stage of crop in PC dripper

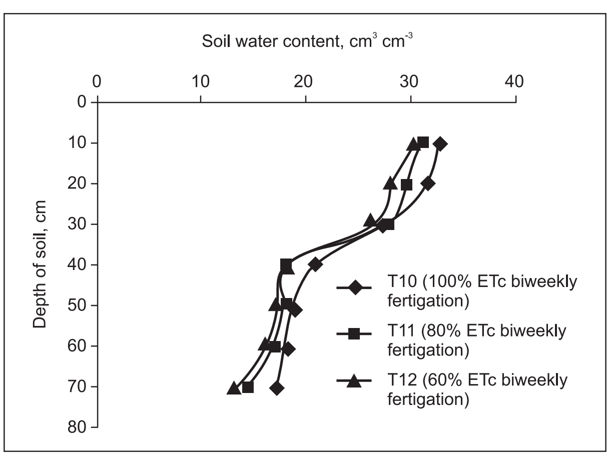

Fig. 13. Soil water distribution at harvesting stage of crop in NPC dripper

Effect of dripper type and levels of irrigation on NO_3-N distribution

NO_3-N was observed in all soil layers (0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm) of all the three selected fertigation frequencies i.e. biweekly, weekly and fortnightly. In the treatment T1 (100 % ET_c with Bi-weekly fertigation) NO_3-N concentration in 0-15 cm soil depth was found more than in 15-30 and 30-45 cm of soil depths but the highest value was noted in 45-60 cm soil depth at the end of crop (i. after the harvest). NO_3-N concentration in soil layers (0-15 cm, 15-30 cm, 30-45 cm) was found more in biweekly fertigation than in weekly fertigation. NO_3-N concentration was found more (22.4 mg Kg^{-1} of soil) at the soil depth 0-15 cm in the fortnightly fertigation frequency at the end of mid-season stage. The pattern of spatial distribution of NO_3-N in treatments with biweekly fertigation was found same as for the weekly fertigation frequency.

In treatment T7 (100% of ET_c with fortnightly fertigation), maximum NO_3-N content was found at 15-30 cm soil depth (Fig. 14). At 45 cm soil depth, the average NO_3-N in fortnightly fertigation was found more than biweekly and weekly fertigation. Similarly, at 60 cm soil depth the NO_3-N was found more in treatment T7 in comparison to other two treatments. Uptake of nitrogen under fortnightly fertigation was less as a result considerable amount of nitrogen remained in soil beyond 50 cm soil depth. On an average, higher content of NO_3-N were observed in all soil layers at lower fertigation frequency. At 45 cm soil depth, the average NO_3-N in fortnightly fertigation was found 22.4 ppm that was more than biweekly fertigation (19.6 ppm). At the end of maturity stage, when fertigation program was over, NO_3-N present in 0-45 cm soil depth leached to 60 cm soil depth although the rest of a profile remained practically unchanged.

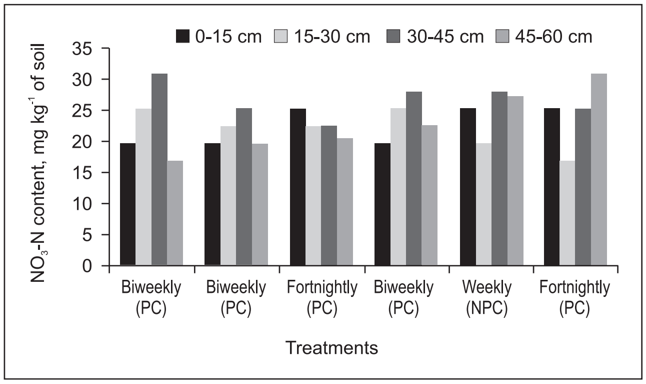

Fig. 14. NO_3-N concentration at dripper at the end of mid-season stage of growth

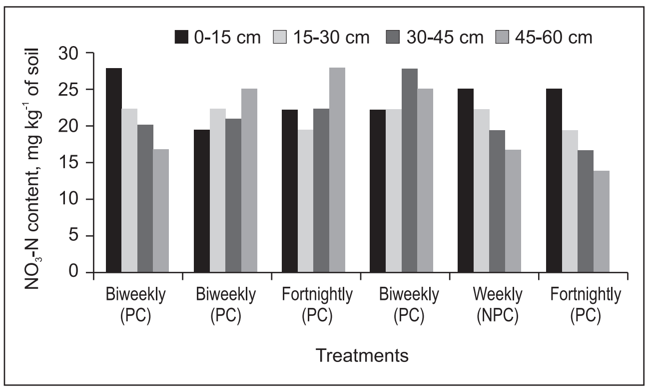

Fig. 15. NO_3-N concentration at 15 cm away from the dripper at the end of mid season stage of growth

Distribution of NO_3-N in all three irrigation treatments over the three-fertigation frequencies was monitored. Increasing drip uniformity in PC dripper reduced the amount of water drained through the soil, and decreased the amount of NO_3-N content leaching into lower soil profile.

CONCLUSIONS

Design and management of a drip irrigation and fertigation system depends upon a better understanding of water and nutrient distribution through the soil. The performance of inline drip system with PC drippers was better than NPC drippers. It was observed that with the increasing discharge rate of dripper both the wetted soil width and depth increased but increase in wetted soil depth was more than the wetted width. In 3 h operation of drip system, maximum wetted radius 23 and 25.5 cm were observed in PC and NPC drippers, respectively. While maximum wetting depth 24 and 26 cm was observed in PC and NPC drippers, respectively. At all growth stages of crop, adequate water was available within the root zone of cabbage crop in PC drip system but in NPC drip system soil water content extended beyond the cabbage root zone. More NO_3-N leached through the profile (beyond the root zone) in fortnightly fertigation frequencies in case of NPC drippers as compared to PC drippers.

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Runoff assessment through effective models in micro-watersheds of foothill region of India

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ABSTRACT

The assessment of peak runoff rate and volume is a pre-requisite for undertaking purposeful and judicious soil and water management programs i.e., designing appropriate land and water management practices, generating supplemental irrigation facilities etc. There is scanty information on the accurate runoff records for the watersheds. But on the other hand, daily rainfall records are usually available which can be utilised to simulate runoff. Some empirical, semi-empirical and process based approaches have been attempted and evaluated during studies conducted in watersheds of Siwalik foothills. Most of these models lack in extrapolation of the results outside their range and conditions over which parameter values have been calibrated and these have not been tested on independent data sets at different sites. One of the recently developed model for estimation of runoff using modified soil moisture accounting procedure needs suitable modification to simulate runoff at higher rainfall amounts. Attempts have been made to employ parameter optimization techniques to simulate runoff more accurately from micro-watersheds in the area.

Key words: Artificial neural network; Numerical techniques; Rainfall-Runoff, Siwalik foothill; Water budget equation

INTRODUCTION

The demand for food from natural resources that sustain man's existence has increased enormously in recent years. But the ability of land to produce food is limited. The limits of production are set by soil, water, climatic conditions and management practices applied. It is estimated that by the turn of the century, there will be one third less topsoil throughout the world per person than at present. If the erosion continues at this pace, it could possibly force large areas out of arable cultivation during the century. To meet the future demand of food and fibre, agricultural production needs to be increased from the present level, a large portion of which will come from an intensification of agriculture on lands already being cultivated. There is an uncertainty in these estimates about land which is being lost through degradation and how much land will be required to make up for the loss of productivity.

Poor land and water management practices have resulted in 35-45 per cent of rain becoming runoff and 25-225 t / ha / year as soil loss in North -Western (N-W) foothill region of India. The mathematical models for estimating runoff and sediment yields from small watersheds can be valuable for land management planning. The simulation models of sediment yield are integrated with models capable of simulating the rainfall-runoff response of the watershed because of the close dependence of sediment yield process on surface and channel runoff. Most of these models, which are available at present, are conceptual in nature and usually incorporate simplified forms of physical laws. A wide range of runoff models are currently used by researchers and practitioners, however the applications of these models are highly dependent on the purposes for which the modeling is made. Many runoff models are used merely for research purposes in order to enhance the knowledge and understanding about the hydrological processes that govern a real world system. Other types of models are developed and employed as tools for simulation

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and prediction aiming ultimately to allow decision makers to take the most effective decision for planning and operation while considering the interactions of physical, ecological, economic, and social aspects of a real world system (Moradkhani and Sorooshian, 2008). Most of the models require sophisticated mathematical tools, significant amount of calibrated data and some degree of expertise and experience with the use of models. Therefore, the implementation and calibration of such models can typically present various difficulties for the users. Keeping these points in view, attempts have been made by the scientists to develop empirical, semi-empirical and artificial neural network and process based models which requires less exhaustive information on rain, land, soil and vegetation characteristics in N-W tract of India. Most of the developed and calibrated models use the information on rainfall, runoff, and sediment yield data from micro-watersheds and comparatively requires less detailed inputs in order to model runoff and soil loss.

Modified Small watershed monthly hydrologic modelling

The time series hydrological and metrological data from the Targhadia watershed have been scientifically analyzed using various statistical tools (Khandelwal, 1999). Rainfall depth, duration and rainfall- runoff relationships have been developed. Generation of rainfall induced harnessable runoff (water yield) has been thoroughly studied and statistically compared with other models including United States Department of Agriculture (USDA), Soil Conservation Service-Curve Number (SCS-CN) procedure. The small watershed monthly hydrologic modelling system (SWMHMS) model with some modifications in constants and coefficients have been found to be the best adaptable for assessment of probable harnessable water yield on monthly basis followed by USDA and SCS-CN method (basic form), which performs better on daily basis. The computer programme with normal rain and extreme rains based on data of 1971-97 was used for the design of rainwater harvesting structures. The computer is then used for each year of rainfall data to design parameters of rainwater harvesting structures which have been supported through statistical tests. The recommended agronomic measures (crop coefficient, dates of sowing and harvest, duration, critical growth stages) for the specified regions are considered to compute water requirement and irrigation scheduling (at 66.7 per cent field application efficiency) of prevailing crops in the regions under a variety of conditions *viz*. i) no deficiency of irrigation water ii) yield reduction by 10 per cent and iii) yield reduction by 20 per cent. The results of Linear Programming Problems (LPP) suggest a set of optimal plans (alternatives) for cultivation during either summer monsoon (kharif), winter (rabi) or summer only under different situations (with unit irrigable command area) .

The SWMHMS model (on monthly basis) yielded best relationships between computed and observed runoff for the periods P_1 (1975-97) and P_2 (1975-86) under CN=59 (optimized = 59.5) and CN = 88. Therefore, the present model can be used for design of rainwater harvesting structures.

The application of the developed computer program KRWHSK for design of rainwater harvesting structure suggests construction of a square based trapezoidal shape irrigation tank with assumed depth of excavation of 1.0 m and mean base width of 31m (range 26.7-32.6 m) for the Targhadia watershed. Application of KRWHSK also offers certain alternatives under different conditions of runoff coefficients and use of CN = 88 for assessing runoff.

Modified rational formula

After calibration, the peak runoff rate model was developed by Duggal (1992) for Patiala-Ki- Rao micro-watershed, District Ropar, India was of the type:

i) For low intensity storms
(Intensity less than or equal to 5 cm / h)

$$Q_p = \text{CI A}^{0.55} \quad (1)$$

ii) For high intensity storms
(Intensity more than 5 cm / h)

$$Q_p = \text{CI A}^{0.95} \quad (2)$$

Wherein equation (1) and (2), Q_p is peak runoff rate in m^3/s, C is runoff coefficient, I is the rainfall intensity corresponding to the time of concentration in cm / h, A is the watershed area in ha.

The comparison of simulated and historical runoff rates of low intensity storms for micro-watershed (II) showed that per cent error in observed (historical) and predicted (simulated) runoff rate varied from –5.5 to as large as 40.7 per cent.

Similarly, the comparison of the simulated and historical peak runoff rates for high intensity storms for micro watershed (II) showed per cent error varied from –28.6 to as high as 49.9. So, both for low and high intensity storms, peak runoff rate is mostly over predicted compared to historical peak runoff rate reported for different years.

Artificial neural network approach

In four Saleran micro-watersheds, District Hoshiarpur in N-W tract of India, using data which are easily available without the need to explicitly representing the internal hydrologic structure of the watershed. Artificial neural network simulator based on back propagation algorithm was developed in C^{++} computer language (Sabu, 1999). Initial mode inputs were four rainfall inputs (present days as well as previous three days), maximum 15 minutes and 30 minutes rainfall intensity, duration of storm, area and slope of watershed. The model input data were selected by using the prior knowledge of the problem and by examining the underlying physical processes causing runoff and erosion. Both runoff and erosion processes are dependent on rainfall as well as watershed characteristics. Since the available information on watershed was limited, it was decided to incorporate more rainfall characteristics in the input data. The input data contained four rainfall inputs such as rt-0, rt-1, rt-2 and rt-3 where rt-0 represents present day's rainfall, rt-1 the previous day, rt-2 the day before the previous day and so on. The model outputs were fixed as sediment yield, runoff depth and peak flow rate. Neural networks having one input layer, two hidden layers and one output layer were used to develop the models. The network was trained using the data for the period 1993-1996 and trained network were validated using the data for the period 1997. A sensitivity analysis was carried out to determine the relative significance of the selected inputs with the aim of discarding the less sensitive inputs and thereby simplify the architecture.

Three-network architectures were selected and the relative performance of each model was analyzed by comparing the observed values with those predicted by the models. It was observed that the accuracy of the models depended on the number of inputs as well as the network architectures. The neural network with 9 input nodes, 22 nodes in the first hidden layer, 9 nodes in the second hidden layer and 3 nodes in the output layer yielded best predictions on calibration as well as validation of data sets. There is a considerable difference in root mean square error (RMSE) values among the three network structures (Table 1). The RMSE values were found the least in case of NN_2. In case of NN_3, RMSE values were found less than those of NN_1 but higher than those of NN_2, indicating poor performance. A combined measure of low RMSE and high correlation coefficient can be considered a better statistic for evaluating the accuracy of each model. These measures indicate that NN_2 performs better than NN_1 and NN_3. Since the intensity and duration of rainfall are correlated inputs, one of them can be discarded to avoid redundancy. This can be justified by the improved performance of NN_2 which discarded duration of rainfall from the input set.

Table 1. Summary of results of artificial neural network models for calibration in micro-watershed

Year	Outputs	NN_1		NN_2		NN_3	
		RMSE	R	RMSE	R	RMSE	R
1993	Sediment yield (t)	14.802	0.999	4.409	0.999	7.569	0.999
	Runoff (mm)	1.658	0.999	0.550	0.999	0.920	0.999
	Peak flow (m^3/s)	0.113	0.999	0.027	0.999	0.042	0.999
1994	Sediment yield (t)	29.303	0.975	4.465	0.997	7.201	0.995
	Runoff (mm)	5.524	0.971	1.270	0.998	3.798	0.994
	Peak flow (m^3/s)	0.334	0.983	0.073	0.998	0.106	0.998
1995	Sediment yield (t)	14.875	0.994	3.91	0.999	6.058	0.999
	Runoff (mm)	1.832	0.998	0.680	0.999	1.350	0.999
	Peak flow (m^3/s)	0.142	0.985	0.044	0.998	0.071	0.995
1996	Sediment yield (t)	8.326	0.986	3.079	0.998	6.855	0.993
	Runoff (mm)	1.308	0.998	0.499	0.999	0.954	0.999
	Peak flow (m^3/s)	0.173	0.990	0.097	0.997	0.105	0.996

Source: Sabu (1999); NN_1 = neural network 1; NN_2 = neural network 2; NN_3 = neural network 3.

Numerical techniques

Runoff was simulated by solving the hydrodynamic equations of continuity and momentum in conjunction with kinematics' wave approximation (Sharda, 1990). For time integration, four numerical schemes viz. Explicit, fully Implicit, Crank-Nicolson and Predictor-Corrector methods were used and compared for their accuracy and stability. To generate rainfall excess rate under unsteady conditions, infiltration has been simulated by solving Richards's equation with a sink term for one-dimensional flow in an aquifer-soil-plant continuum. The sink term defines the plant water uptake through different soil layers depending upon root distribution. To compute this term the potential evapo- transpiration has been calculated by employing modified Penman's method. The plant transpiration is computed through Richie's (1972) model depending upon leaf area index. The actual plant transpiration under prevailing moisture conditions has been obtained by the methods of Feddes *et al*. (1978), Belmans *et al*. (1983), Van Genuchten and Hoffman (1984) and Van Genuchten (1987). The total transpiration is then distributed in different soil layers of root zone depending upon root distribution as suggested by Van Genuchten and Hoffman (1984). The root depth with respect to plant growth is computed using the empirical relationship developed by Borg and Grimes (1986). It was assumed in the model that daily evapo- transpiration occurs sinusoidally during the day time only whose length is taken as 12 hours and during night it may be neglected.

To simulate soil erosion, the sediment continuity equation or the sediment mass conservation equation has been numerically solved by employing finite element technique in conjunction with fully implicit scheme for time integration. The sediment inflow in governing equation which consists of inter-rill and rill erosion has been computed using expressions of Lattanzi *et al*. (1974) and Haan *et al*. (1982). Yalin (1963) equation has been used to compute the sediment transport capacity of overland flow which when compared with sediment supply decides the net soil erosion and deposition at a given time step. The mathematical model developed for rain generated runoff and soil erosion simulation has been validated and compared with the analytical solution and field data.

Moisture accounting procedure and curve number technique

A runoff model for micro-watersheds in N-W tract of India has been developed that uses the modified soil moisture accounting procedure and SCS curve number technique to estimate runoff volume (Hadda *et al.*, 2002). The soil moisture accounting procedure was based on the assumptions viz: i). whenever there was rainfall or irrigation, the upper layer was fully charged before any moisture is transmitted to the lower layer, ii). The daily evaporation loss occurred uniformly and exclusively from the top 30 cm soil layer. Only after moisture in this layer was depleted then evaporation loss would occur from the lower layers (below 30 cm depth), iii). The transpiration demand was met by plants extracting water uniformly from the entire root-zone. The soil evaporation (E) and transpiration (T) were computed using the following equations:

$$E = \frac{(1-\beta)\,E_0}{t^*} \tag{3}$$

$$T = \beta\,(E_0) \tag{4}$$

In equations 3 and 4, E_0 is daily open pan-evaporation, b is light interception coefficient (ranges from 0 to 1), T is daily transpiration and t* is the time factor. The value of t* depends upon the frequency of the soil wetting and the light interception coefficient β (representing light intercepted by tree / bushes etc).

The agreement between simulated and measured runoff appeared closely related as indicated by large values of coefficients of determination (R^2 =0.90-0.95) and low value of root mean square error (RMSE= 8.9-10.5). These low value of RMSE and high value of R^2 are due to close values of observed and simulated runoff at low to moderate amount of rainfall. But, generally there is not good agreement between the daily observed and simulated runoff volume. The simulated runoff volume values are larger than the observed runoff amounts at higher rainfall amounts. This is attributed to the under prediction of deep percolation rate as indicated by low value of sensitivity coefficients (β=0.27-0.29) for this component as compared with other components of water budget equation (Table 2).The predicted runoff volume was most sensitive to evapo-transpiration rate (β = - 0.86 to -0.90) and least sensitive to deep percolation rate (β = 0.26 to 0.29) as indicated by multiple linear regression analysis.

Table 2. Sensitivity coefficient (β) of hydrologic variables for storm based runoff model

Parameter or variable	Sensitivity of runoff volume		
	Linear	Expo-nential	Power
	β values in micro-watershed-I		
Rainfall	0.75	-0.45	0.18
Evapotranspiration	-0.90	-0.09	5.30
Soil moisture storage	-0.65	0.50	10.3
Deep percolation rate	0.29	-0.68	-19.0
R^2	0.90	0.58	0.70
F ratio	216.0	16.0	33.0
	β values in micro-watershed-II		
Rainfall	0.79	-0.42	0.21
Evapotranspiration	-0.86	-0.12	5.80
Soil moisture storage	-0.62	0.45	12.3
Deep percolation rate	0.27	-0.64	-18.2
R^2	0.95	0.61	0.77
F ratio	218.7	16.1	35.0

Source: Hadda *et al*. (2002)

As sensitivity coefficients were obtained by regression procedure, a positive index means that an increase in the input variable increase the predicted model output in proportion to the sensitivity index and a negative index means that a decrease in the input variable decreases the model prediction in proportion to the index. Since the sensitivity analysis was performed from the results of only two watersheds, the same could not be extrapolated for other locations having different land use conditions.

CONCLUSION

The assessment of runoff in field of every watershed unit is not possible, therefore, simulation models have been developed using soil, hydrological and meteorological data. There is several simulation models developed for the runoff assessment and these are empirical, semi-empirical and process based, that are calibrated and validated for different watersheds. Some of the models like SWMHS, modified rational formula, artificial neural network approach and numerical approach simulation were calibrated for watersheds of Siwalik foothills with large percentage of error to the observed runoff. Runoff models accounting in-situ soil moisture and curve numbers are effective for micro-watersheds of Siwalik foothill region, however, for each watershed, the model should be calibrated and validated, keeping in view the soil properties, physiography and rainfall.

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Effect of drip-fertigation on soil moisture distribution and irrigation water use efficiency of banana in West Bengal

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ABSTRACT

The aim of the study was to assess the feasibility of N, P & K application on soil moisture distribution of drip fertigation method in banana cultivation. The experiment was laid out in Augmented Factorial Complete Block Design with four replications. Main factor was irrigation at 3 levels (I_1= 50% CPE, I_2= 60% CPE and I_3= 70% CPE), Sub-factor was fertilizer at 3 levels (F_1=50% RDF, F_2=60% RDF and F_3=80% RDF) [Recommended dose of fertilizer of N, P and K @ 250:50:300 (g / plant / year)] and control is augmented in four replications. Control treatment includes irrigation at 100 per cent at CPE and fertilizer at 250: 50: 300 g N: P: K / plant. Total number of treatments was 3 x 3+1 = 10. Plot size was 6 m x 4m. Banana [var. Martaman (AAB, silk)] was planted at a distance of 2m x 2m (square planting). Drip irrigated treatments recorded higher soil moisture content than conventional irrigated treatments. The maximum soil moisture of 22.82 % and 23.49 % was recorded under I_3F_1 treatment and minimum of 19.89 % and 20.66 % under I_1F_3 treatment in 0-15 and 45-60 cm soil depth, respectively. However, under drip irrigation system moisture content in 0-15, 15-30, 30-45 and 45-60 cm soil depths were relatively uniform with a little difference of 3.53 to 2.88 % whereas, in conventional irrigation system abrupt variation of 7.85 to 8.59 % was observed. The average water applied under drip and conventional irrigation was 528.95 mm and 900 mm, respectively including both plant and ratoon crop. Under the same drip fertigation higher yield increase (%) of plant crop (32.48) & ratoon crop (26.40) over conventional was obtained in I_2F_3 treatment. Considerable saving in water has occurred (41.69 and 40.41 for plant crop and ratoon crop respectively) in drip fertigation under I_2F_3 treatment. The high initial cost of investment for the system is one of the major constraints, but if the benefits are considered, cost is fully compensated by the better returns.

Key words: Banana; Drip fertigation; Conventional irrigation; Soil moisture; Irrigation water-use-efficiency

INTRODUCTION

Water and fertilizer are the most important crucial basic resources for augmenting crop production. It is a high time to manage these commodities in efficient way, so as to feed the teeming population of the country. Injection of soluble or liquid fertilizer through micro-irrigation system is gaining importance nowadays (Deolankar and Firake 2002). However, the cost of fertilizer is the important prohibiting factor in the use of soluble or liquid fertilizer. Hence, it is necessary to find out the response of crop to liquid fertilizer with optimum and maximum dose. There is scarcity of water due to uneven and erratic rainfall. Besides, there are considerable losses of water and nutrients due to deep percolation and run-off under conventional flooding (Kumar et al. 2007). Adoption of drip irrigation and use of water soluble fertilizers through drip irrigation are recent developments in banana production in India. Owing to beneficial effects of drip irrigation in banana, an optimum irrigation scheduling of banana has been worked out by many workers (Narayanamoorthy 2006; Kumar 2008). Under drip irrigation only a portion of soil volume around each plant is wetted and thus traditional method of fertilizer application is less.

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Drip irrigation in banana plantations has helped in saving water and offers a great promise, owing to precise and direct application of water in the root zone of plants (Shashidhara et al. 2007; Agrawal and Agrawal 2005). In addition, due to higher frequency of irrigation, ensuring availability of moisture at critical crop growth stages saves the plants from moisture stress throughout the growing period (Dahiwalkar et al. 2004). Moreover, there is considerable water saving as small amount of water is applied at a time under drip irrigation (Wadatkar et al. 2005). Keeping all these in view, a field experiment was conducted to study the effect of drip irrigation and N, P & K application on soil moisture distribution and irrigation water use efficiency of banana in New Alluvium Zone of West Bengal.

MATERIALS AND METHODS

The investigation was carried out during 2008-10 at the Teaching Farm under Bidhan Chandra Krishi Viswavidyalaya, Mondouri, Nadia, West Bengal. The farm where the experiment was conducted is situated in the New Alluvial Zone of West Bengal at 23.5^0 North latitude and 80^0 East longitudes having on altitude of 9.75 meters above mean sea level. The aim of the study was to assess the feasibility of N, P & K application on soil moisture distribution of drip fertigation method in banana cultivation. The soil (0-15 cm) of the research station was silty clay in texture having pH 6.46, EC 0.10 ds / m, 0.46 % organic carbon and 156.49, 31.37 and 142.06 kg N, P_2O_5 and K_2O / ha respectively. The experimental soil had 1.76 $10^{-6}MS^{-1}$ saturated hydraulic conductivity with 50.25% water holding capacity. Topographically the land is called medium / medium-high. The experiment was laid out in Augmented Factorial Complete Block Design (AFCBD) with four replications. Main factor was irrigation at 3 levels (I_1= 50% CPE, I_2= 60% CPE and I_3= 70% CPE), Sub-factor was fertilizer at 3 levels (F_1=50% RDF, F_2=60% RDF and F_3=80% RDF) [Recommended dose of fertilizer of N, P and K = 250:50:300 (g / plant / year)] and control is augmented in four replications. Control treatment includes irrigation at 100 per cent at CPE and fertilizer at 250: 50: 300 g N: P: K / plant. Total number of treatments was 3 x 3+1 = 10. Plot size was 6 m x 4m. The uniform healthy 2 months old sword suckers of cv. Martaman (AAB, silk) 1.5 kg weight were planted in pit (1ftx1ftx1ft) at a spacing of 2m x 2m (square planting) after treating them in 10g Carbendazim + 1g Streptocycline + 10ml Monocrophos in 10 liters of water for 30 minutes. Farm yard manure (FYM) @ 5 kg / pit was applied before planting of sucker. Recommended plant protection measures and cultural operations were made throughout the period of study.

Method of irrigation

Nine treatments were considered under three levels of cumulative pan evaporation replenishment. Three levels of depth of irrigation as 70%, 60% and 50% of cumulative pan evaporation 3 days for summer and 5 days for winter were considered. Recorded pan evaporation data at various growth stages were obtained on regular basis and the amounts of irrigation water through drippers were calculated before rates application. The evaporation data were collected from a USWB class A pan located on meteorological observatory near the experimental field. The irrigations were skipped where considerable amount of rainfall was received and thereby keeping the soil profile wet for few consecutive days. Depending on the amount of effective rainfall (> 2.25mm) received, the next date of irrigation was adjusted (Dastane, 1967).

Discharge rate of drippers

Uniformity coefficient (Uc) of application of water was determined by collecting the discharge of the drippers in the buckets for a specified period at selected laterals and using the following formula (Raina et al. 1999).

$$Uc = \frac{1 - \nabla q}{q} \qquad \text{............. (1)}$$

where q, mean emitter discharge rate (l / h); ∇q, mean deviation of the emitter discharge from mean value.

There were two drippers at each plant bottom of standard capacity 2 l / h. The actual discharge of both the drippers was measured to be 3.6 l / h (1.8 x 2 l). The discharge of drippers at remote and head ends of flow net in the orchard were taken to adjust time of operating the drippers according to the volume of water exactly required on the basis of varying irrigation requirement throughout the crop season. Irrigation water was made available from a shallow tube well adjacent to the research field. Liquid fertilizer solutions were injected into the drip system through a fertilizer injector at weekly interval starting from 45 days after planting to 210 days except rainy month, when the irrigation was not required as per cumulative evaporation rate. Nutrients namely N, P and K were applied in the form of urea (46 % N), phosphoric acid (31.68 % P) and muriate of potash (60 % K_2O). In cases of drip fertigation, all the nutrient sources were dissolved in a tank along with irrigation water and applied at different times as per the requirement of the banana crop.

Soil moisture measurement

Soil samples were collected during pre and post irrigation from 0-15, 15-30, 30-45 and 45-60 cm depths around the plant bottom at 15, 30, 45 & 60 cm distances away from the plant towards equal spaced 3 directions. Soil moisture samples were collected from the wetted area around the plants as described above and gravimetric method was used to determine the soil moisture contents.

Moisture retention at different suction

Soil moisture retention of soils collected from different depths for two suction levels viz. 0.01 & 1.5 (MPa) were determined by using the pressure plate extractor (Richards, 1967).

Irrigation water use efficiency

This may be defined as the ratio of the amount of economic crop yield to the amount of irrigation water applied for crop growing. It is obtained by the following formula.

$$\text{Irrigation water use efficiency (Kg/ha cm)} = \frac{\text{Yield (Kg/ha)}}{\text{Irrigation water applied (cm)}}$$

Methods of statistical analysis of data

The data obtained for soil moisture and yield, were analyzed statistically by the technique suitable for Augmented Factorial ANOVA (Federer, 1956). Here three levels of irrigation along with three levels of fertilizer made 9 fertigation treatments in 3 x 3 factorial form and one conventional technique made the design as ‘Augmented’ one. Soil data had additional source of variation as depth with level 4 for measuring different parameters and both soil and yield data were repeatedly observed in same banana orchard. So the ANOVA technique is repeated discretely for each year of observations and lastly the result is analyzed pooling over two years of study. SPSS ver- (7.5) along with MS-Excel software was used to do all statistical analysis.

RESULTS AND DISCUSSION

Soil moisture distribution

The results showed considerable variations in soil moisture distribution pattern under drip and conventional irrigations, and were also influenced by the amount of nutrients applied (Table 1). At 0-15 cm soil depth, the highest moisture content was observed under the treatment where 50% of recommended doses N, P and K (I_3F_1) were applied whereas, the lowest moisture content was recorded under the treatment having application of drip fertigation along with 80% of recommended doses N, P and K (I_1F_3). Moisture content decreased with the increasing depth of soil (15-30, 30-45 and 45-60 cm) for drip fertigation and conventional method of irrigation. At 45-60 cm soil depth, lower values of moisture content in soil was obtained under (I_1F_3) treatments, even lower than conventional irrigation practices at depth 0-15cm. The moisture distribution pattern is in conformity to the usual distribution pattern in soil profile transition zone of infiltrated water. Ramah et al. (2008) stated the soil moisture distribution under the drip fertigation treatments that it was relatively higher near the dripper and decreased from the dripper point increased.

Under the conventional irrigation practice the moisture content did not remain uniform and abrupt variations of 7.85 to 8.59 (%) were observed at 0-15, 15-30, 30-45 and 45-60 cm soil layers causing higher fluctuations in matric suction values (Table 2). It might be due to high volume of water applied at a time, which increased the transmission zone with relatively higher water content into the lower soil depths. Under drip irrigation, difference in moisture content between upper and lower depth was 3.53 to 2.88 (%), as less quantity of water was applied frequently which resulted in minimum fluctuations in matric suction and lesser movement of water in lower soil depth compared to conventional irrigation. This might be the reason for better soil moisture redistribution and availability under drip irrigation. Badr (2007) experimented for distribution of drip water for radial and horizontal distribution. After the irrigation ceased, he observed the vertical elongation pattern extended nearly to 30 cm

Table 1: Soil moisture content (%) in different soil depth under drip irrigation and conventional irrigation with N, P and K application

Treatment	0-15cm			15-30cm			30-45cm			45-60cm		
	2008-09	2009-10	Mean	2008-09	2009-10	Mean	2008-09	2009-10	Mean	2008-09	2009-10	Mean
Drip fertigation												
I_3F_1	22.88	22.73	22.80	23.49	23.39	23.44	24.40	24.31	24.35	23.61	23.78	23.69
I_2F_1	22.26	22.59	22.42	23.03	23.24	23.13	23.74	23.85	23.79	23.15	23.21	23.18
I_1F_1	21.69	21.78	21.73	22.46	22.40	22.43	23.08	22.95	23.01	22.54	22.44	22.49
I_3F_2	22.46	22.18	22.32	23.22	23.00	23.11	24.00	23.78	23.89	23.29	23.15	23.22
I_2F_2	22.04	21.63	21.83	22.49	22.28	22.38	23.38	23.14	23.19	22.47	22.63	22.55
I_1F_2	20.89	21.02	20.95	21.58	21.70	21.64	22.42	22.11	22.05	22.08	21.43	21.75
I_3F_3	21.74	21.32	21.53	22.46	22.13	22.29	23.31	22.95	23.13	22.73	22.32	22.54
I_2F_3	20.86	20.60	20.73	21.49	21.26	21.37	22.20	21.89	22.04	21.57	21.44	21.50
I_1F_3	19.95	19.83	19.89	20.53	20.38	20.45	21.18	21.00	21.09	20.74	20.59	20.66
SE(m)	0.172	0.169	-	0.177	0.220	-	0.226	0.284	-	0.174	0.217	0.172
CD(0.05)	0.498	0.488	-	0.513	0.637	-	0.652	0.821	-	0.504	0.626	0.498
SE(m) for treatment	0.172	0.169	-	0.177	0.220	-	0.226	0.284	-	0.174	0.217	0.172
CD (0.05) for treatment	0.498	0.488	-	0.513	0.637	-	0.652	0.821	-	0.504	0.626	0.498
Mean drip	21.64	21.52	21.58	22.31	22.20	22.25	23.08	22.89	22.95	22.46	22.33	22.40
Conventional method	20.68	20.85	20.76	22.30	22.48	22.39	24.15	24.35	24.25	26.19	26.48	26.33
SE(d) of contrast	0.187	0.179	-	0.186	0.230	-	0.231	0.291	-	0.205	0.258	0.187
CD(0.05) of contrast	0.541	0.518	-	0.537	0.667	-	0.667	0.842	-	0.594	0.746	0.541

Table 2. Moisture retention at different suction (cm^3)

Depth (cm)	0.01 (MPa)	1.5 (MPa)
0-15	0.32	0.11
15-30	0.33	0.14
30-45	0.30	0.10
45-60	0.28	0.08

horizontally and 70 cm vertically directly beneath the dripper and maximum water content between 10 and 40 cm soil depth.

Yield of banana

The result summarized in the (Table 3) indicates that the variation of banana yields (t/ha) were significant among different fertilizer and irrigation levels. I_2 irrigation level gave the highest yield (41.17 t/ha) followed by I_3 (39.74t/ha) and I_1 (34.17 t/ha), respectively whereas, F_3 fertilizer level produced higher yield (42.28 t/ha) than the other fertilizer levels. In both the cases ratoon crop produced lower

Table 3. Effect of different levels of drip fertigation on the banana yield (t/ha)

Treatments	Yield		
Irrigation	Plant crop	Ratoon crop	Pooled
I1	35.33	33.00	34.17
I2	42.86	39.48	41.17
I3	41.40	38.07	39.74
SE(m)	0.296	0.424	0.287
CD(0.05)	0.854	1.225	0.587
Fertilizer			
F1	33.75	31.21	32.48
F2	41.71	38.91	40.31
F3	44.13	40.43	42.28
SE(m)	0.296	0.424	0.287
CD(0.05)	0.854	1.225	0.587
Irrigation x Fertilizer			
I1F1	29.25	25.76	27.50
I1F2	37.59	36.09	36.84
I1F3	39.17	37.15	38.16
I2F1	34.07	32.40	33.24
I2F2	45.37	41.99	43.68
I2F3	49.14	44.04	46.59
I3F1	37.94	35.48	36.71
I3F2	42.18	38.64	40.41
I3F3	44.09	40.10	42.09
SE(m)	0.512	0.735	0.498
CD(0.05)	1.479	2.121	1.017
SE(m) for treatment	0.512	0.735	0.498
CD (0.05) for treatment	1.479	2.121	1.017
Mean drip	39.87	36.85	38.36
Conventional method	37.09	34.84	35.96
SE(d) of contrast	0.540	0.774	0.525
CD(0.05) of contrast	1.559	2.236	1.072

yield than that of plant crop. Among different interaction levels, significantly higher yield was obtained under I_2F_3 level (46.59 t/ha) closely followed by the treatment combination I_2F_2 (43.68 t/ha). The results indicates that drip fertigation method resulted in considerably higher yield in plant (39.87 t/ha) and ratoon crop (36.85 t/ha) as compared with those obtained by conventional method of irrigation (37.09 and 34.84 t/ha for plant and ratoon crop respectively) (Table 3). There was a significant increase in banana yield with drip fertigation method under plant and ratoon crop as compared to conventional method of irrigation. The differences in branch characteristics; mainly, bunch length, weight, hands per bunch etc. were comparable to yields. Kavino et al. (2002) also stated that higher levels of N, P and K, the application of required fertilizers in balanced proportions along with different irrigation levels at different crop stagers could be strongly attributed for the higher yields. Similar results had also been obtained with the first crop of banana by other workers (Dahiwalkar et al. 2004; Badgujar et al. 2004)

Date and amount of irrigation water applied to banana

Under surface method of irrigation, total 900 mm of water was applied through 30 numbers of irrigation (depth of irrigation 3 cm at 100 % CPE under each irrigation) for both plant and ratoon crop. While under drip irrigation practice, altogether 80 number of irrigation were given at each of 50, 60 and 70 % CPE (Table 4). The amount of irrigation water applied at 50, 60 and 70 % CPE were 408.01, 528.95 and 617.18 mm, respectively including both plant and ratoon crop.

Irrigation water applied

Water applied under different irrigation treatments is presented in (Table 5) Irrigation water use was found to be highest under conventional method of irrigation (57.00 cm and 33.00 cm for plant crop and ratoon crop respectively) for the entire life cycle of the crop. The Irrigation requirement of the crop was found to be lowest in plants under drip fertigation particularly under I_2F_3 treatments. Considerable saving in water has occurred (41.69 and 40.41 % for plant crop and ratoon crop respectively) in drip fertigation under I_2F_3 treatment. Under the same drip fertigation treatment yield of both plant as well as ratoon crop was higher (32.49 and 26.40 % for plant crop and ratoon crop respectively) as compared to conventional method of irrigation. Biswas et al. (1999) conducted a field experiment to study the efficiency of drip irrigation in papaya. The outcome of the study also indicates 54 % saving of irrigation water and 28.84 % increase in yield in best treatment of drip irrigation.

WUE was found to be higher in plants under drip fertigation then those conventional methods of irrigation (Table 5). Highest WUE was recorded in

Table 4. Date and amount of irrigation water applied to banana through drip and conventional method during the year, 2008-09 (plant crop) and 2009-10 (ratoon crop).

Month	Total irrigation water applied (mm)							
	I_1(50 % CPE)I_2		(60 % CPE) I_3		(70 % CPE)		Control	
	Plant Crop	Ratoon Crop	Plant Crop	Ratoon Crop	Plant Crop	Ratoon Crop	Plant Crop	Ratoon Crop
January	120	—-	120	—-	120	—-	120	—-
February	4.25	—-	5.1	—-	5.95	—-	—-	—-
March	29.55	—-	35.46	—-	41.37	—-	60	—-
April	36.9	42.1	44.28	50.52	51.66	58.9	90	90
May	40.75	23.9	48.9	28.68	57.05	33.46	90	30
June	—-	—-	—-	—-	—-	—-	—-	—-
July	—-	—-	—-	—-	—-	—-	—-	—-
August	—-	—-	—-	—-	—-	—-	—-	—-
September	—-	—-	—-	—-	—-	—-	—-	—-
October	—-	13.5	—-	16.2	—-	18.9	—-	30
November	32.8	26.8	39.36	32.16	45.92	37.52	60	60
December	22.3	24.65	26.75	29.58	31.22	34.51	30	30
January	30.81	26.25	36.96	31.5	43.12	36.75	60	60
February	33.9	6.65	40.68	7.98	47.46	9.31	60	30
March	45.7	—-	54.84	—-	64.08	—-	120	—-

Table 5. Comparison of yield and water consumption in banana under different levels of drip fertigation over conventional method of irrigation.

Treatments	Irrigation water applied (cm)		Yield (Kg / ha)		Irrigation water use efficiency (Kg / ha cm)		Percent increase in yield over conventional	
Irrigation	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop
I_1	27.696	16.385	35,330	33,000	1,275.63	2,014.03	-4.74	-5.28
I_2	33.233	19.662	42,860	39,480	1,289.68	2,007.93	15.55	13.31
I_3	38.783	22.935	41,400	38,070	1,067.47	1,659.90	11.62	9.27
Irrigation x Fertilizer								
I_1F_1	27.696	16.385	29,250	25,760	1,056.10	1,572.16	-21.13	-26.06
I_1F_2	27.696	16.385	37,590	36,090	1,303.07	2,202.62	1.34	3.58
I_1F_3	27.696	16.385	39,170	37,150	1,414.28	2,267.31	5.60	6.63
I_2F_1	33.233	19.662	34,070	32,400	1,025.18	1,647.84	-8.14	-7.00
I_2F_2	33.233	19.662	45,370	41,990	1,365.20	2,135.59	22.32	20.52
I_2F_3	33.233	19.662	49,140	44,040	1,478.65	2,239.85	32.48	26.40
I_3F_1	38.783	22.935	37,940	35,480	978.26	1,546.98	2.29	1.83
I_3F_2	38.783	22.935	42,180	38,640	1,087.58	1,684.76	13.72	10.90
I_3F_3	38.783	22.935	44,090	40,100	1,136.83	1,748.41	18.87	15.09
Mean Drip	33.237	19.660	39,870	36,850	1,199.56	1,874.36	7.49	5.76
Conventional	57.000	33.000	37,090	34,840	650.70	1,055.75	—-	—-

plants under I_2F_3 treatments (1,478.65 and 2,239.85 Kg / ha cm for plant crop and ratoon crop respectively) primarily due to increased yield, while the lowest WUE was recorded in the conventional irrigated plants (650.70 and 1,055.74 Kg / ha cm for plant crop and ratoon crop respectively). Salvin et al. (2000) studied the efficiency of drip irrigation in banana. They stated that highest WUE was recorded in plants under drip irrigation at lowest WUE was recorded in the basin irrigated plants (146.09 Kg / ha cm).

In summing up, the studies clearly bring out the advantage of drip fertigation in economizing water use and in increasing water use efficiency (WUE) in banana as compared to conventional system of irrigation.

Economic analysis of banana cultivation per hectare per year

Revealing the table 6 it is observed that the drip fertigation system is more profitable as compared to surface irrigation (conventional method) due to increase in yield of banana plant. Gross returns from the sale of the produce were found to be higher under the treatments I_2F_3 (Rs. 2,79,540 / ha / year) closely followed by the treatment I_2F_2 (Rs.2,62,080 / ha / year). Net returns (Gross return from sale of the produce - total cost of cultivation) by drip fertigation treatments were found to be higher as compared to conventional method of irrigation except I_1F_1 treatment. Out of different drip fertigation treatments, both I_2F_3 and I_2F_2 the treatment gave maximum net returns (Rs.1,44,748 and Rs.1,40,171 / ha / year respectively). Return per rupee investment (Gross return / total cost of cultivation) was determined to be higher in drip fertigation treatments I_2F_2 (Rs 2.14) and I_2F_3 (Rs 2.07). It indicated that investment for drip fertigation is economically viable. More et al. (2005) stated that major portion of human labour was used for irrigating the banana crop. Narayanamoorthy (2006) conducted a study to evaluate the impact of drip irrigation on cost of cultivation, production and productivity of different crops. He mentioned that water saving and the water use efficiency of different crops cultivated under drip irrigation are significantly higher when compared to those under flood irrigation. Hence, there is strong basis to encourage the farmers to adopt the drip irrigation method.

Drip fertigation system reduced labour cost by 15-20% and favours mechanized and easy cultivation. Therefore, it can be inferred that even though the initial investment for drip fertigation system is much higher than conventional method, but long - term benefits can be achieved through saving water, increasing the productivity and higher return from banana cultivation.

Table 6. Economic analysis of banana cultivation under drip fertigation & conventional method (per ha per year basis)

Treatments	Total cost of Cultivation (Rs./ha)	Yield of banana (t/ha)	Gross returns (Rs./ ha)	Net returns (Rs./ ha)	Return per rupee Investment (Rs.)
Drip Fertigation					
I_1F_1	1,14,622	27.50	1,65,000	50,378	1.43
I_1F_2	1,21,235	36.84	2,21,040	99,805	1.82
I_1F_3	1,34,118	38.16	2,28,960	94,842	1.70
I_2F_1	1,15,296	33.24	1,99,440	84,144	1.72
I_2F_2	1,21,909	43.68	2,62,080	1,40,171	2.14
I_2F_3	1,34,792	46.59	2,79,540	1,44,748	2.07
I_3F_1	1,15,786	36.71	2,20,260	1,04,474	1.90
I_3F_2	1,22,399	40.41	2,42,460	1,20,061	1.98
I_3F_3	1,35,282	42.09	2,52,540	1,17,258	1.86
Conventional Method	1,44,525	35.96	2,15,760	71,235	1.49

Assumed cost of banana: Rs.6.00 per kg (average)

CONCLUSION

It is concluded from the study that soil moisture distribution was better under drip irrigation than conventional irrigation owing to application of small quantities of water at a time. Drip irrigation favourably influenced the banana yield which resulted in higher irrigation WUE against lower amounts of water applied. Apart from advantage of water saving over conventional irrigation, drip system proved to be very effective and efficient method of irrigation for cultivation of banana crop. Moreover, benefit-cost ratios with different discount rates indicated that drip investment in banana cultivation is economically significant. Drip irrigation also proved effective on silty clay textured soils like Inceptisols and water constraint situation in New Alluvium Zone of West Bengal.

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Prioritization of mini watersheds in Badri Gad watershed using GIS technique

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ABSTRACT

The prioritization of watershed is important for efficient planning and management of an area on a watershed basis. Morphometric analysis is commonly used for the prioritization of ungauged watersheds. In this study, an attempt has been made to prioritize eight mini watersheds of the Badri Gad watershed of Uttarakhand, India on the basis of morphometric analysis using PCI Geomatica v.10.0 GIS software. The morphometric parameters are determined for each mini watershed. Since shape parameters show negative correlation with runoff as well as soil erosion, while the other parameters show positive correlation with soil erosion. Rating is done by assigning highest priority i.e. 1 for the mini watershed having maximum value of the parameter, priority 2 for the next higher value and so on. Ranking was assigned for each parameter in relation to the extent of soil erosion. The compound parameter values were estimated and mini watershed having lowest compounded parameter will be assigned highest priority. The study reveals that the Ghorakhuri-1 mini watershed with a minimum compound parameter value of 2.67 is likely to be subjected to the maximum soil erosion and hence suitable soil and water conservation measures should be adopted in this watershed.

Key words: *:* Soil erosion, morphometric, ungauged, prioritization, watershed

INTRODUCTION

Now-a-days, watershed management is becoming a blue print for agricultural development in most parts of the country. The watershed management is necessary for proper use of all the land and water resources for optimum agricultural production with a minimum hazard to the natural resources. For better planning and management, the prioritization of watershed is the prerequisite before they have to be considered for drainage line treatments and soil conservation measures. According to the Watershed Atlas prepared by AIS & LUS (1990), the mean area of the watershed is generally considered less than 500 km^2 (± 50%). In its technical guidelines for IMSD project, NRSA (1995) classified the watershed into sub-watersheds (30-50 km^2), mini watersheds (10-30 km^2) and micro-watersheds (5-10 km^2). The watersheds are prioritized in manner so that higher value of sediment yield or runoff gets top priority. The following models are used for prioritization of watershed

Universal soil loss equation (USLE) model : This equation is being employed as a guide for conservation planning of small agricultural watershed. It is given as:

$$A = R\,K\,L\,S\,C\,P$$

where

A = Estimated gross soil erosion, t / (ha / year)
R = Rainfall erosisvity factor, Joules / (ha / year)
K = Soil erodibility factor, (t / ha) / erosivity factor (R)
L = Slope length factor,
S = Slope gradient factor.
C = Crop cover or crop management factor, and
P = Supporting conservation practice factor.

Sediment yield index (SYI) model: Sediment Yield Index (SYI) conceptualizes sedimentation as a multiplicative function of erosivity and delivery ratio. It is expressed as:

$$SYI = (AE_i \times E_i \times D_r) / (A_w)$$

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where

SYI = Sediment yield index of the watershed

AE_i = Area of i^{th} erosivity mapping unit,

E_i = Weighted erosivity value of i^{th} mapping unit,

D_r = Delivery ratio, and

A_w = Area of watershed.

Runoff model : The SCS (1972) equation used for predicting runoff from the watersheds is:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where

Q = Runoff depth, mm

P = Rainfall depth, mm

S = Maximum retention potential, mm

$$S = \left(\frac{25400}{CN}\right) - 254 \text{, mm}$$

I_a = Initial abstraction

The Soil Conservation Service (now Natural Resources Conservation Service) method (SCS, 1972) is one of the most popular method for computing depth of runoff for a given rainfall event from small agricultural, forest and urban watershed. This method is widely used for estimating runoff of un gauged watershed. The curve number method requires individual storm rainfall, land use type, hydrologic soil group and antecedent moisture condition of watershed as input. Curve number method was also used for prioritization of mini watershed as the mini watershed having higher value of curve number produce more runoff, hence will cause more erosion.

Morphometry is the measurement and mathematical analysis of the configuration of earth surface, shape and dimension of its landform. The evaluation of the morphometric parameters necessitates for preparation of drainage map, ordering of various streams, measurement of the catchment area and its perimeter, length of the drainage channels, drainage density and its frequency, bifurcation ratio, texture ratio, form factor, circulatory ratio, elongation ratio, and compactness ratio, which helps to understand the nature of the drainage basin (Nag, 1998; Vittala *et al.*, 2004; Chopra *et al.*, 2005; Nookaratnam *et al.*, 2005). The parameters such as bifurcation ratio, drainage density, texture ratio, stream frequency, circulatory ratio, form factor, compactness ratio, and elongation ratio have been used for the prioritization of mini watersheds for conservation measures. Studies have shown that shape parameters show negative correlation with runoff as well as soil erosion, while the other parameters show positive correlation with soil erosion (Biswas, 2000; Thakkar *et al*. 2007). For assessing the terrain and morphometric parameters of the watershed, the Geographical Information System (GIS) have been used by various researchers as they provide flexible environment and powerful tool for the manipulation and analysis of spatial information, particularly for the feature identification and the extraction of information for better understanding.

The prioritization of mini-watersheds, on the basis of morphometric analysis using remote sensing and GIS, was attempted by various researchers (Biswas *et al.*, 1999; Thakkar *et al.* 2007; Hlaing *et al.*, 2008; Javed *et al.*, 2009). In this study, the prioritization of the ungauged Badri Gad watershed for soil erosion vulnerability assessment was carried out on the basis of the morphometric analysis using the Geomatica v. 10.0 GIS software.

STUDY AREA

The study area is located in Narendra Nagar block of Tehri Garhwal district of Uttrakhand as shown in figure 1. The outlet of the watershed is located near the Yamuna bridge on the Dehradun-Yamunotri National Highway route, which is about 55 km away from Dehradun. The watershed is located in between the longitudes of 78^0 00’ 21.02"E and 78^0 10’ 21.43" E, and latitudes of 30^0 32’ 23" and 30^0 38’ 19.63" N. The total area of the watershed is 11,668.20 ha (116.68 km^2) with a perimeter of 51.82 km. The elevation of the watershed varies from 760 to 3000 m above mean sea level (AMSL). About 70% of the watershed area is having a land slope of 15-50%.

The climate of the study area is humid temperate with an average rainfall of 1234.76 mm (1985-2008) of which about 70 to 80% is received during June to September.. The average temperature in this area varies from 3 ^oC to 30 ^oC. Forest is the dominating land cover which mainly lies above 1600 m AMSL. However, a major part of the agricultural area is found at the elevations of about 1200 to 1600 m AMSL.

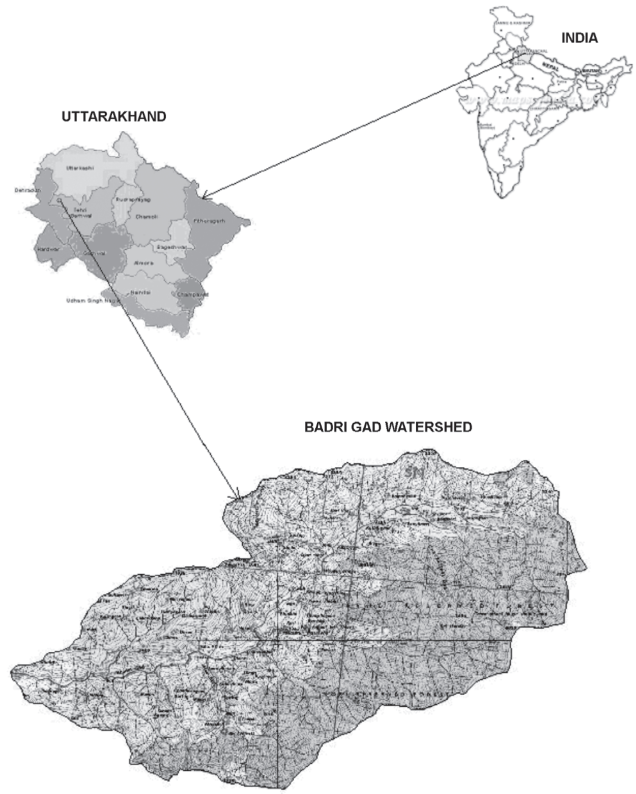

Fig. 1. Index map of Badri Gad watershed.

The chemical properties of the soils in the study area are neutral to slightly acidic with high organic matter content, which are shallow in depth and fairly highly permeable. At the mid and lower hills (1500-2200 and 800-1500 AMSL) , sandy clay loam and clay loam soils are found, whereas sandy loam soils are found at higher elevation (2200-2900 AMSL).

MORPHOMETRIC ANALYSIS

The Survey of India Toposheet (53 J / 2) at the scale of 1:50, 000 was used for the watershed delineation and derivation of the slope-area classification. The toposheet was scanned (*tiff format*), translated to the *pix format* (PCIDSK format) using the utility option of the "Geomatica v. 10.0" GIS software, and geo-referenced using the Ortho Engine module of the software. This geo-referenced map was utilized to delineate the boundary of the watershed. The drainage map from the toposheet was vectorized to derive the drainage information. The stream ordering was carried out using the Horton's law. The geomorphologic parameters, namely, stream length, area, perimeter, number of streams and basin length were derived from the drainage layer. The morphometric parameters for the delineated watershed area were calculated using the formulas as suggested by Miller (1953), Horton (1945), Schumn (1956) and Strahler (1964) (see Table 1). The values of the morphometric parameters, namely, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, elongation ratio, circulatory ratio and compactness ratio were calculated and they have been used for the prioritization of mini watersheds for conservation measures. Previous studies have shown that shape parameters show negative correlation with runoff as well as soil erosion, while the other parameters show positive correlation with soil erosion **(Biswas, 2000; Thakkar *et al.* 2007).** For first four parameters (bifurcation ratio, drainage density, texture ratio and stream frequency), rating is done by assigning highest priority i.e. 1 for the mini watershed having maximum value of the parameter, priority 2 for the next higher value and so on. The mini watershed which got the lowest value was assigned the last priority number. Remaining four parameters (circulatory ratio, form factor, compactness ratio and elongation ratio) rating is done by assigning highest priority 1 for the mini watershed having minimum value of the parameter, and similar procedure was followed till the last priority number. The prioritization rating of all the eight mini watersheds of the Badri Gad watershed was carried out by calculating the compound parameter values by taking the average of assigned ranking of particular watershed. The mini watershed with the lowest compound parameter value was given the highest priority.

Table 1. Formula used for computation of the morphometric parameters

Sl. No.	Morphometric Parameters	Formula	Reference
1.	Stream order (U)	Hierarchical rank	Strahler (1964)
2.	Stream length (L_u)	Length of the stream	Horton (1945)
3.	Mean stream length (L_{sm})	$L_{sm} = \frac{L_u}{N_u}$	Strahler (1964)

Sl. No.	Morphometric Parameters	Formula	Reference
		where L_u = Total stream length of order 'u' N_u = Total number of stream segments of order 'u'	
4.	Bifurcation ratio (R_b)	$R_b = N_u / N_{u+1}$ where Nu = Total no. of stream segments of order 'u' N_{u+1} = Number of segments of the next higher order	Schumn (1956)
5.	Mean bifurcation ratio (R_{bm})	Average of bifurcation ratios of all orders	Strahler (1957)
6.	Drainage density (D_d)	$D = L_u / A$ where D = Drainage density L_u = Total stream length of all orders, km A = Area of the basin, km^2	Horton (1945)
7.	Stream frequency (F_s)	$F_s = N_u / A$ where F_s = Stream frequency N_u = Total number of streams of streams of all orders A = Area of the basin, km^2	Horton (1945)
8.	Circulatory ratio (Rc)	$R_c = 4 * Pi * A / P^2$ where R_c = Circularity ratio Pi = Pi value i.e., 3.14 A = Area of the basin, km^2 P^2 = Square of the perimeter, km	Miller (1953)
9.	Elongation ratio (Re)	$Re = \sqrt{(4 \times A / Pi)} / Lb$ where R_e = Elongation ratio A = Area of the basin, km^2 Pi = ' pi' value i.e., 3.14 L_b = Basin length	Schumm (1956)
10.	Form factor (R_f)	$R_f = A / Lb^2$ where A = Area of the basin Lb^2 = Square of basin length	Horton (1945)
11.	Compactness ratio (R_c)	$Rc = 0.2821 P / A^{0.5}$ where A = Area of the basin, km^2 P = Basin perimeter, km	Horton (1945)
12.	Texture ratio (T)	$T = N_u / P$ where N_u = Total number of streams of streams of all orders P = Basin perimeter, km	Horton (1945)

RESULTS AND DISCUSSION

The drainage map vector layer of drainage network was digitized using topological line option of the software. The drainage map of the study area is shown in figure 2 and the drainage network parameters are given in table 2. It is clear from figure 2 that the Badri Gad watershed is of 5^{th} order watershed. The relationship between log (number of stream) versus and stream order for Badri Gad watershed as well as all eight mini watersheds are shown in figure 3. The plot of log (number of stream) versus and stream order shows a deviation from straight line indicating a regional upliftment.

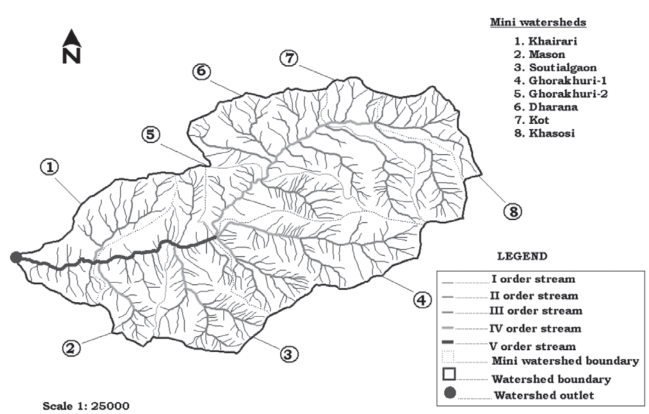

Fig. 2. Drainage map of the Badri Gad watershed.

Table 2. Drainage network parameters in the Badri Gad watershed

Sl. No.	Parameters	Stream order				
		1st	2nd	3rd	4th	5th
	Badri Gad watershed					
1.	Count	431	87	19	6	1
	Min. length (m)	224.33	48.73	183.58	818.71	9103.67
	Max. length (m)	1942.63	2937.85	5013.80	3711.62	9103.67
	Mean length (m)	562.91	696.41	2056.57	3396.44	9103.67
	Total Length (m)	242617.7	60587.78	39074.91	20378.66	9103.67
	Khairari Mini watershed					
2.	Count	39	10	2	1	1
	Min. length (m)	224.33	122.62	670.98	818.71	3648.43
	Max. length (m)	1301.66	2302.11	1507.38	818.71	3648.43
	Mean length (m)	576.40	816.57	1089.18	818.71	3648.43
	Total Length (m)	22479.90	8165.76	2178.36	818.71	3648.43
	Mason Mini watershed					
3.	Count	42	8	2	1	1
	Min. length (m)	299.69	80.11	183.58	2495.86	3502.76
	Max. length (m)	930.40	1417.20	339.60	2495.86	3502.76
	Mean length (m)	510.91	564.80	261.58	2495.86	3502.76
	Total Length (m)	21458.40	4518.47	523.18	2495.86	3502.76
	Soutialgaon Mini watershed					
4.	Count	79	12	4	1	1
	Min. length (m)	256.72	78.31	777.07	2954.34	1879.11
	Max. length (m)	1942.63	2937.85	1796.01	2954.34	1879.11
	Mean length (m)	578.43	596.35	1326.08	2954.34	1879.11
	Total Length (m)	45696.50	7156.08	5304.33	2954.34	1879.11
	Ghorakhuri-1 Mini watershed					
5.	Count	92	16	4	2	1
	Min. length (m)	298.18	213.96	1453.24	1142.81	73.37
	Max. length (m)	1564.59	1121.16	3460.91	3711.62	73.37
	Mean length (m)	593.28	609.01	2153.25	2427.21	73.37
	Total Length (m)	54582.50	9744.36	8613.34	4854.43	73.37
	Ghorakhuri-2 Mini watershed					
6.	Count	47	8	1	1	-
	Min. length (m)	275.79	225.91	2362.92	3578.11	-
	Max. length (m)	1436.97	1143.41	2362.92	3578.11	-
	Mean length (m)	544.01	685.97	2362.92	3578.11	-
	Total Length (m)	25568.60	5487.83	2362.92	3578.11	-
	Dharana Mini watershed					
7.	Count	79	18	4	1	-
	Min. length (m)	266.80	48.72	2171.13	3697.54	-
	Max. length (m)	1881.44	1866.16	4728.20	3697.54	-
	Mean length (m)	549.96	700.62	3208.88	3697.54	-
	Total Length (m)	43447.40	12611.25	12835.54	3697.54	-
	Kot Mini watershed					
8.	Count	31	9	2	1	-
	Min. length (m)	255.91	135.31	71.30	1979.67	-
	Max. length (m)	1000.73	1520.78	5013.80	1979.67	-
	Mean length (m)	546.12	696.56	2542.44	1979.67	-
	Total Length (m)	16929.90	6269.08	5084.89	1979.67	-
	Khasosi Mini watershed					
9.	Count	22	6	1	-	-
	Min. length (m)	323.84	710.85	2172.35	-	-
	Max. length (m)	944.75	2411.46	2172.35	-	-
	Mean length (m)	566.14	1105.80	2172.35	-	-
	Total Length (m)	12454.50	6634.95	2172.35	-	-

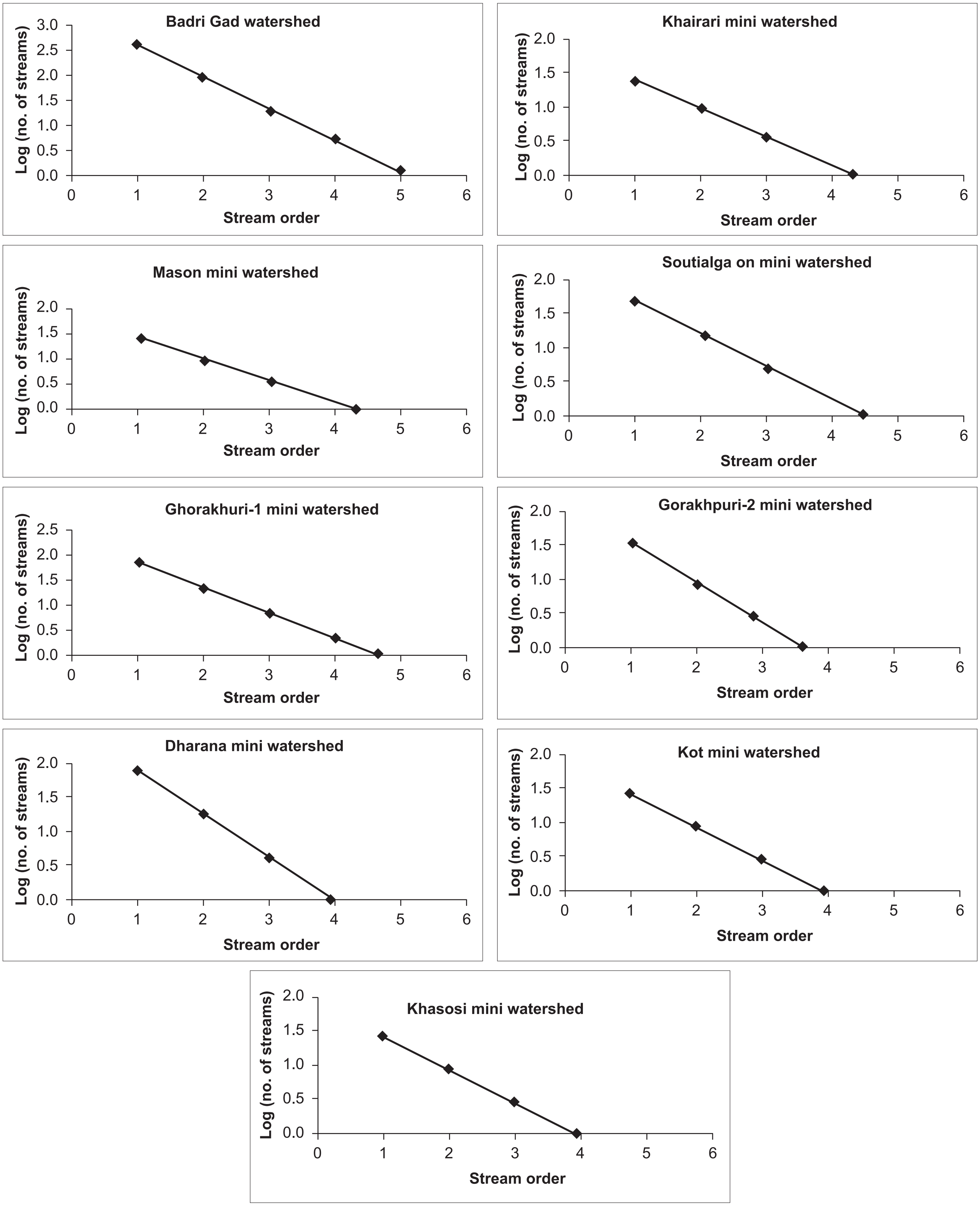

Fig.3. Relationship between Log (Number of Streams) and Stream Order

The entire watershed was divided into eight different mini watersheds, namely, Khairari, Mason, Soutialgaon, Ghorakhuri-1, Ghorakhuri-2, Dharana, Kot, and Khasosi. The mini watersheds were named after the villages at the outlet. Basin area, perimeter, length of basin and stream length for each mini watershed were estimated using the PCI Geomatica v. 10.0 GIS software as shown in table 3. The stream analysis for all the eight mini watersheds of Badri Gad watershed is shown in table 4. The stream morphometric parameters, namely, bifurcation ratio, drainage density, stream frequency, form factor, texture ratio, elongation ratio, circulatory ratio and compactness ratio were calculated (Table 5). The highest value of bifurcation ratio was found to be 4.95 for the Ghorakhuri-2 mini watershed. The highest value of the circulatory ratio was 0.586 for the mini watershed Ghorakhuri-1. The Kot mini watershed had the highest elongation ratio indicating less vulnerability of soil erosion.

Table 3. Mini watershed parameters of the Badri Gad watershed

Mini watershed	Area (km^2)	Parameter (km)	Length of watershed (km)	Mean stream length (km)
Khairari	13.97	19.50	6.22	0.70
Mason	10.82	15.36	3.86	0.60
Soutialgaon	17.00	21.62	5.09	0.65
Ghorakhuri-1	22.02	21.72	8.31	0.67
Ghorakhuri-2	10.82	18.13	3.04	0.64
Dharana	24.32	26.57	5.18	0.71
Kot	11.00	19.93	2.81	0.70
Khasosi	6.69	13.03	2.81	0.73
Badri Gad	116.68	51.82	18.77	0.68

Prioritization on the basis of curve number was

Table 4. Stream network analysis of the mini watersheds

Sl. No.	Parameters	Stream order 1st	2nd	3rd	4th	5th
	Khairari Mini watershed					
1.	No. of streams	39	10	2	1	1
	Stream length (m)	22479.90	8165.76	2178.36	818.71	3648.43
	Cumulative stream length (m)	22479.90	30645.66	32824.02	33642.73	37291.16
	Mason Mini watershed					
2.	No. of streams	42	8	2	1	1
	Stream length (m)	21458.40	4518.47	523.18	2495.86	3502.76
	Cumulative stream length (m)	21458.40	25976.87	26500.05	28995.91	32498.67
	Soutialgaon Mini watershed					
3.	No. of streams	79	12	4	1	1
	Stream length (m)	45696.50	7156.08	5304.33	2954.34	1879.11
	Cumulative stream length (m)	45696.50	52852.58	58156.91	61111.25	62990.36
	Ghorakhuri-1 Mini watershed					
4.	No. of streams	92	16	4	2	1
	Stream length (m)	54582.50	9744.36	8613.34	4854.43	73.37
	Cumulative stream length (m)	54582.50	64326.86	72940.20	77794.63	77868.00
	Ghorakhuri-2 Mini watershed					
5.	No. of streams	47	8	1	1	-
	Stream length (m)	25568.60	5487.83	2362.92	3578.11	-
	Cumulative stream length (m)	25568.60	31056.43	33419.35	36997.96	
	Dharana Mini watershed					
6.	No. of streams	79	18	4	1	-
	Stream length (m)	43447.40	12611.25	12835.54	3697.54	-
	Cumulative stream length (m)	43447.40	56058.65	68894.19	72591.73	
	Kot Mini watershed					
7.	No. of streams	31	9	2	1	-
	Stream length (m)	16929.90	6269.08	5084.89	1979.67	-
	Cumulative stream length (m)	16929.90	23198.98	28283.87	30263.54	
	Khasosi Mini watershed					
8.	No. of streams	22	6	1	-	-
	Stream length (m)	12454.50	6634.95	2172.35		
	Cumulative stream length (m)	12454.50	19089.45	21261.80	-	-

Table 5. Morphometric parameters of the Badri Gad watershed

Name of the mini watershed	Bifurcation ratio (R_b)	Drainage density (D_d)	Texture ratio (T)	Stream frequency (F_s)	Circulatory ratio (R_c)	Form factor (R_f)	Compactness ratio (C_c)	Elongation ratio (R_c)
Khairari	2.978	2.668	2.716	3.791	0.461	0.361	1.472	0.678
Mason	3.062	3.001	3.515	4.987	0.576	0.725	1.316	0.960
Soutialgaon	3.645	3.704	4.484	5.704	0.456	0.655	1.479	0.913
Ghorakhuri-1	3.437	3.534	5.293	5.220	0.586	0.318	1.305	0.637
Ghorakhuri-2	4.958	3.417	3.142	5.265	0.413	1.166	1.555	1.218
Dharana	4.296	2.984	3.838	4.193	0.432	0.906	1.519	1.074
Kot	4.833	1.932	1.455	2.635	0.348	1.388	1.694	1.329
Khasosi	3.314	4.523	3.300	6.427	0.495	0.844	1.421	1.036

Table 6. Watershed prioritization on the basis of the derived morphometric parameters of the Badri Gad watershed

Name of the mini watershed	Bifurcation ratio	Drainage density	Texture ratio	Stream frequency	Circulatory ratio	Form factor	Compactness ratio	Elongation ratio	Total	Compound parameter	Final priority
Khairari	8	7	7	7	5	2	4	2	42	5.25	7
Mason	7	5	4	5	7	4	2	4	38	4.75	5
Soutialgaon	4	2	2	2	4	3	5	3	25	3.13	2
Ghorakhuri-1	5	3	1	4	8	1	1	1	24	3.00	1
Ghorakhuri-2	1	4	6	3	2	7	7	7	37	4.63	4
Dharana	3	6	3	6	3	6	6	6	39	4.88	6
Kot	2	8	8	8	1	8	8	8	51	6.38	8
Khasosi	6	1	5	1	6	5	3	5	32	4.00	3

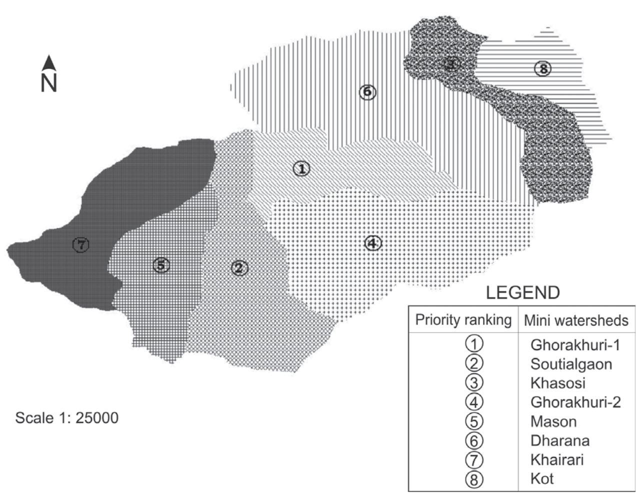

Fig. 4. Prioritization map of the Badri Gad watershed.

also done, as the curve number is an index that represents the combination of a hydrological soil group and land use class. The curve number, computed with respect to entire area, was taken as index of runoff, so higher the curve number, lower will be the value of potential maximum storage of the watershed and higher would be the runoff. Study showed that maximum value of weighted curve number (74.14) was obtained for Ghorakhuri-1 mini watershed, followed by 72.88, 72.03, 71.36, 71.08, 67.95, 58.55 and 56.08 for Soutialgaon, Khairari, Ghorakhuri-2, Mason, Dharana, Khasosi and Kot mini watersheds, respectively.

CONCLUSIONS

The present study demonstrates the usefulness of the GIS for morphometric analysis and prioritization of the mini watersheds of Badri Gad watershed of Uttrakhand. Moreover, this technique is suitable mostly for ungauged watersheds of the hilly areas for the identification of critical areas and implementation of watershed management programmes. The results of the morphometric analysis indicated that the Ghorakhuri-1 mini watershed is more susceptible to soil erosion moreover texture ratio, form factor, compactness ratio and elongation ratio play significant role in relation to erosion subsequently drainage density, stream frequency, bifurcation ratio and circulatory ratio. Ghorakhuri-1 mini watershed was found under top priority by both the methods. Moreover, mini watersheds Soutialgaon, Ghorakhuri-2, Mason and Dharana were having common priority i.e. 2, 4, 5 and 6, respectively, as per morphometric analysis as well as from curve number analysis. It is clear that out of 8 mini watersheds 5 mini watersheds were having similar priority rating by both the methods i.e. curve number and using morphometric analysis. Hence, suitable soil conservation measures should be initiated from Ghorakhuri-1 mini watershed of the Badri Gad watershed to preserve the land from further degradation.

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Response of soybean (*Glycine max*), toria (*Brassica compestris*) and Indian mustard (*Brassica juncea*) to supplemental irrigation through harvested rainwater in Central India

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ABSTRACT

A field experiment was conducted during 2002-03 to 2004-2005 in red soils to explore the possibilities of rain water harvesting through a farm pond for providing supplemental irrigation to soybean, toria and Indian mustard for increasing growth, yield and water use efficiency. Harvested rainwater was available for supplemental irrigation in farm pond from middle of August to end of October during all the years. Growth and yield attributes of soybean (plant height, number of primary and secondary branches / plant, pods / plant, pod length, number of seed / pod, seed weight / plant and 1000-seed weight), toria and Indian mustard (plant height, number of primary and secondary branches / plant, number of siliqua / plant, siliqua length, number of seed / siliquae, seed weight / plant and 1000-seed weight) increased with supplemental irrigation which in turn increased the yield of the crops during all the years. Yield of soybean and toria increased by 31 and 138% with supplemental irrigation given at pod filling and 30 days after sowing, respectively over no irrigation. Yield of Indian mustard increased by 91% with one pre-sowing irrigation, and by 343% with pre-sowing + irrigation at branching stage, over rainfed crop. Water use efficiency of all the crops increased with supplemental irrigation. The water use efficiency of soybean and toria increased by 15 and 37% with supplemental irrigation at pod filling and at 30 days after sowing, respectively, over no irrigation. The water use efficiency of Indian mustard also increased by 25 and 45% with pre-sowing and pre-sowing + irrigation at branching stage, respectively, over no irrigation. The results suggested that the productivity of large rainfed areas in the country could considerably be increased even in red soils through rainwater harvesting and providing supplemental irrigation at critical stages of crop growth from a farm pond to some of the selective crops such as soybean during *kharif* season further available water can also be utilized for providing pre-sowing / supplemental irrigation to post monsoon / *rabi* season crops such as toria or Indian mustard for increasing the growth, yield and water use efficiency in semi-arid conditions.

Key words: Indian mustard, Red soils, Soybean, Supplemental irrigation, Toria, Water harvesting, Water use efficiency

INTRODUCTION

Rainfed area contributes only 45% to national food basket due to inadequate and highly erratic rainfall while 37% of the irrigated area accounts for 55% of the total food production. An important avenue for achieving increased production is to enhance the productivity of vast areas under rainfed agriculture, which constitute nearly 60% of the net cultivated area of the country. The Bundelkhand region with a geographical area of 7.04 m ha in Central India has only 20.5% of net sown area under irrigation, and even if all the irrigation potential is utilized even then only 30% of the area can be covered under irrigation. During *kharif* season only about 20% area is cultivated and 80% area remains fallow (Pathak *et al.*, 2005) consequently the crop intensity is about 111% in the region. Rainfed agriculture is a common practice in the region in view of limited ground water availability. Long dry spells during *kharif* season are very common feature and the overall trend of rainfall is remain very erratic and uncertain which may be virtually responsible for creating scarcity of soil moisture and crop failures in the

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region. Red soils are in about 50% of geographical area of the region and characterized by limited soil depth, coarse texture, low water holding capacity and found on higher elevation in topo sequences, hence major part of rainfall is lost as surface runoff and crops experience water stress condition even in short dry spells during rainy season (Narayan and Lal, 2009). Red soils have considerable agronomic potential but long duration common *kharif* crop such as soybean [*Glycine max* (L.) Merr.] or even low water requiring post monsoon / *rabi* season oil seed crops such as toria [*Brassica compestris* L. subsp. Oleifera (Metzer) sinsk. var. Toria] or Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson] cannot be grown successfully without supplemental irrigation. The yield potential of soybean and toria is affected adversely because of insufficient soil moisture during pod filling and branching stage, respectively, due to early recession of monsoon rains. The vegetative and reproductive growth of Indian mustard is also affected adversely because of insufficient soil moisture at the time of sowing and little or no rains during the entire crop growth period. Collection and recycling of rainwater for a life saving irrigation to *kharif* crop and a pre-sowing / supplemental irrigation to a *rabi* crop, can increase the crop production and enhance the cropping intensity considerably. Water harvesting ponds are generally constructed in black soils because of low seepage loss. As the information on water harvesting and recycling for red soils is meagre, therefore present field study was undertaken to explore the possibilities of rainwater harvesting for providing life saving / supplemental irrigation to *kharif* crop soybean and pre-sowing / supplemental irrigation to post monsoon */rabi* season oil seed crop toria and Indian mustard to enhance the growth, yield and water use efficiency in red soils through a farm pond under semi-arid conditions.

MATERIALS AND METHODS

A field experiment was conducted during 2002-03 to 2004-2005 at Research Centre, Central Soil and Water Conservation Research and Training Institute, Datia (25^0 40'N, 78^0 28' E; 342.42 m above mean sea level), Madhya Pradesh. The climate of Datia is semi-arid with an average rainfall of 860 mm. Most of the rainfall (70-80%) is received from July to September. The July and August months experience the heaviest rainfall. Long dry spells (7 to 22 days) during monsoon season are also common features. There is very little or no rain during winter season (November to February). The maximum temperature touches 47°C in the month of May - June while the minimum temperature goes as low as 1°C in the month of December - January. Due to high wind velocity and high temperature the evaporation rate remains very high. High annual evaporation rates (1400 mm to 1700 mm) leave a large water deficit. The experimental site was located in one of the blocks of Research Farm in red soils where only *kharif* crops are taken under rainfed condition, as there is no availability of ground water. The soil of the experimental site belongs to Lithic Ustorthents, has a pH 7.1, is sandy loam in texture with 76.5% sand, 8.9% silt and 13.6% clay, low in organic carbon content (0.32%), EC 0.12 dS / m, bulk density 1.60 g / cc, available N, P and K 205.0, 19.7 and 295.0 kg / ha, respectively. The field capacity and permanent wilting point of surface soil layer were 13.93 and 4.91%, respectively. A dug out pond with approximate 0.3 ha-m capacity was constructed having 5.0 ha catchment area. Rain water from adjoining fields having 1.5 to 3.0% slope was diverted to the farm pond and collected water was used for providing pre-sowing / supplemental irrigation. Daily observations on depth of water were recorded for calculating the volume of water in the farm pond. The rainfall distribution and volume of storage of harvested rainwater in the farm pond during crop growth period of soybean, *toria* and Indian mustard in various years has been depicted in Fig. 1 to 3. There were seven treatment combinations (T_1- soybean as rainfed; T_2 - soybean with irrigation at pod filling; T_3- toria as rainfed; T_4- toria with one irrigation at 30 days after sowing (DAS); T_5 - Indian mustard as rainfed; T_6 - Indian mustard with pre-sowing irrigation; T_7 - Indian mustard with pre-sowing and irrigation at branching) which were laid in randomized block design with three replications. The experimental plot size was 15 x 6 m. Sowing of soybean was done each year in July with the onset of monsoon. Toria was sown with cessation of monsoon on conserved soil moisture in September. Sowing of Indian mustard was done in the month of October. A measured quantity of 5 cm water was applied to the field at each irrigation out of the harvested rainwater. Soybean received 592.0, 838.1 and 491.3 mm rainfall, toria received 0.0, 20.6 and 136.7 mm rainfall and Indian mustard received 50.6,

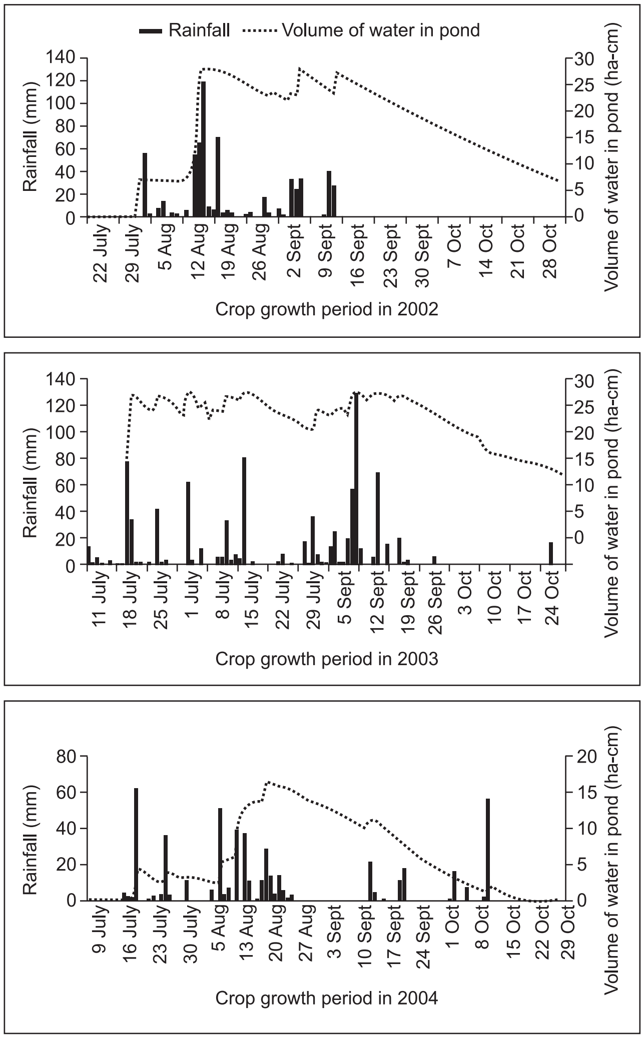

Fig. 1. Crop growth period of soybean, rainfall distribution and volume of water storage in the pond during 2002, 2003 and 2004

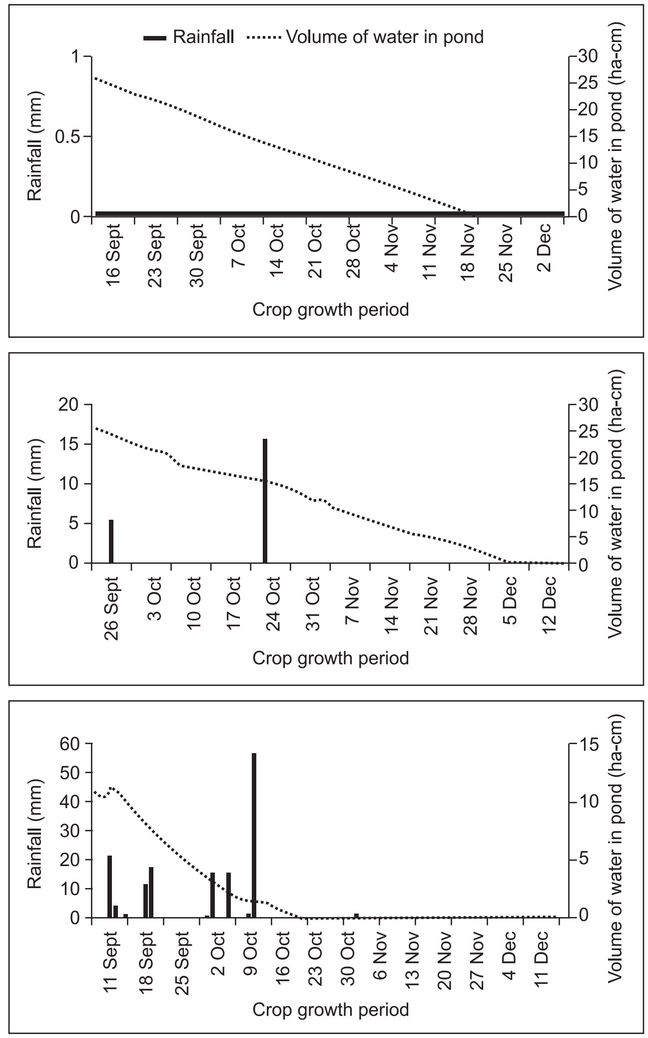

Fig. 2. Crop growth period of *toria*, rainfall distribution and volume of water storage in the pond during 2002, 2003 and 2004

60.1 and 1.0 mm rainfall during crop growth period in 2002-03, 2003-04, and 2004-05, respectively. Soybean variety 'PK 1029', toria 'JT 1' and Indian mustard 'Rajat' were grown. A fertilizer doze of 20 kg N and 60 kg P_2O_5 / ha to soybean, 60 kg N and 40 kg P_2O_5 / ha to toria and 80 kg N and 60 kg P_2O_5 / ha to Indian mustard was applied as basal. Standard package of practices were followed to raise a good crop. Soil moisture from 0-45 cm soil depth at sowing and harvest was taken in to account for computing the soil moisture use by the crop and further water use efficiency. Observations on plant height, yield and yield attributes of different crops were recorded at harvest. Soybean equivalent yield was calculated by converting the yield of toria and Indian mustard on the basis of existing market price of individual crop during 2004-05. The data on different growth and yield attributes of soybean and toria under rainfed and supplemental irrigation was analyzed using t – test, however, the data of Indian mustard under different irrigation regimes by analysis of variance. The soybean equivalent yield under various treatments was analyzed as per statistical procedure of the randomized block design. Soil analysis was done using standard chemical procedures (Jackson 1967). The statistical analysis of data was done as per standard statistical procedure as described by Gomez and Gomez (1984). Pooled data for 3 years (2002-03 to 2004-2005) pertaining to different parameters has been presented in tables 1 to 3 and 7 to 8 and crop wise and year-wise data on effective amount of rainfall received during crop growth

Table 1. Yield attributes of soybean (at harvest stage) as influenced by different treatments (mean of 3 years)

Parameter	Rainfed	Supplemental irrigation at pod filling stage	CD (P= 0.05)
Plant height (cm)	37.8	42.1	1.4
No. of branches / plant	5.9	7.1	NS
No. of pod / plant	66.3	78.9	8.7
Pod length (cm)	3.9	4.4	NS
No. of seed / pod	2.2	2.7	0.3
Seed weight / plant (g)	12.0	16.7	2.5
1000-seed wt. (g)	115.2	120.5	3.9

Table 2. Yield attributes of *toria* (at harvest stage) as influenced by different treatments (mean of 3 years)

Parameter	Rainfed	With supplemental irrigation at branching stage	CD (P= 0.05)
Plant height (cm)	113.8	134.4	3.0
No. of primary branches / plant	6.1	8.6	0.9
No. of secondary branches / plant	5.9	10.7	1.49
No. of siliqua / plant	172.7	280.1	78.5
Siliquae length (cm)	4.6	5.7	0.7
No. of seed / siliquae	13.9	18.2	2.8
Seed weight / plant (g)	5.3	10.1	2.1
1000-seed weight (g)	2.5	2.9	0.4

Table 3. Yield attributes of Indian mustard (at harvest stage) as influenced by different treatments (mean of 3 years)

Parameter	Irrigation level			CD (P= 0.05)
	Rain-fed	Pre-sowing	Pre-sowing + supple-mental irrigation at branching stage	
Plant height (cm)	131.8	159.3	178.3	20.3
No. of primary branches / plant	4.3	5.2	6.5	0.4
No. of secondary branches / plant	5.4	6.8	10.0	0.9
No. of siliqua / plant	137.9	175.4	229.2	32.0
Siliquae length (cm)	4.0	4.7	5.4	0.6
No. of seed / siliquae	13.3	15.2	16.4	1.0
Seed weight / plant(g)	9.2	15.4	25.9	NS
1000-seed weight (g)	6.1	6.4	6.8	NS

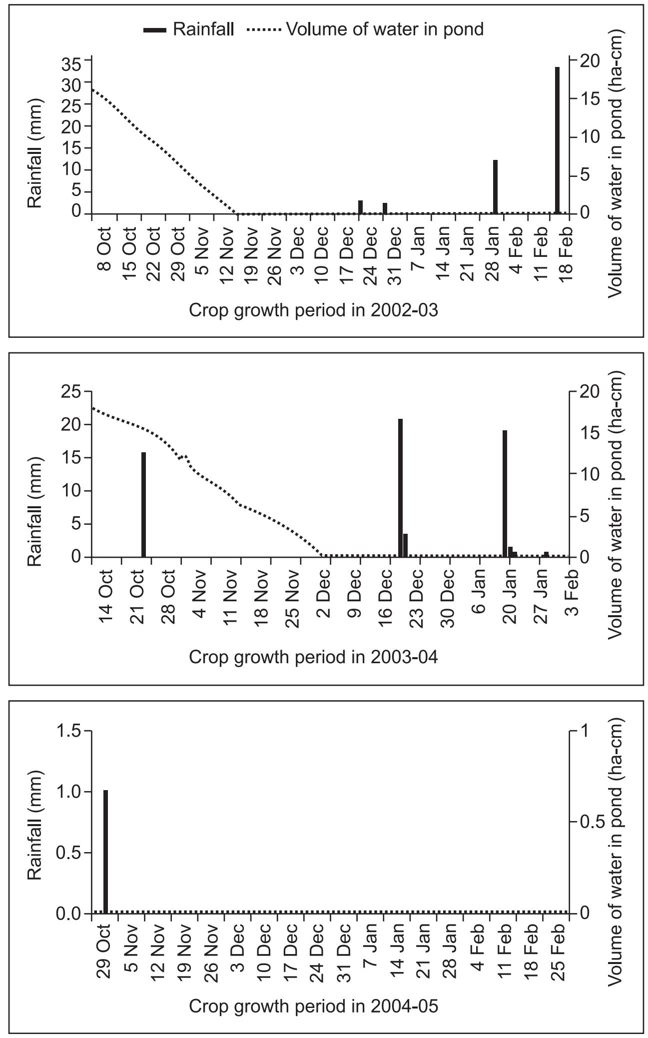

Fig. 3. Crop growth period of Indian mustard, rainfall distribution and volume of water storage in the pond during 2002-03, 2003-04 and 2004-05

period and amount of irrigation applied and seed yield in table 4 to 6 in results and discussion section.

RESULTS AND DISCUSSION

Rainfall distribution and water storage in farm pond during crop growth period

The rainfall distribution pattern and water storage in farm pond during crop growth period of soybean, *toria* and Indian mustard during different years have been shown in figs. 1 to 3. The availability of harvested rainwater in the farm pond followed the trend of available rainfall during the monsoon season.

Soybean: During 2002, no rain was received after September 13, consequently rainfed crop of soybean (T_1) experienced water stress during pod filling stage and a seed yield of 478 kg ha^{-1} was obtained (Table 4). However, when a supplemental irrigation to soybean (T_2) through harvested rainwater was provided during pod filling period, it resulted in 42% increase in seed yield over rainfed crop of soybean (T_1) as the harvested rainwater was available in the farm pond from first week of August till harvest of the crop (Fig. 1). During 2003, there were no rains from September 30^{th} to October 25^{th} which caused moisture stress during pod filling stage of the rainfed crop (T_1), however, harvested rainwater was available throughout the growth period of the crop in the farm pond starting from 3^{rd} week of July onwards. A supplemental irrigation provided at pod filling stage to soybean crop under T_2 resulted in 23.7% increase in seed yield over rainfed crop (T_1). During, 2004, rainfed crop of soybean (T_1) experienced 3 dry spells of 18, 10 and 18 days during reproductive growth phase. However, a supplemental irrigation provided at pod filling stage under T_2 resulted in 40.4% increase in seed yield over rainfed crop (T_1) as the harvested rainwater in farm pond remain available for supplemental irrigation from 3^{rd} week of July till last week of September.

Toria: During 2002, no rain was received during the entire crop growth period, however, harvested rainwater was available in the farm pond since

Table 4. Effective amount of rainfall received, supplemental irrigation provided through harvested rainwater during crop growth period and seed yield of soybean as influenced by different treatment during 2002, 2003 and 2004

Treatment	Effective amount of rainfall received from sowing to pod filling (m.m)	Effective amount of irrigation applied at pod filling (mm)	Effective amount of rainfall received from irrigation to maturity (mm)	Actual seed yield (kg ha^{-1})
		2002		
Soybean as rainfed	287.0	0.0	0.0	478
Soybean with irrigation at pod filling	287.0	50.0	0.0	680
		2003		
Soybean as rainfed	444.0	0.0	15.0	1373
Soybean with irrigation at pod filling	444.0	50.0	15.0	1698
		2004		
Soybean as rainfed	253.0	0.0	120.4	475
Soybean with irrigation at pod filling	253.0	50.0	120.4	667

Table 5. Effective amount of rainfall received, supplemental irrigation provided through harvested rainwater during crop growth period and seed yield of *toria* as influenced by different treatment during 2002, 2003 and 2004

Treatment	Effective amount of rainfall received from sowing to 30 days (mm)	Effective amount of irrigation applied at 30 DAS (mm)	Effective amount of rainfall received from irrigation to maturity (mm)	Actual seed yield (kg ha^{-1})
		2002		
Toria as rainfed	0.0	0.0	0.0	8.7
Toria with one irrigation at 30 days after sowing	0.0	50.0	0.0	428
		2003		
Toria as rainfed	5.2	0.0	15.2	476
Toria with one irrigation at 30 days after sowing	5.2	50.0	15.2	960
		2004		
Toria as rainfed	0.7	0.0	1.0	522
Toria with one irrigation at 30 days after sowing	0.7	50.0	1.0	991

Table 6. Effective amount of rainfall received, supplemental irrigation provided through harvested rainwater during crop growth period and seed yield of Indian mustard as influenced by different treatment during 2002-03, 2003-04 and 2004-05

Treatment	Effective amount of rainfall received during 5 days before sowing (mm)	Effective amount of pre-sowing irrigation (mm)	Effective amount of rainfall received from sowing to branching (mm)	Effective amount of irrigation applied at branching (mm)	Effective amount of rainfall received from branching / irrigation to maturity (mm)	Actual seed yield (kg ha^{-1})
2002-03						
Indian mustard as rainfed	0.0	0.0	0.0	0.0	50.6	75
Indian mustard with pre-sowing irrigation	0.0	50.0	0.0	0.0	50.6	198
Indian mustard with pre-sowing + irrigation at branching	0.0	50.0	0.0	50.0	50.6	876
2003-04						
Indian mustard as rainfed	0.0	0.0	0.0	0.0	60.1	569
Indian mustard with pre-sowing irrigation	0.0	50.0	0.0	0.0	60.1	1111
Indian mustard with pre-sowing + irrigation at branching	0.0	50.0	0.0	50.0	60.1	1738
2004-05						
Indian mustard as rainfed	0.0	0.0	1.0	0.0	0.0	241
Indian mustard with pre-sowing irrigation	0.0	50.0	1.0	0.0	0.0	379
Indian mustard with pre-sowing + irrigation at branching	0.0	50.0	1.0	50.0	0.0	1303

Table 7. Actual seed yield and soybean equivalent yield as influenced by different treatments (mean of 3 years)

Treatment	Seed yield (kg ha^{-1})	
	Actual seed	Soybean equivalent
T_1- Soybean as rainfed	775	775
T_2 - Soybean with irrigation at pod filling	1015	1015
T_3- Toria as rainfed	333	354
T_4- Toria with one irrigation at 30 days after sowing	793	843
T_5- Indian mustard as rainfed	295	365
T_6- Indian mustard with pre-sowing irrigation	563	694
T_7- Indian mustard with pre-sowing + irrigation at branching	1306	1612
CD (P=0.05)	-	223

sowing till last week of November (Fig. 2). Supplemental irrigation at branching stage in T_4 resulted 428 kg/ha seed yield whereas the rainfed crop in treatment T_3 failed because of moisture stress (Table 5). During 2003, a rainfall of 21.6 mm was received in vegetative growth phase but the crop experienced moisture stress during reproductive growth phase in treatment T_3. As the harvested rainwater was available in farm pond starting from sowing of the crop till first week of December which enabled to provide a supplemental irrigation at branching stage and it resulted in 102% increase in seed yield in T_4 over rainfed crop (T_3). During 2004, a rainfall of 136.7 mm was received during vegetative growth phase but crop experienced water stress during reproductive phase. As the harvested rainwater was available since the beginning of crop growth period till 3rd week of October and a supplemental irrigation provided at branching stage resulted in 89.8% higher seed yield in treatment T_4 over rainfed crop (T_3).

Table 8. Water use efficiency as influenced by different treatments (mean of 3 years)

Treatment	Water use efficiency (kg / ha-mm)
Soybean	
Soybean as rainfed	1.96
Soybean with irrigation at pod filling	2.26
CD (P=0.05)	NS
Toria	
Toria as rainfed	5.03
Toria with one irrigation at 30 days after sowing	6.87
CD (P=0.05)	NS
Indian mustard	
Indian mustard as rainfed	9.94
Indian mustard with pre-sowing irrigation	12.41
Indian mustard with pre-sowing + irrigation at branching	14.38
CD (P=0.05)	NS

NS = Non – significant

Indian mustard: The harvested rainwater was available in the farm pond up to second week of November and second week of December during the crop growth period of Indian mustard in 2002-03 and 2003-04, respectively (Fig. 3). However, during 2004-05, the harvested rainwater was available only up to 3rd week of October. During 2002-03, no rain was received during vegetative growth phase, however, a rainfall of 50.6 mm was received during reproductive growth phase, consequently the vegetative growth of the rainfed crop was adversely affected and a seed yield of 75 kg / ha was obtained which was lowest among the three years under treatment T_5. The seed yield was increased considerably (by 2.6 times) with pre-sowing irrigation (T_6) and further with pre-sowing + supplemental irrigation at branching stage (11.6 times) under T_7 over rainfed crop of Indian mustard (T_5). During 2003-04, 15.4 and 44.7 mm rainfall was received in vegetative and reproductive growth phase, respectively and a seed yield of 569, 1111 and 1738 kg / ha was obtained under rainfed (T_5), pre-sowing irrigation (T_6) and pre-sowing + irrigation at branching stage (T_7), respectively. During 2004-05, only 1.0 mm rainfall was received after sowing and a seed yield of 241, 379 and 1303 kg / ha was obtained under rainfed (T_5), pre-sowing irrigation (T_6) and pre-sowing + irrigation at branching stage (T_7), respectively

Growth, yield and yield attributing characters

Mean data of three years on crop growth in terms of plant height, seed yield and yield attributing characters of soybean, *toria* and Indian mustard indicated that supplemental irrigation given through harvested rainwater was found helpful in increasing growth and yield attributing characters of all the crops. Plant height of soybean increased significantly with supplemental irrigation provided at pod filling stage (Table 1). It increased by 11.4% under supplemental irrigation over no irrigation (rainfed). Yield attributing character of soybean also increased under supplemental irrigation. Number of branches / plant, number of pod / plant, pod length, number of seed / pod, seed weight / plant and 1000-seed weight increased by 21.6, 19.0, 10.7, 23.6, 39.4 and 4.6%, respectively, with supplemental irrigation over no irrigation (rainfed). Similarly, the plant height, number of primary branches / plant, secondary branches / plant, number of siliqua / plant, siliqua length, number of seed / siliqua, seed weight / plant and 1000-seed weight increased by 18.1, 39.9, 79.8, 62.2, 23.7, 30.8, 91.9 and 15.6%, respectively, with supplemental irrigation provided at 30 days after sowing over no irrigation (Table 2). Similarly, the growth and yield attributes of Indian mustard increased with pre-sowing irrigation and further with pre-sowing + supplemental irrigation at branching stage (Table 3). Plant height of Indian mustard increased by 20.9 and 35.3% with pre-sowing irrigation and pre-sowing + supplemental irrigation at branching stage, respectively, over no irrigation (rainfed). Yield attributes viz., number of primary branches / plant, secondary branches / plant, number of siliqua / plant, siliqua length, number of seed / siliqua, seed weight / plant and 1000-seed weight increased by 20.1, 26.2, 27.2, 17.8, 14.3, 68.7 and 5.1% with pre-sowing irrigation, and 49.9, 84.4, 66.2, 35.2, 23.0, 183.1 and 10.9% with pre-sowing + supplemental irrigation at branching stage, respectively, over no irrigation (rainfed).

Mean seed yield of soybean, toria and Indian mustard increased with supplemental irrigation over rainfed crop (Table 7). Seed yield of soybean increased by 31% with supplemental irrigation at pod filling stage over no irrigation (rainfed). Similarly, the seed yield of toria increased by 138.0% with supplemental irrigation at 30 days after sowing. Seed yield of Indian mustard also increased with pre-sowing irrigation and pre-sowing + supplemental irrigation at branching by 90.8 and 342.7%, respectively, over no irrigation (rainfed). The seed yield of various crops in terms of soybean equivalent yield also increased significantly and followed the similar trend as that of seed yield.

In general, the monsoon receded prior to pod filling stage of soybean consequently the rainfed crop suffered with the soil moisture stress condition which led earlier leaf senescence, early maturity and low yield under rainfed conditions. However, supplemental irrigation provided at pod filling stage helped the crop by providing higher soil moisture status than under rainfed conditions for proper seed development hence higher seed yield was obtained under supplemental irrigation than the rainfed crop. There was insufficient soil moisture to sustain a good crop under rainfed conditions hence lowest seed yield of Indian mustard was obtained under rainfed conditions. Pre-sowing irrigation provided adequate soil moisture for proper germination and vegetative growth but crop suffered with soil moisture stress during reproductive phase hence intermediate seed yield of Indian mustard was obtained under pre-sowing irrigation. Pre-sowing + supplemental irrigation at branching provided sufficient soil moisture for proper germination, vegetative and reproductive growth which led to higher vegetative and reproductive growth as reflected by higher magnitude of all yield attributes hence highest seed yield was obtained.

Water use efficiency

Water use efficiency of all the crops increased with supplemental irrigation, though the increase was statistically non-significant (Table 8). Water use efficiency of soybean and toria increased by 15.3 and 36.6% with supplemental irrigation at pod filling and 30 days after sowing, respectively, over no irrigation (rainfed). Water use efficiency of Indian mustard increased by 24.8 and 44.7% with pre- sowing and pre-sowing + supplemental irrigation at branching stage, respectively, over no irrigation (rainfed).

The above results are in congruence with the rainwater harvesting and recycling results obtained by Anonymous (2005); Rajput *et al.* (2004); Samra *et al.* (2002) and Singh (2000).

In red soils, the harvested rainwater may not remain available for a longer period as in case of black soils because of higher seepage loss hence it should be utilized for supplemental irrigation as early as possible. These results are in agreements with the findings of Diwivedi (2004) and Sharda and Ojasvi (2005).

CONCLUSION

Rainwater harvesting and recycling through a farm pond can successfully be adopted for providing supplemental irrigation at critical growth stages to a long duration *kharif* crop such as soybean or pre-sowing / supplemental irrigation to low water requiring post monsoon/*rabi* season oil seed crop such as toria or Indian mustard for increasing the growth, yield and water use efficiency in red soils and a large rainfed area could be brought under irrigation in the country in semi – arid condition for obtaining sustainable production.

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A simulation model for predicting the prodcutivity & production of agricultural land/watershed

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ABSTRACT

Simulation process is generally adopted to extend the application of mathematical models to other areas of interests. In the paper, a compound growth rate equation is developed to be applicable to predict the productivity and production of agricultural crops/ lands. A practical example has been worked out to test the application of the model, by using the past data and information of rice crop. The technical options where production advances are possible have been indicated in the end for the extension of its application.

Key words: Productivity, Compound growth rate, Water shed

INTRODUCTION

Agriculture is the primary profession for majority of the population in India. Even though it contributes about 18% of Gross domestic product of the country, Sustainable agricultural production has been the main objective in agricultural land use planning and food grain production in the recent years. Since Earth's water circulating system taking place on land regions is dynamic in nature, static land resource assumes dominance for any purpose; but it is not an expandable resource. Land's capacity to support biological system varies according to its suitability and capability for different purpose. Therefore, careful planning of its use without degradation assumes paramount importance.

Watershed concept

A watershed (or a catchment) is a geographical area that drains its rainwater through a common source of outlet, which makes it an ideal planning unit for conservation and promotion of soil (Land) and water. It may consist of one or several villages containing both arable and non-arable lands, with various categories of land holdings and land use. It offers an easy approach to adopt system techniques for its holistic development. lt traces its use as a concept in our land and water use planning during 3rd Five year plan; but was popularly adopted in agricultural development planning from 7th and 8th Five year plan onwards. Our national water policy (Anon 1987) and national agricultural policy (Anon 2000) and national land use policy outline (1988) had clearly suggested its adaptation in our land use planning efforts. In the year 2000, central ministries of agriculture and rural development of Govt of India have formulated a common approach for watershed development to be followed in all the land based schemes and projects being implemented in the country (Anon 2000).

Components of watershed development

Components

Based on the water resources availability point of view on the land surface (i.e., following drainage pattern) All India Soil and Land Use Organization(AlSLUS) under the ministry of Agriculture, Govt of India, New Delhi had delineated the country into six water resources regions, 35 Basins, 112 Catchments, 500 Sub-Catchments and 3237 watersheds. This five stage delineation provides a basis for an integrated development of land and water resources of an area for any purpose. Watershed development involves conservation, regeneration and judicious utilization of natural

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resources particularly Land, water, vegetation and animals. Accordingly the various components of watershed development may be grouped as under:

I. Soil and Land management
II. Water management
III. Crop management
IV. Afforestation
V. Pasture and fodder development
VI. Livestock management
VII. Rural Energy management
VIII. Other farm and Non-farm activities and development of community skills and resources

All these components are interdependent and interactive. There is a close relationship between the environment and the human community living there for its livelihood.

Current land use statistics (Anon, 2004)

Out of total geographical area of 329 M.Ha, of the country, agricultural land is about 184 M.Ha, 156 M.Ha is cultivated. 10 M.Ha is old fallow and 14 M.Ha is cultural waste land out of the cultivated area, about 142 M.Ha is net sown area and 14 M.Ha in the current fallow. Besides, 69 M.Ha is under forest land and 54.5 M.Ha is under irrigated land. Further, accordingly to National commission on Agriculture (1976), about 175 M.Ha is under different soil erosion and degraded conditions. Wind and water erosion alone shares 86% of this problem land.

Rainfed area accounts 62% of the total cultivated (net sown) land of 142 M.Ha. In fact, rainfed region of around 87.5 M.Ha is almost twice that of irrigated land. Yet the irrigated area (38%) account for 55% of total food grain production whereas the rainfed region (62%) contributes only 45% of total food grain production. Rainfed agriculture is characterized by low levels of productivity and low input usage. Being dependant on rainfall, crop production is subjected to considerable instability from year to year. More than 200 million rural poor live in the rainfed regions. These risk prone area exhibit wide variation and instability in yields. Gap between yield potential and actual yields are very high when compared to irrigated areas. Prediction of actual yield from agricultural land becomes necessary input in our planning efforts towards sustainable production and productivity.

The Prediction of productivity and Production

The system simulation model can be conceived to be formatted as follows (Frank, 1977)

A watershed of area A, with several crops grown in sub area A1, A2, A3,…… A_n has a compound productivity growth rate of R1, R2, R3 … R_n for a selected crop C1, C2, C3 … C_n respectively. It is required to calculate the yield, or productivity, P after a period of N years. From the past records, average compound growth rate of productivity, R is determinable for the known past period, T. Similarly, compound growth rate of area A, can be worked out if expansion or contraction takes place. Now, the production P, for the future period, N, can be mathematically written as follows:

$$P = A\left(1+\frac{R_a}{100}\right)^N * P_f\left(1+\frac{R_P}{100}\right)^N$$

Where A is area (Ha), R_a is compound growth rate of A, P_f is the productivity (Kg / Ha), R_p is the compound rate of productivity, N is the number of future years, and P is the total production (Kg).

Now, total production from the area, A1, A2, A3,…… A_n of the crop C1, C2, C3 … C_n, with productivity P_{f1}, P_{f2} , P_{fa} …. P_{fn} is given by,

$$P_T = \sum_{1}^{n} A_n\left(1+\frac{R_{an}}{100}\right)^N * \sum_{1}^{n} P_{fn}\left(1+\frac{R_{pn}}{100}\right)^N$$

Where P_T is total production (Kg); A_n is Sub area (Ha); N is number of Years by which total production is required; P_{fn} is Productivity / Ha of sub area A_n; R_{an} is compound growth rate of Sub area A_n; R_{pn} is the compound growth rate of productivity or yield of sub area A_n. "n" is the number of sub area $A_{n.}$ of total watershed area.

Now, in a particular case where no area expansion takes place and therefore R_{an} is zero, the total production for an sub area 100 Ha (A_1) with a productivity of 1938 Kg / Ha (P_{f1}) having a compound growth rate of 2.1% (R_{p1}). Can be worked out as follows. Now, the above equation reduces as follows:

$$P_T = A_1 * P_{f1}(1+R_{p1})^5$$

$$= 100 * 1938\left(1+\frac{2.10}{100}\right)^5$$

$$= 215021 \text{ Kg}$$

$$= 215 \text{ Metric Ton}$$

215 Metric Ton of production potential will accrue after a period of 5 years in the watershed.

For more or any other number of years, logarithmic table can be used to calculate / simplify the above equation. In fact for higher number of power functions logarithmic process is the fundamental approach to calculate the eventual figures. The calculation done above is for the Rice crop for which the basic data and information have been collected from agricultural statistics booklet published by the Ministry of Agriculture (Anonymous 2004).

Summing the figures for all the crops grown in the watershed, the total food grain production can be arrived at by using this mathematical model, for any desired period of time. In cases of practical situations prediction of future production potential is many times required for planning and development of agricultural schemes and projects. In such times, this model is most useful.

From several sources, the information on possible future options which have bearing on a sustainable agriculture production have been collected and furnished in the table 1 which is self-explanatory and related to the model, for its application. The technologies adopted in the watershed development are amply explained in references 5, 8, 10 which improve the productivity of agricultural lands / crops.

CONCLUSION

On several occasions, prediction of future potential of agricultural crop / land productivity and production becomes a necessity in our planning efforts for agricultural development. The simplified simulation model proposed in this paper renders it's possible to predict the future potentials of agricultural production independently as well as collectively. A practical / actual example from the data and information given in the agricultural statistics, bulletins (Anon 2004) for the case of rice crop has been worked out and result shown elsewhere in the paper which is self-explanatory and extendable to other crops grown in the watershed.

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Table 1. Possible future options for sustainable agriculture production and their impact on economy in India

S. No.	Options	Possible (P) Not Possible (NP)	Impact on Economy
1.	Area expansion in agriculture	P*	Positive
2.	Additional irrigational facilities	P***	Positive
3.	Soil & water conservation methods	P****	Positive
4.	Water management	P***	Positive
5.	Yield increase through genetic improvement	P****	Positive
6.	Hybrid vigour technology	P****	Positive
7.	Organic farming	P****	Positive
8.	Chemical fertilizer use	P***	Positive
9.	Integrated pest & disease management	P****	Positive
10.	Chemical pest and disease control	P*	Negative
11.	Local input technology for eco-agriculture	P****	Positive
12.	Small farmers oriented mechanisation	P***	Positive
13.	Eco-friendly economic policies	P****	Positive
14.	Special agricultural developmental programmes like horticulture, rice, pulse, technology missions on oil seeds, maize etc.	P****	Positive
15.	Post harvest technology	P****	Positive
16.	Social engineering	P****	Positive
17.	Measures of demographic policy (especially for population control through legal, economic and education means)	P****	Positive

* - Very meagre scope, ** - Meagre scope, *** - Some scope, **** - Ample scope

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Nutritional status of soil under litchi orchards of Uttarakhand

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ABSTRACT

A nutritional survey of 65 orchards of the major litchi growing belt in Pantnagar, Ramnagar, Kichha, Kotdwar, Haridawar, Dehradun and Pithouragarh (Quety) of Uttarakhand has been conducted during 2006 to determine the N, P, K, Zn, Fe, Cu, Mn B & S status of soil and plants. Organic carbon content was found to be minimum of 0.5% in soils of Kichha and maximum of 2.10 % in Pithoragarh area. Nitrogen content in soils of Pithoragarh was also high (466 kg/ha). All the soils were high in available P content. Potassium status in litchi growing soils of Uttarakhand is medium to high. Nitrogen status in leaf samples was lowest (1.19%) in Pithoragrah belt, whereas phosphorus content was particularly low in Dehradun (0.16%) and Pithoragarh (0.13%) litchi belt. As regard to potassium content in leaf samples, it was also very low in Dehradun (0.67%), Pithoragarh (0.67%) and Haridwar (0.95%). The Zn and Mn were low in *Tarai* soils as compared to the soil of hilly litchi orchards. The soils of all orchards were sufficient in Cu and B. As regards to micronutrients concentration in leaves, Zn and Fe contents were comparatively lower in orchards of *Tarai* and *Bhaver* regions as compared to hilly orchards. Taking 20 ppm as threshold value of Mn in leaves, it was noted that all the litchi orchards are deficient in Mn except orchards of Dehradun and Kotdwar.

Key words: Litchi, macronutrient, micronutrient

INTRODUCTION

The litchi (*Litchi chienensis Sonn*) is a sub tropical fruit and is very delicious, flavored and sweet juicy aril. It belongs to family Sapindaceae and sub family Nephele and native of southern China. At global level litchi production is confined to few countries like China, India, Thailand, Taiwan, Medagascar, South Africa and Australia. India is the second largest producer of litchi. The major litchi producing states are Bihar, Tripura, Jharkhand, Assam, Punjab and Uttarakhand. It is less sensitive to edaphic factors than the climatic factors (Groff 1943). Nevertheless, the whole issue of soil type and fertilization schedule in litchi is still confusing and this is often reflected in low yield. Determination of nutritional need of the plant is an important aspect of nutrient management in litchi.

The need of the fruit plants for mineral nutrients differs from those of annual crops in a number of ways, many of which are related to its perennial nature. In perennial tree crops, there is need to supply nutrients both for fruit production as well as for vegetative organs which persists from year to year. The need for leaf analysis in perennial horticultural crops has proved its superiority over other diagnostic methods. This is essential because of the deeper root system and the fact that nutrients supplied in one year may have its effect on both the nutrition and crop production (Bhargava and Chadha 1988). The national productivity of litchi is about 6.1 t/ha with highest productivity of about 10 t/ha in Punjab and about 2 t/ha in Uttarakhand (Indian Horticulture Database 2005). Lower productivity of litchi in Uttarakhand is due to major

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area of litchi orchards planted under Hotriculture Mission in recent year and also due to poor nutrient management.

One of the major factors limiting litchi production in Uttarakhand is lack of suitable nutrient management programme. Yields may be low because of excessive vegetative growth in winter following late or heavy N fertilization. Deficiencies of B, Zn and Cu, limits yield by restricting the flower set and subsequent development of fruit. No leaf nutrient standards are available for litchi in Uttarakhand, and farmers are also reluctant to apply chemical fertilizers.

MATERIALS AND METHODS

Based on productivity level, 65 litchi orchards located in hills and plains in different districts of Uttarakhand were selected. Ten soil samples were taken from a particular orchard and mixed together thoroughly. A representative soil sample was drawn by quartering technique for analysis. Soil samples collected were analyzed for pH, EC, OC., $CaCO_3$-, available N, P, K, Fe, Cu, Mn, Zn, B & S. The pH of the soil was determined by Systronic pH system 361 using glass electrode in 1: 2 soil water suspensions. The EC of soil was determined by Systronic Conductivity meter 306 in 1:2 soil water suspensions. The organic carbon in soil sample was determined by Walkley and Black method as described by Tandon (1993). Available Nitrogen was estimated by alkaline $KMnO_4$ method (Subbiah and Asija 1956). The liberated ammonia was absorbed in boric acid containing mixed indicator. The amount of ammonia absorbed was estimated by titrating with standard H_2SO_4. Available phosphorus in soil was extracted by 0.5 M $NaHCO_3$ adjusted the pH 8.5 as per method of Olsen *et al.* (1954) and determined by ammonium molybdate blue colour method. The intensity of blue colour was recorded on spectrophotometer at 720 nm wavelength. The available potassium in soil was determined by extracting soil with neutral normal ammonium acetate (Pratt 1965) and aliquot was determined by flame photometer. Determination of $CaCO_3$ in soil was done by rapid titration method (Piper 1966) using bromothymol blue as indicator.

Available micronutrients cations Zn, Cu, Fe and Mn in soil was determined by DTPA (Diethylene Triamine Penta Acetic Acid) extraction method developed by Lindsay and Norvell (1978) using double beam atomic absorption spectrophotometer (GBC Avanta-M). The available sulphur in soil was extracted by 0.5 M $NaHCO_3$ adjusted the pH 8.5 (Kilmer and Nearpass 1960) and determined by turbidimetric method (Chesnine and Yien 1951). Available quantities of B was extracted by Hot water (Gupta 1979) and determined by Azomethane – H color method using colorimeter with 420 nm wavelengths as per procedure described by Singh *et al.*

Twenty representative plants from each orchard were selected. Fully mature 3^{rd} to 4^{th}, 3 month old leaves from each plant at all sides were collected and representative sample for each orchard was taken after mixing all the leaves. The leaf samples washed sequentially in detergent solution (0.2% liquid detergent), HCl (0.1 Normal) and deionized water and dried in oven at 70^0C. Finely ground samples were digested in diacid mixture (HNO_3: $HClO_4$, 3:1 v/v). The nitrogen content in leaf samples were determined by micro – Kjeldhal method, phosphorus in acid digest determined by ammonium molybdate -vandate yellow color method using spectrophotometer and potassium by flame photometrically (Bhargava and Raghupathi 1998). Digested plant samples were analyzed for Zn, Cu, Fe, Mn by atomic absorption spectrometer, whereas, S and B was estimated using standard procedures (Tandon 1993).

RESULTS AND DISCUSSION

Soil properties of litchi orchard

The relevant soil physico-chemical properties viz pH, EC, OC, $CaCO_3$-, of the various litchi orchards of litchi growing belts of Uttarakhand are presented in table 1. The pH of the soil in litchi orchards of Uttarakhand varied from 5.8 to 8.2 with an average of 7.07. These soils are suitable for litchi cultivation, although the best pH range for litchi growth is 5.5 to 7.0 as under this range mycorrhizas are active to supplement the litchi nutrition (Katyal and Chug 1961). As regards hilly areas of Dehradun and Haridwar, the mean pH is about 6.5, but the shallow soil depth with hard and stony subsoil is the major constraint. However, in Quety valley of Pithoragarh mean pH of soil is about 7.7 (7.4–8.0). Alkaline pH in hilly area is attributed to highly calcareous nature of the parent material in which Ca ion controls soil reaction. Satisfactory growth of litchi in India in alkaline soil up to 30% free lime was reported (Nijjar 1972).

Table 1. Physico-chemical properties of soils

S. No.	Locations	pH		$EC(dSm^{-1})$		OC (%)		$CaCO_3$ (%)	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
1.	Pantnagar	6.68-8.16	7.2	0.106-0.346	0.201	0.33-0.67	0.53	2–12	6.0
2.	Dehardun	5.8-6.9	6.4	0.147-0.557	0.373	0.99-1.59	1.23	1–4	2.1
3.	Pitthragrah	7.4-8.0	7.7	0.191-0.472	0.287	1.30-4.86	2.10	16–91	61.22
4.	Ramnagar	6.6-7.6	7.0	0.175-0.403	0.267	0.70-1.33	0.91	1–8	2.75
5.	Kichha	6.8-8.2	7.3	0.213-0.405	0.320	0.37-0.61	0.50	5–13	7.0
6.	Kotdwar	6.8-8.2	7.4	0.156-0.223	0.191	0.63-0.93	0.77	5–7	5.67
7.	Haridwar	5.8-7.3	6.5	0.161-0.383	0.213	0.18-1.74	0.82	1–7	4.8

The EC Values were well within the prescribed level of less than 0.4 dSm^{-1} best suited for litchi production. Salinity of the soil is not a problem in Uttarakhand because high rainfall removes salts from the soil as they tend to release during the weathering. Value of organic carbon (OC) ranged from 0.18-4.86 in various litchi growing belts of Uttarakhand. Mean value of organic carbon was found to be minimum of 0.5% in Kichha area and maximum of 2.10 % in orchards of Pithoragarh area. High content of organic carbon in litchi growing belt of hilly areas might be due to low temperature resulting slow decomposition of organic material. Available $CaCO_3$ varied from 1.0 – 91 % with an average of 12.79%. Soils of Quety litchi orchards of Pithoragarh is exceptionally high (16-91%) in calcium carbonate content. A critical perusal of the soil revealed that parent material is limestone and several mines of limestones are situated in the area. It was observed that a good quality litchi with desired colour, sweetness and size is being produced in this area.

Macronutrient status of soil and leaves

The relevant soil and leaf N, P and K status of the various litchi orchards of Uttarakhand are presented in Table 2. The mean value of available N in soil and leaves varied from 228 to 466 kg/ha and 1.19 to1.78 %, respectively in different litchi orchards of Uttarakhand. Similarly, mean value of available P varied from 36-221 kg/ha and 0.13-0.26%; and available K 199 to 416 kg/ha and 0.67 to 2.68 %, respectively in soil and leaves. As such, no information is available about the critical level of soil N, P and K for orchard crops. Most of the soils are in low range of nitrogen except in Pithoragarh and Dehradun which appears to be in medium range as per soil test rating established for common cultivated crops. High N content in soils of Pithoragarh and Dehradun litchi belt might be attributed to its high organic matter content as nitrogen supply of the soil is solely governed by its organic pool. All the soils are high in available P content. Soils of Haridwar and Dehradun litchi belts are very high in available P content, which might be due to P rich parent material as well as regular application of P containing fertilizers that leads to accumulation of P in surface soils. Similarly, K status in litchi growing soils of Uttarakhand is medium to high. High content of available K in Pantnagar and Dehradun belt might be ascribed to regular addition of potassium containing fertilizers by farmers.

As per the leaf nutrient standard of N (1.3-1.4 %), P (0.08-0.1 %) and K (1.5-2.5 %) for litchi (Cull 1977), it appears that most of the orchards in Uttarakhand are sufficient in leaf N and P. However, most of the

Table 2. Macro nutrients status (Mean) of litchi orchards

Locations	N			P			K		
	Soil (kg/ha)	Leaf (%)	Correlation coefficient	Soil (kg/ha)	Leaf (%)	Correlation coefficient	Soil (kg/ha)	Leaf (%)	Correlation coefficient
Pantnagar	246	1.78	0.36	90	0.25	0.11	348	2.68	0.34
Dehardun	298	1.55	0.42	201	0.16	0.19	416	0.67	0.75
Pitthragrah	466	1.19	0.46	98	0.13	0.24	328	0.67	0.63
Ramnagar	281	1.60	0.17	90	0.25	0.75	199	1.15	0.27
Kichha	228	1.62	0.67	36	0.21	0.32	202	1.18	0.82
Kotdwar	232	1.33	0.03	99	0.26	0.80	205	1.12	0.94
Haridwar	277	1.74	0.53	221	0.26	0.37	283	0.95	0.14

litchi orchards are deficient in leaf K content except Pantnagar. Low nutritional status of litchi orchards of hilly areas *viz.,* Dehradun, Pithoragarh and to some extent Haridwar belt might be attributed to shallow soil depth as well as lack of a suitable nutrient management practices. Taking nutrient status in litchi orchards of Pantnagar, which is adequately supplied with nutrients, as a standard leaf nutrient concentration, it was found that orchards of hilly areas are particularly prone to nutrition deficiency and requires a proper nutrient management plan to increase the productivity of litchi in the state.

Micronutrient status of soils and leaves

The relevant soil and leaf micronutrients (Zn, Cu, Fe, Mn & B) and also S status of the various litchi orchards of Uttarakhand are presented in table 3. As regards to micronutrients, Zn content varied from 0.88 to 5.05 ppm in soils and 17.1 to 37.25 ppm in leaf. Zinc status in litchi growing soils of Uttarakhand was medium to high. Soils of Dehradun, Pithoragarh and Haridwar were rich in Zn which may be due to Zn rich parent material in soils of Hill region. The leaf Zn was comparatively lower in Ramnagar (17.1 ppm) and Kichha (18.7 ppm) while in other locations it appeared to be sufficient taking 20 ppm as general limit (Mortvedt 1972) for sufficient Zn in leaves. Copper content ranged between 6.0 ppm (Pithoragarh) to 13 ppm at Pantnagar. Value of available copper in soil and leaf ranged from 1.76 to 2.38 and 6 to 13.08 ppm, respectively in various litchi orchards of Uttarakhand. Although the Cu status may be rated as sufficient in all the orchards taking 5 ppm as general limit for Cu sufficiency in plants (Mortvedt 1972). Its content was found to be approaching to the threshold level of deficiency in most of the orchards and may pose problem in near future. Copper deficiency can induce pollen sterility and hence limited fruit set in crops, although vegetative growth was normal.

The content of Fe in soil and leaf was found to vary between 5.39 to 32.61 ppm and 118 ppm to 474 ppm, respectively. It was noticed that Fe content in litchi belts of hilly areas as Kotdwar, Dehradun, Pithoragarh and Haridwar was very high as compared to orchards of *Tarai* plain (Pantnagar, Kichha and Ramnagar) areas. Taking 50 ppm of Fe as threshold value in leaves (Mortvedt 1972), it was found that Iron was sufficient in all the orchards. Mean value of Mn in soils and litchi leaves varied between 7.47 to 29.85 ppm and 8 ppm to 25 ppm, respectively. Taking 20 ppm as threshold value of Mn in leaves (Mortvedt 1972), it was noted that virtually all the litchi orchards were deficient in Mn except Dehradun and Kotdwar. Its status was particularly low in litchi orchards of Ramnagar and Kichha area. Mean value of available Boron varied from 0.55 to 2.08 ppm in soil and 29.65 to 72.72 ppm in leaves. As per the deficiency limit of < 15 ppm B content in mature leaf tissue (Mortvedt 1972), it appears that most of the orchards in Uttarakhand are sufficient in leaf B content. Litchi orchards in Pantnagar recorded highest concentration of B in leaf tissues (72.72ppm) followed by Ramnagar, Kichha, Dehradun and Haridwar.

Available Sulphur in soils and leaves ranged from 35.16 to 103.08 ppm and 840 to 2070 ppm, respectively. Soil S status in litchi growing soils of Uttarakhand has no defined pattern. Soils of Pantnagar, Dehradun and Pithoragarh appears to be high in available S content, while soils of Ramnagar, Kichha, Kotdwar and Haridwar have low S content. Taking 1700-1900 ppm as the nutrient standard for sufficient concentration of S in leaves (Tandon 1993), it appears that most of the orchards in Uttarakhand are sufficient to marginal in leaf S content except Pithoragarh belt where all the litchi orchards are deficient in leaf S content thus expected to respond S fertilization.

Correlation analysis (Table 2 and Table 3) of available soil and leaf macro and micro nutrient status revels that in general there is poor correlation between the nutritional status of soil and leaf for most of the orchard of Uttarakhand. It was expected in orchards as the root distribution pattern and nutrients absorption of perennial crops did not match with the content of nutrients present in surface soils. It is always difficult to draw a representative soil sample to reflect the nutrients need of perennials plants. Therefore, the need for leaf analysis in perennial horticultural crops has proved its superiority over other diagnostic methods (available soil nutrient) for determination of nutrient requirement and its scheduling. This is essentially because of the deeper root system and the fact that nutrients supplied in one year may have its effect on both the nutrition and crop production in following years (Bhargava and Chadha 1988).

Table 3. Micro nutritional status in litchi orchards of Uttarakhand

	Soil	leaf	Correlation coefficient	Soil	leaf	Correlation coefficient	Soil	leaf	Correlation coefficient
	Zn (ppm)			Cu (ppm)			Fe (ppm)		
Pantnagar	0.88	24.75	0.07	1.885	13.08	0.44	5.391	169.97	0.24
Dehardun	3.58	20.46	0.47	1.759	8.25	0.37	23.707	203.01	0.09
Pitthragrah	3.44	26.51	0.24	2.290	6.00	0.57	10.100	206.72	0.40
Ramnagar	2.45	17.10	0.64	2.069	7.98	0.86	20.330	192.21	0.38
Kichha	1.09	18.70	0.83	2.210	8.00	0.71	13.948	118.60	0.77
Kotdwar	1.29	23.90	0.49	2.711	6.80	0.98	25.164	474.70	0.96
Haridwar	5.05	37.25	0.42	2.380	7.9	0.07	32.613	399.81	0.05
	Mn (ppm)			B (ppm)			S (ppm)		
Pantnagar	7.49	13.37	0.35	1.45	72.72	0.08	61.84	1630	0.30
Dehardun	29.85	25.25	0.32	1.62	41.69	0.09	103.08	1420	0.28
Pitthragrah	7.57	20.18	0.05	2.08	44.25	0.04	56.68	840	0.06
Ramnagar	15.26	16.69	0.03	1.85	54.25	0.04	35.16	1410	0.09
Kichha	7.47	8.15	0.50	0.74	48.29	0.99	ND	2070	-
Kotdwar	12.35	25.40	0.38	0.55	29.65	0.22	40.19	1910	1.0
Haridwar	13.49	16.62	0.42	1.14	35.61	0.16	21.86	1840	0.38

CONCLUSIONS

It is concluded that leaf tissue testing is a reliable tool to assess the fertilizer need of litchi orchards. Most of the orchards in Uttarakhand are sufficient in leaf N and P content. However, only Pantnagar litchi orchards are sufficient in leaf K content while other orchards have leaf K content below the stipulated K standard. Micronutrients analysis of leaves indicated the need for application of Zn in *Tarai* soils. Manganese was found to be deficient in all orchards. Copper was identified as requirement of future whereas S was found to be deficient only in Pithoragarh area. A comprehensive study is needed to establish location specific leaf nutrient standards supplemented with data of soil analysis and other yield affecting factors based on DRIS approach. It also appears that surface soil samples in orchards does not reflect the real nutritional status of plants, thus fertilizer recommendation made on the basis of soil analysis would be misleading and fertilizer recommendation on the basis of leaf analysis appears to be more reliable in orchards. Based on the study it is concluded that there is no direct correlation soil available nutrients and leaf nutrients content in litchi orchards. Thus, the leaf nutrient standard is a better indicator of plant health.

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Effect of integrated use of organic manure and nitrogen fertilizer on grain yield, nutrients uptake and use efficiency in wheat (*Triticum aestivum* L.) in Northern India

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ABSTRACT

A field experiment was conducted during two consecutive rabi seasons of 2006-07 and 2007-08 on loamy sand soil of KVK farm, Sonipat, Haryana (INDIA) to study the effect of integrated use of farm yard manure (FYM) and urea on grain yield, nutrient uptake and their use efficiency in wheat (*Triticum aestivum* L.). The experimental design was split plot having four levels of FYM (0, 7.5, 15 and 30 t / ha) in the main plots and five levels of N (0, 75, 150, 187.5 and 225 kg / ha) in the sub-plots. The results indicated that the increasing levels of FYM increased the wheat grain yield and nutrient uptake (N, P and K) at all levels of applied N. The agronomic efficiency, partial factor productivity and apparent N recovery were highest at 15 t FYM / ha and 150 kg N / ha application. However, application of 187.5 kg N / ha along with and 15 t FYM / ha produced optimal yields of 5.3 and 5.2 t / ha during the year 2006-07 and 2007-08, respectively. Regarding economic of production, the higher net monetary return was obtained with combined application of 187.5 kg N / ha along with and 15 t FYM / ha with a highest B: C ratio as compared to other treatment combination, irrespective of wheat growing year.

Key words: FYM, fertiliser N, wheat, yield, nutrient use efficiency

INTRODUCTION

Wheat is one of the major food crops in the world cultivated over an area of about 226.45 m ha with a production of 161.9 m tones. In India, the wheat production is about 72 m tonnes from an area of around 25 m ha (Chanda et al., 2008). Although, India is well placed in meeting its needs for food grains, yet the major objective of food and nutritional security for its entire population has not been achieved. The demand for wheat in India by 2020 has been projected to be between 105 to 109 m tonnes as against 72 m tonnes production of present day. Most of this increase in production will have to come from increased productivity, as the land area under wheat is not expected to expand.

Like Haryana, yields in other areas of the country have started declining because of decrease in factor productivity (Yadav, 1998) and farmers are now using greater than recommended levels of fertilizer nitrogen to maintain the yield levels which they were getting a few years back. Therefore, one of the most promising means for increasing wheat yield is to develop alternative nutrient management practices for increasing factor productivity. The integrated use of organic materials and inorganic nitrogenous fertilizers has received considerable attention in the past with a hope of meeting the farmer's economic need as well as maintaining favorable ecological conditions on long-term basis (Kumar et al., 2007). The integrated nutrient management helps to restore and sustain fertility and crop productivity. It may also help to check the emerging deficiency of nutrients secondary and micronutrients. Further, it brings economy and efficiency in fertilizers. The integrated nutrient management favorably affects the physical, chemical and biological environment of soils. Integrated use of FYM and inorganic N increases the productivity and monetary returns of wheat by maintaining or improving soil fertility (Sarma et al., 2007)

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Limited availability of land for additional crop production, along with declining yield of major food crops like wheat have heighted concerns to focus on using available nutrient resources more efficiently. In views of these facts, this study was designed to study the effect of combined use of FYM and fertilizer N on crop yield, nutrient uptake and N use efficiency in wheat crop grown on an alluvial soil in Haryana, India.

MATERIALS AND METHODS

A field experiment was conducted during 2006-07 and 2007-08 at the farm of Agriculture Science Centre (KVK), Sonipat, Haryana approximately 50 KM North West of New Delhi. The soil was loamy sand, alkaline in pH (8.3) with low organic carbon (0.34%), N (120.4 kg / ha), P (18.4kg / ha) contents and medium in available K(150.0kg / ha). The precipitation received during the crop seasons (November to April) of 2006-07 and 2007-08 was 37.0 and 94.9 mm, respectively. The experiment was conducted with Split Plot Design consisting of four levels of farm yard manure (FYM) - 0, 7.5,15.0 and 30 t / ha as main plots and five levels of N - 0, 75,150, 187.5 and 225 kg / ha as sub plots with three replications. Well decomposed FYM (0.58 and 0.62% N and 0.25 and 0.30% P and 0.72 and 0.74% K during the year 2006-07 and 2007-08, respectively) was applied uniformly and incorporated in soil 15 days before the sowing of the crop. Recommended dose of P (60kg / ha), K (30 kg / ha) and Zn SO_4 (25 kg / ha) was applied at sowing time while N as top dressing was applied in three split doses -1 / 3 each at sowing, 1st irrigation and 2nd irrigation. Wheat WH-711 was sown on 15th and 12th December in 2006-07 and 2007-08, respectively at 20 cm row to row distance with 125 kg seed / ha. Surface soil samples were collected before sowing and after harvesting of the crop and were analysed for N content. Wheat crop was harvested at maturity and grain samples were analysed for N by Nessler's Reagent method (Linder, 1944), P by Vanadomolebdo phosphoric acid yellow colour method (Koenig and Johnson, 1942) and K by flame photometer method. The data was subjected to economic analysis and the following computations were used-

Agronomic efficiency (kg / kg): {Yield (N) – Yield (N_0)} / applied fertiliser N

Apparent Recovery of N (%): {Uptake (N) – uptake (N_0)} / applied fertiliser N

Partial factor productivity of applied (kg / kg): Yield (N) / applied fertiliser N

RESULTS AND DISSCUSSION

Grain yield of wheat

The results suggest that the average grain yield of wheat increased significantly with the increasing levels of N and FYM (Fig 1). The magnitude of increase in yield with N was higher as compared to applied FYM. In general, the application of N up to

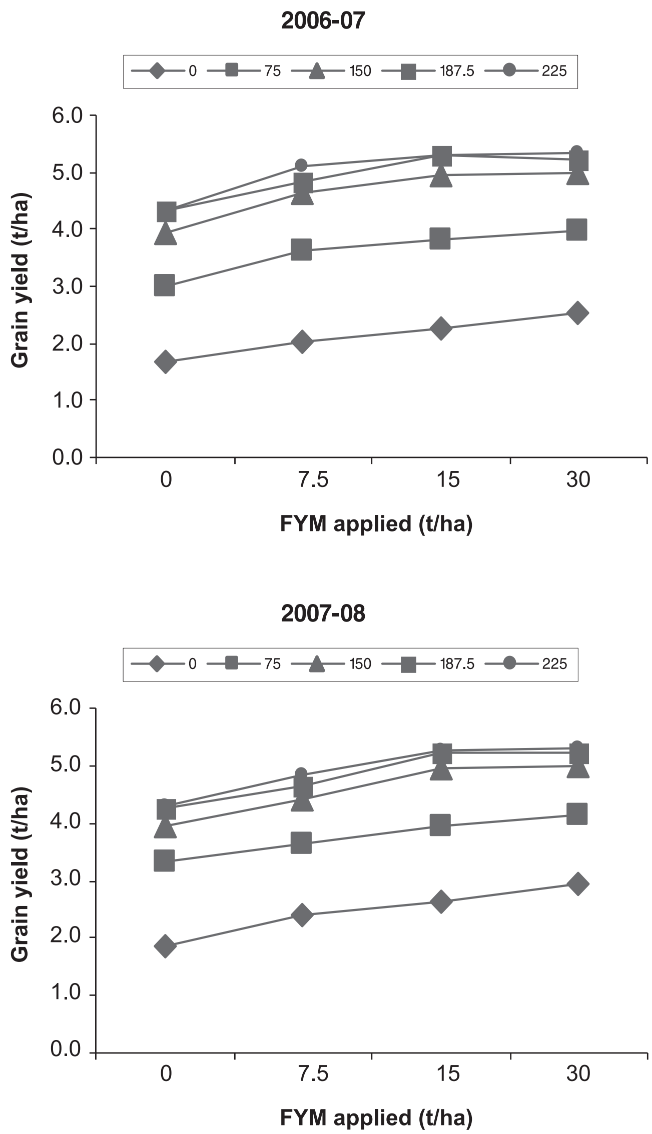

Fig. 1: Interactive effect of N fertiliser and FYM on grain yield of wheat. (LSD ($p<0.05$): N=1.14, FYM=0.88, N x FYM=2.16, 2006-2007; N=1.07 , FYM=0.81, N x FYM=2.08, 2007-08).

187.5kg /ha and FYM up to 15 t /ha increased the grain yield significantly. The application of FYM @7.5 and 15 t /ha increased the grain yield significantly by 17.1 and 25.2 during 2006-07 and 12.7 and 23.7% during 2007-08 over control. The average grain yield increased significantly with successive increase in N levels up to 225kg N /ha being 69.0, 117.4, 129.6 and 136.2% with 75, 150, 187.5 and 225 kg /ha, respectively, over control. The improvement in yield with the application of N and FYM might be due to balanced nutrition supplied by treatments. The interaction between N and FYM was found to be synergistically significant in improving the grain yield during both the years. Similar kind of synergistic interaction between N and FYM has also been reported by (Singh and Aggarwal, 2005). The optimum yield (5.3 and 5.2t /ha) of wheat was obtained with the application of 187.5 kg N /ha and 15 t FYM /ha during 2006-07 and 2007-08, respectively. The optimal wheat yield obtained on plots receiving 187.5 kg N /ha and 15 t FYM /ha were possibly caused by the better nutrient supply pattern and improved physical conditions (Yadvinder-Singh et al., 2004). Mundra et al., 2003 also reported higher grain yield with 125% of recommended N, P and K (120+60+30) application along with 10 t FYM /ha.

Nutrient uptake

The total uptake of N, P and K was significantly enhanced by the application of farm yard manure and nitrogen (Table 1). The application of 7.5 and 15 t FYM /ha increased the total N, P and K uptake by 28.2 and 43.8%, 27.5 and 43.5%, 24.3 and 38.3% during 2006-07 and 22.5 and 40.1%, 20.7 and 40.0%, 16.5 and 34.2% during 2007-08, respectively over control. The total N, P and K uptake was enhanced significantly and subsequently with the application of N up to 225kg /ha. The increase in total uptake of N, P and K was 94.6, 83.8 and 78.7% with 75kg N /ha, 172.5, 147.5 and 145.5% with 150kg N /ha, 198.3, 157.5 and 171.2% with 187.5kg N /ha and 213.9, 168.8 and 187.8% with 225kg N /ha, respectively during the year 2006-07. The corresponding increase during 2007-08 was 76.5, 68.1 and 66.8% with 75kg N /ha, 136.9, 117.0 and 119.7% with 150kg N /ha, 158.0,

Table 1. Effect of different levels of farm yard manure and nitrogen on nutrients uptake (kg /ha) in wheat

	N Applied (kg /ha)					Mean		N Applied (kg /ha)					Mean
FYM Applied (t /ha)	0	75	150	187.5	225		FYM Applied (t /ha)	0	75	150	187.5	225	
	2006-07							2007-08					
Nitrogen Uptake (kg /ha)													
0	29.7	59.1	83.5	96.6	98.5	73.5	0	31.5	63.1	83.2	93.1	96.3	73.4
7.5	39.2	76.4	109.0	117.6	125.7	93.6	7.5	44.9	76.1	102.3	111.6	117.6	90.5
15	44.0	85.3	122.8	135.2	140.4	105.5	15	50.8	85.9	120.8	126.5	133.6	103.5
30	48.8	93.7	125.2	137.3	142.6	109.5	30	53.6	94.2	122	135.2	138.9	108.8
Mean	40.4	78.6	110.1	121.6	126.8		Mean	45.2	79.8	107.1	116.6	121.6	
CD $_{(0.05)}$N=2.29 , FYM=1.86, N x FYM=4.06							CD $_{(0.05)}$N=1.88 , FYM=1.32, N x FYM=3.16						
Phosphorus Uptake (kg /ha)													
0	5.7	11.1	15.2	17.0	17.1	13.2	0	6.5	12.7	15.8	17.2	17.5	13.9
7.5	7.6	14.2	19.5	20.3	21.7	16.7	7.5	9.2	14.6	19.3	20.1	21.2	16.9
15	8.9	16.3	22.3	23.1	23.7	18.9	15	10.6	17.4	23.1	23.4	23.9	19.7
30	9.8	17.1	22.0	22.9	23.6	19.1	30	11.4	18.4	23.5	24.1	24.4	22.6
Mean	8	14.7	19.8	20.8	21.5		Mean	9.4	15.8	20.4	21.2	21.8	
CD $_{(0.05)}$N=0.72, FYM=0.58, N x FYM=1.26							CD $_{(0.05)}$N=0.97 , FYM=0.71, N x FYM=1.58						
Potassium uptake (kg /ha)													
0	37.1	70.5	97.3	104.8	106.7	83.3	0	39.9	80.5	102.2	107.1	111.4	88.2
7.5	46.3	85.4	115.1	129.2	138.4	102.9	7.5	54	88.5	115.6	125.9	132.6	103.3
15	52.7	92.2	128.7	147.3	154.4	115.1	15	62.6	98.1	135.2	147.7	152.1	119.1
30	56.9	96.9	133.2	147.7	156.5	118.2	30	66.3	104.6	136.5	152.5	154.8	122.9
Mean	48.3	86.3	118.6	132.3	139		Mean	55.7	92.9	122.4	133.3	137.7	108.4
CD $_{(0.05)}$N=2.82 , FYM=2.28, N x FYM=5.16							CD $_{(0.05)}$N=2.26 , FYM=1.81, N x FYM=4.18						

124.5 and 139.0% with 187.5kg N / ha and 171.7, 134.0 and 149.7% with 225kg N/ha, respectively. The increase in N, P and K uptake with the application of FYM lies in the fact that apart from supply of nutrients, it also enhanced the availability of these nutrients to the plants. It also improved the soil environment, which encourage proliferous root system resulting in better absorption of moisture and nutrients and thus resulted in higher biomass production. Singh et al. (2011) reported that wheat crop needs to be fertilized with organic and inorganic sources of N to have higher wheat yield and nutrient uptake. These results are in conformity with those of Paikaray et al. 2002 and Singh and Agarwal, 2005.

Nutrient Use Efficiency

Agronomic efficiency

Agronomic efficiency increased from 14.6 and 14.5 to 20.4 and 19.3 with the application of FYM only upto 15 t/ha during 2006-07 and 2007-08, respectively (Table 2). Reduced losses of N and balanced availability of nutrients with the application of FYM might lead to improvement in grain yield of wheat and consequently the higher agronomic efficiency. On the other hand agronomic efficiency decreased with increasing levels of N because of low utilization of applied N which is supported by low apparent recovery and partial factor productivity of applied N. Reduced losses of N and higher availability of nutrients with the application of farm yard manure might lead to improvement in grain yield of wheat and consequently the higher agronomic efficiency. Sharma, 2002 also observed similar results in wheat.

Apparent recovery of N

Apparent recovery of N increased with the application FYM but decreased with the application of N fertilisation (Table 2). Higher apparent recovery of fertilizer N with FYM application might be attributed to lower nitrogen losses and synchronization of N supply as per crop need. Dwivedi et. al., 2003 and Singh and Agarwal, 2005 also reported higher agronomic efficiency and apparent N recovery in wheat with the use of organic manures.

Partial factor productivity of applied N

Partial factor productivity increased only upto 15t/ha of FYM and then dropped in both the growing years (Table 2). The maximum average partial factor productivity of 43.5 and 45.3 was recorded at 75kg N / ha $^{-}$and it decreased by 32.6, 41.4 and 50.3 per cent during 2006-07 and 36.0, 44.8 and 52.3 percent during 2007-08 at 150, 187.5 and 225 kg N/ ha over 75kg N / ha application.

Physiological use efficiency

In general, the physiological use efficiency of N, P and K decreased with application of N and FYM at all levels. Physiological use efficiency of N,P and K decreased by 8.9, 8.2 and 5.4% during the year 2006-07 and 12.8, 10.8 and 5.3 during the year 2007-

Table 2. Effect of different levels of FYM and fertiliser N on agronomic efficiency, apparent recovery, partial factor productivity of applied N in wheat

FYM applied (t/ha)	Agronomic efficiency (kg grain/kg N applied)		Apparent N recovery(%)		Partial factor productivity (kg grain/kg N applied)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
0	14.6	14.5	35.1	34.6	27.2	28.2
7.5	18.8	16.7	49.5	45.3	30.8	29.9
15	20.4	19.3	56.2	53.1	32	32.1
30	19.3	18.8	56.4	56.4	30.1	30.7
Mean	18.3	17.3	49.3	47.4	30.0	30.2
N applied (kg/ha)						
75	23.1	23.1	58.5	58	43.5	45.3
150	18.7	17.3	50.8	48.4	29.3	29
187.5	16.8	15.5	46.3	43.9	25.5	25
225	14.4	13.5	41.6	39.2	21.6	21.6
Mean	18.3	17.4	49.3	47.4	30.0	30.2

08 with the application of 7.5 t FYM / ha over no FYM application, respectively (Table 3). The highest physiological efficiency of N and K was recorded at 150 kg N / ha. Increasing level of N from 150 to187.5kg / ha reduced the physiological efficiency of N and K significantly in both the years where as the physiological efficiency of P increased with the application of N up to 187.5 kg / ha and further increase in N levels, the physiological efficiency of P reduced. Increasing levels of farmyard manure in combination with N also reduced the physiological efficiency of N, P and K. Similar results were also observed by Singh and Aggarwal 2005 in wheat.

Economic analysis

The data suggested that the highest average benefit: cost ratio of 2.23 and 2.54 was obtained at 15 t FYM / ha during 2006-07 and 2007-08, respectively (Table 4). Likewise the benefit cost ratio increased from 1.23 and 1.58 with no N applied to 2.48 and 2.73 at 187.5kg N / ha application during 2006-07 and 2007-08, respectively. However the highest benefit: cost ratio of 2.63 and 2.91 was obtained at 15 t FYM ha and 1875kg N / ha application during the year 2006-07 and 2007-08 respectively as compared to all other treatments. Increase in FYM beyond 15 t / ha reduced the benefit cost ratio due to higher cost of

Table 3. Effect of different levels of farm yard manure and nitrogen on physiological use efficiency of nutrients in wheat

FYM Applied (t / ha)	N Applied (kg / ha) 75	150	187.5	225	Mean	FYM Applied (t / ha)	N Applied (kg / ha) 75	150	187.5	225	Mean
		2006-07						2007-08			
Physiological N- use efficiency (kg grain / kg N absorbed)											
0	45.2	42.2	39.6	38.5	41.4	0	47.5	41.0	39.1	40.7	42.1
7.5	41.8	37.5	35.8	35.6	37.7	7.5	40.4	36.6	34.8	34.8	36.7
15	38.5	35.2	34.1	33.5	35.3	15	38.6	35.1	34.3	33.7	35.4
30	35.9	34.6	33.0	32.5	34.0	30	36.8	34.7	32.8	32.4	34.2
Mean	40.4	37.4	35.6	35.0		Mean	40.8	36.9	35.3	35.4	
Physiological P- use efficiency (kg grain / kg P absorbed)											
0	246.3	238.9	234.9	232.5	238.2	0	241.9	228	225.2	239.5	233.7
7.5	229.4	215.2	215.8	213.8	218.6	7.5	222.2	202.3	205.1	204.1	208.4
15	201.9	197.6	207.7	206.1	203.3	15	192.7	188.6	198.8	197.7	194.5
30	201.8	202.5	206.4	205	203.9	30	194.1	184.7	193.2	191.4	190.9
Mean	219.9	213.6	216.2	214.4		Mean	212.7	200.9	205.6	208.2	
Physiological K- use efficiency (kg grain / kg K absorbed)											
0	39.8	37.7	39.2	38.1	38.7	0	36.9	34	35.9	36.9	35.9
7.5	40.4	38.1	34.2	33.8	36.6	7.5	37	34.2	32.4	32.4	34.0
15	38.8	35.8	32.7	31.6	34.7	15	36.1	32.8	30.5	30.7	32.5
30	38.5	34.3	32.1	30.7	33.9	30	35.7	32.5	30.2	30.3	32.2
Mean	39.4	36.5	34.6	33.6		Mean	36.4	33.4	32.3	32.6	

Table 4. Effect of different levels of FYM and fertiliser N on benefit: cost ratio (B: C ratio) in wheat

FYM Applied (t / ha)	N Applied (kg / ha) 0	75	150	187.5	225	Mean	FYM Applied (t / ha)	N Applied (kg / ha) 0	75	150	187.5	225	Mean
			2006-07								2007-08		
0	1.08	1.82	2.24	2.39	2.32	1.97	0	1.33	2.26	2.52	2.62	2.58	2.26
7.5	1.24	2.07	2.50	2.53	2.59	2.19	7.5	1.62	2.32	2.67	2.71	2.76	2.62
15	1.30	2.06	2.53	2.63	2.60	2.23	15	1.68	2.41	2.84	2.91	2.86	2.54
30	1.31	1.94	2.31	2.38	2.36	2.06	30	1.70	2.27	2.59	2.66	2.62	2.37
Mean	1.23	1.97	2.40	2.48	2.47		Mean	1.58	2.32	2.66	2.73	2.71	

these inputs. The increase in net returns by application of organic manure is attributed to increase in yield as a consequence of combined use of FYM and N application

CONCLUSIONS

The present investigation highlights the importance of combined use of organic and mineral fertilisers in supplying judicious and balanced plant nutrition for profitable and sustainable cropping systems. Our study has suggested that a combined use of 187.5kg of fertiliser N and 15 t of FYM / ha produced the highest grain yield and ultimately the highest net returns in what crop.

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Study on yardsticks of additional production from the use of micronutrients for various crops

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ABSTRACT

Experiments have been conducted in factorial R.B.D. and Split plot designs at various C.S.R. centres from 1990-91 to 2005-06. These experiments have 13 or 14 treatments with combination of two factors. One factor has two levels of three micronutrients, Sulphur, Zn Cl_2 or ZnO, $ZnSO_4$ and control. Other factor has time of application of micronutrients - Every year in kharif and alternate year in kharif with four replications. Doses of Sulphur applied were 25 &50 kg/ha. Doses of Zn Cl_2 or ZnO and $ZnSO_4$ applied were 5 &10 kg/ha. The yardsticks for each level of micronutrients were calculated for these experiments. The yardstick is a measure of the average increase of production per unit given improvement measures singly or jointly under the typical agronomic and climatic conditions of the region. The result revealed that yardsticks for every year application of micronutrients were more than alternate year application of micronutrients at most of the centres. The yardsticks for lower level of micronutrients gave better results than higher level of micronutrients in most of the cases. The dose 5 kg/ha of $ZnSO_4$ gave higher value of yardsticks at most of the centres.

Key words: Yardsticks, micronutrients and fertilizer

INTRODUCTION

In the present day of agriculture, micronutrients play important role for improved crop production and during the last 5 decades field deficiency symptoms of N, Fe, P, Zn, K, Mn and Mo have been reported from different parts of the country. With large scale adoption of high yielding varieties of crops in our intensive agricultural production system using liberal quantities of chemical fertilizer and lesser organic manures, the soils are showing deficiency of micronutrients, since such elements removed by the crops are not adequately replaced. The micronutrients are not only expensive but also become toxic if used indiscriminately. Hence any injudicious use of these micronutrients will not only affect the economic out turn of the farmer but also may cause an irreversible damage to the health of the soil and ultimately that of the people. Nambiar and Abrol (1989) analyzed long-term fertilizer experiments conducted in India and evinced the declining trend in productivity despite balanced use of NPK fertilizers. The decrease in productivity was observed to be associated with the new emerging problems of deficiency of micronutrients such as zinc (Zn) and of secondary nutrients such as Sulphur (S). Singh et al. (1989) examined the effect of changing cropping pattern and fertility levels on crop yields and also studied the micronutrients status of soil after five cycles of crop rotation. Khanday and Thakur (1992) studied on economic efficiency of nitrogen fertilization in rain fed maize with and without FYM and zinc. Sakal et al. (1994-95) evaluated in calcareous soil up to 8 cropping cycles at Pusa Farm on direct, residual and cumulative effects of different Zn doses in rice-wheat system.Kaylal and Rattan (2003) studied on secondary and micronutrients: Research gaps and future needs. So, without properly knowing the soil structure, climate and crop need, indiscriminate use of the micronutrient fertilizer is not advisable. Therefore, the judicious use of micro nutrients is more important.

Yardsticks of additional production of cereals, pulse and oilseeds from the use of fertilizers obtained from the farmers' fields over the decade 1967-76 were summarized by Leelavathi et al. (1979) and updated subsequently by Leelavathi, Bapat and Narain (1986).

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Iyer, V.N. and Onkar Swarup (1985) brought out a report on yardsticks of additional production of rice from the use of fertilizers. The study related to the yardsticks obtained at the district and state levels based on the data of experiments from 50 districts spread over all rice growing areas.

Narain, P. and Leelavathi, C.R. (1989) worked out a methodology for estimation of yardsticks for the combined application of irrigation with other inputs. Rao, C.H., Seema Jaggi and Khurana, G.L. (1999) studied on yardsticks of additional production of pulses and oilseeds from the combined application of fertilizers.

Considering the importance of yardsticks of additional production due to an input (micronutrients) and obtain yardsticks of additional production of various crops utilizing the data of experiments conducted at various C. S. R. Centres in the country, this attempt has been made in this paper.

MATERIAL AND METHODS

Under the Project for cropping systems research, the data of the experiments on monitoring of secondary and micronutrients in intensive cropping system are being supplied at the Institute. These experiments were conducted in factorial R.B.D. and Split plot designs at various C.S.R. centres from 1990-91 to 2005-06. These experiments have 13 or 14 treatments with combination of two factors. Fourteen treatment combinations of two factors were (A) Seven levels of micronutrients with NPK – T_0=Control,T_1= S at 25 kg/ha as basal,T_2= S at 50 kg/ha as basal,T_3= Zn at 5 kg/ha as basal in the form of Zn Cl_2 or ZnO,T_4= Zn at 10 kg/ha as basal in the form of Zn Cl_2 or ZnO,T_5= Zn at 5 kg/ha as basal in the form of $ZnSO_4$ and T_6= Zn at 10 kg/ha as basal in the form of $ZnSO_4$. (B) Two frequencies (F) of application- F1: Every year in kharif and F_2: Alternate year in kharif with four replications.

Yardstick: The yardstick is a measure of the average increase of production per unit given improvement measures singly or jointly under the typical agronomic and climatic conditions of the region.

A yardstick is a ratio between response (R_m) measured in some manner and the input applied=m (quantity of micronutrients). The yardstick as follows:

Yardstick = Rm / m

RESULTS AND DISCUSSION

At Bhubneshwar in kharif season yardsticks of every year application of micronutrients for rice at 5 kg/ha of $ZnSO_4$ was 143.6 kg/kg and for alternate year application of micronutrients at 10 kg/ha of $ZnSO_4$ was 51.1 kg/kg which were maximum. In rabi season yardsticks of every year application and alternate year application of micronutrients for rice at 5 kg/ha of $ZnSO_4$ were 90.8 kg/kg and 86.4 kg/kg respectively which were maximum (Table 1).

At Kalyani in kharif season yardsticks of every year application of micronutrients for rice at 5 kg/ha of $ZnSO_4$ was 120.6 kg/kg and alternate year application of micronutrients at 5 kg/ha of ZnO was 122.0 kg/kg which were maximum. In rabi season yardsticks of every year application and alternate year application of micronutrients for wheat at 5 kg/ha of $ZnSO_4$ were 90.0 kg/kg and 68.2 kg/kg respectively which were maximum (Table 1).

At Kanpur in kharif season yardsticks of every year application and alternate year application of micronutrients for rice at 5 kg/ha of $ZnSO_4$ were 95.6 kg/kg and 147.4 kg/kg respectively which were maximum. In rabi season yardsticks of every year application and alternate year application of micronutrients for wheat at 5 kg/ha of $ZnSO_4$ were 155.6 kg/kg and 117.6 kg/kg respectively which were maximum (Table 1).

At Varansi in kharif season yardsticks of every year application and alternate year application of micronutrients for rice at 5 kg/ha of $ZnSO_4$ were 75.6 kg/kg and 58.0 kg/kg respectively which were maximum. In rabi season yardsticks of every year application of micronutrients for wheat at 5 kg/ha of $ZnSO_4$ was 80.0 kg/kg and alternate year application of micronutrients at 5 kg/ha of ZnO was 50.6 kg/kg which were maximum (Table 1).

At Rewa in kharif for soybean yardsticks of every year application of micronutrients for at 10 Kg/ha of $ZnSO_4$ was 22.1 Kg/Kg and alternate year application of micronutrients at 5 Kg/ha of ZnO was 37.8 Kg/Kg which were maximum. In rabi season yardsticks of every year application and alternate year application of micronutrients for wheat at 5 kg/ha of $ZnSO_4$ were 121.4g/kg and 53.2 kg/kg which were maximum (Table 1).

At Sehore in kharif for soybean yardsticks of every year application of micronutrients for at 5 kg/ha of $ZnSO_4$ was 128.0kg/kg and alternate year application of micronutrients at 10 kg/ha of $ZnSO_4$

was 33.8 kg / kg which were maximum. In rabi season yardsticks of every year application and alternate year application of micronutrients for wheat at 5 Kg / ha of $ZnSO_4$ were 149.8 kg / kg and 106.2 kg / kg which were maximum (Table 1).

The result revealed that yardsticks for every year application of micronutrients were more than alternate year application of micronutrients at most of the centres. The yardsticks for lower level of micronutrients gave better results than higher level of micronutrients in most of the cases. The dose 5 kg / ha of $ZnSO_4$ gave higher value of yardsticks at most of the centres.

Table 1. Yardsticks for various crops at various levels of micronutrients at different C.S.R. Centres

S. No.	Name of the Centre	Season / crop	Name and levels of micronutrients	Yardsticks for every year application of micronutrients in kg / kg	Yardsticks for alternate year application of micronutrients in kg / kg
1.	Bhubaneshwar	Kharif	S-25kg / ha	12.9	5.0
	(Orissa)	Rice	S-5okg / ha	5.7	0.91
			ZnO-5kg / ha	44.4	9.4
			ZnO-10kg / ha	62.4	38.4
			$ZnSO_4$-5kg / ha	143.6	37.4
			$ZnSO_4$-10kg / ha	79.2	51.1
2.	Bhubaneshwar	Rabi	S-25kg / ha	11.7	2.48
	(Orissa)	Rice	S-5okg / ha	6.8	5.7
			ZnO-5kg / ha	78.0	63.4
			ZnO-10kg / ha	69.4	59.0
			$ZnSO_4$-5kg / ha	90.8	86.4
			$ZnSO_4$-10kg / ha	79.3	64.9
3.	Kalyani	Kharif	S-25kg / ha	16.5	10.4
	(West Bengal)	Rice	S-5okg / ha	13.9	6.3
			ZnO-5kg / ha	83.6	122.0
			ZnO-10kg / ha	43.3	34.4
			$ZnSO_4$-5kg / ha	120.6	91.0
			$ZnSO_4$-10kg / ha	47.8	32.7
4.	Kalyani	Rabi	S-25kg / ha	15.4	17.5
	(West Bengal)	Wheat	S-5okg / ha	5.5	10.9
			ZnO-5kg / ha	37.4	60.2
			ZnO-10kg / ha	36.1	42.8
			$ZnSO_4$-5kg / ha	90.0	68.2
			$ZnSO_4$-10kg / ha	21.8	43.6
5.	Kanpur	Kharif	S-25kg / ha	19.5	21.5
	(U.P.)	Rice	S-5okg / ha	14.2	17.8
			ZnO-5kg / ha	55.4	113.8
			ZnO-10kg / ha	60.9	79.5
			$ZnSO_4$-5kg / ha	95.6	147.4
			$ZnSO_4$-10kg / ha	74.3	83.3
6.	Kanpur	Rabi	S-25kg / ha	20.2	21.52
	(U.P.)	Wheat	S-5okg / ha	18.8	18.00
			ZnO-5kg / ha	123.4	101.0
			ZnO-10kg / ha	96.8	88.5
			$ZnSO_4$-5kg / ha	155.6	117.6
			$ZnSO_4$-10kg / ha	108.8	91.2
7.	Varanasi	Kharif	S-25kg / ha	13.6	12.3
	(U.P.)	Rice	S-5okg / ha	12.7	8.2
			ZnO-5kg / ha	53.6	30.6
			ZnO-10kg / ha	43.8	28.5
			$ZnSO_4$-5kg / ha	75.6	58.0
			$ZnSO_4$-10kg / ha	55.3	44.5

S. No.	Name of the Centre	Season / crop	Name and levels of micronutrients	Yardsticks for every year application of micronutrients in kg / kg	Yardsticks for alternate year application of micronutrients in kg / kg
8.	Varanasi (U.P.)	Rabi	S-25kg / ha	17.9	7.8
			S-5okg / ha	9.1	8.6
			ZnO-5kg / ha	72.5	50.6
			ZnO-10kg / ha	38.5	24.8
			$ZnSO_4$-5kg / ha	80.0	42.0
			$ZnSO_4$-10kg / ha	58.5	35.3
9.	Rewa (M.P.)	Kharif Soybean	S-25kg / ha	3.5	7.5
			S-5okg / ha	3.9	3.4
			ZnO-5kg / ha	13.2	37.8
			ZnO-10kg / ha	5.4	13.7
			$ZnSO_4$-5kg / ha	13.4	36.6
			$ZnSO_4$-10kg / ha	22.1	23.1
10.	Rewa (M.P.)	Rabi Wheat	S-25kg / ha	24.4	13.8
			S-5okg / ha	10.6	9.0
			ZnO-5kg / ha	91.4	42.0
			ZnO-10kg / ha	49.0	29.9
			$ZnSO_4$-5kg / ha	121.4	53.2
			$ZnSO_4$-10kg / ha	38.2	31.6
11.	Sehore (M.P.)	Kharif Soybean	S-25kg / ha	15.0	2.8
			S-5okg / ha	12.5	3.4
			ZnO-5kg / ha	63.4	8.0
			ZnO-10kg / ha	44.3	15.1
			$ZnSO_4$-5kg / ha	128.0	27.4
			$ZnSO_4$-10kg / ha	89.7	33.8
12.	Sehore (M.P.)	Rabi Wheat	S-25kg / ha	13.7	7.7
			S-5okg / ha	14.4	11.3
			ZnO-5kg / ha	94.2	67.0
			ZnO-10kg / ha	71.5	44.3
			$ZnSO_4$-5kg / ha	149.8	106.2
			$ZnSO_4$-10kg / ha	113.3	105.2

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Response of pigeon pea [*Cajanus cajan* (L.)] to farm yard manure, phosphorus and zinc application and economics of cultivation system under rainfed condition of Chitrakoot, Madhya Pradesh

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ABSTRACT

The present field experiment was carried out at Rajaula Agriculture farm, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P.), India with the objectives (1) To study the response of FYM, phosphorus and zinc on growth, yield attributes and yield of pigeonpea (2) To assess the interaction affect of FYM, phosphorus and zinc on growth, nodulation, yield attributes and yield of pigeonpea and (3) To evaluate the economic feasibility of FYM, phosphorous and zinc for pigeonpea under rainfed condition of Chitrakoot region. Two levels of FYM (0 and 10 tonnes/ ha) was applied in combination with 3 levels of phosphorus (0, 40 and 80 kg P_2O_5/ha) and 2 levels of Zinc (0 and 5 kg Zn/ ha). Twelve treatments were tested in a randomized block design with three replications. The application of FYM, phosphorus and zinc significantly increased the number of trifoliate leaves, number and dry weight of nodules, number and length of pod, number of primary and secondary branches, seed weight per plant, seed yield and harvest index of pigeon pea. The study concluded that addition of FYM @ 10 tonnes/ ha combined with phosphorus @ 80 kg P_2O_5/ ha and zinc @ 5 kg Zn/ ha was the most appropriate treatment for pigeonpea production , both in terms of plant performance and net return per rupee invested in rainfed area of Chitrakoot region (Kymore plateau).

Key words: FYM Farm yard manures, phosphorus, pigeon pea and zinc

INTRODUCTION

In India, pulses are the major source of our daily dietary protein and also an integral part of cropping system especially in rainfed areas. Pulse crops have the unique potentiality to associate symbiotically with *Rhizobium Spp.* and fix atmospheric nitrogen thereby enriching the soil. Pulses are grown in area of 22.39 million hectares with production of 13.39 million tonnes during 2005-06 (Anonymous, 2007). However, the productivity of pulses remains low (598 kg/ha), which is below the domestic requirement leading to import of pulses to the tune of 1.47 million tonnes (Ali and Kumar, 2006). It is estimated that at least 23.88 million tonnes of pulses are required by 2015 which is expected to touch 29.30 million tonnes by 2020. To make the nation pulses sufficient, productivity levels of pulses has to be increased substantially to 1200 kg/ha by 2020 (Ali and Kumar, 2005). India is the largest global producer of pigeonpea with 3.58 million ha of area, 2.74 million tonnes of production and productivity of 765 kg/ha in 2005-06. The low productivity of pigeonpea in the country may be ascribed to many reasons including inadequate and imbalanced fertilization, flower drop and poor dry matter partitioning. Madhya Pradesh is a leading producer of pigeonpea where it grows over an area of 0.32 million ha with production of 0.24 million tonnes and productivity of 739 kg/ha in year 2005-06 (Anonymous, 2007). Chitrakoot is adjoining area of U.P. and M.P. having good potential to produce pulse crop abundantly.

Being considered as a hardy crop, pigeonpea thrives well under water stress condition. The crop is largely grown under rainfed condition and its agronomic practices are required to be constantly

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refined for realizing yield potential. Among different management practices, the conjunctive use of organic manures and inorganic fertilizers are of prime importance. FYM, an organic manure provides a good substrate for development of many microorganism and maintaining favourable nutritional balance and soil physical properties (Khiriya and Singh, 2003). Phosphorus is required mainly for root development, nodule formation, seed development and quality improvement of pigeon pea. Indian soils are generally poor in available P and therefore, it is necessary to apply P in balance amount for improving the productivity of pulses including pigeonpea. Zinc is a vital element which play an important role in synthesis of protein, Indole acetic acid, chlorophyll formation, carbohydrates metabolism and in auxin metabolism.

The response of phosphorus to pigeonpea was found to be varied from 40 to 80 kg P_2O_5 / ha (Khiriya and Singh, 2003; Shivran *et al.* 2000). The application of FYM (5t ha^{-1}) along with micronutrient (ZnSo4 @ 15 kg ha^{-1}) and seed inoculation with Rhizobium recorded significantly higher plant height, primary and secondary branches per plant, seed yield (Sharma *et al*., 2009). Meena *et al*. (2002) reported that the application of farm yard manure @ 10 tonnes/ ha conserved maximum soil moisture and improved the number of branches as well as leaves per plant of chick pea. A similar result have been found in case of ground nut also (Akbari *et al.*, 2003). Meena and Sharma (2005) working on a clay loam soil of Udaipur, reported that application of phosphorus @ 80 kg P_2O_5/ ha significantly increased plant height, primary and secondary branches/ plant of pigeonpea. Shivran *et al.* (2000) reported at New Delhi that application of phosphorus @ 80 kg P_2O_5/ ha gave the maximum net returns from pigeonpea-wheat cropping system. Application of Zn at 5 kg/ ha and S at 60 kg/ ha resulted in the highest grain yield, which was 66.98 % higher than that in control (Mali *et al.*, 2003). Acharya and Biswas (2002) reported that the application of Zn @ 15 kg/ha significantly increased the nodulation of different pulse crops. With this background, The present investigation was undertaken with two objectives:

1. To study the response of FYM, phosphorus and zinc on growth, yield attributes and yield of pigeonpea.
2. To evaluate the economic feasibility of FYM, phosphorous and zinc for pigeonpea under rainfed condition of Chitrakoot region.

MATERIALS AND METHODS

The experiment was carried out during the year 2005-06 on a well levelled field at Rajaula Agriculture farm of Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P.). The farm is situated in Kymore Plateau of Northern Madhya Pradesh. Geographically Chitrakoot is situated at the 25^0 10'N latitude and 80^0 52'E longitude and about 190-210 meter above mean sea level. Agro-ecologically Chitrakoot is characterised by semi-arid and sub-tropical climate with hot dry summer and cold winters. The total mean annual rainfall of Chitrakoot area is 950 mm while, in experimental year, it was received 1020.5 mm annual rainfall out of which 665.5 mm rainfall received during cropping season i.e. July to April. July and March was hottest month with maximum temperature of 36.09^0C, January is the coldest month of the year with average minimum temperature of 7.33^0C. The maximum relative humidity was recorded in August (80%) and minimum in January, February and March (40%).

A number of soil samples were taken randomly from the experimental field before the sowing of crop from 0-15 cm depth. Soil samples were air-dried and ground to pass through a 2-mm sieve. A combined glass–calomel electrode was used to determine the pH of aqueous suspensions (1:2.5 soil:solution ratio). Electrical conductivity (dS m^{-1}) was measured in the supernatant liquid of soil water suspension (1:2) with conductivity bridge. Soil organic carbon (OC) was determined using the wet digestion method of Walkley and Black (1954). Available nitrogen (N) was measured by the alkaline permanganate method as described by Subbiah and Asija (1956). Available phosphorus (P) was determined by the Olsen method (Olsen, 1954). Potassium content was determined by flame photometer (Rich, 1965). Available Zn was determined by DTPA extraction method (Lindsay and Norvell, 1978), followed by determination in atomic absorption spectrophotometer. The initial physicochemical properties of the experimental soil are as follows: soil texture: sandy loam, pH (1:2.5) soil: water: 7.09; electrical conductivity (dS/m) 0.22; organic Carbon (%) 0.165; total nitrogen (kg N/ ha) 78.37; available phosphorus (kg P/ha) 12.32; available potash (kg K/ ha) 180.00 and available zinc (ppm) 0.3.

The treatments consisted of 2 FYM levels (0 and 10 tonnes/ ha), 3 levels of phosphorus (0, 40 and 80 kg P_2O_5/ha) and 2 levels of Zinc (0 and 5 kg Zn/

ha). The treatments were tested in a three factor randomized block design with three replication.

The required quantity of seeds were treated uniformly with Bavistin @ 2.5 g / kg seed followed by *Rhizobium* culture @ 400g / 10 kg seed + Phosphorus solubilizing bacteria (PSB)- *Pseudomonas striata* @ 800g / 10 kg seed. Farm yard manure, phosphorus and zinc were applied as per treatment. Phosphorus was applied through Diammonium phosphate. An uniform dose of @ 31.3 kg N / ha and potassium @ 30 kg K_2O / ha were given through urea / DAP and murate of potash respectively to all the experimental plot.

The lines were marked at desired distance and shallow furrow were opened with the help of desi plough at 60 cm row distance for sowing of pigeonpea. The seeds were drilled manually in the furrow using the recommended seed rate of pigeonpea (cv. Azad) @ 20 kg / ha. For controlling the weeds, two hands weeding were done first at 27 days and second on 62 days after sowing with the help of khurpi. Chloropyriphosh @ 1.5 lt / ha with 1000 liter water was sprayed on pigeonpea at pod formation stage to control of pod borer.

Yield attributes recorded were number of trifoliate leaves and primary and secondary branches , pods per plant, pod length, seeds per pod, seed weight per plant, seed yield and harvest index. To evaluate the economics of cultivation system, cost of cultivation, gross return, net return (gross return - cost of cultivation), return per rupee invested (net return / cost of cultivation) were computed.

Data obtained in the experiment was subjected to analysis of variance (ANOVA) appropriate to the experimental design. For statistical analysis of data Microsoft Excel (Microsoft Corporation, USA) and MSTATC packages were used.

RESULTS AND DISCUSSION

The Result showed that number of trifoliate leaves per plant of piegeonpea was significantly affected with applied FYM, phosphorus and zinc (Fig. 1). Combined application (T12) of FYM, phosphorus and zinc recorded 16% higher number of leaves per plant as compared to control. Among other treatments combined application of FYM and phosphorus at varying levels produced significantly higher number of trifoliate leaves (136 and 139 in T6 and T10, respectively) as compared to other treatments. Such improvement in growth character is attributed to a better nutrient and moisture availability to the plant due the application of FYM. This result is in accord with the finding of Ganeshmurthy and Reddy (2000). Supply of phosphorus and zinc might have promoted better root establishment leading to more number of trifoliate leaves.

The number of nodule per plant was highest in case of T12 and least in case of control (Fig. 2). Nodule dry weight followed a similar trend as that of nodule number (Fig. 3). This increase in nodules per plant and nodule dry weight might be due to improvement in soil environment, which enhanced proliferous root system, resulting more nodule formation on roots. The rapid multiplication of *Rhizobium* bacteria under FYM applied soil could be formed more number of nodules. These results corroborate the findings of Sharma and Bhandari (2002). Akbari *et al.* (2003) also reported better yield attributes of groundnut with FYM application. The improvement in nodules per plant and nodule dry weight per plant with each

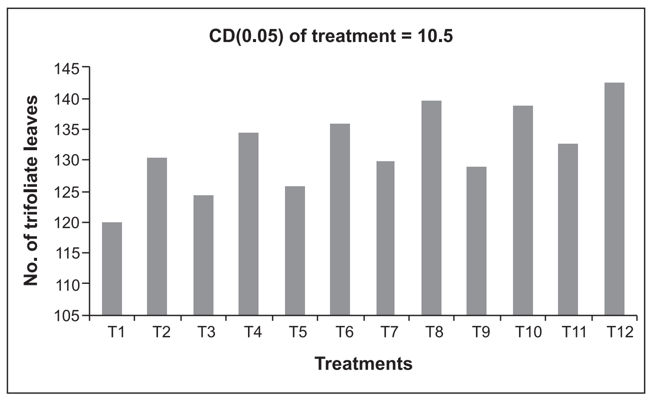

Fig. 1. Effect of FYM, phosphorus and zinc on no of trifoliate leaves of pigeonpea at 110 days

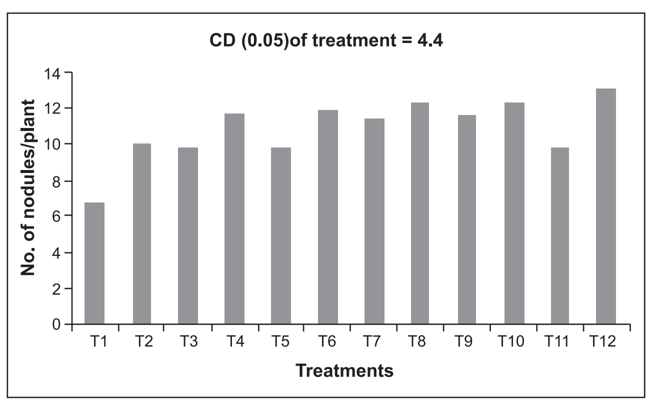

Fig. 2. Effect of FYM, phosphorus and zinc on no. of nodules / plant at 90 days

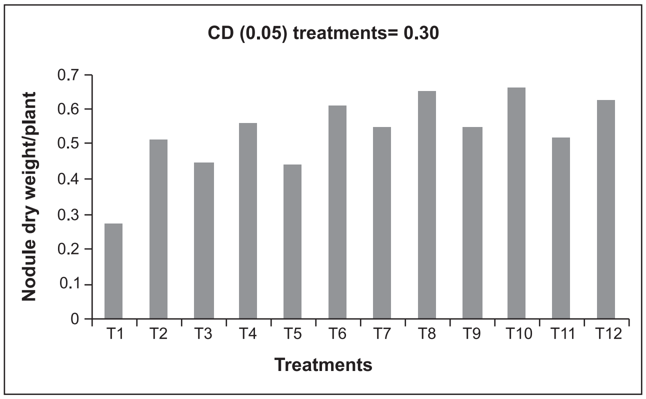

Fig. 3. Effect of FYM, phosphorus and zinc on nodule dry weight / plant at 90 days

increment of phosphorous might be due to vital role of phosphorus in enhancing cell division, photosynthesis, root growth. Similar behavior of applied P on nodulation was also noticed by Abidi *et al*. (2001). Number of nodules and nodules dry weight per plant of pigeonpea significantly enhanced with zinc application as compared to control. Such improvement in nodule formation is due to increase in activity of enzymes and IAA. Yadav *et al*. (1987) reported the higher nodules number per plant and nodule dry weight in legumes due to zinc application.

The application of FYM, phosphorus and zinc significantly affected the pod length of Pigeon pea (Fig. 4). The highest pod length was recorded in T12 (4.26 cm), followed by T10 (4.16 cm), T8 (4.03 cm) and was least in case of control (3.16 cm). The number of pod per plant, number of primary and secondary branches at harvest followed a similar trend (Fig. 5, 6 and 7). An identical trend was found in case of seed weight per plant also. Seed yield (kg / ha) was found to be in the order T12 (30.87 kg / ha) > T10 (32.36 kg / ha)>T11 (29.37 kg / ha)>T8 (26.59 kg / ha). Similar results have been reported by Khiriya and Singh (2003) in fenugreek (Figure 8 and 9). Such an increase in growth of pigeonpea with application of zinc was possible due to its involvement in synthesis of IAA (Indole Acetic Acid) and metabolism of auxin. Positive response of soybean and chickpea due to zinc application was reported by Singh and Singh (1995). Similar finding were also observed by Puste and Jana (1988) in pigeonpea. The harvest index (Figure 10) was highest in case of T11 (0.296), followed by T12(0.295) and was least in case of T1 (0.236). Such enhancement in harvest index might be due to higher proportional increase in seed yield over respective straw yield. The results are in conformity with the findings of Khiriya and Singh (2003).

The effect of FYM, phosphorus and zinc on economics of pigeonpea cultivation have been

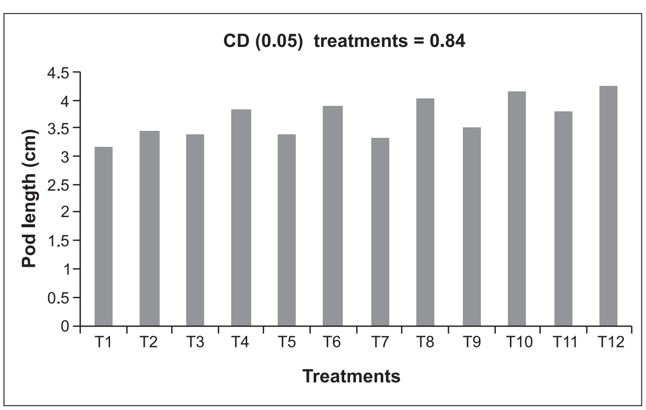

Fig. 4. Effect of FYM, phosphorus and zinc on pod length (cm)

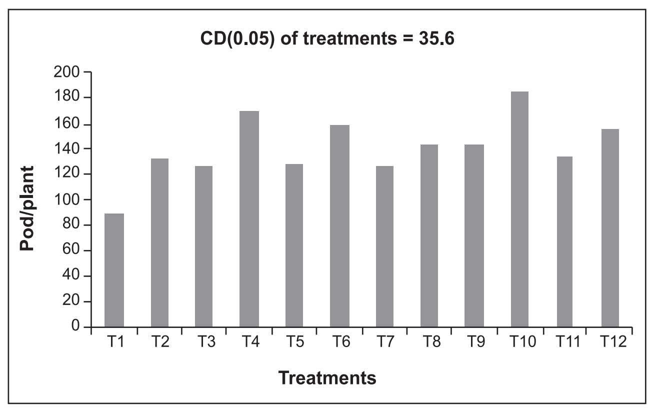

Fig. 5. Effect of FYM, phosphorus and zinc on pod / plant of pigeon pea

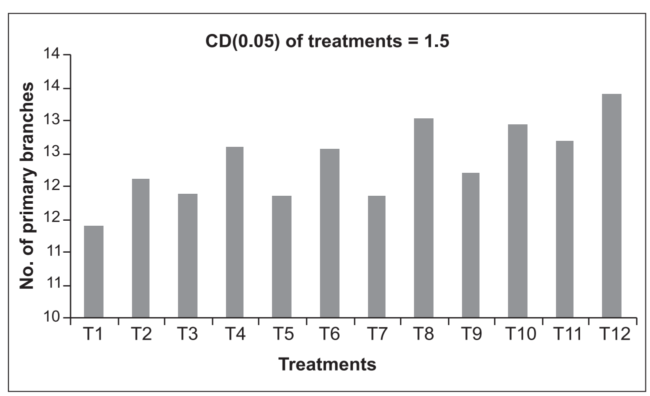

Fig. 6. Effect of FYM, phosphorus and zinc on number of primary branches of pigeon pea

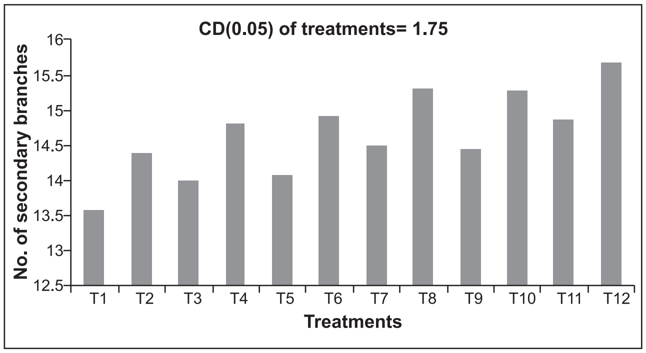

Fig. 7. Effect of FYM, phosphorus and zinc on number of secondary branches of pigeon pea

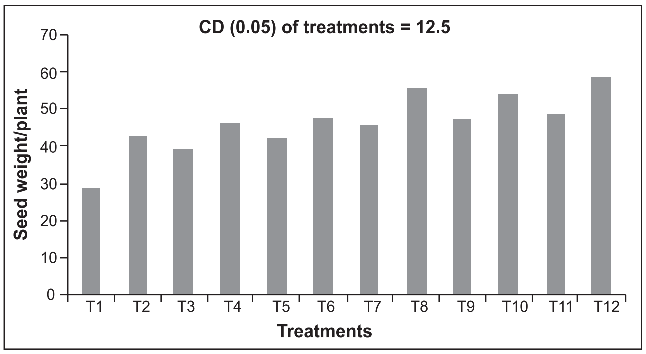

Fig. 8. Effect of FYM, phosphorus and zinc on seed weight / plant of pigeon pea

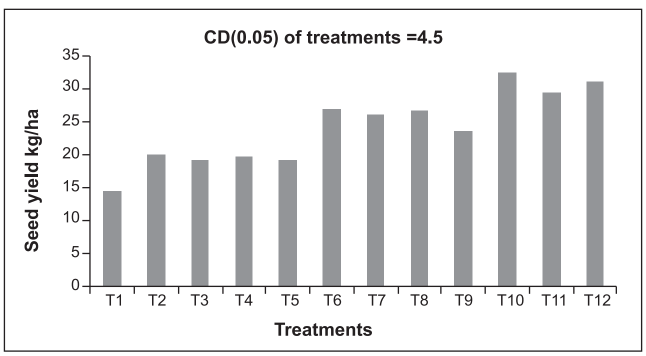

Fig. 9. Effect of FYM, phosphorus and zinc on seed yield (kg/ha) of pigeon pea

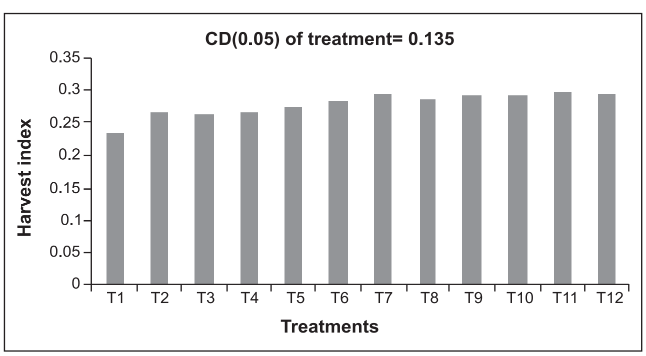

Fig. 10. Effect of FYM, phosphorus and zinc on seed harvest index of pigeon pea

presented Table 1. Cost of cultivation of pigeonpea was highest under T12 (21909 Rs/ha), followed by T8 (21680 Rs/ha) and least in case of control (19534 Rs/ha). The maximum net return was recorded in case of T12 (32749 Rs/ha). The result of Meena *et al.* (2002) in chickpea supports the above finding.

Table 1. Effect of FYM, phosphorus and zinc on economics of pigeonpea cultivation

Treat-ment		Cost of Culti-vation (Rs/ ha)	Gross return (Rs/ ha)	Net return (Rs/ ha)	Net return per rupee invested
T1	F0P0Zn0	19534	39655	20121	1.03
T2	F10P0Zn0	20609	44761	24152	1.17
T3	F0P0Zn5	20376	42485	22109	1.09
T4	F10P0Zn5	21451	47592	26141	1.22
T5	F0P40Zn0	19763	43535	23772	1.20
T6	F10P40Zn0	20838	48641	27803	1.33
T7	F0P40Zn5	20605	46365	25760	1.25
T8	F10P40Zn5	21680	51472	29792	1.37
T9	F0P80Zn0	19992	46721	26729	1.34
T10	F10P80Zn0	21067	51828	30761	1.46
T11	F0P80Zn5	20834	49552	28718	1.38
T12	F10P80Zn5	21909	54658	32749	1.49

CONCLUSION

The application of FYM, phosphorus and zinc significantly increased the number of trifoliate leaves, number and dry weight of nodules, number and length of pod, number of primary and secondary branches, seed weight per plant, seed yield and harvest index of pigeon pea. Finally, the study concluded that addition of FYM @ 10 tonnes/ ha combined with phosphorus @ 80 kg P_2O_5/ ha and zinc @ 5 kg Zn/ ha was the most appropriate treatment for pigeonpea production , both in terms of plant performance and net return per rupee invested in rainfed area of Chitrakoot region (Kymore plateau).

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Drip fertigation with marginally saline water in horticultural crops grown in vertisols under semi-arid subtropic climate

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ABSTRACT

A study was carried out during 2006-10 to monitor effect of drip fertigatoin with marginally saline well water on salinity and economics of horticultural crops grown in Vertisols at farmer's field of Bagda Khurd village of Bedia tehsil, Khargone Distt, Madhya Pradesh. The study reveals that EC increases as number of irrigation applied progresses in case of all the crops grown. In case of Tomato (Abhinav) crop average values of EC were recorded 0.40, 0.46, 0.55, 0.64, 0.0.69 and 0.35 dS / m on sampling point on-dripper for 1st, 2nd, 3rd, 4th, 5th and 6th sampling respectively. Similar trend has been obsreved with all the crops grown. EC increases as we move away from the drippers i.e. side of the ridge and between drippers. The minimum values were recorded at sampling point on drippers. The difference between maximum and minimum average value of EC were 0.29 dS / m, 0.41dS / m, 0.50 dS / m and 0.43dS / m on the sampling locations viz. on drippers, between two drippers, side of the ridge, side of dripper respectively. Recorded EC values also indicate that higher salt accumulation was observed on sampling points side of ridge, side of drippers and between drippers as compared to sampling point "on drippers" in case of all the crops. It implies that salt accumulation was more as we move away from drippers and it was maximum on Sampling point "side of the ridge". Growing horticultural crops with drip fertigation with marginally saline well water in Vertisols is a feasible and economically viable venture as indicated by B:C ratio. B:C ratio obtained is greater than 1 in case of all grown crops. The highest B:C ratio of 3.50 was obtained in Garlic crop and next to it was in potato crop as 3.20. The lowest was obtained in case of onion and capcicum crops as 1.25 and 1.60. The lowest B:C ratio was obtained in case of Capsicum. It may be due to the reason that capsicum crop was adversely affected in later stage by salinity increase with frequency of drip fertigation. The highest WUE was obtained as 8.5 q ha $^{-1}$cm $^{-1}$ in case of potato crop with B: C ratio 2.25 and lowest was with the chili crop as 0.58 q ha $^{-1}$cm $^{-1}$. Next to Potato crop was water melon which gave WUE as 6.03 q ha $^{-1}$cm $^{-1}$ with the B: C ratio of 3.2. Bitter Gourd crop gave WUE as 2.92 q ha $^{-1}$cm $^{-1}$ with 3.11 B: C ratio.

Key words: Drip fertigation, vertisols, marginally saline water and horticultural crops and B:C ratio

INTRODUCTION

A large chunk of area (18 million ha) under Vertisols in Central India is known to occur with scarcity of water in semi-arid and arid regions which stressed the need to utilize the irrigation water judiciously. Method of irrigation can play vital role in achieving high effectiveness of water use. Most of the farmers in India are still practicing surface irrigation. However drip irrigation is fast expanding technology in modern irrigated agriculture. Irrigation so far in India and abroad has shown that this method leads to not only appreciable saving of irrigation water but also resulted in achieving higher crop yields as compared to conventional methods (INCID, 1994).Vertisols are potentially saline soils and having poor hydraulic properties (Murthy *et. al*, 1981). These soils pose problem of salinity when irrigated with marginally saline waters (Anonymous, 1997-98). The physical properties of the soil starts deteriorating even at low salinity of irrigation waters (Verma, *et. al*, 1993) The accumulation of water soluble salts in the root zone also hinders crop

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production (.Verma, *et. al*, 2006). While visiting the area it has been noticed that some progressive farmers of Nimar valley (Agro-climatic zone - 11) and Malwa Plateau (Agro-climatic zone - 10) started growing vegetable crops through use of drip system for irrigation and fertigation to achieve targeted yield. The salt efflorescence has been observed within area commanded by drip irrigation (Bagda Khurd and Padali villages). As such, study is planned to monitor the effect of marginally saline water and drip fertigation on vegetable production in Vertisols at Farmers field of Bagda Khurd village, Bedia, Tehsil, Khagoan district, Madhya Pradesh.

MATERIALS AND METHODS

The study was carried out during 2006-10 to monitor effect of drip fertigatoin with marginally saline well water on salinity and economics of horticultural crops grown in Vertisols at farmer's field of Bagda khurd village of Bedia tehsil, Khargone Distt, Madhya Pradesh. Farmer grew Capsicum, chilli, tomato, ladyfinger, water melon in the year 2006-07, bitter gourd, potato, chilli, Onion in the year 2007-08, tomato, bitter gourd, garlic in the year 2008-09 and tomato bitter gourd during the year 2009-10 . The crops were planted on ridges with recommended package of practices. Periodically soil samples were taken at the interval of 15 days for all the crops at sampling points viz. on drippers, between two consecutive drippers, 15 cm away from dripper (side of dripper) and 30 cm away from dripper (Side of ridge). The collected samples were analyzed for pH and EC. The soil samples were taken from sampling depths of 0-5 cm, 5-15 cm and 15-30 cm at each sampling points. The farmer is using water of two existing wells of his field for irrigating crops. Well water samples were analyzed as per standard methods to ascertain quality of water used for irrigation. The water of both the wells was found marginally saline with EC value 0.92 and 1.15 dS/m. The limits of EC (dS/m) for classification of irrigation water prescribed by USDA, 1954 are 0.25, 0.25 to 0.75, 0.75 to 2.25 and 2.25 for safe, probably safe, marginal and unsuitable categaries respectively. To work out economics of growing different crops information on marketable yield, cost of cultivation including drip installation cost and prevailing market rates was also collected. The collected information was used to find out B:C ratio for different crops grown.The soils of study area classified as fine montmorillonitic hyperthermic family of typic haplusterts with particle size distribution as clay > 55%, silt > 30% and sand < 15%. Study area comes under Semi-arid sub-tropic climate with annual rainfall range of 600-800mm.

RESULTS AND DISCUSSIONS

Among the various crops grown by the farmer the details of results of one of the Tomato Abhinav crop are discussed as sample example in respect of EC, quantification of irrigation water, water use efficiency and B:C ratio etc. Similar procedure was followed for other crops grown and abstracted results are discussed.

Tomato abhinav crop

Tomato Abhinav crop was sown on 15th of November 2009 in 1.5 acres of area. The crop was planted on ridges with recommended package of practices. The soil samples were drawn from 0-5 cm, 5-15 cm and 15-30 cm at each sampling point (viz. on drippers, between two drippers, side of the ridge, side of dripper) at the interval of 15 days on six consecutive instances (1st, 2nd 3rd, 4th 5th, and 6th) and analyzed for EC and pH. The data indicates that EC (salt concentration) increased with number of irrigations applied (Table1). Maximum EC was observed at sampling point between drippers followed by side of the ridge. The minimum values were recorded at sampling point on drippers. Average values of EC were recorded 0.40, 0.46, 0.55, 0.64, 0.0.69 and 0.35 dS/m in case of on drippers sampling point for 1st, 2nd , 3rd , 4th , 5th , and 6th sampling respectively. EC increases as we move away from the drippers i.e. side of the ridge, sideof the dripper and between drippers. The difference between maximum and minimum average value of EC were 0.29 dS/m, 0.41dS/m, 0.50 dS/m and 0.43dS/m on the sampling location viz. on drippers, between two drippers, side of the ridge, side of dripper respectively. Recorded EC values also indicate that higher salt accumulation was observed on sampling points side of ridge, side of drippers and between drippers as compared to sampling point "on drippers" in case of all the crops. It implies that salt accumulation was more as we move away from drippers and it was maximum on Sampling point "side of the ridge". Reduction in EC values after 5th sampling is due to surface irrigation given to the crop.

Quantification of irrigation

The depth of irrigation water applied during crop period to tomato abhinav crop was worked out and the details are shown in table 2. The quantity of irrigation water per dripper came around 174 liters for tomato abhinav crop. This quantity is multiplied by total Nos. of drippers (57600) used per ha divided by area to work out depth of irrigation in cm / ha. The depth of irrigation for tomato abhinav crops came around 100 cm which was used for computing water use efficiency later on.

Economics

Area distribution, along with marketable yield, yield per ha and wholesale rate of tomato (Abhinav) crop are shown in table 3. The crop wise cost of production as per actual, gross return and calculated B:C ratio are shown in table 4 . The gross return was calculated by considering marketable yield per ha and prevailing whole sale marketable price at that time at the market. The cost of production includes cost of installation of drip system and the cost of cultivation as per actual starting from field

Table 1. Recorded values of EC (dS / m) in tomato abhinav crop (2010)

Sampling Point	Depth, cm	1st	2nd	3rd	4th	5th	6th
		EC	EC	EC	EC	EC	EC
On dripper	0-5	0.33	0.44	0.56	0.71	0.7	0.29
On dripper	15cm	0.48	0.48	0.57	0.62	0.73	0.38
On dripper	30	0.38	0.46	0.53	0.59	0.63	0.38
Average		0.40	0.46	0.55	0.64	0.69	0.35
Between drippers	0-5	0.78	0.96	1.11	1.16	1.21	0.58
Between drippers	15cm	0.35	0.45	0.51	0.74	0.18	0.41
Between drippers	30	0.32	0.43	0.69	0.78	0.49	0.53
Average		0.48	0.61	0.77	0.89	0.63	0.51
Side of ridge	0-5	0.39	0.56	0.76	0.89	1.09	0.47
Side of ridge	15cm	0.47	0.54	0.66	0.78	0.86	0.56
Side of ridge	30	0.4	0.57	0.61	0.74	0.81	0.64
Average		0.42	0.56	0.68	0.80	0.92	0.56
Side of Drip	0-5	0.43	0.51	0.75	0.88	0.91	0.53
Side of Drip	15cm	0.42	0.48	0.58	0.66	0.76	0.59
Side of Drip	30	0.42	0.49	0.61	0.73	0.89	0.67
Average		0.42	0.49	0.65	0.76	0.85	0.60

Table 2. Details of quantity of irrigation water applied in tomato abhinav crop

Month	No. of irrigations	Discharge (L / hr)	Period of irrigation (hr)	Quantity of irrigation (L)	Quantity of irrigation (cm)
1	2	3	4	5 = (2x3x4)	6
December 08	8	1.3	2	21	12
January 08	8	1.3	2	21	12
February 08	10	1.3	2	26	15
March 08	10	1.3	2	26	15
April 08	15	1.3	2	40	23
May 08	15	1.3	2	40	23
Total	66	1.3	2	174	100

preparation to till crop is finally reached to market. The B:C ratio of tomato abhinav crop came around 2.15 (Table 4) indicates that growing tomato abhinav crop with drip fertigation in black soils is an economically viable venture.

Table 3. Areal extend and marketable yield of tomato (Abhinav) grown under drip fertigation with marginally saline well water

S. No.	Name of crop	Area, ha	Marketable yield, t	Yield, t/ha	Wholesale rate, Rs/t
1	Tomato (Abhinav)	0.6	24.6	41	5000

Table 4. Economic analysis of tomato (Abhinav) grown under drip fertigation with marginally saline well water

S. No.	Name of crop	Cost of production, Rs/ha	Gross return, Rs/ha	Net return	B:C ratio
1	Tomato (Abhinav)	95000	205000	110000	2.15

Table 5. Water use efficiency along with B:C ratio of Tomato (Abhinav) crop grown under drip fertigation with marginally saline well water

S. No.	Crops	Water, cm ha^{-1}	Yield, q/ha	WUE, q $ha^{-1}cm^{-1}$
1	Tomato (Abhishek)	100	410	4.10

Water use efficiency

The water use efficiency worked out for tomato (Abhinav) crops are shown in table 5.The WUE was obtained as 4.10 q ha $^{-1}$cm $^{-1}$ in case of crop Tomato (Abhinav).

Similar procedure was followed in case of all other crops grown and only abstracted results are discussed.

Effect on salinity

The Average values of EC for soil depth 0-30 cm recorded during the year 2006-07, 2007-08 and 2008-09 are shown in table 6. It is clear from the EC data that EC increases as the number of irrigation applied progresses in case of all the crops grown. For example average values of EC were recorded (0.40, 0.38 and 0.50 dSm^{-1}) in case of Capsicum crop “on drippers” sampling point for 1st, 2nd and 3rd sampling respectively. The EC values indicate that there was an increase in average values of EC within 15days and 30 days period at sampling points on drippers and similar trend observed in all the crops and sampling points. The study further reveals that higher salt accumulation was observed on sampling points side of ridge, side of drippers and between drippers as compared to sampling point “ on drippers” in case of all the crops. It implies that salt accumulation was more as we move away from drippers and it was maximum on side of the ridge.

Water use efficiency and economics

The water use efficiency worked out for different crops are shown in table 7. The highest WUE was obtained as 8.5 q / ha / cm in case of potato crop with B:C ratio 2.25 and lowest was with the chili crop as 0.58 q / ha / cm . Next to Potato crop was water melon which gave WUE as 6.03 q ha $^{-1}$cm $^{-1}$ with the highest B:C ratio of 3.2. The over all WUE came around 3.31 q / ha / cm with the B:C ratio of 2.21 for all the crops grown on by the farmer. The record of details of irrigation water actually applied to various crops was also kept. The highest B:C ratio of 3.50 was obtained in Garlic crop and next ot it was in water melon crop as 3.20. The lowest was obtained in case of Onion and Capcicum crops as 1.25 and 1.60. B:C ratio is more than one in allthe crops grown which implies that drip fertigation with marginally saline well water for cost intensive cultivation of horticultural crops in Vertisols under sub tropic semi-arid climate is a feasible and economically viable proposition.

Quality of irrigation water

The vegetable crops grown in study area were irrigated by water of 2 open wells existing in the farmer’s holding. The water samples of these two wells were collected and analyzed in SAS project lab for quality parameters and same are presented in Table 8. It is obvious that water used for irrigation as well as fertigation is marginally saline in nature.

Table 6. Average Value of EC for 0-30 cm profile depth recorded during years.

Crop	Sampling pts.	Recorded EC (dS/m) at various Sampling No.					
		1st	2nd	3rd	4th	5th	6th
		2006- 07					
Capsicum	On dripper	0.40	0.38	0.50	-	-	-
	Between drippers	0.62	0.65	0.66	-	-	-
	Side of ridge	0.30	0.52	0.83	-	-	-
	Side of drippers	0.4	0.83	0.89	-	-	-
Chilli	On dripper	0.53	0.59	0.61	-	-	-
	Between drippers	0.62	0.65	0.66	-	-	-
	Side of ridge	0.52	1.12	0.73	-	-	-
	Side of drippers	0.82	0.89	0.96	-	-	-
Tomato	On dripper	0.42	0.72	0.33	-	-	-
	Between drippers	0.80	1.33	0.68	-	-	-
	Side of ridge	0.67	0.99	0.68	-	-	-
	Side of drippers	0.37	0.42	0.55	-	-	-
Lady fingure	On dripper	0.46	0.58	0.35	-	-	-
	Between drippers	0.64	0.83	0.62	-	-	—
	Side of ridge	0.56	0.32	0.61	-	-	-
	Side of drippers	0.38	0.53	0.59	-	-	-
Water Melon	On dripper	0.48	0.31	0.37	-	-	-
	Between drippers	0.51	0.34	0.78	-	-	-
	Side of ridge	0.39	0.51	0.69	-	-	-
	Side of drippers	0.50	0.62	0.74	-	-	-
		2007- 08					
Bitter Gourd	On dripper	0.49	0.48	0.50	1.07	0.62	0.51
	Between drippers	0.69	0.50	0.69	0.96	0.75	0.74
	Side of ridge	0.68	0.74	0.56	3.35	1.11	0.65
	Side of drippers	0.86	0.45	0.64	0.98	0.81	0.36
Potato	On dripper	0.48	0.56	0.70	0.81	0.82	0.55
	Between drippers	0.65	0.55	0.58	0.93	0.86	0.68
	Side of ridge	0.74	0.61	0.93	0.97	1.25	0.73
	Side of drippers	0.82	0.77	0.45	0.93	0.96	0.65
Chilli	On dripper	0.53	0.39	0.73	0.91	0.91	0.74
	Between drippers	0.37	0.33	0.77	1.29	0.83	1.29
	Side of ridge	0.38	0.22	1.00	0.86	0.77	0.75
	Side of drippers	0.75	0.86	0.66	1.73	0.73	0.75
Onion	On dripper	0.55	0.42	0.91	0.96	0.83	0.72
	Between drippers	0.87	0.99	0.83	1.22	0.75	0.87
	Side of ridge	0.45	0.54	0.63	1.61	0.84	0.86
	Side of drippers	0.71	0.83	0.77	1.45	0.86	0.79
		2008- 09					
Tomato	On dripper	0.38	0.47	0.60	1.05	0.63	0.51
(Abhishek)	Between drippers	0.43	0.52	0.71	1.00	0.63	0.74
	Side of ridge	0.51	0.61	0.86	1.63	1.11	0.65
	Side of drippers	0.33	0.46	0.71	0.99	0.69	0.60
Tomato	On dripper	0.35	0.52	0.63	1.06	0.68	0.68
(Abhinav)	Between drippers	0.31	0.55	0.76	1.02	0.59	0.68
	Side of ridge	0.45	0.67	0.85	1.54	0.81	0.65
	Side of drippers	0.41	0.56	0.77	0.98	0.72	0.54
Bitter gourd	On dripper	0.57	0.67	0.77	0.99	0.62	0.60
	Between drippers	0.57	0.70	0.85	1.23	0.86	0.74
	Side of ridge	0.40	0.68	0.85	1.52	1.11	1.01
	Side of drippers	0.55	0.66	0.91	1.28	0.81	0.72
Garlic	On dripper	0.45	0.55	0.69	0.83	0.54	0.65
	Between drippers	0.41	0.59	0.81	1.06	0.74	0.85
	Side of ridge	0.64	0.90	1.06	1.75	1.11	1.02
	Side of drippers	0.58	0.82	0.94	1.21	0.81	0.92

Table 7. Water use efficiency along with B:C ratio of various vegetable crops grown under drip fertigation with marginally saline well water

S. No.	Crops	Water, cm ha $^{-1}$	Yield, q/ha	WUE, q/ ha/ cm	B:C ratio
1	Potato	053	450	8.50	2.25
2	Water melon	053	320	6.03	3.20
3	Chili	120	070	0.58	1.94
4	Capsicum	120	080	0.67	1.60
5	Lady finger	053	210	3.96	2.10
6	Bitter Guard	120	350	2.92	3.11
7	Onion	053	250	4.72	1.25
8	Tomato	075	410	5.47	2.16
9	Garlic	076	180	2.37	3.50
Total	647	2140	3.31	2.21	

Table 8. Recorded quality parameters of well water used for irrigation

Parameters	Unit	Results	
		Well 1	Well 2
pH		8.16	8.01
EC	dS/m	0.95	1.15
Calcium	meL^{-1}	6.60	8.00
Magnesium	meL^{-1}	1.40	1.80
Sodium	meL^{-1}	1.33	1.62
Potassium	meL^{-1}	0.02	0.00
Carbonate	meL^{-1}	0.20	0.00
Bicarbonate	meL^{-1}	5.60	6.80
Chloride	meL^{-1}	2.40	3.40
Sulphate	meL^{-1}	1.00	0.94
Rasidual Sodium Carbonate	meL^{-1}	Nil	Nil
Sodium adsorption Ratio	(mmolL^{-1})$^{1/2}$	0.66	1.14

CONCLUSION

In conclusion, the study indicates that drip fertigation with marginally saline well water for cost intensive cultivation of horticultural crops in Vertisols under sub-tropic semi-arid climate is a feasible and economically viable proposition. Drip fertigation with marginally saline water showed salt accumulation in irrigated area around drippers as number of irrigation applied progresses. The salt accumulation can be duly taken care of by simply practicing one surface irrigation after a period of 75-90 days or may be by Monsoon rain in natural course.

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Sustainable production management for rice-wheat cropping system under irrigated condition of Jammu

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ABSTRACT

A field experiment was conducted in clay loam soil having neutral in soil reaction with medium in soil organic carbon, available P, K and low in available N under assured irrigated condition on fixed site for four consecutive years at FSR centre research farm, SKUAST-J, R.S.Pura, Jammu in randomized block design with five replications, to identify sustainable production management for rice and wheat in a system. Highest average grain yield of rice (6570 kg / ha) and wheat (4789 kg / ha) was recorded in treatment (T_3) where recommended dose of fertilizer + green leaf manuring of leucaena @ 5t / ha to rice crop only with maintained 25 % higher plant population then followed by T_4 & T_2 where 25% higher dose of fertilizers from the recommended dose and recommended dose coupled with green leaf manuring of leucaena @ 5t / ha was applied. Mean productivity in rice-wheat system was 23.6% and 13.0% higher in T_3 & T_4 over recommended practices treatment (T_1) with sustainability yield index (SYI) of 0.89, 0.85, 0.84 and 0.84 in T_3, T_2, T_4 and T_1, respectively. Similarly, highest productivity efficiency of 44.03 kg / ha / day, energy use efficiency of 12.25 and energy productivity of 0.4 were also obtained in the same treatment where 25% higher plant population was maintained coupled with recommended dose of fertilizer + green leaf manuring(T_3). After 4 years of study, available N, P & K content in the soil was increased over their initial value, where 25% higher dose of fertilizer and 25% higher plant population maintained with green leaf manuring of leucaena, while organic carbon content in soil declined in the recommended package of practices (T_1). However, there was a buildup of SOC in the treatment where incorporation of green leaf manuring alone or along with higher plant population practices was done during study period.

Key words: Rice, wheat, green leaf manure and plant-population

INTRODUCTION

Rice-wheat is a predominant cropping system in north India in J&K state, the total area under rice and wheat is 263 and 279 thousand hectares, productions with an average productivity of 2135 and 1782 kg / ha, respectively (Anonymous 2007-08). Both these crops are heavy nutrient feeders and continuous cropping with rice-wheat may cause an imbalance in nutrition of the crop, resulting in declining productivity of rice-wheat system (Singh *et al* 2009). Therefore, judicious application of nutrients and other sustainable production management practices like, plant population, organic / green manuring etc. can ensure soil health security and sustainable yield of rice and wheat. Therefore, present study was undertaken to develop eco-friendly production management strategies for sustainable production of rice-wheat system under sub-tropical condition of Jammu region.

MATERIALS AND METHODS

A field study was conducted at Farming System Research farm, SKUAST-J, R.S.Pura, Jammu (32^0 $39^/$ N, 74^0 $58^/$ E, 356 m amsL) during khar*if* 1999 to *rabi* 2002-03 in rice-wheat cropping system under irrigated conditions. The soil of the experimental farm was clay loam in texture with pH of 6.4 and organic carbon of 0.70 %. Available N, P & K content was 215.0, 18.80 and 114.80 kg / ha, respectively. The experiment comprised of four treatments *viz.* T_1:

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recommended package of practices (33 plants / m^2, 120:60:30 kg $N:P_2O_5:K_2O$ / ha, chemical weed control through Sencor @ 200g / ha for wheat; through Butachlor 50 EC @ 1.5 kg a.i / ha for rice and 20 cm row spacing, 100:50:25 kg $N:P_2O_5:K_2O$ / ha, chemical weed control; T_2: T_1 + 5 t / ha green manuring (green leaves of *leucaena* containing 1.25% N content) for rice only and recommended practices for wheat; T_3: T_2 + 25 % higher plant population *i.e.* 42 hills / m^2 for rice and 125 kg seed / ha for wheat; and T_4: T_1 + 25 % higher dose of fertilizer for rice (150:75:37.5 kg $N:P_2O_5:K_2O$ / ha) and 125:62:31.5 kg $N:P_2O_5:K_2O$ / ha for wheat crop. Rice (*Jaya*) and wheat (*PBW-343*) used as a test crop. The experiment was laid out in randomized block design with five replications. Entire quantity of P and K and half dose of N was given at the time of transplanting / sowing, rest half of N was applied at 30 and 60 DAT / DAS in two equal splits. All the agronomic practices were carried out as per the treatment to both the crops. Soil composites (0-15cm) samples after harvesting each crop as well as plant (grain & straw) samples of rice & wheat were collected, processed and analyzed to study the change in nutrient status for its initial values as well as nutrients uptake by the crop (Jackson, 1967). Productivity efficiency (kg / ha / day) was calculated by dividing the mean productivity of the system by the total duration of both crops in a system. System economic efficiency (Rs / ha / day) was calculated by dividing net returns / ha of the system by 365 days (Urkurkar *et al* 2008). Sustainable yield index (SYI) was calculated using formula (Nanda *et al* 2007),

$$SYI = \frac{Y\ mean - ó}{Y\ max}$$

Where

SYI = Sustainable Yield Index;
Ymean= Mean Yield ;
ó = Standard Deviation;
Ymax = Maximimm yield during study period

Energy use efficiency (EUE) and energy productivity (EP) were worked out as per Dazhong and Pimental (1984)

$$\text{Energy use efficiency} = \frac{\text{Energy output}}{\text{Energy input}}$$

$$\text{Energy productivity} = \frac{\text{Productivity (kg / ha)}}{\text{Energy input (MJ / ha)}}$$

RESULTS AND DISCUSSION

Grain yield

Average grain yield of rice and wheat crop was highest in treatment (T_3) with the corresponding values of 6570 kg / ha and 4789 kg / ha, respectively wherein green manuring @ 5t Leucaena leaves / ha was incorporated in *kharif* season (rice) only along with recommended package of practices with maintaining of 25 % higher plant population to both crops, followed by the treatment T_2 (5916 kg / ha) and T_4 (5883 kg / ha) in rice and T_4 (4505 kg / ha) and T_2 (4434kg / ha) in wheat crop, respectively (Table 1).

In the first year, the highest grain yield of rice (5948 kg / ha) was recorded in T_4 where 25 % higher recommended dose of fertilizers was applied followed by T_3 (5500 kg / ha), where 25 % higher plant population was maintained along with green manuring @ 5t leucaena leaves / ha and recommended dose of fertilizers, but the treatments T_4 and T_3 were statistically at par. It might be due to immobilization of nutrients during decomposition of green manuring in first year of study, while 2nd, 3rd and 4th year of study a significant higher grain yield of rice was recorded in T_3 and T_2 with highest SYI of 0.85 and 0.83 in T_3 and T_4, respectively. Similar findings were also obtained by Yadav *et al* (2005). Same trend was observed in grain yield of wheat too. The highest year wise grain yield of wheat was recorded in T_3 where 25% higher plant population was maintained along with recommended dose of fertilizer and green manuring which performed significantly higher than recommended package of practice (T_1).

Mean grain yield data of four years of wheat (Table 1) also showed a highest grain yield of 4789 kg / ha and SYI of 0.97 in T_3 followed by T_4 (4505 kg / ha with SYI of 0.94), T_2 (4434 kg / ha with SYI of 0.92) and T_1 (3817 kg / ha with SYI of 0.84 kg / ha), respectively. Better performance of green leaf manuring may be explained that it has helped in improving the nutrient availability for a longer period in rice (Thakur *et al* 2003), whereas in wheat more roots penetration due to improvement of physical conditions of soil allowed more utilization of plant nutrients from soil. These results are in close conformity to Singh *et al* (2000), who also reported that combined application of green manure and

Table 1. Grain yield of rice and wheat as attested by the treatments

Treatments	Rice grain yield kg / ha					Sustainability yield Index (SY1)	Wheat grain yield kg / ha					Sustainability yield Index (SY1)
	1999	2000	2001	2002	Average		99-2000	2000-01	2001-02	2002-03	Average	
T_1: Recommended package of practices	4810	6326	5144	5220	5375	0.74	4205	3706	3690	3614	3817	0.84
T_2: T_1 + green leaf manuring @ 5 t / ha (Leucaena)	5360	6921	5644	5740	5916	0.76	4606	4427	4572	4133	4434	0.92
T_3: T_2 + 25 % higher plant population / seed rate	5500	7081	6890	6812	6570	0.85	4703	4798	4881	4772	4789	0.97
T_4: T_1 + 25 % higher dose of fertilizers	5948	6966	5412	5208	5883	0.83	4302	4520	4636	4561	4505	0.94
CD (*P*=0.05)	463	220	266	301	-		427	647	409	309		

inorganic fertilizers in rice-wheat system produced about 75 % higher root biomass than the application of fertilizers alone .

System productivity

Total productivity in rice-wheat system was highest (11359 kg / ha) under the treatment T_3 where green leaf manuring with *Leucaena* along with recommended package of practices with 25 % higher plant population was adopted (Table 2) this was closely followed by T_4 (10388 kg / ha) where 25% higher dose of NPK was applied. However, mean productivity in rice-wheat system was 23.6%, 13.0% and 10.68%, higher in T_3, T_4 and T_2 over recommended package of practice (T_1), respectively with sustainability yield index was 0.89 and 0.85 in T_3 and $T_{2,}$ respectively and 0.84 % in each T_4 and T_1. Similarly the highest productivity efficiency of 44.03 kg / ha / day was obtained in treatment $T_{3,}$ where 5t green manuring leaves / ha along with increasing 25% plant population was maintained with recommend dose of fertilizer followed by T_4 where 25% higher dose of recommended NPK was applied (40.26 kg / ha / day) and T_2 (39.43 kg / ha / day), where recommended dose of fertilizers along with green manuring was applied indicating sustainability of production with the use of green manuring. Similar findings were also reported by Hegde (1988) and Thakur *et al*, (2003). They reported that productivity of rice-wheat could be enhanced and there is a saving of 25 to 50% inorganic fertilizer with the use of green manuring / FYM.

Economics

In rice-wheat system, maximum net profit of Rs. 45805 / ha with B:C ratio of 1.95 with system economic efficiency of Rs. 115.00 / ha / day was recorded when green leaf manuring @ 5t / ha along with recommended fertilizers and 25 % higher plant population was adopted (T_3) followed by T_4, T_2 and T_1 treatments (Table 2). These results corroborate to the findings of Tiwana *et al* (1999). However cost of production for rice was Rs. 12300 / ha during Ist and 2nd year and Rs. 13000 / ha during 3rd and 4th year, respectively. Similarly in case of wheat the cost of production was worked out to Rs. 8800 / ha in 1st and 2nd year and Rs.9380 / ha in 3rd and 4th year, respectively under recommended package of practices in sub-tropical condition of Jammu region. This increase in cost of production might be due to

Table 2. System productivity, economics and energy efficiency & productivity of rice -wheat system as affected by the treatments

Treatment	System productivity (Mean of 4 years)	% increase over T_1	Sustainability yield Index (SY1)	Production Efficiency kg/ha/day	System economic Efficacy kg/ha/day	Net return Rs./ha	B:C ratio	Energy Input MJ/ha	Energy Out put MJ/ha	Energy Use Efficiency	Energy Productivity (EP)
T_1: Recommended package of practices	9192	-	0.84	35.63	88.92	34432	1.59	23579	279809	11.87	0.39
T_2: T_1 + green leaf manuring @ 5 t/ha (Leucaena)	10174	10.68	0.85	39.43	103.75	39828	1.72	28079	311228	11.08	0.36
T_3: T_2 + 25 % higher plant population/ seed rate	11359	23.57	0.89	44.03	115.00	45805	1.95	28691	348460	12.15	0.40
T_4: T_1 + 25 % higher dose of fertilizers	10388	13.01	0.84	40.26	112.00	41450	1.72	27292	319956	11.72	0.38

enhancement of input cost during the last two years. Average farm gate price of paddy and wheat during study period was Rs. 575/qt and Rs.650/qt, respectively.

Energetics

The highest energy use efficiency (EUE) of 12.15 and energy productivity (EP) of 0.4 was recorded in treatment T_3 where green leaves manuring of Leucaena @ 5t/ha alongwith recommended fertilizers dose with maintained plant population of both rice and wheat crops then followed byT_1 (EUE of 11.87 and EP of 0.39) where recommended package of practices was adopted to both crops and T_4 (EUE of 11.72 and EP of 0.38) where 25% higher dose of fertilizer from the recommended doses was applied (Table 2), while minimum energy use efficiency of 11.08 and energy productivity of 0.36 were recorded in T_2.

Soil fertility status

After final harvest(4 years) of experiment, green leaf manuring @ 5t/ha alongwith recommended fertilizer dose of fertilizer and 25% higher plant population (T_3) maintained highest content of organic carbon of 0.79%, then followed by T_2 (0.77) over its initial value of 0.70% , which was 13% and 10% higher over initial value, while available N, P & K was maximum in T_4 where 25% higher dose of fertilizer was applied, which was immediately followed by green manuring with recommended dose of NPK (T_2) & T_3. However, the content of soil organic carbon and available N & P were declined to the tune of 3, 7 and 4%, respectively over their initial level in T_1: where recommended practices were adopted after 4 years of study (Table 3). The highest uptake of N (112.43 kg/ha), P (16.59 kg/ha) and K (199.49 kg/ha) by the rice crop and N (99.85 kg/ha), P (28.90 kg/ha) and K (126.15 kg/ha) by wheat crop were recorded inT_3 treatment, then followed by T_2 in rice and T_4 in wheat, but highest value of soil organic carbon in T_3 also depicts the importance of green manuring to maintain soil health. The results are in close conformity to Thakur, *et al* (2003).

CONCLUSION

Results indicated that only recommended dose of fertilizer N, P and K for both rice and wheat crop is not found to be sufficient to sustain the yield and

Table 3. Average nutrient (N, P & K) uptake by rice and wheat and fertility status after final harvest (4 yrs study)

Treatment	Nutrient uptake, (kg/ha)						Nutrient status after harvest (kg/ha)				
	Rice			Wheat			pH	O.C %	Available nutrients		
	N	P	K	N	P	K			N	P	K
T_1: Recommended package of practices	91.25	14.61	100. 50	72.34	18.83	102.41	6.41	0.70	200.70	18.00	116.70
T_2: T_1 + green leaf manuring @ 5 t/ha (Leucaena)	110.98	15.67	104.17	87.38	22.92	118.15	6.42	0.77	222.52	18.40	121. 25
T_3: T_2 + 25 % higher plant population/ seed rate	112.43	16.58	119.49	89.85	28.90	126.15	6.45	0.79	202.95	18.10	118. 20
T_4: T_1 + 25 % higher dose of fertilizers	102.46	15.10	106.55	92.51	28.0	110.88	6.48	0.74	228.50	19.2	120. 50
Initial						6.43	0.70	215.00	18.80	114. 80	

productivity of rice and wheat in a system. Incorporation of green manuring, 25% higher plant population coupled with recommended dose of fertilizers was identified for sustainable higher productivity of rice and wheat in a system under sub-tropical conditions of Jammu region.

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Communication support for environment protection and development

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ABSTRACT

The last century has seen an unmanageable increase in population, placing a tremendous burden on natural resources. There is not enough food for the world's hungry. Also, the earth itself is worn out due to excessive farming, use of pesticides and chemicals and excessive use of ground water. Water resources are badly polluted and emission of toxic fumes from industry and vehicles has deprived us of clean air. Industrialization and a growing consumer economy have led to the creation of huge megapolises with their problems of indisposed garbage and uncontrolled sewage. The conservation & survey of flora, fauna, forests and wildlife, prevention and control of pollution, afforestation & regeneration of degraded areas, Protection of environment, all within the frame work of legislations. Over the years, the ministry has passed innumerable laws to help them in their task of environmental protection, but all regulations and acts have not enough to protect the environment. Misuse of the laws and ruthless exploitation of the land, leading to ecological destruction, over exploitation of resources has polluted our earth, water and air. There is a need of well planned strategy for environmental protection for reducing pressure on natural resources; phase out non-renewable inputs – in energy, agriculture and industry, educate and inform the people about the gains of environmental protection and sustainable development through various means of communication.

Key words: flora, fauna, ecological destruction, carbon dioxide, ozone layer

INTRODUCTION

It is important for every sector and every section of the society to understand that protecting the environment is not a luxury. It is an intimate part of promoting the economic welfare of people. Presenttly, 45 per cent of the population did not have access to safe drinking water and air quality is poor in most Indian city.

The Central Pollution Control Board (CPCB), monitored almost 88 per cent of 110 cities in the country which do not even meet the existing norms of pollution control. One crucial reason why this is so, because in India's Environment Protection Act does not provide for strict penalties to be imposed on defaulters. The models adopted in the US and UK, foster cooperation between various levels and branches of government and empower the local bodies to take action. In the US which has federal set up like us, the US Environment Protection Agency (USEPA) works with federal state, and tribal government to ensure complains and enforcement. In UK the environment agency and Department of Environment, Food and Rural issue guidelines and give muscle to local bodies.

Environment and development

In 1987, World Commission on Environment and Development, a United Nations body published its findings in 'Our Common Future', known as the **Brundtland Report**. It says that problems of environment and development are interlinked, and that economic interdependence among nations is increasing. Focused areas includes:

- population and food security;

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- the loss of species and genetic resources;
- energy; and
- industry

It calls for economic growth based upon 'sustainable development'-meeting the needs of the present without the compromising the ability of the future generations to meet their own needs. The **Brundtland Report** called for continued economic growth, while emphasizing the need to integrate environment and development.

Activities such as the burning of coal and other fossil fuels, and the use of CFCs as aerosol propellants are leading to a build-up of green house gases in the atmosphere, resulting in damaged to earth climate. The Inter-governmental Panel on Climate Change (IPCC) looking at the climate process, concludes that, if there is no changed in emissions of green house gases, global mean temperature would rise by about 0.3C a decade in the 21st century, faster than at any time in the past 10,000 years and increase in global temperature in terms lead to major problems for mankind.

However, as the problem is global in scope, it is important that the different countries of the world take measures to control green house gases together. India is an active member of the IPCC, which was set up in 1988, and is jointly sponsored by the UNEP and the world Meteorological Organisation. In December 1990, the UN establishes an intergovernmental negotiating committee to prepare a framework convention on climate change. India is playing a prominent role in this negotiation, and also supports the IPCC which provide help to the negotiation by scientific advice on climate change.

Deforestation can also contribute to the build up of greenhouse gases in the air, both by the loss the trees' ability to absorb CO_2 and by realizing the carbon stored in them as CO_2 and methane. Apart from encouraging afforestation, the government should support projects that promote good forest management.

In recent years, the scientists have become very concerned about damages to the ozone layer, which protect the earth from ultra-violate raise of the sun. Much scientific evidence has been gathered which clearly implicates CFCs in atmospheric ozone depletion. In 1985 the scientists on the Antarctic Expedition discover a 'hole'-an area of major depletion- in the ozone layer over the Antarctic, and evidence now shows that this significant ozone layer threatens main kind with increased diseases such as skin cancer, as well as the possibility of reducing the productivity of crops.

Environment and economic growth

The environmental problems that countries face vary with their respective stages of development, the structure of their economy, and their environmental policies. Some problems are associated with the lack of economic development inadequate sanitation and availability of potable water, and indoor air pollution from bio-mass burning. Many types of land degradation are a root cause of poverty in the developing countries. Here, the challenge is to accelerate equitable income growth and promote access to the necessary resources and technology. But, many other problems are made worse by the growth of economic activity. Industrial and energy-related pollution (local and global), deforestation caused by commercial logging, and over use of water are the result of economic expansion that fails to take account of the value of the environment. With or without development, rapid population growth may make it more difficult to address many environmental problems.

Rapid population growth can worsen the mutually reinforcing effects of poverty and environmental damage. The poor are both victims and agent of environmental damage. Since they lack resources and technology, the farmers resort to cultivating hill sides and move into the tropical forest areas, where crop yields on cleared fields usually drop sharply after a few years. What pressures will economic growth placed on the natural environment in the coming years? If environmental pollution and degradation were to rise in step with rise in output, the result would be appalling environmental pollution and damage. Millions of people would become sick or die each year from environmental caused diseases or disasters. Water shortage would be intolerable, and tropical forests and other natural habitats would decline to a fraction of their current sizes. Fortunately, such an outcome need not occur, if sound policies and strong institutional arrangement are put in place.

Development support communication for environment

Ignorance is an important cause of environmental damage and a serious impediment to finding solutions. The principle holds true for international negotiation and poor house hold alike, as the global damage done to the ozone layer by the CFCs and the serious implications of indoor air pollution, like smoking, for family health. First it is necessary to know the facts; second to determine values and analyze the benefits and costs of alternative measures; third, to ensure that information is available for the public widely.

The Development Support Communication (DSC) regarding environmental issues increases access to information. Many governments encourages involvement of local population in tackling environmental issues. In order to make it more effective, the local people need to be well-informed. Some ways to achieve this are:

(a) to share/supply information to the local communities at the early stage for identifying a project;
(b) to discuss local environmental problems with the affected communities;
(c) to allow public comments on the DSC-inputs; and
(d) to encourage public comments and discussion on the proposed environmental solutions.

Media promotes environment

Global temperatures are rising, leading to changes in the climate and it is casting its side effects such as skin cancer, are increasing. The earth has neither the resources to provide for unlimited greed of human beings, nor the capacity to absorb the ever increasing pollution. Man has to control his greed, otherwise his actions will destroy the earth it self. Clean environment is not only necessary for good health of human being but also for their very survival on earth. The mass media have played an important role in spreading the awareness about environment.

Till late 1960s, little thought was given to the need to protect the environment. Even the world 'Ecology' was absent from many dictionaries. But today mass media is being used to spread the awareness about the environment by government agencies, activists, NGOs, etc.

Contributions of media for highlighting environment issues

One of the examples of how the mass media have shaped society's responses to the environment is Rachel Carson's book 'silent spring' published in 1962. Carson wrote about the danger of pesticides and how their use can destroy nature the book became a very important means of spreading awareness about the environment it made the pesticides the initial focus of the environmental movement in the 1960s. It was able to influence many fields including government, agriculture, economics and education. Works such as 'Silent Spring' highlighted the various environment issues and helped generate a public debate on the problems.

In our own country, media have helped to know the contribution of environmentalist. The investigative journalism helps to reveal matters of vital public interest that are at times concealed by concerned departments and institutions. The focus on large dames in India is one of such examples.

A study of the American Environment Movement reveals how the mass media have contributed to the growth of movement by highlighting its activity. In1969, the tragic Santa Barbara oil spills created an alarmed in the US. Almost 3.25 million gallons of oil were dumped over 800 square miles of water and shoreline. People in California could see with their own eye the suffocating while spills along a 100 mile stretch of coastline. This laid to the first wave of grassroots activity on the West Coast. But the mass media took the event to the doorsteps of the entire American nation and even beyond. People reacted to pictures those published in "Life" magazine showing thousands of bird's mammals and fish smothered due to oil spill. The mass media focused on the health of American people and the planet earth. It brought report to the people showing babies in Manhattan and Chicago breathing air so dirty that the particles on their white clothes. Then in 1970, the Lake Eire caught fire due to another environmental accident. The coverage of this entire event by the mass media led to crystallization of the American Environment Movement.

Raising the problems of the industrial workers of Mandasaur, Madhya Pradesh, 'Nai Dunia', a Hindi daily from Indore, succeeded in providing medical and monitory benefits for the workers who were affected by the fine slate dust.

Bhopal Gas Tragedy in 1984 was the worst industrial disaster in the world. More than 3,000 people died and lakhs of people became disabled fully or partially. They required specialized medical treatment for a long time to come. The location of this dangerous chemical manufacturing plant within city limits should have been questioned by the media. But at that point of time media failed to comprehend the enormity of the disaster and highlight the same. It was only after the lower court gave a simple imprisonment of two years to a handful of accused persons in 2010, the media came into the fore in highlighting the sufferings of the victims of the tragedy, in full force. The government was compelled to look afresh about the enormity of the tragedy and constituted a group of ministers, which has recommended to increase the compensation to the victims up to Rs 1 lakh each and also take necessary action against Union Carbide Chief Anderson and explore legal options for his extradition from the US.

Making media work to improve environment

The environment problem can not be solved by just science, technology or management skill only. The blind race of technological development and economic drive are largely responsible for the environmental problems. In spite of all these, the society undertakes such development. The silent majority, can no longer remain simple spectators, and has to exert it self against such development to solve the environmental problems. The media has to play a decisive role in this regard. It can not only expose the designs of the select few but also help mobilize support for the transfer of power from the hands of the select few into those of people at large.

The powerful elites are using the mass media, in order to maintain the status quo in which they remain in control of the situation. It is in the interest of our environment that the mass media be used to protect the aims of those who believe in universal justice. The mass media can help realize the need for change in the present state of affairs.

The mass media should educate the people about the dynamics of power relations that work both at the national and international level. Developed nations have been using the mass media to perpetuate various myths about environment degradation. According to them, the poor and developing countries should follow a path of development which is designed by these developed nations. Such development largely involves transfer of out dated technology which has become obsolete for the developed nations. Even this obsolete technology is sold to developing countries under agreements which force them to ask loans from the developed countries. These agreements benefit the rich nations at the cost of the development of poor countries. The products under the agreement are transported to developed countries as raw materials by the poor countries and the finished goods prepared from these raw materials are imported by the developing countries at a much higher costs.

Unless the mass media expose the imbalances in the relation between the rich few and the exploited many there can be no check on environmental degradation. The media must sensitize the people on issues such as;

(i) the ill-effects of the present unequal international political relation on the poor and on the environment; and

(ii) the need to treat nature as income and not capital. That means that society should value its forest not in terms of timber that it can produce for export but as purifiers of the atmosphere. In fact we should value the forest as the lungs of our mother earth’s living bodie.

To change perceptions and to persuade people to adopt processes that are environment friendly, we need to have a deeper understanding of how the mass media affect the people. Putting more and more environment content into our mass media alone will not turn us all into environmentalist. There is no magic formula that can be apply to the mass media which would convinced the people to change their view point, because each of us is unique and so is each situation.

Efforts of the Ministry of Environment and Forest

The Ministry of Environment and Forest is the implementing agencies for environmental related policies and programmes. It is guided by the principle of sustainable development and enhancement of human well- being. The Ministry serves as the nodal agencies in the country for the United Nations Environment Programme (UNEP), South Asia Co-operative Environment Programme (SACEP), International Center for Integrated Mountain Development (ICIMOD) and for the follow- up of the United Nation Conference on Environment and Development (UNCED). It is also entrusted with the issues relating to multilateral bodies such as the Commission on Sustainable Development (CSD), Global Environment Facility (GEF) and of regional bodies like Economic and Social Council for Asia and Pacific (ESCAP) and

South Asian Association for Regional Cooperation (SAARC) on matters relating to environment.

The main objectives of the ministry are conservation and survey of flora, fauna, forest and wild life, prevention and control of pollution, afforestation and regeneration of degraded areas, protection of environment and ensuring the welfare of animals. For the preservation and protection of environment a National Conservation Strategy and Policy Statement on Environment and Development 1992; National River Policy, 1988, Policy Statement on Abatement of Pollution, 1992 and National Environment Policy, 2006 have also been evolved. These objectives are sought to be fulfill through environmental impact assessment, eco-regeneration, assistance to organizations implementing environmental and forestry research, education and training, dissemination.

Wetlands are lands transitional between terrestrial and aquatic system where the water table is usually or the water surface and land is covered by shallow water. Identification of wetlands can be attributed to the following three main factors; firstly, when an area is permanently or periodically inundated; secondly, when an area supports hydrophytic vegetation; and thirdly, when an area has hydric soils that are saturated or flooded for a sufficiently long period to become anaerobic in the upper layers. Recently, a number of wetlands have been identified for inclusion in National Wetland Conservation Programme.

Environment Information System

Realising the need of environmental information, the Ministry has set up an Environmental Information System (ENVIS) as a plan programme and as a comprehensive network in environmental information collection, collation, storage, retrieval and dissemination to varying users, which include decision makers, researchers, academicians, policy planers, research scientist, etc. ENVIS has been conceived as a distributed information network with the subject-specific centers to carryout the mandates and to provide the relevant and timely information to all concerned. Association of various state governments/ Union Territories was made possible in promoting the ENVIS network and they were also involved in thematic subject areas and state government department were to make it more comprehensive.

Environmental legislation

A Comprehensive National Environment Policy was formulated to harmonise the demands of development and environment in response to the need to weave environmental considerations into the fabric of development processes and national life. The Ministry in consultation with experts prepared the National Environment Policy, 2006 to harmonise the demands of development and environment.

The Ozone Cell of the Ministry and United Nations Environment Programme (UNEP) jointly launched a new global initiative to raise awareness on the Ozone Layer Protection and Remembering our Future: Commemorating Closure of ODS Production Sites, under the Montreal Protocol on 8 March, 2005.

National Natural Resources Management

The basic objective of the National Natural Resources Management System (NNRMS) is the utilization of Remote Sensing Technology with the conventional methods of monitoring of natural resources such as land, water, forests, mineral, ocean, etc for attaining sustainable development by addressing the following aspects:

(i) Optimal utilization of the country’s natural resources by a proper and systematic inventory of the resource availability;
(ii) Reducing regional imbalance by effective planning and intone with the development efforts.
(iii) Maintain the ecological balance with a few to evolve an implement the environmental guidelines.

The Standing Committee on Bio-resources and Environment constituted by the Planning Commission advises on the methods of using the remote sensing technology for optimal use and management of natural resources in the country.

Drawbacks of the media

Many environmentalists have attracted the attention of the media through dramatic activities which involve indulging in antics which may not always be desirable. It is a drawback of mass media that they select only those events which are likely to invoke interest and captivate the audience. On the other hands, they ignore the events which may be very beneficial to the society, though they are not perceived attractive enough. Thus constructive work of a serious nature is ignored while activities of destructive nature, which attract immediate attention, get coverage in the mass media more often.

Another drawback of the mass media is what is called the corruptive influence of the mass media. For example, advertisements of cigarettes depict the themes related to conservation of wild life. In order to promote their product, the promoters of the advertisement want to link their viewers' minds, qualities such as gallantry, courage and kindness to animals, with the mainly puffing of a cigarette. Since both smoking and wild life are popular, the chances are that more people may be attracted by them. Since the advertisements for tobacco products are banned, tobacco companies take shelter of protection of wild life to promote their products.

CONCLUSION

Holes in the ozone layer, noxious fume in the air, denudation of forests extinction of wild life species, raising global temperature, and acid rains- are some of the facets of environment pollution. Untreated and non-decomposable wastes are wreaking havoc on the environment. From nuclear wastes, chemical effluents and harmful refrigerants to countless polythene covers, plastic materials and suspended particle material in water and air. Our desire to conquer nature and environment to fulfill our material needs has known no bounds. There is a need to build dams over reverse to divert the natural course of water to dry lands. The forest trees utilized for our fuel, furniture and making paper. We hunt animals, birds and fish for food, wool and leather. These bounties of nature are non-replenishable. The advanced technologies have harmed the environment particularly the industries and automobiles have polluted the air, land and water with their emissions. The entire population has to be made aware of this danger to their survival. Both print and electronic media has to play a vital role in disseminating the awareness to the masses. The media can informed and educate the people, making them environmentally conscious. Media is an effective platform to contact the masses and convinced them of the urgency of their role in protecting the environment. Environment friendly experiments can be propagated and popularized through the media.

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