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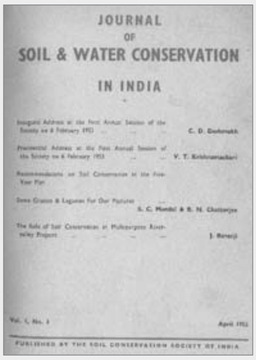

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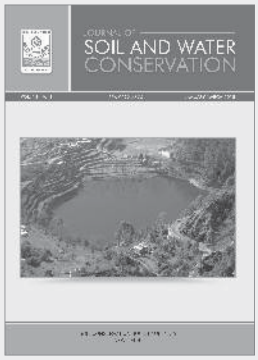

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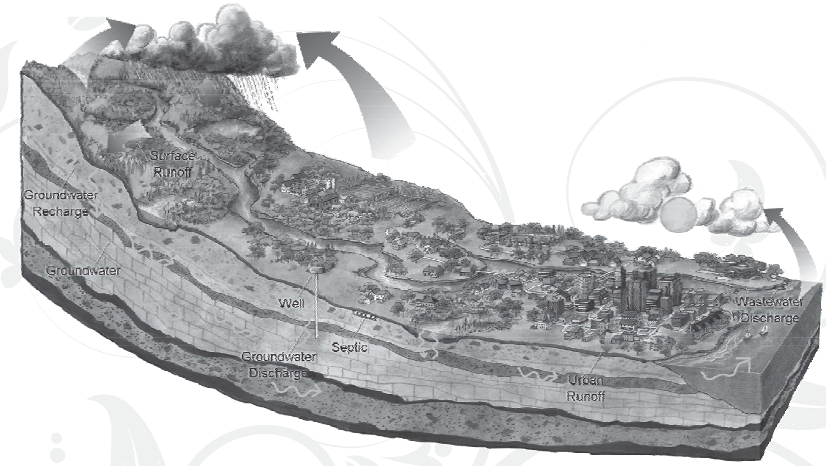
Contents

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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Dynamics of gully erosion in lower Shiwaliks

RAJAN BHATT[1] and S.S. KUKAL[2]

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ABSTRACT

Gully erosion is an important soil erosion process and although its damage is very intense, little research on the same has been published. A detailed field survey was carried out in 2003 and 2008 in 4 catchments in Hoshiarpur district of Punjab to study the temperament advancement of gullies. The average gully density and texture (in four catchments) increased by 2.5 km km^{-2} and 518.4 km^{-2} from 2003 to 2008, respectively. The average length of 1^{st} order gullies, which are primary points of runoff water collection, was increased to 13.0%, whereas the average number of 1^{st} order gullies increased to 92.0 per cent. South-west sides of the catchments reported to be more prone to gully erosion. Also, detailed vegetation survey was conducted in 2008 that shows that the average density of bushes increased down the slope by 20 per cent. However, the increase was 76% in catchment IV compared to 14.6 % in catchment III and 36.6% in catchment II. In catchment I, the bushes density rather deceased down the slope. As in case of vegetation density, the density of bushes was highest (28.9%) in catchment III, followed by catchment I (26.2%), II (24.3%) and IV (22.2%). The extent and severity of 1^{st} order gullies was significantly higher than other order gullies. Hence, first order gullies are the main culprit which collect the runoff water from each nook and corner of the catchments and supplied it to the higher ordered gullies, and thus needs to be attended on the priority basis while planning strategies to mitigate erosion losses in the foothills of lower Shiwaliks.

Key words: Gully erosion, gully density, gully texture, slope, lower Shiwaliks

INTRODUCTION

Foothills of lower Shiwaliks occupies an area of 2.14 mha and represents the most fragile eco-system of the Himalayan mountain range because of its peculiar geological formations. It lies mainly in the states like Jammu and Kashmir (Jammu, Udampur and Kathua) (0.80 mha), Punjab (Hoshiarpur, Ropar, Nawanshahr and Gurdaspur) (0.14 mha), Haryana (Ambala and Yamuna Nagar) (0.06 mha) and Himachal Pradesh (Kangra, Una, Bilaspur, Hamirpur, Chamba, Solan and Southern parts of Sirmaur) (1.14 mha) (Kukal *et al*., 2006). Prior to the middle of 18^{th} century, the Shiwalik hills were strictly preserved for hunting and no cultivation, grazing or exploitation of timber was permitted. The increased population of mankind along with the livestock density far exceeding the current carrying capacity of the land, frequent forest fires and mismanagement of land resources, resulted in the steady but obvious natural resource degradation and presently the garden of Punjab has changed to more or less a desert, which is still highly exploited by various anthropogenic activities (Kukal and Bhatt, 2006).

Ecological degradation in Shiwalik hills is the outcome of the overexploitation and mismanagement of soil resources through deforestation, overgrazing and clearance of the vegetation for the agricultural purposes disregard to their slope and topography (Bhatt *et al*., 2004; Arora and Saygin, 2011). The whole belt experiences severe problem of soil erosion because of undulating slopes and highly erodible soils coupled with highly intensive rain storms and represents the most fragile ecosystem of Himalayan mountain range because of its peculiar geological formations, and highly erodible soils (Singh and Khera, 2009; Thakur *et al*., 2013). It is reported that runoff and soil loss in the region varies from 35-45% and 25-225 t $ha^{-1}year^{-1}$ (Sur and Ghuman, 1994). Minimum tillage coupled with rice straw mulching @ 6t ha^{-1} reported to mitigate the losses of soil erosion to a significant extent (Bhatt and Khera, 2006; Arora and Bhatt, 2006). Assessing the

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impacts of climatic and land use changes on rates of soil erosion by water is the objective of many projects (Favis-Mortlock and Boardman, 1995;Williams *et al*., 1996; Poesen *et al*., 1996; Van Oost *et al*., 2000; Nearing, 2001). Among different types of soil erosion, gully erosion is the most serious one in the region as around 20% of the area is already under gullies (Kukal and Sur, 1992) and spatially advances at an increased rate on upslope the catchment as organic carbon and clay content decreased up the slope (Kukal *et al*., 2005). Thus, the problem of soil erosion is quite serious in the region and farmers mostly depend on their indigenous technical knowledge (ITK) to grow their crops sustainably in the region and many of these techniques are scientifically sound also (Kukal and Bhatt, 2006; Bhatt, 2013).

Ephemeral gully erosion has been reported to account for 48.5 to 72.8% of the total soil loss (Zheng *et al.*, 2009). About 70-80% of the gully erosion control structures have failed in the region (Kukal *et al.*, 2002). The reasons attributed for the failure of gully control structures in the region include lack of information on gully network including distribution and extent of different order gullies, gully density, gully texture, behaviour and development of gullies in the region (Kukal *et al*., 2006). Secondly, the installation of gully control structures is generally done in the highest-order gully. After some time, these structures get silted up along the upstream side, after which the runoff water starts falling down from the crest height of the structure and causes higher erosion losses. The lower order gullies are seldom tackled in the region while controlling the runoff and soil loss and are generally ignored in all the soil conservation programmes (Kukal *et al.*, 2006). To evaluate the temporal advancement of gullies both in terms of their number and length, two surveys were conducted in the four catchments of Hoshiarpur district viz. firstly in 2003 and secondly five years thereafter in 2008 this detail survey was conducted in 2003 and then on 2008 in the four catchments of Hoshiarpur district of Punjab with the objectives (1) To evaluate the spatial variation of vegetation all along the slopes, (2) To study distribution of gullies on either side of main gully, (3) To study temporal advancement of gullies from 2003 to 2008 both in terms of gully density and texture and (4) To formulate strategies for the assessment of gullies and bring effective techniques for mitigating the adverse effects of gully erosion in particular and soil erosion in general.

MATERIAL AND METHODS

Study area and its characteristics

The survey was carried out in four catchments of Hoshiarpur district of Punjab in the Shiwaliks region of Lower Himalayas in North India. The region lies between 30^0 10' to 33^0 37' N latitude and 73^0 37' to 77^0 39' E longitude and stretches to about 530 km lengthwise and 25-95 km width wise. The climate of the region varies between semi-arid to sub-humid. The maximum temperature (41-42 °C) is recorded in the first fortnight of June, whereas minimum temperature (5-6 °C) is recorded in the month of January. Majority of the soils range from loamy sand to sandy loam in texture and have low to medium moisture retention capacity and are highly erodible. It is reported that majority of soils (67%) are loam followed by loamy skeleton (28%), sandy skeletal (1.0%) and sandy (0.7%) (Sidhu *et al*., 2000). Soils vary widely in (shallow to very deep), texture (sand to clay loam), organic carbon (0.1 to 1.1%) and pH (5.3 to 8.4) depending upon the physiography, parent material, vegetation cover and climatic conditions. The area receives an average annual rainfall of about 800-1400 mm with a high coefficient of variation (28-30%). About 80% of this rain occurs in the three months of monsoon season (July to September) with high intensive rainstorms. In Shiwaliks of Punjab, rainfall aggressiveness (ratio of highest monthly rainfall to total annual rain), an index of rainfall concentration in a period, varies from 55.9 to 502.4 with an average value of 218 $\pm$ 121.7 (Singh, 2000). Rainfall constitutes the major water resource and is sufficient to take two crops annually, but because of its poor distribution in time and space, the farmers are unable to utilize it properly for agricultural purposes. Sidhu *et al.* (2000) reported that in the region, 40% land has steep slopes (>15%), 10% moderate (8-15%), 17% gentle (3-8%) and 25% very gentle slopes (10-13%). Further, Kukal *et al*. (2006) reported that convexo-concave (NE side) and concave slopes (SW sides) dominate in the region with a conclusion that SW sides of a catchment exposed to greater sunshine hours which resulted in greater evaporation, lesser moisture, lesser vegetation, lesser organic matter and greater erosion intensity. In the present study, four catchments of Hoshiarpur district of Punjab were surveyed to study the temporal advancement of gully texture and density from 2003 to 2008.

Gully erosion survey

Various factors controlling gully growth are catchment characteristics viz. area (Burkard and Kostaschuk, 1997), slope shape (Meyer and Martinez-Casasnovas, 1999), gully development parameters, slope steepness (Kukal *et al*., 1991), surface runoff, precipitation, soil moisture and piping (Stocking, 1980). In the present study, detailed field survey for gully erosion was carried out by dividing catchments into grids of 50 × 50 m^2 each and then each gully line was sketched on the contour maps (at a scale of 1: 1000) manually (Fig. 1) after measuring the distance between wooden pegs laid out in the grids. The gullies up to the first order were marked on the maps. Slope angles across the slope transacts were measured at certain intervals in the selected catchments with an Abney level and measuring tape to determine the slope shape profiles. Gully heads were also marked in each catchment on the base maps and their status of activeness found out. Gullies were classified as 1st, 2nd, 3rd, 4th and 5th order gullies, depending upon extent of their bifurcation. Lemniscate ratio is $L^2/4A$ where, L is the maximum length (m) and A is the area of the catchment (m^2). The length of different ordered gullies was measured in each catchment from the gully erosion map. The total length of all the gullies in the catchment were expressed as "gully density" (km/km^2). The number of first-order gullies per unit area was expressed as "gully texture" (number/km^2).

RESULTS AND DISCUSSION

Temporal variation in gully erosion

A detailed survey was made in the year 2003 in the Saleran catchments of Hoshiarpur district and then after 5 years, similar catchments were surveyed again to to have an idea regarding the advancement in gullies both from their length as well as their number. A comparison of "gully density" (km/km^2) and "gully texture" (number/km^2) surveyed in 2003 and 2008 show that both gully texture and gully density has increased over the years (Table 1).

The catchment II experienced highest increase in gully texture (167%) and gully density (25.2%) followed by catchment I (91.8% and 12.9%), catchment IV (85% and 9.3%) and catchment III (59.5% and 7.6%) (Table 1). Interestingly, the per cent increase in gully texture was significantly higher than gully density in all the catchments. This indicates that more number of first-order gullies were added every year than the addition in the gully length. In fact, the rainfall aggressiveness (ratio of highest monthly rainfall to the average annual rainfall) recorded to be higher (Matharu *et al*., 2003) in the region leads to the creation of new gullies (Morgan 2005). It is thus clear that gully networks have been expanding with time in the region. To check this expansion of gully network, gully control strategy as discussed previously needs to be adopted at a wider scale in the region.

Typical soil transacts which were steeper as we move upslope also lead to the quicker removal of rainfall water from a particular catchment. Fig. 2 clearly depicted the steeper upper slopes which on receiving rainfall increased the erosivity of flowing rainwater.

In former catchments, lower segments of the catchments with highest silt load become most erodible and hence prone to gullies which generally originated in the lower slope segments. The concave types of slopes, which were dominant in the region, have been shown to be more prone at the lower slope segments for initiation of the gullies as the runoff water concentrates at the lower slope segments where slope steepness decreases and runoff water starts concentrating (Fig 1).

First order gullies were significantly higher both in number and length (Fig 2), and these are the main feeding braches to the higher ordered gullies. Thus there is an urgent need to control these gullies rather than to construct the check dams in the highest/main gully which also got silted up after some time.

Vegetation Density

The average tree density in different catchments decreased significantly by 76 per cent from top-

Table 1. Temporal variation of gullies in the study catchments (2003-08)

Catchment	Gully texture			Gully density		
	2003	2008	increase (%)	2003	2008	increase (%)
I	758.0	1453.8	91.8	31.7	35.8	12.9
II	439.9	1174.8	167.0	15.5	19.4	25.2
III	722.0	1151.2	59.5	15.8	17.0	7.6
IV	251.2	464.8	85.0	8.6	9.4	9.3

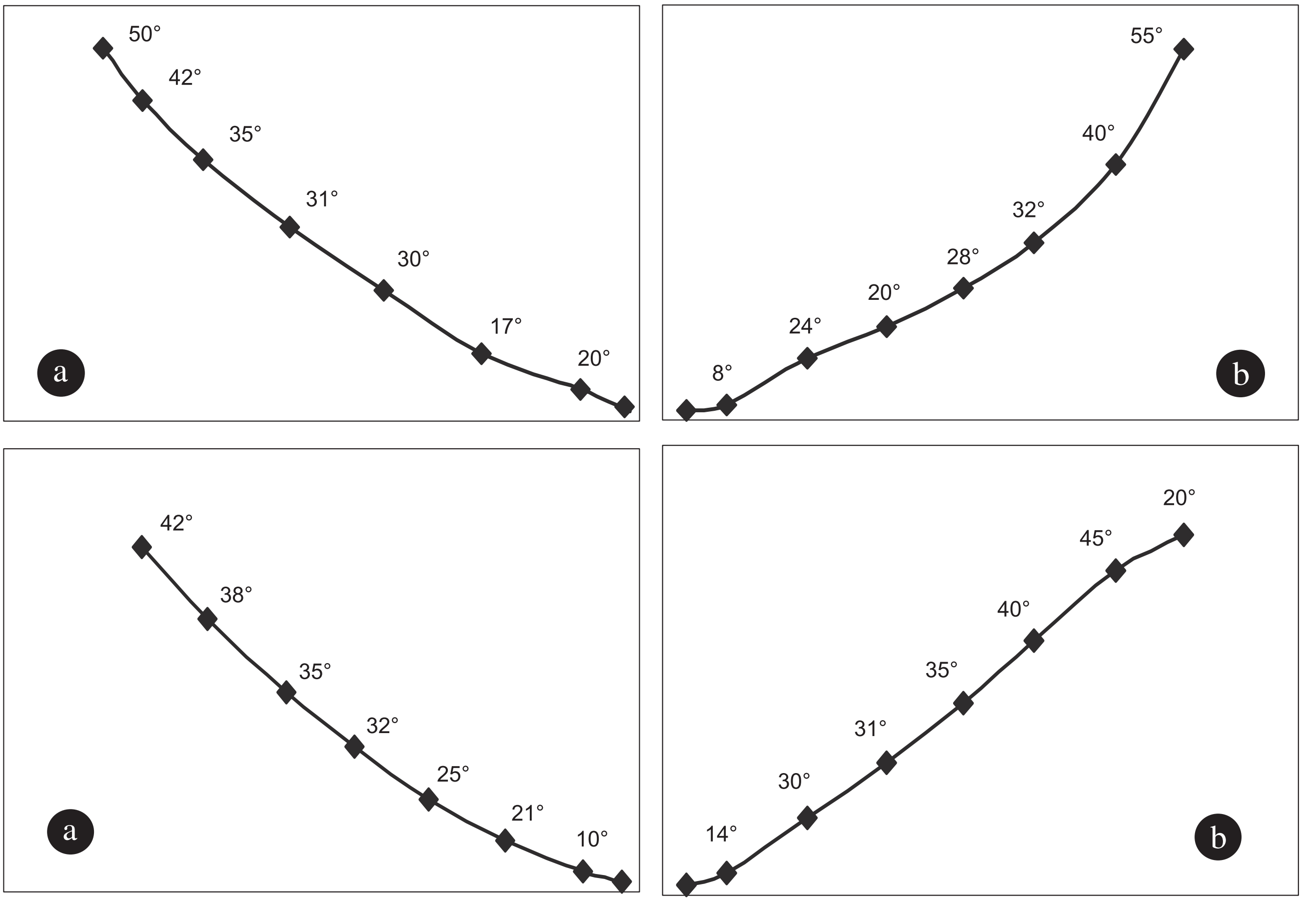

Fig. 1. Typical slope profiles in catchments (a) facing NE and (b) facing SW in the Hoshiarpur

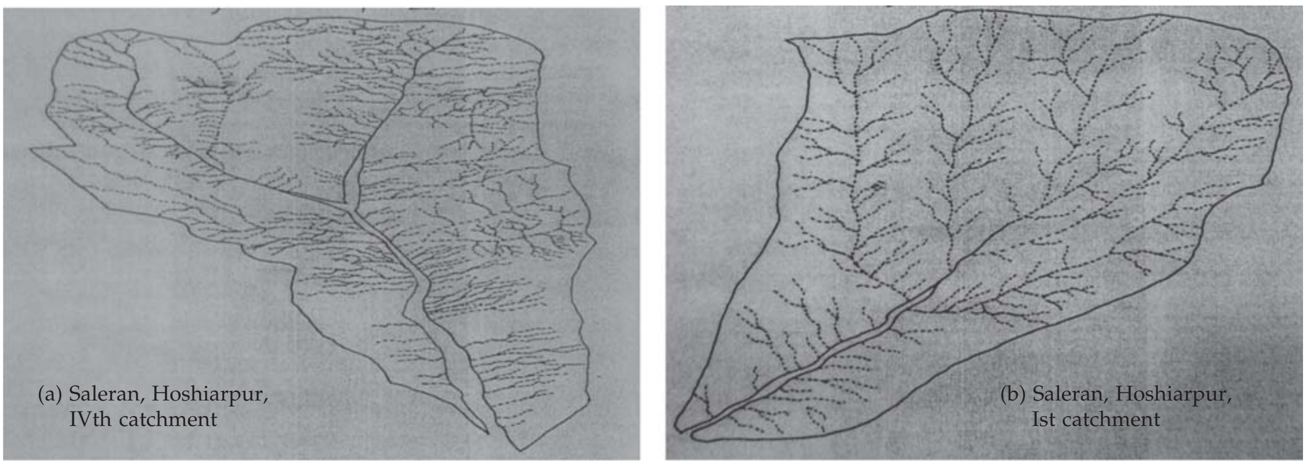

Fig. 2 (a-b). Gully erosion network in the 1st and 4th catchment of Saleran watershed, Hoshiarpur, Punjab

slope to the toe-slope segment (Table 2). The decrease was significantly higher in catchment III (21.8%) compared to catchment I (17.1%), II (18.4%) and IV (16.4%). The decrease in tree density down the slope was also highest in catchment III (83%) compared to 69-78% in other catchments. This decrease in tree density down the slope could be due to the reason that the trees growing on or near the toe-slope segment were more prone to be cut by the local population for timber or fuel purposes. The catchment III being smaller in size and more easily accessible to the human beings and animals could have faced more destruction of vegetation.

The average density of bushes increased down the slope by 20 per cent. However, the increase was 76 per cent in catchment IV compared to 14.6 per

Table 2. Vegetation density on different slope segments in the study catchments

Slope segment	Catch I	Catch II	Catch III	Catch IV	Mean
Tree density (%)					
Top slope	25.2	31.1	41.1	25.4	30.7
Mid slope	18.4	17.3	18.1	16.0	17.5
Toe-slope	7.7	6.8	6.8	7.9	7.3
Mean	17.1	18.4	21.8	16.4	
LSD (0.05)	Catch = 0.67 Slope segment (SS) = 0.58 Catch x SS = 1.16				
Bush density (%)					
Top slope	28.4	19.1	27.4	16.8	22.9
Mid slope	27.8	27.6	27.4	20.3	25.8
Toe-slope	22.4	26.1	31.7	29.6	27.5
Mean	26.2	24.3	28.9	22.2	
LSD (0.05)	Catch = 0.83 Slope segment (SS) = 0.72 Catch x SS = 1.45				
Grass density (%)					
Top slope	13.5	14.6	9.2	11.5	12.2
Mid slope	9.1	13.2	16.1	8.7	11.8
Toe-slope	5.5	14.7	2.7	5.4	7.1
Mean	9.4	14.2	9.4	8.6	
LSD (0.05)	Catch = 0.53 Slope segment (SS) = 0.46 Catch x SS = 0.92				

cent in catchment III and 36.6 per cent in catchment II. In catchment I, the density of bushes rather deceased down the slope. As in case of tree density, the density of bushes was highest (28.9%) in catchment III, followed by catchment I (26.2%), II (24.3%) and IV (22.2%). The overall increase in bush density down the slope could be due to the dominance of *Lantana* spp. which is not liked by animals as fodder. Also this, being thorny and of bad odour is not preferred by the local people for any purpose. Moreover, the higher density of these bushes near the toe-slope segment could be due to higher soil moisture content at the lower slope segments.

Unlike trees and bushes, the density of grasses was higher in catchment II (14.2%) compared to about 8.6-9.4 per cent in other catchments. The average grass density also decreased down the slope by about 42 per cent. However, the extent varied in different catchments with 70.6 per cent in catchment III, followed by 59 per cent in catchment I and 53 per cent in catchment IV. However, in catchment II, it did not vary down the slope.

The density of vegetation was affected by the slope aspect (Table 2). In general, the slopes facing North-East direction had significantly higher tree density than the slopes facing South-West direction at top and toe slope. This is due to the fact that slopes, facing South-West direction experience longer sunshine hours and hence more evaporation losses and greater aridity resulting in lower tree density. However, the average bush and grass density was similar on the two slope aspects, in contrast to the previous studies carried out in the region (Kukal *et al.*, 1999).

The density of trees decreased from top-slope to toe-slope segment on both the slope aspects. However, the decrease was more on slopes facing South-West direction (78.8%) than on slopes facing North-East direction (71.8%) (Table 1). The density of bushes unlike trees increased significantly down the slope. The grass density deceased from top-slope to toe-slope segment by 18.3 per cent on slopes facing north-east in comparison to 60 per cent on slopes facing south-west direction. The highest decrease (95%) in tree density from top-slope to toe-slope segment was observed on south-west facing slopes in catchment III, followed by catchment IV (82%), catchment II (78%) and lowest in catchment I (72%). The trend of variation in bush density down the slope was opposite to that of tree density. The bushes increased down the slope in almost all the catchments except the north-east facing slopes in catchment I, whereas tree density decreased significantly down the slope. The increase in bush density down the slope could be due to the higher prevalence of *Lantana* spp. as discussed earlier.

The grass density as in case of trees, decreased down the slope in all the catchments. As in tree density, the decrease in grass density was more on the slopes facing South-West than those facing North-East. The highest decrease (89.3%) was observed in South facing slopes of catchment III followed by catchment II (76%), catchment IV (70%) and lowest in catchment I (14%).

CONCLUSION

The temporal surveys conducted in 2003 and 2008 in the four catchments of the Hoshiarpur district showed that (1) 1st ordered gullies are the main culprit which collect the rainwater from each nook and corner of the catchment and supplied it to the higher ordered gullies. Governments spend huge amounts to install check dams in the higher ordered gullies which prove to be failure to control the soil erosion at a long time scale. Thus, if we control the 1st ordered gullies in the catchment, then no water supplied in the higher ordered gullies and thus extent of soil erosion could be significantly reduced. (2) Catchment sides facing South-West side reported to have intense gully network as compared to North-East because of greater sunshine hours, more evaporation, lesser vegetation, lesser organic matter, poor aggregation and finally, higher erodibility. (3) The severity of gully erosion was observed to be a function of average relief and lamniscate ratio of the catchments as increased steepness results in increased runoff speed which aids deepening and widening of gullies. Lower value of lamniscate ratio indicates more erosion in the catchment due to its more compact shape with reduced time of concentration. (4) Concave slopes in a particular catchment have been shown to be more prone at the lower slope segments for initiation of gullies as the runoff water concentrates at the lower slope segment where the slope steepness decreases and runoff water starts concentrating. The slope angles were steeper on the upper slope segments and it decreased in the downslope direction.

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Effect of moisture conservation and nutrient management on rice production in rainfed lowland ecology of East and Southern Africa

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ABSTRACT

International Rice Research Institute, East and Southern Africa Regional Office, Tanzania conducted a baseline survey during 2008 to identify the causes of low productivity of rice in rainfed lowland ecology of east and southern African countries. The survey data revealed that poor moisture conservation and nutrient management practices are the major factors responsible for low productivity of rice in rainfed lowland ecosystem. To assess the effect of moisture conservation and nutrient management on productivity of rice under rainfed lowland ecosystem and to make a strategic moisture conservation and nutrient management plan to enhance rice productivity at Bagamayo-2, Bagamayo-3, Lupembe, Milema and Dakawa in different agro climatic regions of Tanzania during 2010. Moisture conservation through bunding increased water availability in upper soil layers at the time of critical dry spell. Substantial yield gains ranging from 0.34 t ha^{-1} to 0.93 t ha^{-1} were recorded following the use of improved technologies. The integration of moisture conservation and nutrient management technologies revealed that the average yield enhancement due to bunding only was 56.14% over no bunding. However, rice yield with good agricultural practices such as bunding + recommended dose of fertilizers ((N80:$P_2O_5$40:K_2O40) was 110.52%, 54.50%, 34.83% and 12.51% higher over no bunding and no nutrients (control), no bunding + 1 bag urea /acre 20 days after germination (Farmers practices), bunding+ no nutrient and no bunding + recommended dose of fertilizers. Relative yield gains decreased in the following order: bunding + recommended dose of fertilizers (110.5%)>no bunding + recommended dose of fertilizers (87.13%), bunding + no nutrient (56.14%), and no bunding + 1 bag (50kg) urea /acre 20 days after germination (Farmers practices). The gains obtained through combined effect of moisture conservation and nutrient management can be further enhanced through use of improved rice cultivars. It is concluded that moisture conservation through bunding enhanced 14.6 % grain yield over the farmer's practices. Bunding + recommended dose of fertilizer gave 117% more income than the prevailing farmer's practices. Therefore, it is recommended that bunding + recommended dose of fertilizers in two splits is advocated/encouraged/recommended for higher productivity of rice in rainfed lowland ecologies of east and southern African countries.

Key words: Moisture conservation, nutrient management, rainfed lowland ecology, rice, East and Southern Africa

INTRODUCTION

The East and Southern African (ESA) region in sub-Saharan Africa has perhaps the greatest concentration of poverty in the world, and for the foreseeable future, it will continue struggling to overcome widespread food insecurity and deprivation. Presently, rates of economic growth vary considerably across the region. But in many East and Southern African countries, poverty and malnourishment are on the rise. About 70 per cent of the region's population, 230 million people live in rural areas, and more than half of those people live on less than US$1(Rs. 60/-) a day. Agriculture is the most important economic activity in the region supporting over 67 percent of the population, but 60 percent of these depends on rain-based rural economies. Rural areas continue to be marked by stagnation, poor productivity, low incomes and rising vulnerability. The vast majority of poor rural people in East and Southern Africa

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are smallholder farmers working in conditions of either static or declining productivity. ESA may suffer more severely from loss of soil fertility. Annual rainfall in ESA ranges from 150 mm in the arid and semi-arid areas to over 2,000 mm in the wet, mostly highland regions. This amount of rainfall itself is capable of ensuring sustainable agricultural productionbut the agricultural production is below potential land capabilities in nearly all the ESA countries, and crop failures are a common occurrence due to prolonged and recurrent drought and dry spells. The importance of rice production in this region has significantly increased over the past decades. Currently, rice plays a pivotal role in improving household food security and national economies in ESA. However, current rice productivity of smallholder farms is low due to a myriad of production constraints and suboptimal production methods, while future productivity is threatened by climate change, water shortage and soil degradation. Rice crop production in ESA is generally below potential, averaging about 2.1 t ha^{-1} (Fig.1). Low yield associated with poor inherent soil fertility (Table 1), continuous cultivation with low inputs and poor soil moisture availability. The region is characterized by semi-humid to semi-arid climate, where 73 percent of the land is classified as dry land. Yet only about 5 percent of the irrigation potential has been exploited. There is, therefore, an urgent need to make rain-fed agriculture more productive. Sometimes the region is described as the "Greater Horn of Africa" (IGAD 2001). East Africa is occupied by some of the poorest communities in the world and over 50 percent of the population lives below the poverty line. Recent studies (Reij and Waters-Bayer 2001; Bittar 2001; Abbay *et al.*, 2000, Critchley *et al.*, 1999; Hatibu and Mahoo 2000) have shown the emergence of success cases of rain-fed agriculture in East Africa, which are transforming the lives of many poor farmers. However, these success cases are few and far between, and there is a need to have continuous collation of information, building on knowledge gained from the successful practices, so as to reach as many farmers as possible, and thereby enhance agricultural development in the region. Feedback from the surveyed farmers revealed that the farmers were not aware of the amount of fertilizer required, timing and method of fertilizer application. During survey it was also elaborated by the 90% farmers that they don't know how to conserve the moisture in rainfed eco- system. They were growing rice in large plots without following any moisture conservation measure even without making any bund. Rain water was lost through runoff immediately after precipitation and crop dried after three to four days if there was no continuous rain. Adequate plant nutrient supply holds the key to improving the food grain production and sustaining livelihood. Nutrient management practices have been developed, but in most of the cases farmers are not applying fertilizers at recommended rates. They feel fertilizers are costly and not affordable and is a

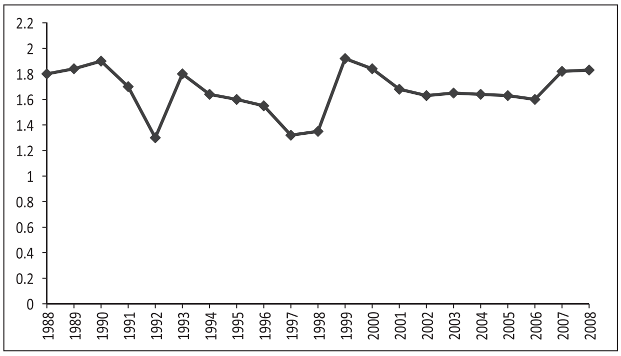

Fig. 1. Rice production pattern in East and Southern African Countries

Table 1. Soil characteristics of experimental sites

Location	Soil Depth (cm)	pH	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)	Na (ppm)	OC (%)	N (%)
Bagamoyo- 3	0-15	5.09	10	258	2669	3133	1798.00	3708.0	2.04	0.11
	15-30	5.43	11	318	1124	3005	9874.00	3226.0	1.02	0.05
Dakawa	0-15	5.60	17	192	525	157	15.68	122.2	1.97	0.11
	15-30	6.60	8	255	429	151	8.52	184.30	0.93	0.05
Lupembe	0-15	4.62	6	220	202	68	12.02	59.81	1.78	0.11
	15-30	4.82	10	232	264	61	11.07	92.23	0.77	0.08
Milama	0-15	6.17	33	431	2251	548	8.56	50.66	1.99	0.11
	15-30	6.92	24	385	2170	533	11.43	54.83	1.73	0.10
Bagamayo- 2	0-15	6.97	10	160	4163	1588	17.83	296.90	1.81	0.12
	15-30	6.82	7	117	3642	1689	16.88	472.90	1.24	0.09

risky undertaking particularly under rainfed agro eco-systems, as they are unsure of the rains. The nutrient use efficiency in rainfed agro-eco systems should be improved through optimizing the nutrient levels with the limited water availability. Crops under rainfed farming systems suffer more from nutrients deficiency rather than moisture inadequacy. Low yields of rainfed crops are due to low level of fertilizer application. Fertilizer use in most of the rainfed areas in the country is suboptimal. Soil organic carbon is the source of energy to fuel for biological activities in the soil, which in turn control the availability of nutrients for plant growth as well as soil water availability. The supply of nutrients in the form of organic manures helps in retaining more moisture, which otherwise will go to waste as runoff water, increasing the water storage capacity and thereby increases water and nutrient use efficiency in rainfed soils. Therefore, International Rice Research Institute, East and Southern Africa Regional Office in Tanzania initiated the study to monitor the effect of moisture conservation and nutrient management to enable farmers to increase rice productivity in Tanzania. They conducted experiments on moisture conservation and nutrient management in rainfed low land conditions with improved rice variety SARO-5 (TXD 306) at 5 locations in different agro-climatic conditions of Tanzania.This study was focused on some of the more commonly adopted moisture conservation and nutrient management technologies and approaches in ESA with special emphasis on Tanzania.

Status of Soil conservation and Nutrient management in ESA

Soil conservation management

Water and soil nutrient management form a critical component of agricultural production. ESA have a rich heritage of indigenous and innovative water and nutrient conservation technologies, including irrigation and water harvesting systems that date back centuries (McCall, 1994; Reij *et al.*, 1996, Wolde-Aregay, 1996; Thomas, 1997, Critchley *et al.*, 1994; Mutunga *et al.*, 2001, SIWI, 2001). Water and nutrient conservation technologies are dictated by the need for soil conservation on usually very steep slopes while draining excess runoff safely, the need for water harvesting and conservation in the drier areas.

Various interventions in soil water conservation (SWC) are implemented by farmers throughout East Africa, and they also form the foundation of many development projects with agriculture and land management on their agendas (Reij *et al.*, 1996; Lundgren, 1993; Hurni and Tato 1992; WOCAT 1997). Indigenousand innovative technologies in SWC (Soil and Water Conservation) and soil nutrient management abound in East Africa (Mulengera, 1998; Reij and Waters-Bayer 2001; Hamilton, 1997), some of which have proved easier to replicate, especially those that are applicable over diverse biophysical conditions and have lowlabor requirements. The more common methods of soil water conservation and nutrient management include: leveling, contour bunds, grass strips, cutoff drains, hill terracing and graded bench terraces (Wolde-Aregay, 1996; Hurni and Tato, 1992). In Tanzania, the main interventions have included the tapping of runoff fromroads, diversion of surface runoff from rocky areas, footpaths, conservation tillage, pitting systems, bunded basins, ridging, terracing and various types of runoff farming systems (McCall, 1994; Reij *et al.*, 1996; Hatibu and Mahoo, 2000).

Soil nutrient management

The declining per capita food production in East Africa is associated with declining soil fertility in small holder farms. This is because nutrient capital is gradually depleted by crop harvest removal, leaching and soil erosion (IFPRI, 1996). The use of crop residues by farmers as fodder, and none or shorter fallow periods due to a shrinking land resource base, should be balanced by addition of chemical fertilizers and organic manure, which most smallholder farmers in the region cannot afford. There is, therefore, a need to develop appropriate soil nutrient and cropping systems that minimize the need for chemical fertilizers and also find ways to integrate livestock into the farming system. The focus of any soil fertility replenishment should be integrated nutrient management involving the application of leguminous mulches, agroforestry, composting as well as technologies that reduce the risks of acidification and salinization. Sanchez *et al.* (1997) suggest that soil fertility replenishment should be considered as an investment in natural resource capital. Studies by Murage *et al.* (2000) showed that soil fertility depletion results from an imbalance between nutrient inputs, harvest removals and other losses, and that it is reaching critical levels among smallholders in East Africa (with depletion of soil organic matter being a contributory factor). For example, Smaling *et al.* (1993) estimated that 112, 2.5 and 70 kg ha^{-1} per year of nitrogen, phosphorus and potassium respectively, are lost from agricultural soil in Kenya. In many small-scale farms, crop residues are harvested and fed to livestock, and very little is returned to the soil to replenish lost nutrients. The depletion of organic matter thus exacerbates this condition. In soil and water management, technologies that improve soil fertility and productivity are as important as those that reduce erosion and loss of water. These include practices such as residue mulching, contour tillage and tied ridging, minimum tillage, sub soiling, crop rotation, cover cropping, rotational grazing, contour cropping and direct application of organic matter, farmyard manure and inorganic fertilizers.

MATERIALS AND METHODS

Farmer survey

To find out the prevailing rice cultivation practices as well as moisture conservation and nutrient management status of both irrigated and rainfed environments in east and southern African countries, a combination of key informant interviews and a questionnaire survey were conducted during 2008. A total of 687 farm families were surveyed in three regions of Tanzania representing east and southern African countries. Purposive sampling methods were used in drawing up a list of interviewees from the sampling frames of each region and the resultant sample constituted of farmers from both irrigated and rainfed lowland ecologies. To find out the moisture conservation and nutrient management status farmers were divided into small (<1.0ha), medium (1.0-2.0ha) and large (>2.0ha) categories based on land holding.

Design and layout of experimental fields

Researcher managed four times replicated experiments were conducted at five (Bagamayo-2, Bagamayo-3, Lupembe, Milema and Dakawa) locations in Tanzania representing rainfed ecology of ESA countries (Fig. 2). Before initiating the experiments composite soil samples were collected from each experimental site and analyzed for soil pH, organic carbon (OC), N, P, K, Ca, Mg, S and Na. The soil of the experimental sites was acidic in nature having soil pH 4.62-6.97. The details of soil status are given in Table 1. The treatments were comprised of no bunding and no nutrient (Control), no bunding + 1 bag urea /acre 20 days after germination (farmers practices), bunding + no nutrient, bunding + recommended dose of fertilizers (N80:$P_2O_5$40:K_2O40) and no bunding + recommended dose of fertilizers. Before dibbling the seed, bunds of 45 cm width and 30 cm height were made to store the rain water within the plots. The plots were leveled properly and dry seeding of traditional high yielding rice variety SARO-5 was done with dibbling method at a spacing of 15 cm x 20 cm before monsoon with a seed rate of 80kgha^{-1}. Recommended fertilizer dose of 80kg N: 40kg P_2O_5:40kg K_2O was applied at all the locations irrespective of amount of rainfall. No fertilizer was applied at the time of dibbling the seed. Half dose of N and full dose of P and K were applied 20 days after germination and the remaining half dose of N was applied at flowering stage. The treatments of the experiment were evaluated by recording yield attributes and grain and straw yields and soil analysis. Five plants were selected and tagged randomly at harvest from each plot. Plant height and panicle length were recorded from these plants and were averaged to express the plant height (cm). Similar practices were followed to record number of tillers/hill, number of effective tillers/hill. For panicle length and grain weight/panicle, five panicles were selected from each five hills and averaged. To measure the weight, random samples were drawn from the produce of each plot, 1000 seeds were counted, weighed and expressed as test weight in both the crops. After harvesting, weighing of sun dried grains and straw collected from each plot was recorded and the same was converted to express in grain and straw yield in t ha^{-1}. Treatments were evaluated based on total variable cost, gross return, net return, and benefit cost ratio (BCR). In order to calculate the total cost of cultivation, variable cost and return was calculated by taking into account the prevailing market prices of inputs (seed, fertilizer, and pesticides) during the study period; costs of human

Fig. 2. Location of experiments

Table 2. Basic statistics of rice cultivation in rainfed ecology of sample regions in Tanzania.

Parameters	Morogoro	Mbeya	Shinyanga	Average
Sample size	175	108	254	537
Paddy yield (t/ha)	2.0	1.5	1.6	1.7
Cultivated area in the sample parcel (ha)	1.0	0.8	1.8	1.2
Share of bunded plot (%)	8.6	15.7	26.1	16.8
Share of hh who levels the plot (%)	22.3	39.8	88.2	61.2
Share of modern variety (%)	17.7	0.0	1.6	11.2
Share of farmers applied fertilizer (%)	5.4	3.8	4.3	4.5
Chemical fertilizer use (kg/ha^{-1})	16.9	15.4	0.9	14.7

Source: Nakano *et al*. (2012)

labor for land preparation, irrigation, fertilizer, and pesticide application, harvesting and threshing; and costs of hiring power tillers for land preparation and an irrigation pump. Gross return was calculated by multiplying the amount of produce (grain and straw) by its prevailing market price at harvest. The net return was computed as gross return – total cost of production and BCR as gross return/total cost of production. The cost economics was analyzed by taking into account the prevailing market prices of inputs, labor, and produce during the year of study in Tanzanian ceilings, and then converted into U.S.$ using the conversion rate of $.

Statistical analysis

The data from the survey was captured and analyzed using SPSS version 15, summary statistics, frequency tables and cross-tabulations and were used to analyze the individual questions. The significance of treatment effect was tested with the help of 'F' test and the differences between treatments by critical differences (CD) at 5% level of probability as per procedure given by Panse and Sukhatme 1985. The data from the experiments were analyzed using Windo STAT. The mean yield for treatments from different sites were separated using least significant differences (LSD) at P < 0.05 significance level.

RESULTS AND DISCUSSION

Farmers survey

From the survey, it was observed that small and marginal farmers in East Africa predominantly produce rice under lowland rainfed ecology and in Tanzania the irrigated ecology constitutes 12% of total land under rice (Kanyeka *et al.,* 1996; Singh *et al.*, 2013). Small and marginal famers contributed largest share of rice without using any good agricultural practices including technologies on management of nutrients, cultivars and water. On the basis of survey, it was observed that, the farmers were not aware about the amount of fertilizer required and time and method of fertilizer application. During survey it was also elaborated by the farmers that they don't know how to conserve the moisture in rainfed eco- system. They were growing rice in large plots without following any moisture conservation measure even without making any bund. The whole rain water lost through runoff immediate after precipitation and crop dried after three four days if there is no continuous rain. The data given in Table 3 summarizes the basic statistics of rice cultivation in sample region in Tanzania. The data revealed that the average land holding of farmers in rainfed ecology is 1.2 ha. However, average paddy yield is 1.7 tha^{-1}. The average share of bunding is only 16.8% which showed that the farmers are not aware of the benefits of moisture conservation measures (Nakano, 2012). Similar to this, usually the paddy fields are leveled to distribute the water equally in the plot but only 61.2 % of household leveled the plot. The share of modern variety is only 11.2% on average which is quite low compared to Asian countries. The use of chemical fertilizer in rainfed ecology is quite low,compared to the Asian countries (Table 2).

Plant growth and yield

Input use of chemical fertilizers on cereals is very low in Sub-Saharan Africa. High cost, low access and limited knowledge of use have been cited as the major reasons for low adoption of this technology by farmers (Mwangi, 1996). However, even readily available low cost organic nutrient sources are not consistently used by farmers. Under rainfed conditions where moisture is a function of rainfall pattern, few farmers (4.5 %) applied fertilizers in rice fields. The average results of five locations revealed that maximum plant height

(88.87cm) was recorded with bunding + recommended dose of fertilizers whereas, minimum with control where farmers are neither making any bund nor using any fertilizer (Fig. 3). Plant growth and yield attributory values of rice were significantly increased with combined effect of bunding and recommended dose of fertilizers. Maximum number of tillers/hill, number of effective tillers/hill, length of panicle, grain weight /panicle, test weight, straw yield and grain yield

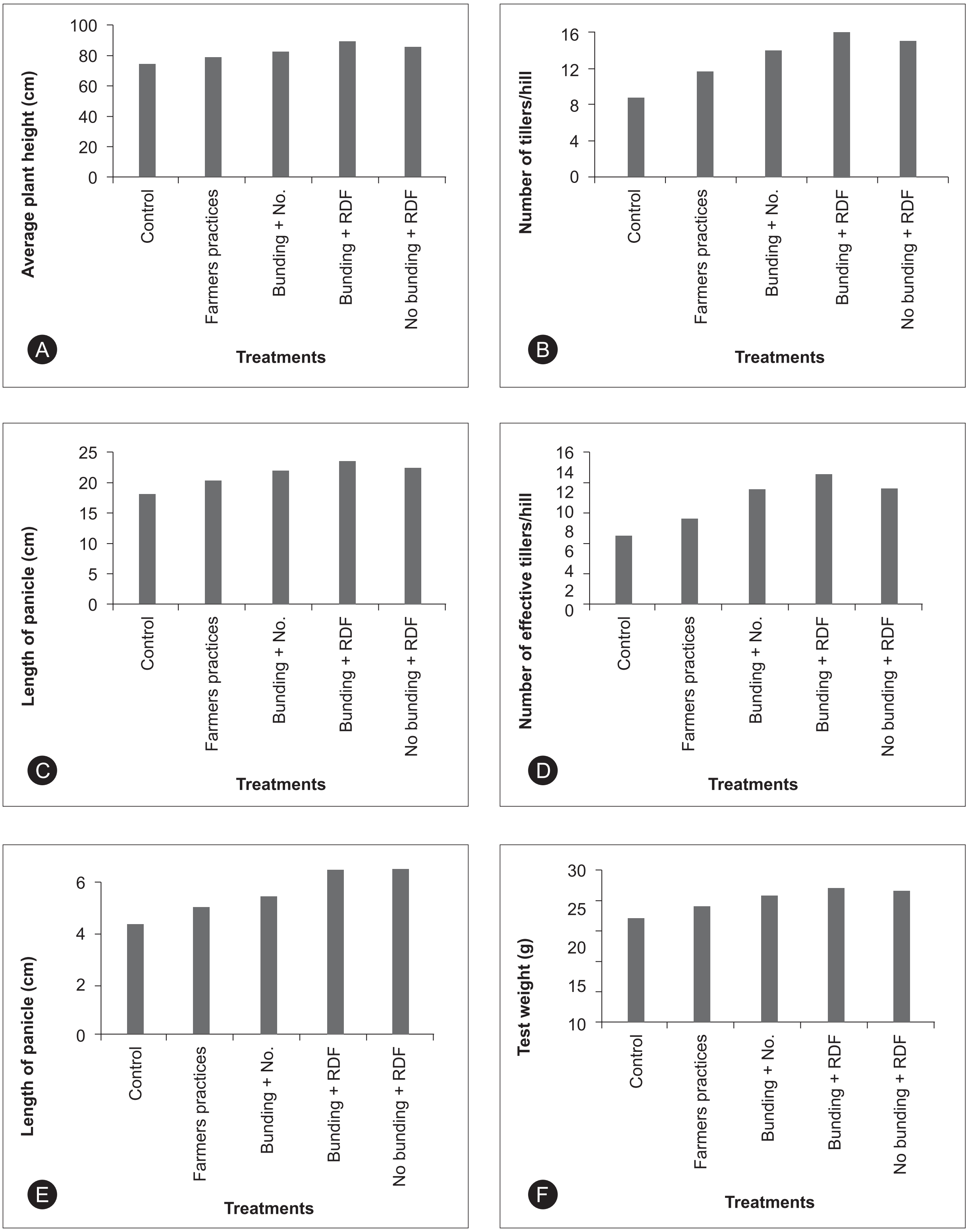

Fig. 3. (A) Plant height (cm), (B) Number of tillers/hill (C) Number of effective tillers/hill (D) Length of panicle (cm) (E) Grain weight/panicle (g) (F) Test weight

Table 3. Effect of moisture conservation and nutrient management on grain straw and biological yields under rainfed environment.

Treatments	Lupembe			Bagamayo-2			Bagamayo-3			Milema			Dakawa		
	Biological yields ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Biological yields ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Biological yields ($t ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Biological yields ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Biological yields ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)
Control	7.02	5.17	1.85	4.10	3.10	1.00	4.30	3.14	1.16	9.30	7.11	2.19	8.80	6.43	2.37
Farmers practices	11.50	8.61	2.89	7.60	5.65	1.95	7.60	5.76	1.84	9.70	7.43	2.27	11.20	8.49	2.71
Bunding + no nutrient	12.46	9.35	3.11	8.20	6.05	2.15	9.00	6.84	2.16	10.10	7.25	2.85	12.65	9.54	3.11
Bunding + RDF	16.60	12.50	4.10	13.10	9.97	3.13	10.10	6.94	3.16	11.60	8.17	3.43	17.10	12.89	4.21
No bunding + RDF	13.30	9.78	3.52	9.20	6.35	2.85	9.43	6.70	2.73	10.10	6.95	3.15	13.80	10.04	3.76
LSD(P=0.05)	1.32	1.51	0.43	1.63	1.14	0.36	1.12	0.86	0.16	ns	ns	0.21	1.46	1.43	0.42

were observed under bunding +recommended dose of fertilizers followed by no bunding + recommended dose of fertilizers. The improvement in plant growth, yield attributing characters and yields under bunding + recommended dose of fertilizers may be due to higher availability of soil moisture for longer duration even during dry spells which helped in better nutrient uptake by the crop which in turn resulted in assimilation of photosynthates towards sink as well as higher dry matter accumulation.

Grain, straw and biological yields of rice markedly increased due to combined effect of bunding the field and application of recommended dose of fertilizer (Table 3). Bunding + recommended dose of fertilizer resulted in highest grain, straw and biological yields at all the locations. The average grain yield with bunding + recommended dose of fertilizer was 110.5%, 54.5%, 34.83% and 12.51% higher than control, farmers practices, bunding + no nutrient and no bunding + recommended dose of fertilizer respectively. The data shows that bunding plays an important role in conserving the moisture. Growing of rice with bunding only even without application of fertilizer enhanced grain yield to 56.14% over without bunding. This is because bunding control rainwater within the plot and maintain moisture in the field for a longer period even in period of dry spell. Mean straw and biological yield exhibited the trend similar to that of seed yield. The use of recommended dose of fertilizer even without bunding results in significant gains in rice grain yield albeit of different magnitude across ecologies but it was remarkably less than the bunding + recommended dose of fertilizer.

Cost economics

The mean value of yield of all the five locations revealed that the maximum grain yield (3.6 $t\ ha^{-1}$) was recorded with bunding + recommended dose of fertilizer followed by no bunding + recommended dose of fertilizer (3.20 $t\ ha^{-1}$) and bunding + no nutrient (2.67 $t\ ha^{-1}$) (Table 4). There was a huge yield gain (1.89 $t\ ha^{-1}$and 0.87 $t\ ha^{-1}$) between the yield recorded from control plot and farmers practices. Net benefit calculated from the data shows that bunding + recommended dose of fertilizer gave 767.82, 475.45, 364.10 and 108.0 US $ additional income over control, farmers practices, bunding + no nutrient and no bunding + recommended dose of fertilizer treatments which shows a positive return to investment in bunding and fertilizer use in rainfed lowland ecologies. Similar responses have been reported by other researchers working on rice in rainfed lowland ecology (Meertens *et al*,. 2003; Kajiru *et al.*, 1998). However, survey interview results showed that farmers are reluctant to apply significantly large amounts of fertilizer especially on rainfed fields probably due to high initial cash outlay required to hire the laborer for making bunds and purchasing inputs, uncertainty of rainfall *vis-à-vis* production, access and lack of confidence in the performance of some technologies which are some of the causes of low adoption (Mowo *et al.*, 2006).

The results of this study suggested that bunding of fields before sowing of seed and application of recommended dose of fertilizer in rainfed lowland rice where there is no control of water, adoption of water conservation techniques e.g., bunds can improve productivity and can be a highly profitable option for East and Southern African countries. The high yield gains following use of good agricultural practices and the positive economic returns warrant the investment required in rice production.

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Development of deterministic runoff prediction model for micro-watersheds of Dal Catchment of Kashmir Valley, India

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ABSTRACT

The present study was conducted in five micro watersheds of Dal catchment in Kashmir valley to evaluatethe runoffyield. Linear and log linear model were developed for annual runoff. At micro level planning, watershed delineation and stream network are the preliminary steps for watershed prioritization, integrated watershed management and sustainable development of natural resources within the watershed. Geomorphological parameters of watershed have been determined, which are interrelated to parameters of watershed characteristics. The value of drainage density was comparatively on higher side ranging from 4.91-5.95 km km^2. The catchment shows low value of bifurcation ratio and the drainage pattern has not been distorted by structural disturbance. The study has shown that the watershed is in conformity with the Horton's law of stream numbers and stream lengths. The runoff developed model has close agreement between observed and predicted values at 5% level of significance. The R^2 value between mean observed and predicted runoff was 0.87 which shows close agreement between field observed and model predicated runoff value.The morphologic parameters have been proved to be efficient tools for morphometric analysis indicates the presence of dendritic drainage pattern pointing out favorable conditions in selecting the soil and water conservation measures and water harvesting systems.

Key words: Watershed, Dal catchment, morphology parameters, runoff, sediment

INTRODUCTION

India's land resources are under immense pressure, it shares only two per cent of the world's geographical area, but supports around 18% of world population and 15% of world's livestock (Kumar *et al.*, 2012). The total geographical area of India is 328 million hectares (mha), of which 69 Mha areacritically degraded, while 106 Mha area severely eroded (Singh, 2000). It has been estimated that about 16.4 ton/ha^{-1} of soil is detached annually because of various agents of destruction. Declining land availability for agriculture, which is expected to be only 0.15 ha per capita by 2035 AD shows the severity of the problem (Singh, 2000).

Hydrologists have developed large number of geomorphological parameter to describe the watershed which are often inter related to determine runoff yield. Different watershed data collected for scientific analysis of different components. The mean annual runoff is significantly correlated with drainage basin area, total stream length and first order stream frequency (Singh, 1997 and Sriniwas, 2004). To develop appropriate technology and strategy for minimizing the land degradation runoff quantification is an urgent need in the recent years (Singh, 1997; Sarangi *et al.*, 2007; Cleveland *et al.*, 2008; Liebe *et al.*, 2009; Gupta and Singh, 2010; Panday *et al.*, 2011; Richardson *et al.*, 2012). Deterministic geomorphic modelling is basic tool for prediction of hydrologic behaviour of a basin. Keeping above facts, present study was carried out to develop the deterministic runoff prediction model to evaluate effect of the different geo-morphological parameters on runoff using regression techniques.

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MATERIALS AND METHODS

Study area

The present study was conducted in Jehlum basin of Dal catchment of five micro watersheds namely Z_2b_8, Z_2b_9, Z_2b_{10}, Z_2b_{11} and Z_2b_{12}. Dal Lake, located in south central Kashmir Valley between, 74^0 48′ N and 34^0 13′S with altitude of 1583 m. The lake is supplied mainly by two main sub watersheds called Dhara Danihama and Dachigam. The climate in the catchment area is a typical temperate climate. The bulk of the precipitation in the area is received during the month of December to February in the form of snow.In month of March-April, the spring's rains are of high intensity that leads to excessive surface runoff and finally finding it ways into the lake. The rainfall pattern in five different micro watersheds is shown in Fig. 1. In order to develop runoff model, data analyzed on rainfall and runoff. The rainfall distribution in study area in spring season was 36, 25, 10 and 29 %, respectively. Watersheds classified on the basis of slope groups in which they fall,area of watershed found in different slope groups is presented in Table 1.

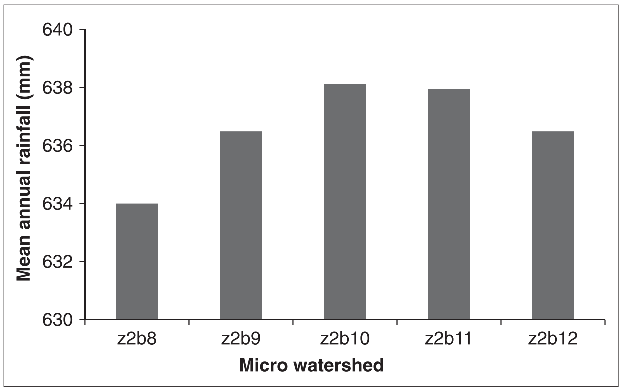

Fig. 1: Mean annual rainfall of five different micro-watershed

The selected micro watershed was gauged by the Department of Soil Conservation, Srinagar, Govt. of Jammu and Kashmir, for measurement of runoff yield. The rainfall data was collected from Division of Agronomy, Sher-e-Kashmir University of Agriculture Science and Technology of Kashmir. For all selected five micro- watersheds, the geo-morphological parameters were determined from relevant topographic sheet published by Survey of India. The different geomorphic parameters of five micro-watersheds were combined together and

Table 1. Area of micro watersheds under different slope groups

Micro watershed	Area in different slop groups (ha)				Total area (ha)
	0-5%	5-15%	15-20%	Above 30%	
Z2b8	-	-	798	31	829
Z 2b9	375	35	265	558	1233
Z2b10	-	279	150	739	1168
Z2b11	375	325	-	6	706
Z2b12	862	-	-	11	873

Source: Soil Conservation Department J&K Forest, 2008

Table 2. Formulae for the Computation of Morphometric Parameters

S. No.	Parameter	Formula	Description
1.	Stream Order (Horton, 1945)	Hierarchical Rank	-
2.	Bifurcation Ratio (R_b) (Horton, 1945)	$R_b = N_u / N_{u+1}$	N_u = No of streams of order uN_{u+1} = No of streams of order u+1
3.	Stream Length	$\bar{L}_u = \frac{\sum_{i=1}^{N} L_u}{N_u}$	L_u = Length of stream of order u
4.	Drainage Density (D_d) (Schumm, 1956)	$D_d = \frac{\sum_{i=1}^{K}\sum_{i=1}^{N} L_u}{A}$	K = Principal order = highest order stream
5.	Stream Frequency (F)	$F = \frac{\sum_{i=1}^{K} N_u}{A_k}$	A_k = Basin area of principal order (K)
6.	Bifurcation Ratio (R_b) (Horton, 1945)	$R_b = N_u / N_{u+1}$	N_u = No of streams of order uN_{u+1} = No of streams of order u+1

taking all these parameters combined for regression analysis, with individual geomorphic parameter as independent variable and runoff as dependent variable. Different formulae for the morphometric parameters are summarized in Table 2.

The geomorphic parameters ordering according to their importance as 1st, 2nd and 3rd principal component and so on. From the principal components first two geomorphic parameters were used in model development along with rainfall. The geomorphic parameters were kept as independent variables and runoff as dependent variable further, SAS (statistical analysis system) software was used to develop dimensionally homogeneous and statistically optimal linear model given as Equation 1:

$$Y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4 + a_5 x_5 \quad \ldots(1)$$

Where, Y is the dependent variable and x_1, x_2, x_3, x_4 and x_5 are the independent variable and a_0, a_1, a_2, a_3, a_4 and a_5 are the regression coefficients. Area lying under different micro watershed in Dal catchment is illustrated in Fig. 2.

RESULTS AND DISCUSSIONS

Geomorphic parameters *i.e.,* stream length, steam order, length of streams of different orders, drainage density, and micro watershed area were calculated using the various formulas from the topographic maps of the five selected micro watersheds. The details of different morophometric parameters are summarized in the Table 3. The detail of drainage density of different micro-watersheds is illustrated in Fig. 3. The drainage density (D_d) of all the micro watersheds are higher, ranging 4.91 to 5.95 km km^2. It is evident from Table 3, that the maximum and minimum values of stream frequency are 6.94 km^{-2} and 4.53 km^{-2}, respectively. The comparative study between drainage density and stream frequency was found that more runoff is generated in watershed having higher values of drainage density and stream frequency, but lower value of constant of channel maintenance.

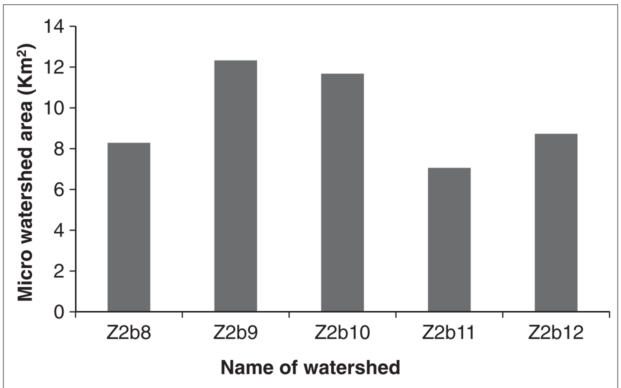

Fig. 2: Area under different micro-watershed

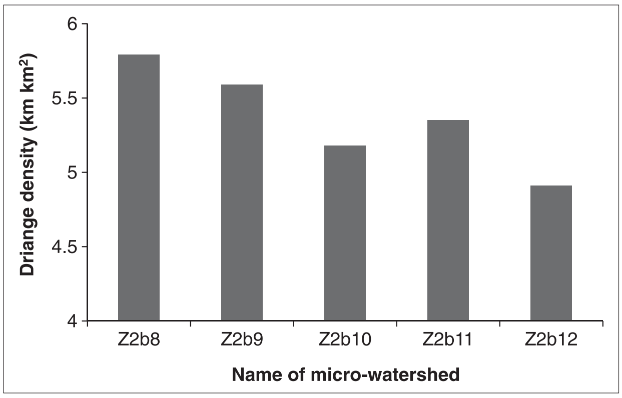

Fig.3: Drainage density of different watersheds in Dal catchment

Linear and log linear model were developed for annual runoff. The linear model with two selected geomorphic parameters *i.e.,* total number of streams, total stream length and rainfall is given as Equation 2:

Runoff= 5372.75+ 3.78 X_1- 2.33 X_2–5.30 X_3 ...(2)

Where X_1= Total number of streams,

X_2= Total stream length (km),

X_3= Precipitation factor (mm)

Log linear model given as Equation 3:

Log Runoff = 6.16710+ 0.00246logX_1 — 0.00205logX_2—0.00542logX_3 ...(3)

Table 3. Comparison between micro-watersheds based on geomorphic parameters

Micro-watershed	Total no. of streams	Total stream length (km)	Micro-watershed area (km^2)	Drainage density (km/km^2)	Stream frequency (km^{-2})	Infiltration number
Z2b8	48	47.7	8.29	5.79	5.79	33.29
Z2b9	68	73.4	12.33	5.95	5.51	32.78
Z2b10	53	60.6	11.68	5.18	4.53	23.46
Z2b11	37	37.7	7.06	5.35	6.94	27.9
Z2b12	46	42.9	8.73	4.91	5.264	25.8

The geomorphological parameters, were put under principle component analysis (PCA). The PCA converted the combined individual geomorphic parameters into principal components such as 1st principal components, 2nd principle components and 3rd principal component and so on. These principal componentsbased on their values of standard deviation, proportion of variance and cumulative proportion with respect to runoff. The details of principal components values are shown in Table 4. The 1st principle component showed that maximum variance in runoff, total number of streams, stream length and infiltration number. The 2nd principal component also effects the runoff, but to a lesser degree as compared to 1st principal component. The first two principle components account for almost 98% variance in runoff.

Table 4. Principal components based on error statistics

Principle components/ error statistics	PC_1	PC_2
Standard deviation	20.244	2.519
Proportion of variance	0.972	0.015
cumulative proportion	0.972	0.987

It is evident from Table 4, that the importance of various components based on their standard deviation, proportion of variance and cumulative proportion, the 1st principal component has the highest value, indicating maximum variation in dependent variable *i.e.* runoff.

The developed model could help to determine the runoff yield which has similar topography and geomorphic conditions. As the model is highly influenced by total number of streams and stream length. The model has high value of R^2 (>0.90) hence, maximum variation in dependent variable *i.e.*, runoff. The lower value of coefficient of variation (CV), indicates that the models are constant.

Table 5. Observed and predicted runoff in different watershed

Micro water-shed	Mean annual precipitation (snow+rain) (mm)	Mean annual runoff observed (mm)	Mean predicted runoff (mm)
Z_2b_8	934.0	572.3	566.8
Z_2b_9	936.4	546.1	544.3
Z_2b_{10}	938.1	517.1	520.6
Z_2b_{11}	937.9	533.2	530.7
Z_2b_{12}	936.4	541.9	554.3

The mean observed runoff and predicted runoff values are summarized in Table 5. It is evident from Table 5 that the observed value and model predicted value have same pattern between field observed and model predicted value. The mean predicted and field observed runoff values plotted and shown in Figs. 4-5. The R^2 value between mean observed and predicted runoff is 0.87, which shows close agreement between field observed and model predicted.

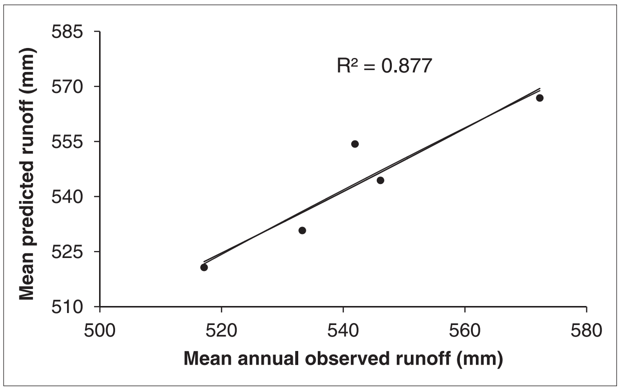

Fig. 4: Comparison between field observed and model predicted runoff in micro watersheds

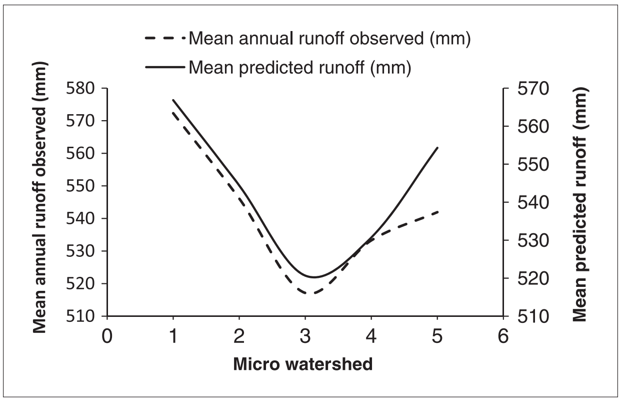

Fig. 5: Comparison between actual and predicted runoff in different micro watershed

CONCLUSION

Assessment of runoff yield is important to prioritize the watershed development work.Runoff modelling permits incorporation of spatially and temporary causative factors which is used as input to generate the desired output. . The total number of streams of micro watersheds Z_2b_8, Z_2b_9, Z_2b_{10}, Z_2b_{11} and Z_2b_{12} are 48, 68, 53, 37 and 46, respectively. There was no effect of individual geomorphic parameters on runoff yield. The runoff developed model has close agreement between observed and predicted values at 5% level of significance. Morphometric analysis indicates, the presence of dendritic drainage pattern pointing out favourable conditions in selecting the soil and water conservation measures and water harvesting systems. Linear and log linear model developed for annual runoff has two selected geomorphic parameters *i.e.* total number of streams, total stream length and rainfall. The R^2 value between mean observed and predicted runoff as 0.87 which shows close agreement between them.The developed model can help to determine the runoff which in turn help soil conservation for various remedial measures to prevent erosion due to runoff which otherwise is causing a heavy loss to agricultural and horticultural lands of valley.

ACKNOWLEDGMENTS

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Study of soil properties under integrated nutrient management in irrigated condition in Allahabad

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ABSTRACT

Field experiment was conducted during Rabi 2005-06 and 2006-07 at the crop Research Farm, Department of Soil and Agricultural chemistry Sciences, Allahabad Agricultural Institute – Deemed University, Allahabad, to study the performance of winter maize as affected by inorganic and organic use of nutrients on the yield of Winter Maize (*Zea mays* L.). The experiment was laid out in randomized block with 13 treatments, each replicated three times, using Maize variety Arjun. The experimental observations were recorded during the cropping time are Length of the cob, weight of the cob, grain yield, pH, Ec, organic carbon, available nitrogen, available phosphorus and available potassium. 25 per cent nitrogen through poultry manure plus 75 percent nitrogen through urea (T_8) found to be best in case of growth parameters.pH of the soil marginally decreased from intial values of soil by the use of different organic nutrient sources and electrical conductivity was found to be highest in 25 per cent poultry manure plus 75percent nitrogen (T_8). Application of 25 per cent poultry manure plus 75 per cent Nitrogen (T_8) emerged as superior over all other treatments in relation to physico-chemical properties of soil of maize (*Zea mays* L.)

Key words: Winter maize, poultry manure, farmyard manure, goat manure and inorganic fertilizer

INTRODUCTION

Maize crop is warm weather loving crop and used as test crop. In maize, sandy soils respond more rapidly to management practices than those of fine texture and can be tuned to high level of production when water and nutrient supplies can be controlled efficiently. Soil pH in the range of 7.5 to 8.5 supports good crop growth, however, pH beyond these extremes creates problems of toxicity with certain elements and essential nutrients (Singh, 1998). Major nutrients plays importantrole in maize crops especially nitrogen in maize is more important than any other nutrient through out its growing period right from seedling stage to grain filling stage and its deficiency at any stage of growth , especially at tasseling and silking stage, may lead to virtual crop failure. The nitrogen utilization pattern is found to be increased from seedling of knee height and reaches to the peak at tasseling stage. Phosphorus helps in development of maize at all phases of growth and shows deficiency mainly at seedling stage and delayed maturity with an imperfect ear formation.. Maize plants need more than half of their potash requirement upto or before flowering stage. The experiment was conducted to find our the chemical changes affected by treatments.

MATERIAL AND METHODS

The field experiment was conducted in randomized block design consisting of four levels of organic manure (poultry manure, goat manure and farmyard manure) and four levels of N (25%, 50%, 75% and 100%). Half nitrogen and full doses of P&K as basal and rest of N applied at knee height stage and tasseling stage. The crop was sown in rows at 60 cm x 30 cm row to row and plant to plant spacing. Compost soil sample was taken for mechanical and chemical analysis which represented sandy loam texture having 7.5 pH, 0.27 Ec (dsm^{-1}), 39 organic carbon, 214kg/ha available nitrogen, 22.81kg ha^{-1} available phosphorus and 240 kg ha^{-1} available potassium. Standard methods of soil analysis were adopated. Maize variety Arjun

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was taken as test crop which were sown on 12 Nov, 2005-06 and 12 Nov, 2006-07.

RESULT AND DISCUSSION

The changes in the soil properties were recorded based on physical and chemical analysis of the soil which are represented as follows:

Soil pH

It is evident from the Table 1 that there had been slightly decrease in soil pH after harvest of the crop during both the years. However the difference were non significant.The decreasing trend was more evident with increasing level of inorganic N which might have been due to transformation of urea into nitrate .Similar results was reported by Unaguri *et al.* (2012).

Electrical conductivity

The observation recorded on Ec Table 2 showed non significant effect during both the years which would have been because of no change in pH as explained above. Similar result was reported in the same pattern by Obi and Ebo (1995).

Organic carbon

The organic carbon content as shown in Table 3 increased significantly with increase in doses of organic manure during both the years. Maximum organic carbon content of 0.48 percent was recorded in 100 percent organic manure (T_1), farmyard manure. The increase in organic manure percent of soil might have been due to addition of organic manure, root debris. Similar results were also reported by Sarkar and Singh (1997).

Available nitrogen

The data presented in Table 4 reveals that the available nitrogen content in soil increased significantly in soil after harvest with increase in inorganic and organic doses during both the years. The lowest available N was found in control (192.54kg ha^{-1}) and maximum of 239.4kg ha^{-1} in 25% PM+75%N, respectively. The reason for this increase would have been because of high dose of N through inorganic and organic source associated with an increased microbial activity in minerlisation. Similar findings has been reported by Bellakki and Badanur (1997) and Gupta *et al.* (2006).

Available phosphrous

Data presented in Table 5 shows available phosphrous content in the soil after harvest of the crop. It further indicates that application of inorganic and organic sources of N influenced positively the availability of phosphrous in the soil which could have been due to additional dose of P

Table 1. pH (1:2 soil water suspension) of soil after harvesting of maize crop

Treatment Combination	pH of post harvest soil		
	2005-06	2006-07	Pooled
T_O Control	7.590	7.600	7.595
T_1 100% Farmyard Manure (FYM)	7.100	7.090	7.095
T_2 75% FYM+25% N	7.250	7.240	7.245
T_3 50% FYM+50% N	7.350	7.340	7.345
T_4 25% FYM+75% N	7.430	7.420	7.425
T_5 100% Poultry Manure (PM)	7.270	7.280	7.275
T_6 75% PM+25% N	7.290	7.280	7.285
T_7 50% PM+50% N	7.380	7.370	7.375
T_8 25 PM+75% N	7.450	7.440	7.445
T_9 100% Goat Manure (GM)	7.310	7.300	7.305
T_{10} 75% GM+25% N	7.330	7.320	7.325
T_{11} 50% GM+50% N	7.400	7.390	7.395
T_{12} 25% GM+75% N	7.490	7.480	7.485
F-test	NS	NS	NS
S.Ed. ($-^+$)	-	-	-
C.D. at 5%	-	-	-

Table 2. Ec (dsm^{-1}) of post harvest soil

Treatment Combination	Ec (dsm-1) of post harvest soil		
	2005-06	2006-07	Pooled
T_O Control	0.290	0.280	0.285
T_1 100% Farmyard Manure(FYM)	0.280	0.290	0.285
T_2 75% FYM+25% N	0.290	0.300	0.295
T_3 50% FYM+50% N	0.330	0.340	0.335
T_4 25% FYM+75% N	0.340	0.340	0.340
T_5 100% Poultry Manure (PM)	0.300	0.310	0.305
T_6 75% PM+25% N	0.350	0.360	0.355
T_7 50% PM+50% N	0.360	0.370	0.365
T_8 25 PM+75% N	0.360	0.370	0.365
T_9 100% Goat Manure (GM)	0.320	0.330	0.325
T_{10} 75% GM+25% N	0.330	0.340	0.335
T_{11} 50% GM+50% N	0.370	0.370	0.370
T_{12} 25% GM+75% N	0.370	0.380	0.370
F-test	NS	NS	NS
S.Ed. ($-^+$)	-	-	-
C.D.at 5%	-	-	-0

Table 3. Organic carbon (%) soil after harvesting of maize crop

Treatment Combination	Organic carbon (%) of post harvest soil		
	2005-06	2006-07	Pooled
T_O Control	0.390	0.400	0.395
T_1 100% Farmyard Manure (FYM)	0.480	0.490	0.485
T_2 75% FYM+25% N	0.470	0.480	0.475
T_3 50% FYM+50% N	0.420	0.430	0.425
T_4 25% FYM+75% N	0.400	0.410	0.405
T_5 100% Poultry Manure (PM)	0.460	0.470	0.465
T_6 75% PM+25% N	0.450	0.460	0.455
T_7 50% PM+50% N	0.410	0.420	0.415
T_8 25 PM+75% N	0.410	0.420	0.415
T_9 100% Goat Manure (GM)	0.440	0.450	0.445
T_{10} 75% GM+25% N	0.430	0.440	0.435
T_{11} 50% GM+50% N	0.400	0.410	0.405
T_{12} 25% GM+75% N	0.400	0.420	0.410
F-test	S	S	S
S.Ed.(-+)	0.0050	0.0051	0.0051
C.D. at 5%	0.0103	0.0106	0.0104

Table 4. Available nitrogen (kg ha^{-1}) in soil after harvesting of maize crop

Treatment Combination	Available nitrogen (kg/ha^{-1}) in post harvest soil		
	2005-06	2006-07	Pooled
T_O Control	192.00	193.08	192.54
T_1 100% Farmyard Manure (FYM)	198.82	200.33	199.58
T_2 75% FYM+25% N	202.39	203.80	203.10
T_3 50% FYM+50% N	216.24	217.33	216.79
T_4 25% FYM+75% N	228.80	229.81	229.30
T_5 100% Poultry Manure (PM)	200.62	202.43	201.53
T_6 75% PM+25% N	211.88	212.59	212.24
T_7 50% PM+50% N	220.00	221.00	220.50
T_8 25 PM+75% N	238.67	240.28	239.47
T_9 100% Goat Manure (GM)	199.50	200.96	200.23
T_{10} 75% GM+25% N	206.20	207.33	206.77
T_{11} 50% GM+50% N	218.05	219.67	218.86
T_{12} 25% GM+75% N	232.62	234.00	233.31
F-test	S	S	S
S.Ed.(-+)	0.27	0.81	0.49
C.D. at 5%	0.56	1.66	1.01

Table 5. Available Phosphorus (kg ha^{-1}) in soil after harvesting of maize crop

Treatment Combination	Available phosporus (kg/ha^{-1}) in post harvest Soil		
	2005-06	2006-07	Pooled
T_O Control	18.80	17.56	18.18
T_1 100% Farmyard Manure (FYM)	17.80	18.49	18.14
T_2 75% FYM+25% N	21.00	18.98	19.99
T_3 50% FYM+50% N	19.00	19.41	19.20
T_4 25% FYM+75% N	17.92	21.00	19.46
T_5 100% Poultry Manure (PM)	19.42	18.61	19.01
T_6 75% PM+25% N	17.84	19.40	18.62
T_7 50% PM+50% N	17.66	20.31	18.98
T_8 25 PM+75% N	20.80	21.93	21.37
T_9 100% Goat Manure (GM)	18.42	18.54	18.48
T_{10} 75% GM+25% N	17.00	19.00	18.00
T_{11} 50% GM+50% N	20.50	19.67	20.08
T_{12} 25% GM+75% N	19.22	21.33	20.28
F-test	S	S	S
S.Ed. (-+)	0.24	0.60	0.28
C.D. at 5%	0.54	1.23	0.59

Table 6. Available Potassium (kg ha^{-1}) in soil after harvesting of maize crop

Treatment Combination	Available phosporus (kg/ha^{-1}) in post harvest Soil		
	2005-06	2006-07	Pooled
T_O Control	172.00	173.36	172.68
T_1 100% Farmyard Manure (FYM)	176.00	178.21	177.11
T_2 75% FYM+25% N	188.00	188.67	188.33
T_3 50% FYM+50% N	198.00	199.33	198.67
T_4 25% FYM+75% N	224.00	224.67	224.33
T_5 100% Poultry Manure (PM)	184.00	185.79	184.89
T_6 75% PM+25% N	192.00	193.00	192.50
T_7 50% PM+50% N	201.00	201.38	201.19
T_8 25 PM+75% N	238.00	240.00	239.00
T_9 100% Goat Manure (GM)	183.00	184.04	183.52
T_{10} 75% GM+25% N	188.00	188.75	188.38
T_{11} 50% GM+50% N	200.00	201.33	200.67
T_{12} 25% GM+75% N	232.00	232.67	232.34
F-test	S	S	S
S.Ed. (-+)	0.30	0.72	0.43
C.D. at 5%	0.61	1.49	0.89

added through organic manure. Similiar results were reported by Gupta *et al.* (2006). The maximium P (21.37 kg/ha) was recorded in 25% PM+75% N in (T_8) which was significant over than other treatments. This enhancement in the P level could have been due to additional dose of P added through organic source of N associated with release of fix P due to production of organic acid during mineralization of organic manure. Similar results were reported by Bellakki and Badanur (1997).

Available potassium

The available potassium content recorded after harvest of the crop was recorded and presented in Table 6. The Table 6 shows the available potassium content after harvest of the crop increased over control and only inorganic fertilizer. Maximium available potassium was 249kg kg ha^{-1} in (T_8) and the difference were significant. The Bellakki and Badanur (1997) and Gupta (2006) has also reported similar findings.

Yield

As Table 7 shows that there had been significant difference in the yield of crop and highest yield of crop 54.8q ha^{-1} was recorded in (T_8) which was at par with T_{12} and T_4. The probable reason for increase in yield could have been due to constant supply of nutrient to maize plant inorganically treated plots. This finding is accordance with those reported by Ghosh *et al.* (2003) and I.A.S. Gudugi (2012).

Table 7: Effect of different treatments of Grain yield (qha^{-1}) maize at different intervals (2005-06 and 2006-07).

Treatments	Grain yield ($qha^{1)}$)
T_O Control	31.3
T_1 100% Farmyard Manure (FYM)	35.7
T_2 75% FYM+25% N	43.9
T_3 50% FYM+50% N	48.3
T_4 25% FYM+75% N	52.4
T_5 100% Poultry Manure (PM)	42.0
T_6 75% PM+25% N	47.9
T_7 50% PM+50% N	52.0
T_8 25% PM+75% N	54.8
T_9 100% Goat Manure (GM)	37.4
T_{10} 75% GM+25% N	46.0
T_{11} 50% GM+50% N	48.6
T_{12} 25% GM+75% N	54.4
C.D. at 5%	13.9

CONCLUSION

The result of the present investigation included that 25 percent nitrogen through poultry manure plus 75 percent nitrogen through urea (T_8) was found to be best in getting highest crop yield without much changes in soil pH and Ec. There has been slight improvement in soil fertility under combine application of inorganic and organic source of Nitrogen.

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Evaluation of storage capacity of ponds and water quality analysis of tubewell and stream in a small watershed

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ABSTRACT

This study deals with determination of various topographic parameters, storage capacity of ponds and water quality analysis of water bodies existing in *Sandhari nala* watershed. Water storage capacity of 34 ponds was determined. Maximum storage capacity of the farm pond is determined on the basis of overall shape, surface area and depth of the pond. Water samples collected from the open streams and tube wells at different locations in the watershed were analyzed for their physicochemical characteristics including pH, TDS, TH, Ca^{++}, Mg^{++}, Na^{+}, K^{+} and Cl^{-} etc. Total storage capacity of ponds existing in the watershed was estimated to be 49, 37,000 m^3. The water is used for different purposes such as domestic, irrigation, fish production etc. and farmers are being benefited in terms of crop production during both *rabi* and *kharif* seasons. Water samples of tube wells and open streams showed acidic nature. However, some other parameters available in the water samples taken from the tube well showed higher values than the open stream. As per the standard specifications the water flowing in the streams and available in the tube wells found to be suitable for domestic and irrigation purpose.

Key words: Pond, storage capacity, water quality, watershed, topography survey

INTRODUCTION

Water is the essential for the survival of all living beings i.e. humans, animals and plants. Water is an essential resource upon which our ecosystem and agricultural production depend. India is facing a serious problem of natural resource scarcity, especially that of water in view of population growth and economic development (Garg *et al.*, 2009). Most of fresh water bodies all over the world are getting polluted, thus decreasing the potability of water (Gupta *et al.*, 2005). Ground water quality is mainly affected due to drastic pollution activities that are taking place on surface waters (Rao *et al.*, 2012). Ground water is getting contaminated at an alarming rate due to rapid industrialization and become unfit for drinking (Gautam *et al.*, 2013) Water resources can be classified into two categories of water body, surface water and ground water. Changes in the water quality affect the biotic community of the aquatic ecosystem which ultimately reduces the primary productivity (Rossiter *et al.*, 2010). The water quality depends on various physico-chemical characteristics and their concentration. The water quality degradation is almost increases due to human activities. Due to natural process of weathering of rocks, leaching of soils and mining processing etc. which contaminates the natural water. It is necessary that the quality of drinking water should be checked at regular time interval, because due to use of contaminated drinking water, human population suffers from varied of water borne diseases (Patil *et al., 2012*). Natural events such as torrential rainfall and hurricanes lead to excessive erosion and landsides in affected rivers and lakes (Balek, 1977). The nature and concentration of chemical elements and compounds in a fresh water system are subject to change by various types of natural processes, that is, physical, chemical, hydrological and biological (Balek, 1977). Permanent natural conditions in some areas may make water unfit for drinking or for specific uses such as irrigation

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(Peavy *et al.,* 1986). The natural aquatic resources are causing heavy and varied pollution in aquatic environment leading to water quality and depletion of aquatic biota. It is therefore necessary that the quality of drinking water and irrigation water should be checked at regular time interval because due to use of contaminated water for drinking, human population suffers from a variety of water borne diseases and for irrigation, affect agricultural productivity and change the soil characteristics also. The world health organization (WHO) estimates that 88% of diarrheal disease is caused by unsafe water, inadequate sanitation and poor hygiene. The physicochemical characteristics like pH, dissolved oxygen, total alkalinity, total hardness, chloride contents etc. in one way or another has significant influence on aquatic life. Aquatic organisms are influenced by changing in water quality (Chatterjee and Raziuddin, 2002).

The growth of urban settlements and growing industrial production, combined with rapidly measuring demand for water are causing water quality problems. Water quality assessment operations are undertaken as preliminary survey, multipurpose monitoring, background monitoring, modeling survey, early warning surveillance etc. (UNESCO/WHO/UNEP/UNEP, 1992, Sanders *et al.,* 1983). Good quality water is essential for living organisms. The indiscriminate use may cause secondary salinization and sodification of soil resulting in serious effect on crop growth. But in emergency these waters can be used with special management practice depending upon the rainfall, crop to be grown and soil type (Sharma *et al.,* 2013).

The quality of irrigation water is concern to its effects on the management of soils and crops. High quality crops can be produced only by using good and safe qualitatively parameter of irrigation water. Characteristics of irrigation water that define its quality vary with the source of the water. Water used for irrigation can also vary greatly in quality depending upon quantity of dissolved salts. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available (Shamsad and Islam, 2005; Islam *et al.,* 1999). Poor quality irrigation water becomes more concern as the climate changes from humid to arid conditions. Salts are originated from dissolution or weathering of rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. These substances are carried with the water to wherever it is used (UCCC, 1974; Tanji, 1990). The evaluation of irrigation water quality to be identifying their acceptable levels of concentrations that are important for plant growth and.

A pond is an earthen container for storing water. The surface area of the stored water will normally vary from a fraction of an acre to tens of acres. Ponds have traditionally been used as an economical and efficient way to retain water for livestock and irrigation.

The main objective of this present work is to be indentified physicochemical characteristic of surface and ground water in watershed. Assessment of water quality for irrigation is to be identifying the characteristics that are important for plant growth, and their acceptable levels of concentrations.

MATERIALS AND METHODS

Study Area: Sanghari nala watershed has been considered for this study, which is in Arang block of Raipur district (Fig. 1). The watershed comprises of several villages namely Rasni, Khamtarai, Kalai, Jaraud, Chhatauna, Ghumrabhata and Bodra. The watershed is located within $81^{0}54'$ to $82^{0}0'$ E longitude and $21^{0}12'$ to $21^{0}16''$ N latitude at an altitude ranged from 270 to 300 m above mean sea level (MSL) covering an area of 54.50 km^2. The average slope of the watershed is 1.5%.

The watershed receives an average annual rainfall of 1420 mm. About 80-90% of total rainfall occurs between June to September as monsoon rains. The daily mean temperature ranges from a maximum of $45^{0}C$ to a minimum of $10^{0}C$. Clay, sandy clay loam and sandy loam soils were found in the watershed area.

Since the Global Positioning System (GPS) was used to determine the specific location of various ponds, tube wells and open wells situated at

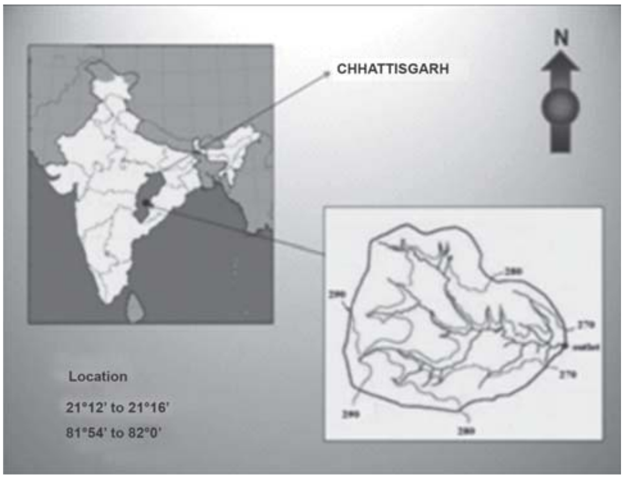

Fig. 1. Location map of the study area

different villages of watershed. The topographic datasets were originally stored as point measurement. Each point had northing, easting, and elevation values.

Storage Capacity of Farm Pond: In general for calculation of volume of a pond the basic information which require includes the overall shape, as well as pond surface area and depth. The estimated capacity or volume of the pond can be determined by multiplying the surface area of the pond with the average water depth measured at the farm pond.

Analytical details of Water Sample: Quality of water directly affects quality of life of inhabited population. It is very essential and important to test the water before it is used for drinking, domestic, agricultural or industrial purpose. Water must be tested with different physico-chemical parameters. Selection of parameters for testing of water is solely depends upon for what purpose we are going to use that water and to what extent we need its quality and purity. Water may contain different types of floating, dissolved, suspended and microbiological as well as bacteriological impurities. Water samples were collected from the surface water and ground water. The water samples collected from the open water body (AM-P1) and tube wells (BD-W3) (Table 2). The samples were collected in polystyrene bottles having 1000 ml capacities as per requirement of the test. The method adopted for the determination of the physic-chemical characteristics of water was given in Table 1. The bottles were kept air tight and labeled properly for identification. These samples were brought to the laboratory for the analysis of different physicochemical characteristics like pH, total alkalinity, boron, calcium, chloride, colour, fluoride, total hardness, Iron, manganese, nitrate, calcium, turbidity, SAR, RSC, SSP and Magnesium hazard for drinking and irrigation purpose and results were compared with IS: 10500 of drinking and irrigation.

RESULTS AND DISCUSSION

The storage capacities of farm ponds were calculated 49, 37,000 m^3 of water was stored in all the ponds which come under the watershed area (Table 3). This water is used for different purposes such as domestic, agricultural landscapes, fish production, irrigation etc. The volume of water in ponds decrease during summer but negligible effect was seen in different water sources like open well, tube well, bore well etc.

Physico-Chemical Characteristics of Water pH: pH is the important parameter for determining the corrosiveness nature of water. Lower the pH value higher is the corrosive nature of water. pH was positively correlated with electrical conductance and total alkalinity (Gupta 2009). As evident from

Table 1: Experimental methods used for analysis of water quality of drinking and irrigation

S.No.	Particulars	Method/Instruments used
1.	pH	Potentiometeric
2.	Electrical conductivity (EC) and TDS	Conductivity Cell Potentiometer
3.	Total hardness and Calcium (Ca^{++})	EDTA Titrimetric
4.	Magnesium (Mg^{++})	Calculation from Total hardness and Calcium
5.	Sodium (Na^{+}) and Potassium (K^{+})	Flame Emission Photometric
6.	Chloride (Cl^{-})	Argentometric Titration
7.	Primary alkalinity	Titrimetric to pH=8.3 (Phenolphthalein)
8.	Total alkalinity	EDTA Titrimetric to pH=4.5 (Methyl Orenge)
9.	Carbonate and Bicarbonate	Calculation from pH and Alkalinity
10.	Sodium Adsorption Ratio (SAR)	Richards, 1954
11.	Soluble Sodium Percentage (SSP)	Todd, 1980
12.	Residual Sodium Carbonate (RSC)	Eaton, 1950
13.	Magnesium Hazards	Szabolcs and Darab (1964)

Table 2: Water samples details of different water bodies

S.N.	Village Name	Sample Code	Location		
			N	E	Elevation (m)
1.	Amethi	AM-P1	21°13.455'	81°59.523'	274
2.	Bodra	BD-W3	21°13.600'	81°55.885'	291

Table 3: Water storage capacity of farm pond

Village Name	Name of Pond	Average Depth (m)	Area of Pond (ha)	Area of Pond (m^2)	Water Storage Capacity(m^3)
Rasni	Dogiha pond	6.5	2.91	29,100	1,89,150
	Bandhwa pond	7.5	2.86	28,600	2,14,500
	Dumrahi pond	6.5	2.14	21,400	1,39,100
	Banjariya pond	6.5	2.2	22,000	1,43,000
	New pond	6.5	1.96	19,600	1,27,400
Jaraud	Dhobani pond	5.5	1.89	18,900	1,03,950
	Bandhuwa pond	7.5	7.30	73,000	5,47,500
	New pond	6.5	1.36	13,600	88,400
	Sendhwara pond	5.5	1.95	19,500	1,07,250
	Balar pond	5.5	1.40	14,000	77,000
	Hajariya pond	7.5	2.65	26,500	1,98,750
	Chudeline pond	7	5.49	54,900	3,84,300
Bodra	Lawan pond	6.5	2.98	29,800	1,93,700
	Chepta pond	6.5	1.07	10,700	69,550
	Banjariya pond	6.5	1.81	18,100	1,17,650
	Darry pond	5.5	0.75	7,500	41,250
	New pond	6.5	1.60	16,000	1,04,000
	Ganwa pond	7.5	2.80	28,000	2,10,000
	Dubey pond	7.5	2.80	28,000	2,10,000
	Raja pond	5.5	0.78	7,800	42,900
	Dogi pond	5.5	0.77	7,700	42,350
Chhatauna	Sargodwa pond	7.5	1.19	11,900	89,250
	Charkhutiya pond	6.5	1.19	11,900	77,350
	Dogiha pond	6.5	2.26	22,600	1,46,900
	Chakoli pond	5.5	0.63	6,300	34,650
	Baramdeya pond	6.5	1.51	15,100	98,150
Khamtarai	New pond	7.5	2.14	21,400	1,60,500
	Bandha pond	7.5	5.89	58,900	4,41,750
Kalai	Gaura pond	5.5	1.55	15,500	85,250
	Ganesh pond	6.5	1.08	10,800	70,200
	Ganganiya pond	6.5	1.39	13,900	90,350
	Nawa pond	6.5	1.47	14,700	95,550
Ghumarabhata	Bade pond	7.5	2.12	21,200	1,59,000
	Niji pond	6.5	0.56	5,600	36,400
	Total Water Storage Capacity				49,37,000

Fig. 2. The pH value of tube well and open stream water were found to be 6.7 and 6.8 respectively. Both samples showed the slightly acidic nature. As per IS: 10500 the tube well water and open stream water both samples were found to be under desirable limit. The higher pH values observed suggests that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physico-chemical condition (Karanth 1987).

Electrical Conductivity: EC is the measure of the ability of an aqueous solution to convey an electric current. The EC value of tube well and open stream water was found to be 3035.20 micromhos cm^{-1} and 463.37 micromhos cm^{-1} respectively. Fig. 3 shows the high EC values of tube well indicating the presence of high amount of dissolved inorganic substances in ionized form as compare to open stream water.

Total Dissolved Solids: Total dissolved solids indicate the salinity behavior of groundwater. In the present study the total dissolved solids 1942.53 ppm and 296.56 ppm was recorded in the water sample of tube well and open stream water respectively. The results indicated that the open stream water comes under desirable limit and tube well water crossed the desirable limit but showed under the permissible limit as per IS: 10500.

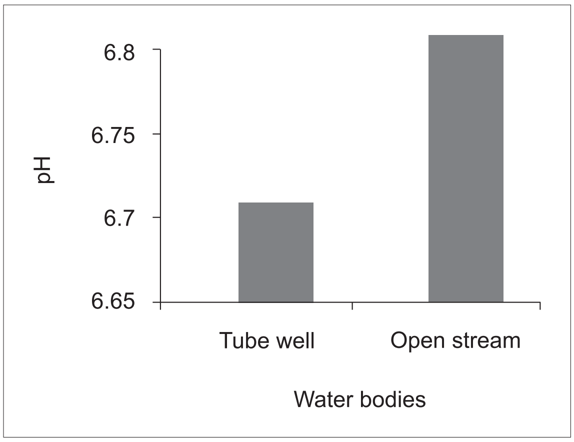

Fig. 2. pH values of water samples

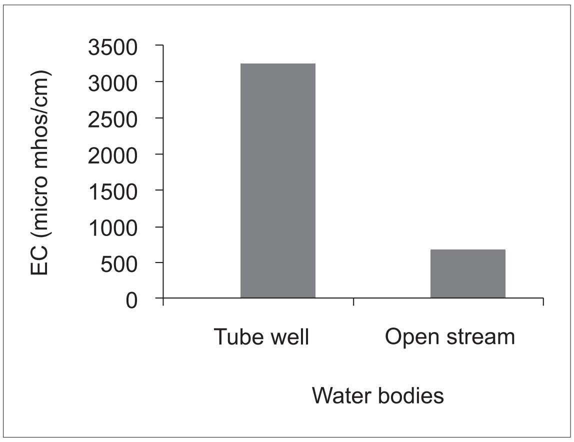

Fig. 3. EC values of water samples

Hardness: Hardness in water is a concentration of multivalent cations. These cations include Ca^{2+} and Mg^{2+}. These ions enter a water supply by leaching from minerals within an aquifer. The calcium and magnesium hardness is the concentration of calcium and magnesium ions expressed as equivalent of calcium carbonate. There are two types of water hardness one of the temporary and next is permanent hardness. The total hardness was found to be 598 ppm and 192 ppm in the water sample of tube well and open stream water, respectively (Fig. 4). The results indicated that the open stream water comes under desirable limit and tube well water crossed the desirable limit but showed under the permissible limit as per IS: 10500. Hard water affects cleaning ability of soap. When hard water is used for washing, large amount of soap is consumed. Hard water can cause scaling inside the pipes. Hard water when used for drinking for long period can lead to stomach disorders. Especially hard water contains magnesium sulphate can weaken the stomach permanently.

Calcium: Calcium and magnesium are directly related to hardness. The calcium was found to be

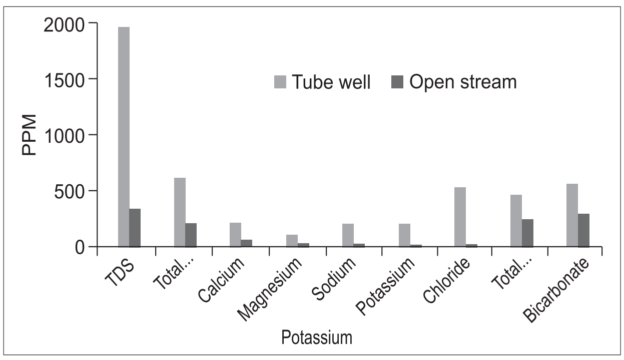

Fig. 4. Variation of different parameter value of water samples

218.01ppm and 44.88 ppm of the water sample of tube well and open stream water, respectively (Fig. 4). As per IS: 10500 results indicated that the open stream water comes under desirable limit and tube well water crossed the desirable limit but showed under the permissible limit.

Magnesium: Magnesium is often associated with calcium in all kinds of water, but its concentration remains generally lower than the calcium. Magnesium is essential for chlorophyll growth and acts as a limiting factor for the growth of phytoplankton (Dagaonkar and Saksena, 1992). The value of magnesium was found to be low 19.39 ppm of the open stream water which indicated that under the desirable limit. The water sample of tube well was found to be 112.5 ppm (Fig. 4) which indicated that crossed the desirable limit but showed under the permissible limit as per IS: 10500.

Sodium: Sodium concentration was recorded as 187.2 ppm and 15.4 ppm in the water sample of tube well and open stream water. As per IS: 10500 results indicated that the open stream water comes under desirable limit and tube well water crossed the desirable limit but showed under the permissible limit.

Potassium: The value of potassium 64.2 ppm and 2.8 ppm was recorded in the water sample of tube well and open stream water, respectively. The sample of tube well showed higher potassium values than the open stream water.

Chloride: Chlorides may get into surface water from several sources such as rocks agricultural runoff, wastewater from industries, oil well wastes, effluent wastewater from wastewater treatment plants, and road salting etc. Excess of chloride in inland water is usually taken as index of pollution. The salts of sodium, potassium and calcium contribute chlorides in water. Large contents of chloride in freshwater is an indicator of pollution (Venkatasubramani and Meenamba, 2007). Chloride plays a very important role in the water quality determination. The chloride concentration was found to be 510.48 ppm and 19.85 ppm in the water sample of tube well and open stream, respectively. The sample of open stream water shows under desirable limit whereas tube well crossed desirable limit but showed under the permissible limit as per IS: 10500.

Alkalinity: The Alkalinity refers to the capability of water to neutralize the acid. Alkali substances in water include hydroxides or bases. They can be detected by their acid taste. Alkalinity of water may be due to the presence of one or more number of hydroxides, carbonates and bicarbonates ions. Total alkalinity of 448 ppm and 228 ppm has been recorded in the water sample of tube well and open stream water, respectively. The sample of open stream water shows under desirable limit whereas tube well crossed desirable limit but showed under the permissible limit as per IS: 10500.

Bicarbonate: The value of Bicarbonate concentration of 546.56 ppm and 278.16 ppm was found in the water sample of tube well and open stream water, respectively. The sample of open stream water shows the lower value of bicarbonate than the tube well.

Salinity Hazard: Electrical conductivity (EC) is the most important parameter in determining the suitability of water for irrigation use and it is a good measurement of salinity hazard to crop as it reflects the TDS in water. The effect of salts on crop growth is largely of osmotic in nature. The osmotic potential of the soil-water solution at root zone relates directly to the electrical conductivity of irrigation water. Saline soils are the soil with high level of total salinity. The most important negative effect on the environment caused by agricultural wastewater is the increases in soil salinity, which if not controlled, can decrease productivity in long Term (Oster *et al.*, 1994). The salinity of water is mainly measured by the electric conductivity or total dissolved solids. In the present study tube well water was showed bad and open stream showed good for irrigation as per IS: 10500.

Sodium Hazard: Sodium is an important factor for irrigation water quality evaluation. Excess of sodium in water shows it unsuitable for irrigation on soil containing exchangeable calcium and magnesium ions. Excessive sodium leads to development of an alkaline soil that can cause soil physical problems and reducing soil permeability (Kelley *et al.*, 1951). Hence, for the suitability for irrigation, assessment of sodium concentration is necessary. The Soluble Sodium Percentage (SSP) was estimated by using the equation suggested by (Todd, 1980):

$$SSP = (Na^{+}) \text{ X } 100 \,/\, (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}) \quad \ldots (1)$$

Where: Na^+, Ca^{2+}, K^+ and Mg^{2+} are in meq/l. The calculated values of SSP were 29.8% and 14.62% of the tube well and of open stream respectively (Fig. 5). The tube well water fall good and open stream water was excellent classes for the use of irrigation as per IS: 10500 (Table 4).

Table 4: Drinking water quality parameters of tub well and open stream water

S. No.	Parameter	Tube well	Open Stream	IS: 10500 for Drinking	
				Requirement Desirable limit	Permissible limit
1.	pH	6.7	6.8	6.5 - 8.5	8.5
2.	Electrical conductivity, micromhos cm^{-1}	3035.20	463.37	-	-
3.	TDS, ppm	1942.53	296.56	500	2000
4.	Total hardness, ppm	598.00	192	300	600
5.	Calcium hardness, ppm	545.02	112.21	-	-
6.	Calcium, ppm	198.01	44.88	75	200
7.	Magnesium, ppm	92.5	19.39	30	100
8.	Sodium, ppm	187.2	15.4	180	-
9.	Potassium, ppm	64.2	2.8	-	-
10.	Chloride, ppm	510.48	19.85	250	1000
11.	Primary alkalinity, ppm	0.0	0.0	200	-
12.	Total alkalinity, ppm	448	228	200	600
13.	Carbonate, ppm	0.0	0.0	-	-
14.	Bicarbonate, ppm	546.56	278.16	-	-

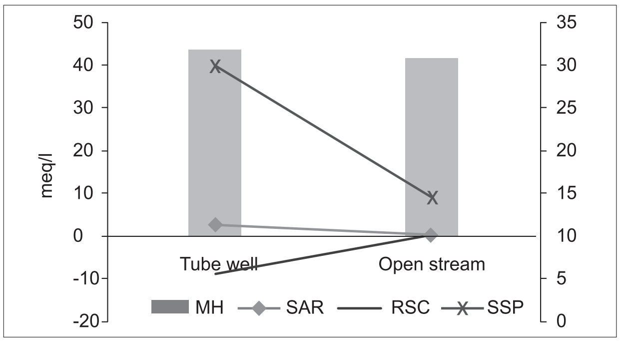

Fig. 5. Variation of different irrigation parameter of water samples

Sodium hazard is usually expressed in terms of Sodium Adsorption Ratio (SAR) and it can be calculated from the ratio of sodium to calcium and magnesium. SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard (Todd *et al.*, 1980). The use of water having a high SAR leads to a breakdown in the physical structure of the soil. SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard (Nagarajah *et al.*, 1988). The sodium adsorption ratio (SAR) was estimated by using the equation suggested by (Richards, 1954):

$$\mathrm{SAR} = \frac{\mathrm{Na}^{+}}{\sqrt{\frac{\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}}{2}}} \qquad \ldots (2)$$

where: Na^{+}, Ca^{2+} and Mg^{2+} are in meq/l. The SAR value was found to be 2.74 meq/l of tube well and 0.48 meq/l of open stream (Fig. 6). Both the samples were showing excellent class for the use of irrigation as per IS: 10500 (Table 5).

Residual Sodium Carbonate (RSC): A major factor in affecting the final SAR value of soil water is the change in calcium and magnesium concentration due to precipitation or dissolution of alkaline earth carbonate. In irrigation water containing high concentration of HCO_3 ions, there is tendency for calcium and to a lesser extent, magnesium to precipitate in the form of carbonate. When total carbonate levels exceed the total amount of calcium and magnesium, the water quality may be decreased. When the excess carbonate (residual) concentration becomes too high, the carbonates combine with calcium and magnesium to form a solid material (scale) which settles out of the water. To quantify the effect an empirical parameter was devised by Eaton (1950) on the assumption that all calcium and magnesium will precipitate. The parameter is termed as Residual Sodium Carbonate. The end result is an increase in both the sodium percentage and SAR. The residual sodium carbonate (RSC) was determined by the equation using the values obtained for $CO^{2-}{}_3$, HCO_3 in me/l (Eaton, 1950):

$$\mathrm{RSC} = (\mathrm{CO}_3^{2-} + \mathrm{HCO}_3^{-}) - (\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}) \qquad \ldots (3)$$

Table 5: Irrigation water quality parameters of tub well and open stream water

S. No.	Parameters	Tube well	Open stream	IS : 10500, for Irrigation		Remark	
						Tube well	Open stream
1.	Salinity /EC (micromhos)	3035.20	463.37	< 250 250 – 750 750 – 2250 2250 – 4000 >4000	Excellent Good Medium Bad Very bad	Bad	Good
2.	Sodicity/SAR, meq/l	2.74	0.48	< 10 10 – 18 18 – 26 > 26 > 26	Excellent Good Medium Bad Very bad	Excellent	Excellent
3.	RSC, meq/l	-8.53	0.76	< 1.25 1.25 – 2.0 2.0 – 2.5 > 2.5	Excellent Good Medium Very bad	Excellent	Excellent
4.	SSP, %	29.80	14.62	< 20 20 – 40 40 – 60 60 – 80 >80	Excellent Good Medium Bad Very bad	Good	Excellent
4	Magnesium hazard, meq/l	43.51	41.51	-	-		

Where all ions are in meq/l. The RSC value < 1.25 meq/l is safe for irrigation, a value between 1.25 to 2.5 meq/l is of permissible quality and a value more than 2.5 meq/l is unsuitable for irrigation (USSL, 1954). The RSC value of tube well and open stream was found to be -8.53 meq/l and 0.76 meq/l respectively. Both the samples were showing excellent class for the use of irrigation as per IS: 10500 (Table 5).

Magnesium Hazards: The Ca^{2+} and Mg^{2+} ions are associated soil aggregation and friability, but they are also essential plant nutrients. High concentration of Ca^{2+} and Mg^{2+} ions in irrigation water can increase soil pH, resulting in reducing of the availability of phosphorous (Al-Shammiri *et al.*, 2005). When water containing Ca^{2+} and Mg^{2+} > than 10 meq/l cannot be used in agriculture (Khodapanah *et al.*, 2009). Magnesium hazards were proposed by Szabolcs and Darab (1964) for irrigation water.

$$\mathrm{MH} = \frac{\mathrm{Mg}^{2+}}{\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}} \times 100 \qquad \ldots (3)$$

Where all ionic concentrations are in meq/l. The value magnesium hazard for tube well and open stream was found to be 43.51 meq/l and 41.51 meq/l respectively. Both the samples were showing safe for the use of irrigation as suggested by Khodapanah, 2009, if the value of MH is less than 50, then the water is safe and suitable for irrigation.

CONCLUSIONS

Storage capacity, 4937000 m^3 water was found in all the ponds of the watershed. This quantity of water is not sufficient for assured irrigation in the watershed but sufficient for supplemental irrigation and protected irrigation. The ponds also meet out the domestic requirement in summer. Different physico-chemical properties of drinking and irrigation water were compared with the water quality standards set for drinking and irrigation. As per the standard specifications both source of water viz. the open stream water and tube well water is found to be slightly acidic nature and suitable for Domestic and Irrigation purpose.

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Status of macro nutrients in soils from Lohara tahsil of Osmanabad district (Maharashtra)

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ABSTRACT

The present investigation was undertaken during 2011 to study the status of available macro nutrients in soils of Lohara tahsil during the year 2011-2012. For this purpose, 180 representative soil samples were collected from 30 different villages of Lohara tahsil. Out of the total surveyed soil samples 37, 40 and 23 per cent soil samples were grouped under the order Vertisol ,Inceptisol and Entisol, respectively and order wise analysis was carried out. These soil samples were analyzed for available N, P and K. According to nutrient index value the soils of Lohara tahsil were low in available N, P, and S while high with respect to available K and exchangeable Ca^{++}, Mg^{++}, of these soils.

Key words: Available N, P, K, S, exchangeable Ca^{++}, Mg^{++} in vertisols, inceptisols, entisols

INTRODUCTION

Nitrogen (N), Phosphorus (P) and Potassium (K) are the major nutrients in crop production. N is required for chlorophyll and protein synthesis. P plays an important role in energy storage and increasing root growth. K is important catalyst in activating the plant enzymes. An attempt has been made during present investigation. To estimate quantities of available nutrient in soils of Lohara tahsil of Osmanabad district.

MATERIAL AND METHODS

The present investigation was undertaken during the year 2011-2012. Thirty (30) villages from Lohara tahsil were selected by grid survey method and from each village six surface (0-20 cm) depth of soil samples were collected and analyzed for standard procedures as outlined by Jackson (1973). The dominant crop history of the agriculturally cultivated land in Lohara tahsil genrrally cultivated jawar, red gram, soybean in Kharif season. Green gram, black gram, bengal gram in rabbi season in summer season oilseed crop cultivated groundnut, safflower. Annual rainfall of Lohara tahsil is 799 mm. The minimum and maximum temperature of this tahsil is 19.1 ^{0}C and 39.7 ^{0} C, respectively. Analysed available N (Subbiah and Asija, 1956), Phosphorus (Olsen *et al.*, 1954), Potassium (Jackson, 1973) and Sulphur (Williams and Steinberg's, 1969). Exchangeable Ca $^{2+}$and Mg $^{2+}$ were determine by Jackson, (1973) were followed for the analysis of the soil samples. Nutrient index was calculated as per the formula suggested by Ramamoorthy and Bajaj (1969) and the values were classified as low, medium and high as <1.67, 1.67-2.33, and >2.33, respectively.

$$\text{NIV} = \frac{\text{No. of samples Low} \times \mathbf{1} + \text{No. of samples Medium} \times \mathbf{2} + \text{No. of samples High} \times \mathbf{3}}{\text{Total number of samples}}$$

RESULTS AND DISCUSSION

Available Primary (Macro) Nutrients in Soils

The data regarding available N, P and K are presented in Tables 1 and 2. The data revealed that the available N content in soils of Lohara tahsil were low. Fig. 1 depict that among the soil orders of Lohara tahsil more numbers of soil samples (79 per cent) from Vertisol were low in available nitrogen as compared to Inceptisol and Entisol. The results are in confirmatory with the results reported by Malewar *et al.* (1998). They reported that the available nitrogen content in soils of semi-arid area

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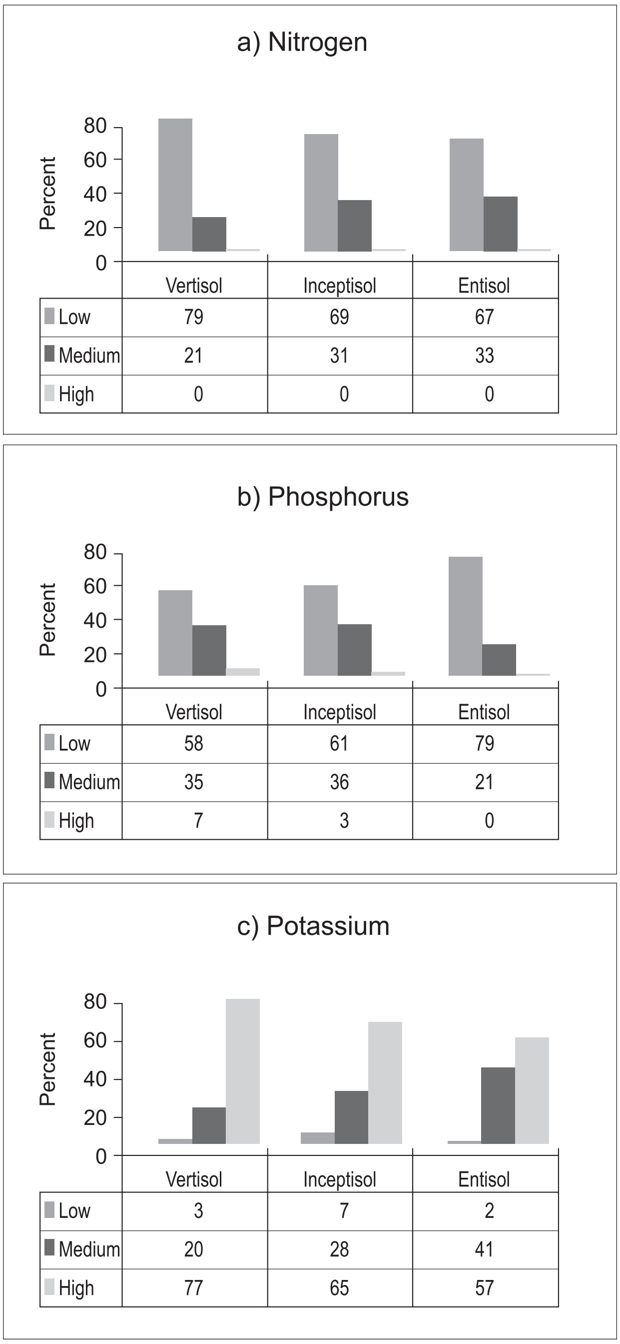


Fig. 1. Order wise characterization of soils according to available N, P and K in Lohara Tahsil of Osmanabad district

of Northan Marathwada were low to medium which ranges between 78.42 to 266.96 kg ha^{-1}. This could be attributed to leaching and volatilization losses of N. Indiscriminate use of irrigation water decline available N content (Malewar, 1995).

The available P in Vertisols, Inceptisols and Entisols ranged from 1.16 to 64.42, 0.90 to 60.75 and 1.25 to 48.65 kg ha^{1} with an average of 32.79, 30.82 and 17.32kg ha^{-1}, respectively. Hence the soils from Lohara tahsil were low to medium in available phosphorus. The Low P content was due to high $CaCO_3$ and alkaline pH. Similar results were also recorded in Marathwada region which ranged from 10.0 to 19.1 kg ha^{-1} available P reported by Waikar *et al.* (2004).

The data presented in table 1 and 2 revealed that the soils of Lohara tahsil were high in available K. The available K content in Vertisols, Inceptisols and Entisols were ranged from 136.98 to 776.16, 106.85 to 775.94 and 135.52 to 703.36 kg ha^{-1} with mean value of 492.34, 427.80 and 393.02 kg ha^{-1}, respectively. Among the soil orders, Vertisols recorded more number of soil samples (77 per cent) high in available K as compaired to Inceptisol and Entisol (Table 2 and Fig. 1). High amount of available potassium in soil probably because of higher potassium bearing mineral like feldspar and mica in the parent material similar trend was recorded by Hundal *et al.* (2006).

Status of exchangeable Ca^{++}, Mg^{++} and available S in soils of Lohara tahsil

The data in Tables 3 and 4 indicated that the dominance of exch. Ca^{++} and Mg^{++} in soils. It was observed that (Table 4) all the soil samples from Vertisols and Inceptisols were high in exch. Ca^{++}. But in Entisols (86 per cent) soils were high and remaining (14 per cent) were medium in exchangeable Ca^{++}. With respective to exchangeable Mg^{++} 95, 100 and 83 per cent soils from Vertisols, Inceptisols and Entisols were in high category. Higher exchangeable Ca^{++} and Mg^{++} are attributed to homogeneous parent material. High base saturation was due to presence of base contributing

Table 1. Available N, P, K in soils of Lohara tahsil

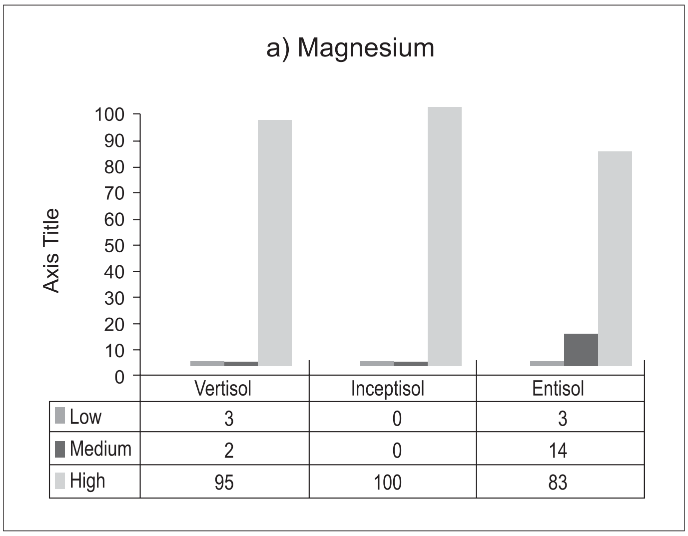
Soil order	No. of samples	Available N (kg ha^{-1}) Range & average	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Vertisols	66	103.49 -439.04	1.16-64.42	136.98 - 776.16
		223.94	32.79	492.34
Inceptisols	72	141.12 - 442.18	0.90 - 60.75	106.85-775.94
		259.81	30.82	427.80
Entisols	42	166.21-385.73	1.25-48.65	135.52-703.36
		260.96	17.32	393.02

Table 2. Order wise categorization of soils from Lohara tahsil on the basis of available N, P and K content.

Parameter		Soil orders								
		Vertisols			Inceptisols			Entisols		
Available N (kg ha^{-1})	Category	Low (< 280)	Medium (280-500)	High (> 500)	Low (< 280)	Medium (280-500)	High (> 500)	Low (< 280)	Medium (280-500)	High (> 500)
	%	79	21	0	69	31	0	67	33	0
	No. of Samples	52	14	0	50	22	0	28	14	0
Available P_2O_5 (kg ha^{-1})	Category	Low (< 22)	Medium (22-56)	High (> 56)	Low (< 22)	Medium (22-56)	High (> 56)	Low (< 22)	Medium (22-56)	High (> 56)
	%	58	35	7	61	36	3	79	21	0
	No. of Samples	38	23	5	44	26	2	33	9	0
Available K_2O (kg ha^{-1})	Category (< 141)	Low (141-336)	Medium (> 336)	High (< 141)	Low (141-336)	Medium (> 336)	High (< 141)	Low (141-336)	Medium (> 336)	High
	%	3	20	77	7	28	65	2	41	57
	No. of Samples	2	13	51	5	20	47	1	17	24

Table 3. Exchangeable Ca, Mg and Available S in Soils of Lohara tahsil

Soil order	No. of samples		Exchangeable Ca (cmol (P$^+$) kg^{-1})	Exchangeable Mg (cmol (P$^+$) kg^{-1})	Available S (mg kg^{-1})
Vertisols	66	Range	19 -58	1.01 to 49.00	1.50 - 51.25
		Mean	35.86	18.39	9.96
Inceptisols	72	Range	15 - 58	1.00 to 50.00	1.25- 57.75
		Mean	36.50	17.02	11.00
Entisols	42	Range	10- 58	5.00- 48.00	1.75- 49.00
		Mean	33.80	17.89	10.34



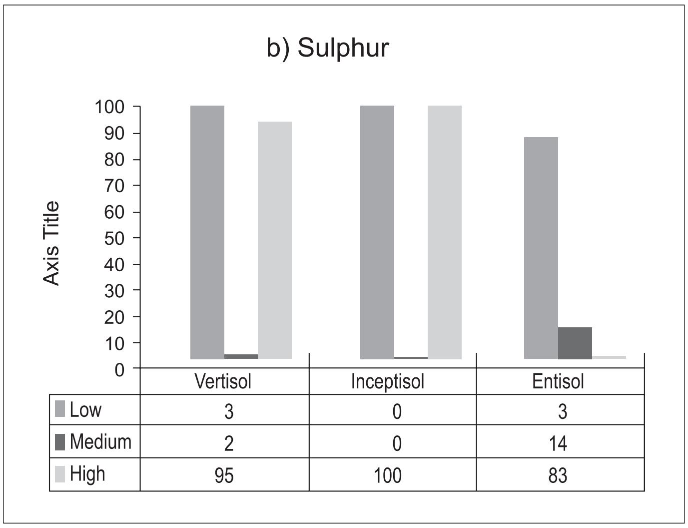


Fig. 2 Order wise characterization of soils according to exchangeable Mg^{++} and available S.

Table 4. Order wise categorization of soils according to exchangeable Ca^{++}, Mg^{++} and available S.

Parameter		Soil orders								
		Vertisols			Inceptisols			Entisols		
Exchangeable Ca^{++} (cmol (P^{+}) kg^{-1})	Category	Low (< 2)	Medium (2- 10)	High (> 10)	Low (< 2)	Medium (2- 10)	High (> 10)	Low (< 2)	Medium (2- 10)	High (> 10)
	%	0	0	100	0	0	100	0	14	86
	No. of Samples	0	0	66	0	0	72	0	6	36
Exchangeable Mg^{++} (cmol (P^{+}) kg^{-1})	Category	Low (< 1)	Medium (1-4)	High (> 4)	Low (< 1)	Medium (1-4)	High (> 4)	Low (< 1)	Medium (1-4)	High (> 4)
	%	3	2	95	0	0	100	3	14	83
	No. Samples	2	1	63	0	0	72	1	6	35
Available S(mg kg^{-1})	Category	Low (< 10)	Medium (10-20)	High (> 20)	Low (< 10)	Medium (10-20)	High (> 20)	Low (< 10)	Medium (10-20)	High (> 20)
	%	100	0	0	100	0	0	86	14	0
	No. Samples	66	0	0	72	0	0	36	6	0

minerals such as Zeolite in these black soils (Bhattacharyya *et al.*, 1993).

The available sulphur in Vertisols, Inceptisols and Entisols were ranged from 1.50 to 51.25, 1.25 to 57.75 and 1.75 to 49.00 mg kg^{-1} with a mean value 9.96, 11.00 and 10.34 mg kg^{-1}, respectively. Among Entisols recorded 14 per cent samples in medium category and remaining 86 per cent in low category (Fig. 2b). All the samples (100 per cent) from Vertisols and Inceptisols were low in available sulphur (Table 4). The available sulphur was low in most of the soils from all the soil order; it might be due to continuous removal of sulphur by crop in intensive cropping system.

CONCLUSION

On the basis of colour, depth and texture, soils are classified into Vertisol, Inceptisol and Entisol orders. The pH of the soils from Lohara tahsil was alkaline in nature. EC of the soils was in safe limit for the crop growth. The organic carbon status was low with calcareous nature. In respect of fertility status, low in available N, P and S while high in K. The exchangeable Ca^{++} and Mg^{++} were in sufficient category.

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Effect of drip fertigation on soil moisture use dynamics, nutrient uptake and productivity of Ashwagandha (*Withania somnifera* L.)

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ABSTRACT

An experiment was conducted for two years during *rabi* seasons of 2005-06 and 2006-07 to study the effect of fertigation on yield parameters and economic benefits of Ashwagandha. The treatments consist of three irrigation regimes (I_1- Drip irrigation at 100% PE, I_2- at 80% PE and I_3-60% PE) and three fertility levels(F_1 -100%, F_2 – 75% and F_3 - 50% of recommended dose of N,P,K) with a control having surface irrigation and soil application of fertilizer @30-20-20 kg N, P_2O_5 and K_2O ha^{-1}. The experimental soil was acidic in reaction and sandy loam in texture. Irrigating the crop at 80% PE with 100% recommended dose of fertilizer (RDF) produced the maximum root yield in comparison to other treatment combinations. Drip irrigation produced more root (795 kg ha^{-1}) and seed (78 kg ha^{-1}) yields. NPK uptake increased with an increase in the level of fertilizer. Application of irrigation at 80 % PE helped to absorb maximum amount of 43.41 kg N, 7.57 kg P and 31.95 kg K. Actual soil moisture content was comparatively higher in 100 % PE than 80% PE and 60%PE.

Key words: Fertigation, root yield, Ashwagandha, nutrient uptake, moisture use dynamics, post harvested soil

INTRODUCTION

Ashwagandha (*Withania somnifera* L., Dunal) is known as Indian ginseng and an important medicinal plant, the roots of which have been used in Indian traditional systems of medicine, Ayurveda and Unani. It is native to the drier parts of India and cultivated in more than 4000 hectares (Singh *et al.,* 2003). While the annual demand increased from 7.028 tons (2001-02) to 9,127 tons (2004-05), it is necessary to depend upon fertigation for saving of fertilizer and obtaining higher production (Kubsad *et al*., 2009). As a root crop, it is very sensitive to nutrient and moisture stress. But the farmers raise this crop under conventional system of cultivation without giving much importance to its nutrient and water requirement. The productivity is low due to abiotic stresses as it is grown in marginal land. The yield can be increased many fold when grown under optimal conditions. Under drip fertigation system, Ashwagandha could give high root and seed yield and net returns (Behera *et al*., 2012)**.** Considering the medicinal value of the crop and meager scientific information on its cultivation, the present investigation was undertaken to study the soil moisture use dynamics, nutrient uptake and productivity with resource conservation technology like fertigation.

MATERIALS AND METHODS

The experiment was conducted at the Directorate of Water Management, Bhubaneswar, Odisha during the *rabi* (winter) seasons of 2005-06 and 2006-07 to assess the performance of Ashwagandha grown in rice fallow under different irrigation and fertility levels through drip system. The experiment was laid out in Factorial Randomized Block Design with three replications. The treatments comprised three irrigation regimes (I_1- drip irrigation at 100% PE, I_2 at 80% PE and I_3 at 60% PE) and three fertility levels of (F_1 -100%, F_2 – 75% and F_3 - 50% recommended dose (RD) of

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NPK) with an extra (control) treatment having surface irrigation and soil application of fertilizer. The soil was sandy clay in texture with pH 5.7, low in organic carbon (0.46%) and nitrogen (159 kg ha^{-1}); medium in available phosphorus (21 kg ha^{-1}) and potassium (183 kg ha^{-1}) in the plough layer (0-15 cm). The variety Jawahar- 20 was sown at a spacing of 30 cm x 10 cm with the recommended dose (RD) of fertilizer (30-20-20 kg N-P_2O_5-K_2O ha^{-1}). Different irrigation levels were imposed on the basis of pan evaporation through meteorological approach (Jenson *et al.*, 1961). The field was irrigated one day prior to planting. The depth of water during each irrigation was maintained at 6 cm in case of surface irrigation at 60 mm Cumulative Pan Evaporation (PE). The total rainfall received during the cropping seasons were 60 mm and 80 mm in 17 and 6 rainy days during 2005-06 and 2006-07 respectively. A Estimation of nutrient uptake and post harvest nutrient status was donee by standard methods.

RESULTS AND DISCUSSION

Root and seed yield

Root yield was significantly influenced by the irrigation method, level of irrigation and fertility (Table 1). Drip irrigation recorded maximum root yield (705 kg ha^{-1}) and seed yield (73 kg ha^{-1}), which was 8.8% and 9 % more than that of surface irrigation method (Table 1). It was mainly due to application of low volume of water with high frequency in case of drip irrigation, which maintained an optimum, level of soil moisture in the crop root zone. Chawla and Narda (2001) made similar observations with 40% increase in yield. Irrigating the crop at 80% PE increased the root yield from 9.4% to 34.1% and seed yield from 3% to 20% over 80% PE and 60% PE (Table 1). High leaf area index resulting in active physiological process which enhanced the root and seed yield as reported Sastry *et al*. (1980). Application of full dose of fertilizer (100% RD) produced maximum root yield (745 kg ha^{-1}), which was 4.9% and 12.9% more than that of 75 % RD (710 kg ha^{-1}) and 50% RD (660 kg ha^{-1}) (Table 1). Application of 100% RD of fertilizer enhanced the plant growth attributes due to better availability of nutrient in a balanced manner (Jayalakshmi, 2003; Prabakaran, 2005). Maximum seed yield (76 kg ha^{-1}) obtained through application of 100% RD. Kubsud *et al*. (2009) observed an increase in seed yield with an increase in fertilizer levels. The interaction effect of irrigation and fertility levels was significant for root

Table 1. Effect of irrigation and fertility on root and seed yield (kg ha^{-1})

Treatment	Root			Seed		
	2006	2007	Mean	2006	2007	Mean
Method of Irrigation						
Control	705	591	648	67	66	67
DF	735	675	705	71	75	73
SE(m)±	2.06	6.35	3.34	0.20	0.43	0.26
CD (0.05)	6.12	19.00	9.93	0.61	1.28	0.79
Irrigation (I)						
I_1 = 100 % PE	739	714	727	72	79	76
I_2 = 80 % PE	837	753	795	75	81	78
I_3 = 60 % PE	629	557	593	66	64	65
SE (m)±	3.57	10.99	5.79	0.36	0.75	0.46
CD (0.05)	10.70	32.65	17.19	1.06	2.22	1.37
Fertility (F)						
F_1 = 100 % RD	770	719	745	71	80	75
F_2 = 75 % RD	756	663	710	72	76	74
F_3 = 50 % RD	678	642	660	69	69	69
SE (m)±	3.57	10.99	5.79	0.36	0.75	0.46
CD (0.05)	10.50	32.65	17.19	1.06	2.22	1.37
Interaction (IxF)						
SE (m)±	6.18	19.03	10.02	0.62	1.30	0.80
CD (0.05)	18.50	57.5	29.78	1.83	NS	2.38
CV (%)	13.16	4.95	2.53	1.52	3.04	1.93

PE: pan evaporation; RD: recommended dose; NS: non-significant

Table 2. Interactive effect of irrigation and fertility on mean root yield (kg ha^{-1})

Irrigation	Fertility level			
	F_1 (100% RDF)	F_2 (75% RDF)	F_3 (50% RDF)	Mean
I_1 (100%PE)	759.6	718.8	707.1	728.5
I_2 (80%PE)	862.1	809.0	716.7	795.9
I_3 (60%PE)	657.9	567.4	541.3	588.9
Mean	759.9	698.4	655.0	
SE(m) =10.02, CD(P=0.05) = 29.78				

Table 3. Interactive effect of irrigation and fertility on mean seed yield (kg ha^{-1})

Irrigation	Fertility level			
	F_1 (100% RDF)	F_2 (75% RDF)	F_3 (50% RDF)	Mean
I_1	78.39	76.79	71.12	76
I_2	82.34	79.98	75.82	78
I_3	64.96	68.23	60.56	65
Mean	75	74	69	
SE(m) =0.80,CD(P=0.05) = 2.38				

and seed yield. Irrigation at 80% PE and 100% RD produced highest root yield (862 kg ha^{-}1) and seed yield (82 kg ha^{-1}).

Nutrient uptake

Drip irrigation increased the mean nitrogen (N) uptake by 8.9%, Phosphorus (P) by 11.6 % and potash (K) by 16.3 %. (Table 4). Increased nutrient availability and higher uptake of nutrients by fertigated crop enhanced the physiological activity resulting in better growth under fertigation. Cassel *et al*. (2001) reported the positive influence of fertigation on growth parameters as compared to soil application of fertilizer to sugar beet. Among drip irrigation, the highest amount of N (43.41 kg ha^{-1}) , P (7.57 kg $ha^{-1)}$ and K 31.95 kg ha^{-1}) was taken up by the crop receiving irrigation at 80% PE. Maximum amount of N (43.42 kg ha^{-1}) was absorbed with application of full dose of fertilizer (100% RD) followed by 75% (42.77 kg ha^{-1}). Application of full dose of fertilizer (100% RD) absorbed highest amount of P (7.45 kg ha^{-1}), which decreased by 3.6% in case of 75% RD and 5.8% in case of 50 % RD. Full dose of fertilizer helped the crop to absorb maximum amount of K (31.66 kg ha^{-1}) as compared to 75% RD and 50% RD. Reduction in fertilizer dose decreased the K uptake by 3.5% in case of 75% RD and 8.5% in case of 50%

Table 4. Effect of irrigation and fertility on N, P and K uptake (kg ha^{-1}) by Ashwagandha

Treatment	N			P			K		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
Method of Irrigation									
Control	39.00	39.43	39.22	6.37	6.55	6.46	29.73	30.64	30.18
DF	42.33	43.13	42.73	6.85	7.58	7.21	34.83	35.73	35.28
SE(m)±	0.04	0.09	0.06	0.02	0.05	0.03	0.60	0.67	0.63
CD (0.05)	0.13	0.29	0.18	0.07	0.14	0.10	1.79	1.99	1.88
Irrigation (I)									
I_1 = 100 % PE	42.24	43.40	42.82	6.78	7.47	7.12	29.52	29.94	29.73
I_2 = 80 % PE	43.14	43.67	43.41	7.19	7.96	7.57	31.21	32.69	31.95
I_3 = 60 % PE	41.59	42.34	41.96	6.58	7.32	6.95	28.46	29.28	28.87
SE (m)±	0.08	0.17	0.10	0.04	0.08	0.06	1.05	1.16	1.09
CD (0.05)	0.23	0.50	0.31	0.13	0.25	0.17	NS	NS	NS
Fertility (F)									
F_1 = 100 % RD	43.00	43.84	43.42	7.01	7.89	7.45	31.06	32.26	31.66
F_2 = 75 % RD	42.33	43.20	42.77	6.81	7.54	7.18	29.39	30.44	29.92
F_3 = 50 % RD	41.64	42.36	42.00	6.72	7.31	7.02	28.74	29.21	28.98
SE (m)±	0.08	0.17	0.10	0.04	0.08	0.06	1.05	1.16	1.09
CD (0.05)	0.23	0.50	0.31	0.13	0.25	0.17	NS	NS	NS
Interaction (IXF)									
SE (m)±	0.14	0.29	0.18	0.07	0.14	0.10	1.81	2.01	1.89
CD (0.05)	0.41	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	0.56	1.18	0.75	1.87	3.35	2.39	10.40	11.19	10.69

NS= Not significant

RD. The gradual increase in levels of N had a positive impact on biomass production. Similar results were reported by Pawar (2000) and Panchabhai *et al*. (2006). The interaction effect of irrigation and NPK was not significant except that of I X N in 2006 (Table 4).

Nutrient availability in post harvested soil

The available N,P and K contents were affected significantly due to effect of irrigation and fertility levels (Table 5).

N content: The irrigation methods had significant effect on nitrogen content in soil in both the years. The maximum N content in soil was obtained under drip fertigation method (Table 5). Surface irrigation method reduced the N content by 6.7% and 5.5% in first and second year respectively due to leaching. The effect of different irrigation schedules on N content of soil was significant and maximum amount was recorded with irrigation at 60% PE. Application of 100% and 75% RD resulted in higher N content in both the years.

P content: Maximum P content was observed in drip method and the magnitude of increase was 2% and 3.2% in first and second year, respectively over surface irrigation. The maximum P content was recorded with irrigation at 60% PE (22.4 to 23.2 kg ha^{-1}) in both the years while 100% RD recorded the highest P content of 22.5 kg ha^{-1}.

K content: The method of irrigation, its level or fertility level did not affect the potassium status in the soil during 2006 but could affect during 2007 (Table 5). Application of irrigation at 60% PE resulted in highest amount of potassium (196.2 kg ha^{-1}) while that of 100% RD had also maximum potassium content (194.1 kg ha^{-1}). The interaction effect of irrigation and fertility level found to be non-significant except that of P in 2006. The higher status of NPK with irrigation at 60% PE resulted from low availability of the individual nutrients under moisture stress. Similarly, N,P,K content was maximum with full dose of fertilizer perhaps due to low exploitation of the nutrients, by the crop, existing in the soil above its requirement. Further it is observed that there was build up of N,P,K content after harvest of the crop as compared to the initial value.

Soil moisture use dynamics

Drip irrigation method

The result revealed that in case of 100% PE, actual soil moisture content was comparatively

Table 5. Effect of irrigation and fertility on available NPK (kg ha^{-1}) in post-harvest soil

Treatment	N		P		K	
Method of Irrigation	2006	2007	2006	2007	2006	2007
Control	168.8	166.8	20.6	20.9	187.7	196.8
DF	170.1	169.7	21.9	21.8	188.5	192.4
SE(m)±	0.23	0.29	0.07	0.11	3.66	0.43
CD (0.05)	0.69	0.86	0.20	0.33	NS	1.28
Irrigation (I)						
I_1 = 100 % PE	169.3	168.7	21.6	21.7	190.0	190.9
I_2 = 80 % PE	168.7	168.4	21.0	21.2	179.8	190.0
I_3 = 60 % PE	172.4	172.0	23.2	22.4	195.7	196.2
SE (m)±	0.40	0.50	0.11	0.19	6.33	0.75
CD (0.05)	1.19	1.49	0.34	0.57	NS	2.25
Fertility (F)						
F_1 = 100 % RD	171.3	171.5	22.5	22.4	192.2	194.1
F_2 = 75 % RD	170.2	169.6	21.9	21.9	190.8	192.2
F_3 = 50 % RD	168.9	167.8	21.4	21.0	182.4	190.8
SE (m)±	0.40	0.50	0.11	0.19	6.33	0.75
CD (0.05)	1.20	1.50	0.34	0.57	NS	2.25
Interaction (IxF)						
SE (m)±	0.69	0.81	0.20	0.33	0.97	1.30
CD (0.05)	NS	NS	0.587	NS	NS	NS
CV (%)	0.71	0.89	1.57	0.89	10.08	1.17

Initial content: N (159 kg ha^{-1}), P (21 kg ha^{-1}) and K (183 kg ha^{-1}), NS= Not Significant

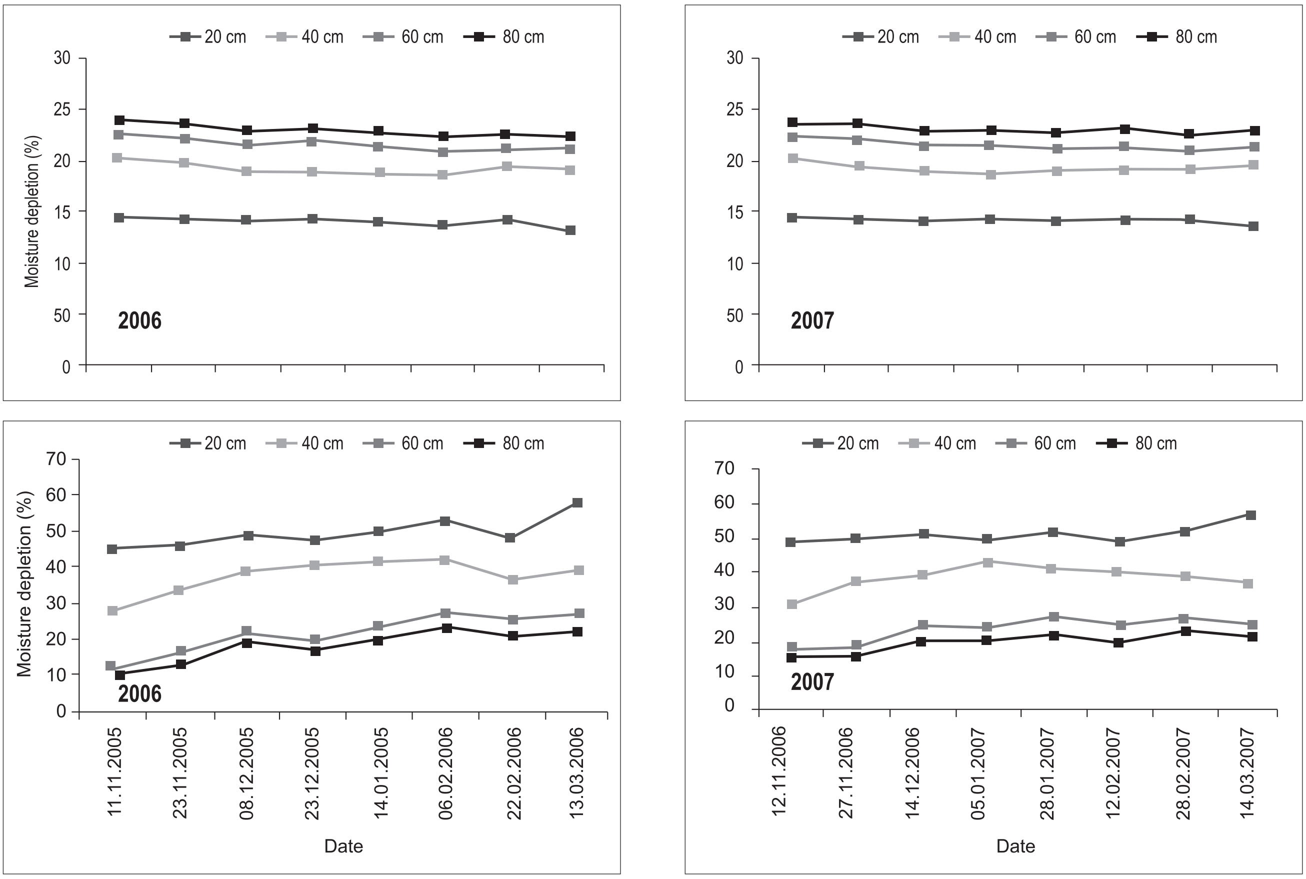

Fig. 1. Variation in soil moisture content and depletion pattern under surface irrigation at different soil depths of Ashwagandha

higher than 80% PE and 60%PE. The depletion of available soil moisture in the 100% PE was 8.9% to 20.8% in 0-20 cm depth. It was slightly low in 20-40 cm depth. Before planting and at each irrigation cycle, the redistribution of irrigation water in shallow depth resulted in more depletion of soil moisture before each irrigation. After each rainy period, when rainwater entered into the profile and redistribution was completed, the depletion of available soil moisture is very low. In case of 80 % PE and 60 % PE similar trend was observed but the depletion was slightly higher than 100 % PE. It has also been observed that during early crop growth period, depletion of available soil moisture was minimum in all the layers. But with advance in plant age, the roots penetrated into the deeper soil layers and the depletion of available soil moisture was enhanced.

Surface irrigation method

In 2006, soil moisture varied ranged from 13.1% to 14.5% in the 20 cm layer, 18.6% to 20.4% in 40 cm, 20.9% to 22.8% in 60 cm and 22.4% to 23.9% in 80 cm soil layer Fig.1. During 2007, the soil moisture content was in the similar order. Depletion of available soil moisture before each irrigation during 2006 was 45.6% to 58.4% in 20 cm, 28.0% to 42.4% in 40 cm, 11.9% to 27.9% in 60 cm and 10.7% to 23.6% in 80 cm depth. Similar trend was observed during 2007. It has been found that depletion of available soil moisture during initial crop growth stage was less than the subsequent periods due to less absorption of moisture for under developed root system. The depletion was intensified due to penetration of roots in to deeper layers with advancement of age.

CONCLUSION

Ashwagandha should be irrigated at 80% PE with full dose of fertilizer to obtain maximum root yield of 862 kg ha^{-1} and seed yield of 82 kg ha^{-1}. It can absorb 44 kg N, 7.8 kg P and 35 kg K. There is an increase in NPK status of soil after harvest of the crop. More depletion occurred from top layers with frequent irrigations at 100% PE in case of drip than surface irrigation. The depletion has been intensified due to penetration of roots in to deeper layers with advancement of age.

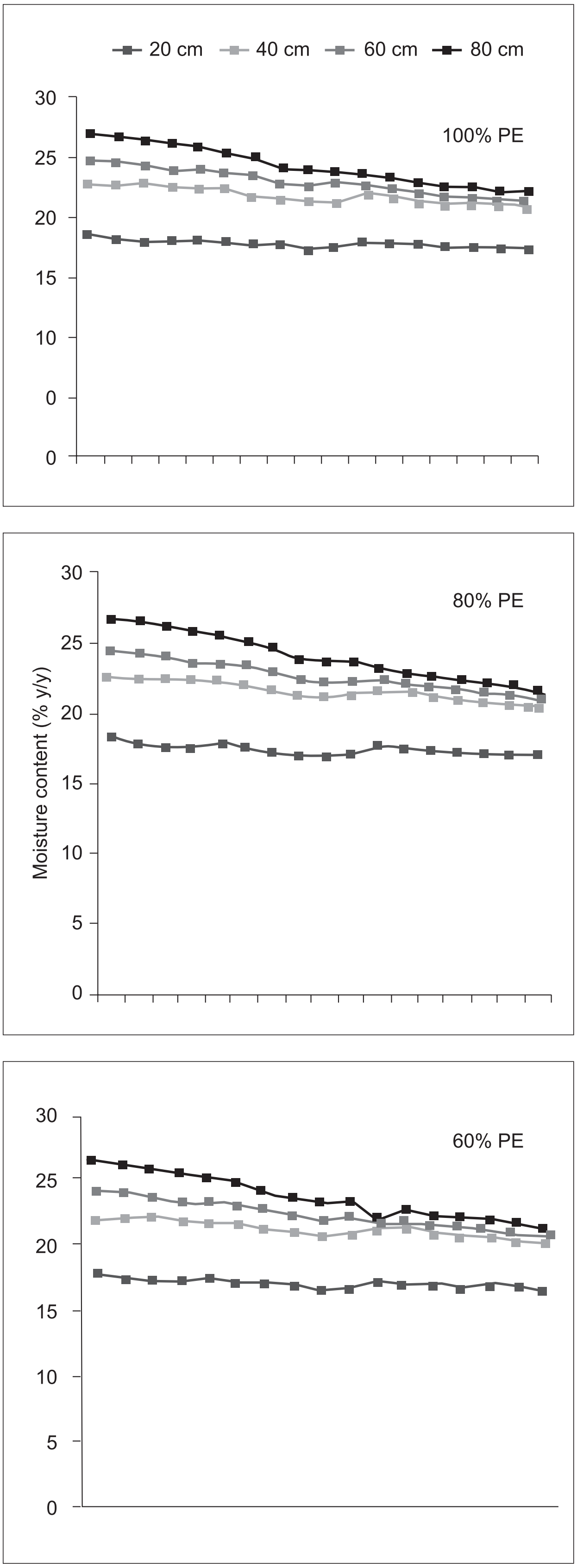

Fig 2 a. Variation in soil moisture content at different levels of irrigation and soil depth in 2006 of Ashwagandha

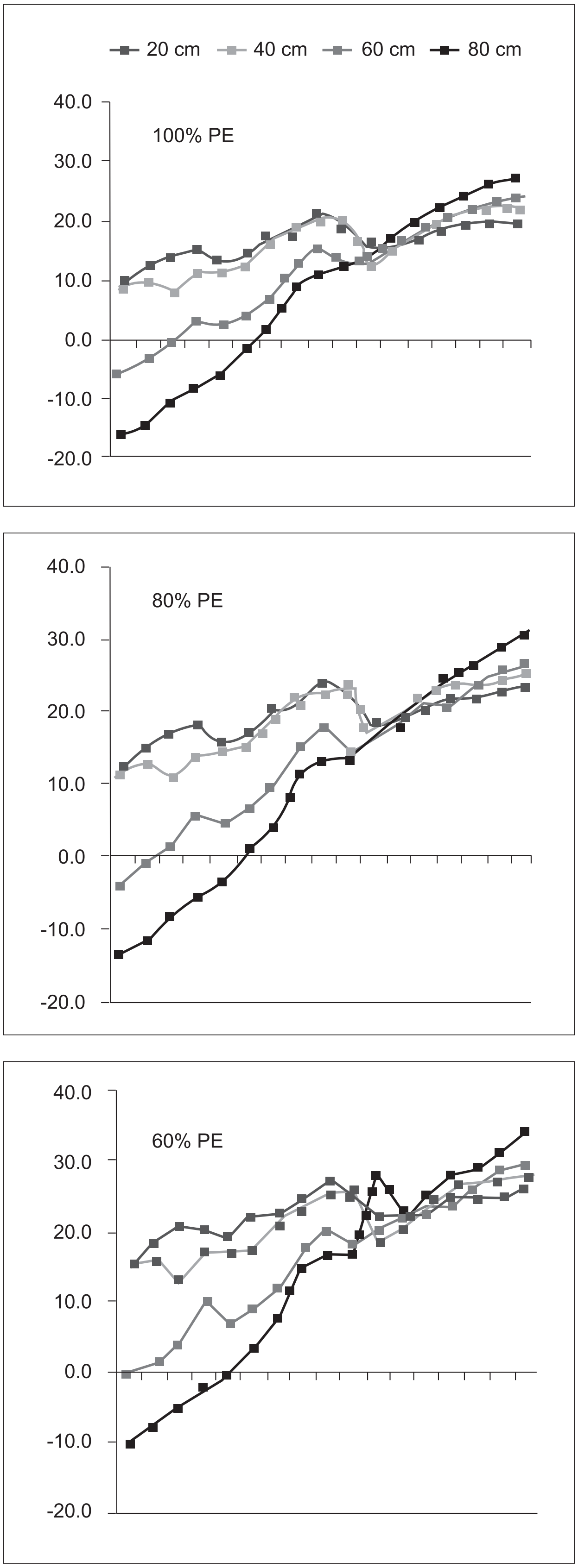

Fig 2 b. Variation in soil moisture depletion at different levels of irrigation and soil depth in 2006 of Ashwagandha.

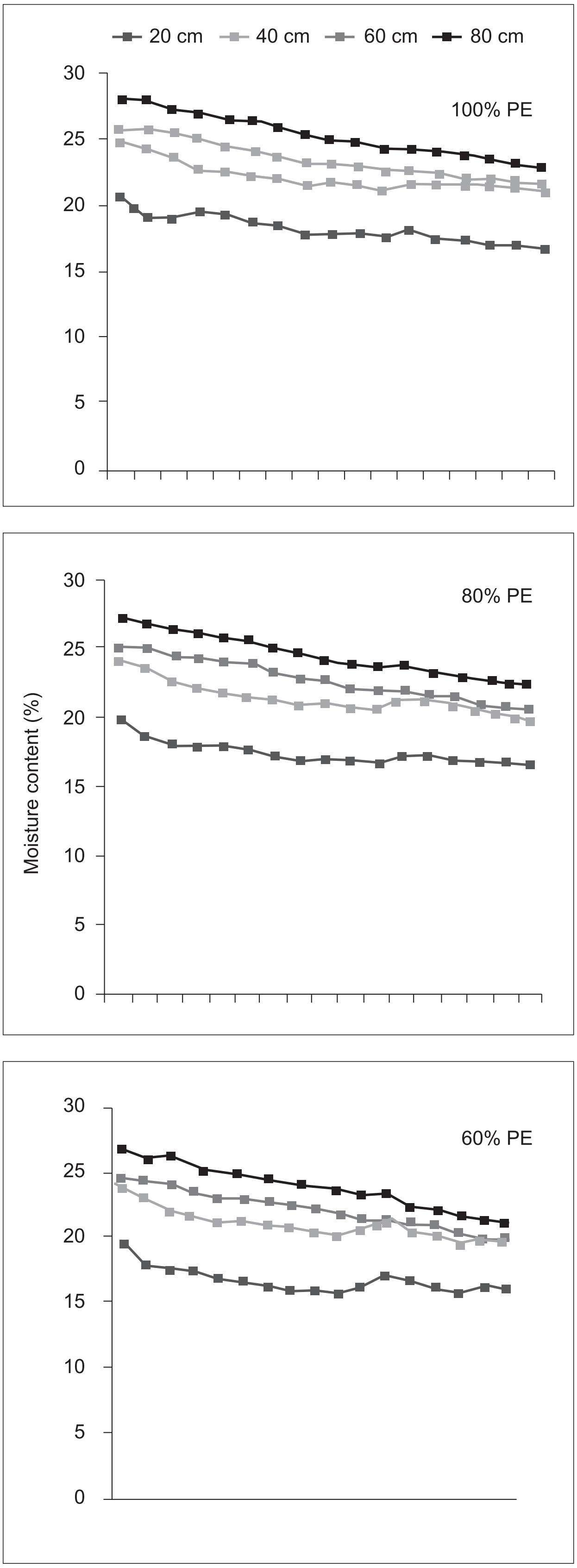

Fig 3 a. Variation in soil moisture content at different levels of irrigation and soil depth in 2007 of Ashwagandha.

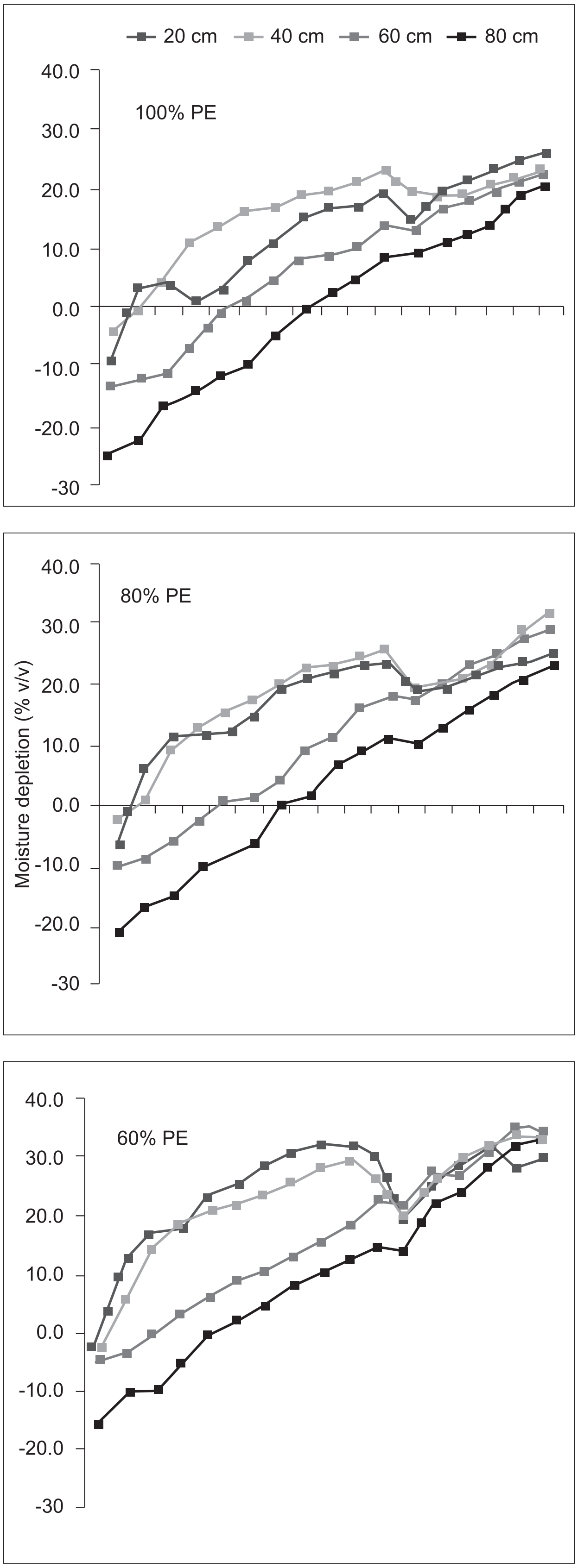

Fig 3 b. Variation in soil moisture depletion at different levels of irrigation and soil depth in 2007 of Ashwagandha

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Water economization in *rabi* maize (*Zea mays* L.) to enhance productivity through land configuration and irrigation scheduling in the Indo-Gangetic Plains of India

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ABSTRACT

A field experiment was conducted during *rabi* seasons (October-May) in the year 2010-11 and 2011-12 at research farm of the Indian Agricultural Research Institute, New Delhi to study the combined effects of land configuration and irrigation scheduling on productivity, profitability and water-use efficiency (WUE) of *rabi* maize. The treatments consisted three land configuration methods *viz.*, L_1:Flat Bed (FB); L_2: Furrow Irrigated Raised Bed (FIRB) and L_3: Ridge and Furrow (RF) were allocated in horizontal strip and six irrigation scheduling *viz.*, I_1: 60 mm Cumulative Pan Evaporation (CPE); I_2:- 80 mm CPE; I_3:- 100 mm CPE; I_4:- Seedling (Sd) + Knee high (KH) + Silking (Si) + Grain filling (GF) + Dough stage (DS); I_5:- Sd + Early knee high (EKH) + Late knee high (LKH) + Si + GF + DS and I_6:- Sd + EKH+ KH + LKH + Si + GF + DS were allocated in vertical strip under strip plot design with three replications. The results revealed that growth (plant height, dry matter accumulation and leaf area index), yield attributes (cob/plant, cob weight/plant, grains weight/cob, grains/cob, 1000 -grain weight and shelling %), yields (grain, stover & biological yields and harvest index), economics parameters (gross return, Net return and B:C ratio) were recorded significantly highest under RF followed by FIRB and least under flat bed. The consumptive use of water was highest with FB and WUE was highest with FIRB system. Among irrigation scheduling, irrigation at 60 mm CPE enabled the crop to highest values of above mentioned growth, yield and economics parameters. However, WUE was recorded highest with 80 mm CPE. Thus, technologies of establishment of *rabi* maize on RF/FIRB and irrigating at either 60 or 80 mm CPE based on availability of water can be adopted to enhance the productivity of *rabi* maize and profitability of farmers under limited availability of irrigation water.

Key words: Economics, irrigation scheduling, land configuration, *rabi* maize, productivity, water-use efficiency

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in India after rice and wheat and its grains are used for human consumption, feed for poultry and livestock, extraction of edible oil and also for starch and glucose industry. It has the highest genetic yield potential and wide adaptability making it as the miracle crop. Currently it is cultivated on 9.3 million ha with a production of 24.2 million tonnes and productivity of 2.6 t ha^{-1} (Economic survey, 2013-2014). Maize contributes ₹ 100 billion to the agriculture GDP apart from the providing employment of nearly 100 million man-days (Economic survey, 2013-2014). Presently maize is gaining more importance in India due to increasing use of maize as animal feed, interest of the consumers in nutritionally enriched products and rising demand for maize seed for industry. Maize is also playing an important role in the crop diversification policy of various states. Therefore, there is a need to explore the possibilities of increasing the productivity through better understanding of constraints in maize production. Maize is grown almost all over India under varied soil and climatic conditions. The seasonal water requirement of maize varies according to evaporative demand of the atmosphere, and hence according to climate, time of season when the crop is grown, and life cycle length of the maize cultivar. As for virtually all crops, leaf expansive growth of maize is the most sensitive for moisture stress (Bradford and Hsiao, 1982; Hsiao and Xu, 2000) a mild water stress, for longer duration leads smaller

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canopy cover during the vegetative stage. If stress is more severe, stomatal conductance also reduced, that leads senescence of older leaves. This also affects the process of transpiration and photosynthesis. As a result of the monoecious nature of maize, fairly mild to severe water stress can cause a peculiar problem of reproduction. The water stress reduced silk growth or delayed emergence of silk from the husk. This difference in delay can cause pollination failure as, by the time the silk emerges, there may not be sufficient pollen left to fully pollinate the crop (Steduto *et al.*, 2012). Like drought stress, intensity and duration of waterlogging at different growth stages may severely affect the maize development and yield. Cob characteristics (grains cob^{-1} and 1000-grain weight) and plant morphology (plant height, cob length, and leaf area index) decreased, whereas the bald tip length increased significantly. The maximum grain-filling rate decreased under waterlogging; furthermore, the dry matter accumulation decreased and dry matter distribution proportions of the stem and leaf increased (Ren *et al.*, 2014). Under these situation establishments of maize with furrow irrigated raised bed (FIRB) or ridge and furrow methods of planting may obviate the effects of water stress. Choudhary (2011) has also reported better yield performance of maize under FIRB over flat planting. Thus, relative to other crops, maize is considered to be more sensitive to drought and waterlogging. Maize does not osmotically adjust as well as cotton, sorghum or wheat to low water status, its high determinacy makes it harder to make up for the loss in productivity after the period of water stress is released by irrigation or rain.

Water is crucial input for augmenting agricultural production towards sustainability in agriculture. Scientific water management aims to provide suitable soil-moisture environment to the crop to obtain optimum yield commensurate with maximum economy in irrigation water and maintenance of soil productivity. During the winter season less water is required at early stage of crop while, at later crop growth stages water requirement increases due to rapid increase in evapo-transpiration demand. Amongst the various irrigation scheduling approaches, climatological approach has been found to be better, since it integrates all the weather parameters giving them their natural weightage in a given climate-water-plant continuum (Prihar and Sandhu, 1987). But, it is the fact that there exists a close relationship between the rate of consumptive use of crop and the rate of evaporation and hence, a more practicable and understandable approach based on the ratio of fixed amount of irrigation water (IW) to cumulative pan evaporation (CPE) is much desired. Moreover, the combined studies involving IW/CPE based irrigation scheduling and crop establishment techniques together are rarely investigated in India. Therefore, the present study was undertaken to ascertain the combined effects of land configuration techniques and IW/CPE based irrigation scheduling on productivity, profitability and water-use efficiency of *rabi* maize.

MATERIALS AND METHODS

The study was conducted during the *rabi* seasons of 2010-11 and 2011-12 at research farm of the Indian Agricultural Research Institute, New Delhi ($28^0$38′ N latitude and $77^0$11′ E, longitude and 228.6 m above mean sea level). It has semi-arid sub-tropical type of climate with dry and hot summer and cold winter. The total rainfall in the study area during the crop growing seasons of first (1November 2010 to 2 May 2011) and second (31 October 2011 to 27 April 2012) years of experimentation was 67.8 and 43 mm, respectively. The total and average evaporation during the above given periods of study were 660.3 and 708.6 mm, and 3.6 and 3.9 mm day^{-1}, respectively. Soil at the experimental field was sandy loam in texture with adequate internal drainage, low in organic carbon (0.48 %) and available N (208 kg ha^{-1}), and medium in available P (14.5 kg ha^{-1}) and available K (227 kg ha^{-1}) and neutral in reaction (7.5 pH). Average values for bulk density, volumetric moisture content at field capacity and permanent wilting point, saturated hydraulic conductivity and EC were 1.5 g cm^{-3}, 20.6 %, 6.35 %, 0.5 cm hr^{-1}, and 0.38 dS m^{-1}, respectively.

Three land configuration *viz.*, L_1 Flat bed (FB); L_2- Furrow irrigated raised bed (FIRB) and L_3- Ridge and furrow (RF) were allocated in horizontal strips and six irrigation scheduling *viz.*, I_1:-- 60 mm Cumulative pan evaporation (CPE); I_2:-- 80 mm CPE; I_3:-- 100 mm CPE; I_4:-- Seedling (Sd) + Knee high (KH) + Silking (Si) + Grain filling (GF) + Dough stage (DS); I_5:-- Sd + Early knee high (EKH) + Late knee high (LKH) + Si + GF + DS and I_6:-- Sd + EKH+ KH + LKH + Si + GF + DS were allocated in vertical strips. Experimental plots were arranged in a strip plot design with three replications. Thus in each replication there were 18 treatment combinations with in all 54 plots covering 1036.8 m^2 area.

Frequency of irrigation was the same as in each flat bed, furrow irrigated raised bed and ridge and furrow. Pre-determined quantity of water was applied in each irrigation to maintain 60 mm depth of irrigation water by using Parshall flume. The entire quantity of P (60 kg P_2O_5 ha^{-1}) and K (60 kg

K_2O ha^{-1}), and 40 kg N ha^{-1} were applied on demarcated lines in each plots before sowing. The remaining dose of N (120 kg ha^{-1}) was applied in three equal split doses at knee high, silking and dough stages. The field was prepared one week before sowing by tractor drawn cultivator. Ridges and furrows were made by the tractor drawn ridge and furrow maker at 60 cm intervals. Maize variety '*HQPM-1*' was sown on 1November, 2010 and 31 October, 2011 with 60 cm row-row and 20 cm plant-plant spacing. Each plot with 4.0 m x 4.8 m dimensions contained 8 rows, and each row had 20 plants. Each row had its own irrigation line positioned both sides of plants. CPE was worked out from the daily E_{pan} data available on IARI website. Irrigation water was applied to crop at 60, 80, 100 CPE and seedling stage, early knee high stage, knee high stage, late knee high stage, silking stage, grain filling stage and dough stage by flat bed, furrow irrigated raised bed and ridge and furrow method of irrigation in rotation according to treatment combination.

Observations on plant height, leaf area, dry matter was taken at monthly interval and at harvest. Biological yield, grain yield, straw yield was recorded at harvest. The yield was recorded from the middle four rows in each plot of the crop. The consumptive use of water for a given period was determined by adding up (i) potential evapotranspiration during the two - three days period immediately after irrigation; (ii) moisture extraction from the soil profile within the period and (iii) effective rainfall. The calculation of consumptive use of water was done as described by Dastane (1972). The WUE was calculated by dividing the grain yield with seasonal consumptive use of water. The crop was harvested manually on 2 May 2011 and 27 April 2012. The experimental data was analysed statistically by applying 'Analysis of Variance' technique for strip-plot design by using MSTAT-C (version 2.1, Michigan State University, 1991) software. The results are presented at 5 % level of significance (P=0.05).

RESULTS AND DISCUSSION

Growth parameters

The growth parameters *viz.*, plant height and dry matter accumulation at harvest and leaf area index at 150 DAS were observed to be significantly highest under ridge and furrow land configuration (Table 1). This can be ascribed to better establishment of the plants and water utilization under the fine tilth, aeration and root support provided by ridge and furrow. The similar results were also reported by Ren *et al.* (2008); Idnani and Kumar (2012) and Ahmad *et al.* (2002). Among irrigation scheduling, irrigation at 60 mm CPE recorded significantly highest values of growth parameters *viz.*, plant height, leaf area index and dry matter accumulation at harvest. The same reason could be attributed to this as well Ge, *et al.* (2012).

Table 1. Growth parameters of *rabi* maize as influenced by different land configuration and irrigation scheduling practices

Treatments	Plant height (cm)			Dry matter (g plant^{-1})			LAI at 150 DAS		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Land Configuration									
L_1	137.5	141.7	139.6	123.7	125.7	124.7	3.62	3.86	3.74
L_2	142.3	147.2	144.7	133.7	137.2	135.4	3.89	4.01	3.95
L_3	146.0	149.7	147.8	140.2	143.7	141.9	3.97	4.11	4.04
SEm±	1.48	1.46	1.36	1.04	1.24	1.03	0.04	0.04	0.03
CD (P=0.05)	5.80	5.75	5.34	4.08	4.87	4.06	0.14	0.14	0.14
Irrigation scheduling									
I_1	163.0	166.9	164.9	168.4	171.4	169.9	4.51	4.70	4.60
I_2	157.4	161.3	159.4	156.9	161.2	159.1	4.43	4.50	4.46
I_3	113.4	117.3	115.4	86.6	89.8	88.2	2.96	3.20	3.08
I_4	115.1	121.2	118.2	90.0	93.3	91.6	3.09	3.25	3.17
I_5	142.4	146.7	144.5	130.3	132.6	131.5	3.53	3.71	3.62
I_6	160.0	163.9	161.9	162.7	164.7	163.7	4.44	4.60	4.52
SEm±	2.35	3.08	2.64	1.81	1.84	0.99	0.05	0.06	0.04
CD (P=0.05)	7.40	9.70	8.32	5.69	5.80	3.11	0.17	0.17	0.14

L_1: Flat bed; L_2: Furrow irrigated raised bed; L_3: Ridge and furrow; I_1: Irrigation at 60 mm cumulative pan evaporation (CPE); I_2: Irrigation at 80 mm CPE; I_3: Irrigation at 100 mm CPE; I_4: Irrigation at seedling stage + knee high stage + silking stage + grain filling stage + dough stage; I_5: Irrigation at seedling stage +early knee high stage+ late knee high stage + silking stage + grain filling stage + dough stage; I_6: Irrigation at seedling stage + early knee high stage + knee high stage + late knee high stage + silking stage + grain filling stage + dough stage

Yield attributes

The yield attributes of maize *viz.*, cobs plant^{-1}, cob weight plant^{-1}, grains weight cob^{-1}, grains cob^{-1}, cob length, cob girth, shelling % and 1000-grain weight were recorded significantly highest in ridge and furrow method over the other land configurations (Tables 2 and 3). This might be due to higher dry matter production and translocation and the conversion of photosynthates in to reproductive parts under ridge and furrow method. Fine tilth and better aeration causing less penetration impedance was responsible for better root development (Choudhary and Behera, 2014) there by producing higher yield attributes. Similar beneficial effect of bed planting on yield attributes of wheat has been reported by Kiliç (2010). Application of irrigation at 60 mm CPE recorded significantly highest values of these yield attributes as compared to the other irrigation scheduling. The enhanced early vegetative growth in terms of higher leaf area index, dry matter accumulation and vigorous root system resulted in more number of

Table 2. Yield attributes of *rabi* maize as influenced by different land configuration and irrigation scheduling practices

Treatments	Cobs plant^{-1}			Cob weight (g plant^{-1})			Grains weight cob^{-1} (g)		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Land Configuration									
L_1	0.88	0.95	0.92	94.5	101.0	97.8	73.0	78.5	75.7
L_2	0.91	0.98	0.94	97.3	103.7	100.5	75.9	81.6	78.7
L_3	0.94	1.01	0.97	98.7	105.0	101.8	77.8	83.7	80.8
SEm±	0.01	0.01	0.01	0.46	0.71	0.57	0.44	0.58	0.47
CD (P=0.05)	0.03	0.04	0.04	1.81	2.80	2.23	1.71	2.26	1.86
Irrigation levels									
I_1	1.09	1.15	1.12	125.4	131.6	128.5	100.5	106.5	103.5
I_2	1.06	1.12	1.09	115.4	121.9	118.6	90.6	96.6	93.6
I_3	0.58	0.64	0.61	57.6	65.1	61.4	42.3	48.3	45.3
I_4	0.72	0.78	0.75	61.8	69.0	65.4	46.5	52.5	49.5
I_5	0.91	1.03	0.97	98.3	102.8	100.6	76.3	80.5	78.4
I_6	1.08	1.14	1.11	122.5	128.8	125.6	97.1	103.1	100.1
SEm±	0.01	0.01	0.01	1.22	1.50	1.20	1.01	1.06	0.92
CD (P=0.05)	0.04	0.03	0.03	3.84	4.73	3.78	3.19	3.35	2.90

Table 3. Yield attributes of *rabi* maize as influenced by different land configuration and irrigation scheduling practices

Treatments	Grains cob^{-1}			1000-grain weight (g)			Shelling (%)		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Land Configuration									
L_1	314	320	317	225.6	231.6	228.6	76.6	77.1	76.9
L_2	326	331	328	231.2	236.8	234.0	77.3	78.0	77.7
L_3	336	343	339	233.9	244.0	238.9	78.2	79.2	78.7
SEm±	3.1	3.5	3.3	1.26	1.58	1.30	0.30	0.40	0.42
CD (P=0.05)	12.1	13.8	12.9	4.95	6.21	5.10	NS	NS	NS
Irrigation levels									
I_1	402	407	405	254.6	262.2	258.4	80.1	80.9	80.5
I_2	372	378	375	234.8	245.3	240.1	78.5	79.3	78.9
I_3	223	229	226	200.6	202.3	201.5	73.3	74.1	73.7
I_4	233	239	236	213.1	218.2	215.6	75.2	76.0	75.6
I_5	331	338	335	230.5	239.2	234.9	77.6	78.3	78.0
I_6	390	396	393	247.6	257.4	252.5	79.3	80.1	79.7
SEm±	4.9	4.8	4.3	2.71	3.31	2.48	0.42	0.32	0.73
CD (P=0.05)	15.5	15.1	13.7	8.55	10.42	7.80	1.31	0.99	2.30

L_1: Flat bed; L_2: Furrow irrigated raised bed; L_3: Ridge and furrow; I_1: Irrigation at 60 mm cumulative pan evaporation (CPE); I_2: Irrigation at 80 mm CPE; I_3: Irrigation at 100 mm CPE; I_4: Irrigation at seedling stage + knee high stage + silking stage + grain filling stage + dough stage; I_5: Irrigation at seedling stage +early knee high stage+ late knee high stage + silking stage + grain filling stage + dough stage; I_6: Irrigation at seedling stage + early knee high stage + knee high stage + late knee high stage + silking stage + grain filling stage + dough stage cobs/plant which consequently increased the grain weight per plant, significantly. Stimulated vegetative growth of maize on account of adequate and prolonged supply of water in treatments manifested itself in increased values of these yield attributes. Kar and Kumar (2010) have also reported the similar cause and effect relationship in maize.

Productivity

The grain and biological yields and harvest index of maize varied significantly due to different land configurations. These were recorded significantly highest under ridge and furrow method, but remained statistically at par with FIRB method of planting (Table 4). Ridge and furrow registered on an average 10.81 % higher grain yield over flat bed. The increase in grain yield of maize under ridge and furrow could be attributed to higher yield attributes whereas, the increase in biological yield was due to higher plant height and dry matter accumulation. The higher grain and biological yields and harvest index recorded in ridge and furrow could also be attributed to better soil environment in ridge and furrow since prolonged ponding reduces yield. The higher grain yield with ridge and furrow land configuration in maize has also been reported by Thind *et al.* (2010) and Bhahma *et al.* (2007). Among different irrigation scheduling treatments, irrigation at 60 mm CPE produced significantly highest grain yield than rest of the treatments during both years with on an average yield increment of 118.5 % over the treatment receiving irrigation at 100 mm CPE. This was closely followed by the treatment receiving irrigation at seedling, early knee high, knee high, late knee high, silking, grain filling, and dough stage. The increase in yields of maize with 60 mm CPE could be attributed to better yields of growth and yield attributes. This also might be due to better crop establishment in early growth period due to optimum soil moisture level maintained under this treatment that support crop to withstand under severe cold conditions prevailed during the December and January months in North India. Root growth is reduced when seedlings are exposed to soils with low water content. This occurs as root growth is reduced directly by water deficits through its effect on cell turgor and cell division (Hsaio, 1973; Kramer, 1983).

Water use parameters

The Consumptive use of water was recorded significantly highest under flat bed than rest of the treatments, whereas lowest under FIRB system. The comparatively higher yield performance and lesser consumption of irrigation water by maize under FIRB system resulted significantly highest WUE (167.6 kg $ha^{-1}cm^{-1}$) than rest of the treatments. Furrow and ridge also registered significantly more values of WUE over flat bed (Table 5). Among irrigation scheduling, irrigation at 80 mm CPE recorded significantly highest WUE (185.6 kg $ha^{-1}cm^{-1}$) in comparison to other irrigation scheduling. This could be attributed to relatively higher economic

Table 4. Yield performances of *rabi* maize as influenced by different land configuration and irrigation scheduling practices

Treatment	Grain yield (t ha^{-1})			Stover yield (t ha^{-1})			Biological yield (t ha^{-1})			Harvest index		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Land Configuration												
L_1	4.07	4.25	4.16	6.29	6.45	6.37	10.35	10.70	10.52	38.89	39.36	39.13
L_2	4.40	4.58	4.49	6.72	6.89	6.80	11.11	11.47	11.29	39.17	39.57	39.37
L_3	4.53	4.68	4.61	6.90	7.03	6.97	11.44	11.72	11.58	39.23	39.62	39.43
SEm±	0.06	0.07	0.05	0.07	0.10	0.07	0.12	0.17	0.12	0.17	0.15	0.14
CD(P=0.05)	0.23	0.29	0.21	0.27	0.40	0.28	0.47	0.67	0.46	NS	NS	NS
Irrigation levels												
I_1	5.70	5.88	5.79	8.23	8.31	8.27	13.94	14.19	14.06	40.90	41.41	41.15
I_2	5.26	5.41	5.34	7.86	7.94	7.90	13.12	13.35	13.24	40.10	40.51	40.31
I_3	2.53	2.78	2.65	4.33	4.62	4.48	6.86	7.40	7.13	36.90	37.51	37.20
I_4	2.69	2.90	2.80	4.53	4.76	4.65	7.23	7.66	7.44	37.28	37.91	37.59
I_5	4.47	4.52	4.50	6.92	7.00	6.96	11.39	11.52	11.46	39.26	39.22	39.24
I_6	5.32	5.53	5.43	7.94	8.10	8.02	13.26	13.63	13.45	40.15	40.55	40.35
SEm±	0.07	0.08	0.06	0.15	0.09	0.10	0.22	0.15	0.15	0.22	0.16	0.15
CD(P=0.05)	0.21	0.24	0.20	0.46	0.28	0.30	0.68	0.48	0.49	0.70	0.49	0.49

L_1: Flat bed; L_2: Furrow irrigated raised bed; L_3: Ridge and furrow; I_1: Irrigation at 60 mm cumulative pan evaporation (CPE); I_2: Irrigation at 80 mm CPE; I_3: Irrigation at 100 mm CPE; I_4: Irrigation at seedling stage + knee high stage + silking stage + grain filling stage + dough stage; I_5: Irrigation at seedling stage +early knee high stage+ late knee high stage + silking stage + grain filling stage + dough stage; I_6: Irrigation at seedling stage + early knee high + knee high stage + late knee high stage + silking stage + grain filling stage + dough stage

Table 5. Consumptive use of water and water-use efficiency of *rabi* maize as influenced by different land configuration and irrigation scheduling practices

Treatment	Consumptive use ofwater (cm)			Water use efficiency(kgha^{-1}cm^{-1})		
	2010	2011	Mean	2010	2011	Mean
Land Configuration						
L_1	37.8	39.4	38.6	106.5	106.3	106.4
L_2	26.2	26.8	26.5	167.2	168.1	167.6
L_3	30.8	31.8	31.3	145.9	145.0	145.5
SEm±	0.35	0.43	0.38	2.25	1.76	1.74
CD (P=0.05)	1.38	1.68	1.48	8.82	6.89	6.81
Irrigation levels						
I_1	36.5	41.0	38.7	161.6	148.2	154.9
I_2	27.5	32.1	29.8	197.2	173.9	185.6
I_3	23.2	27.9	25.6	112.9	103.2	108.0
I_4	29.7	27.1	28.4	92.9	109.8	101.3
I_5	34.4	31.8	33.1	133.5	146.1	139.8
I_6	38.6	36.0	37.3	141.1	157.5	149.3
SEm±	0.35	0.38	0.33	2.65	2.55	2.21
CD (P=0.05)	1.11	1.21	1.04	8.34	8.04	6.96

Table 6. Economics of *rabi* maize as influenced by different land configuration and irrigation scheduling practices

Treatments	Gross Return (₹ha^{-1})			Net Return (₹ha^{-1})			Benefit: Cost Ratio		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Land Configuration									
L_1	52424	62784	57604	23635	32528	28082	0.81	1.06	0.93
L_2	56517	67576	62046	27938	37620	32779	0.96	1.24	1.10
L_3	58218	69080	63649	29159	38603	33881	0.99	1.25	1.12
SEm±	681	674	531	681	835	589	0.02	0.03	0.02
CD (P=0.05)	2675	2649	2085	2675	3279	2313	0.09	0.11	0.08
Irrigation levels									
I_1	72356	85680	79018	41868	53266	47567	1.37	1.64	1.51
I_2	67297	79422	73359	38641	48880	43760	1.35	1.60	1.47
I_3	33474	41874	37674	5734	12268	9001	0.21	0.41	0.31
I_4	35473	43628	39550	7733	14958	11345	0.28	0.52	0.40
I_5	57670	67122	62396	29014	37516	33265	1.01	1.27	1.14
I_6	68046	81157	74602	38474	50615	44545	1.30	1.66	1.48
SEm±	1005	994	787	1005	902	856	0.04	0.03	0.03
CD (P=0.05)	3167	3132	2479	3167	2843	2696	0.11	0.11	0.09

L_1: Flat bed; L_2: Furrow irrigated raised bed; L_3: Ridge and furrow; I_1: Irrigation at 60 mm cumulative pan evaporation (CPE); I_2: Irrigation at 80 mm CPE; I_3: Irrigation at 100 mm CPE; I_4: Irrigation at seedling stage + knee high stage + silking stage + grain filling stage + dough stage; I_5: Irrigation at seedling stage +early knee high stage+ late knee high stage + silking stage + grain filling stage + dough stage; I_6: Irrigation at seedling stage + early knee high stage + knee high stage + late knee high stage + silking stage + grain filling stage + dough stage

yield and lower consumptive use of water under this treatment. Similar findings were also reported earlier by different researchers (Idnani and Kumar, 2013; Mishra *et al.*, 2001; Halima and Razekb, 2014). Significantly lowest WUE was recorded under I_4 followed by I_3 treatments.

Economics

The gross as well as net returns and B:C ratio were recorded highest under ridge and furrow being at par with FIRB methods, but both were significantly higher than the flat bed (Table 6). This could be described to higher economics returns earned due to relatively higher yield performances of the crop under these treatments. In case of the irrigation scheduling, the highest gross returns, net returns and B:C ratio were recorded in irrigation at 60 mm CPE treatment which was significantly higher than rest of the treatments. The next highest values of these economics parameters were recorded under I_6 followed by I_2 treatments which were also significantly higher than the remaining treatment. Significantly lowest values of these parameters were estimated among under I_3 treatment.

CONCLUSION

The study indicated an improvement in growth parameters, yield attributes, yield and economics of maize under RF with its overall benefit as compared to other land configuration. The FIRB system found most beneficial in terms of WUE. In case of irrigation scheduling, irrigation at 60 mm CPE proved to be the most beneficial with respect to growth parameters, yield attributes, yield and economics of maize. Irrigation at 80 mm CPE resulted in highest WUE. Thus, technologies of establishment of *rabi* maize on RF/FIRB and irrigating at either 60 or 80 mm CPE based on availability of water can be adopted to enhance the productivity of *rabi* maize and profitability of farmers under limited availability of irrigation water. The present study leaves a line of future research work on land configurations and irrigation regimes so as to achieve further water economization in this hard hour when water has become very precious commodity.

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Role of irrigation scheduling, puddling intensity and source of nutrients on yield of rice (*Oryza sativa*) and its residual effect on succeeding wheat under irrigated agro-ecosystems of Jammu

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ABSTRACT

A field experiment was conducted during *kharif* 2005-06 and 2006-07 at Agronomy Research Farm, SKUAST-J, Main Campus, Chatha, Jammu to evaluate the effect of different levels of puddling intensity, irrigation scheduling and sources of nutrients on yield of rice and its residual effects on succeeding wheat crop. Puddling 3 times along with irrigation scheduled at soil matric potential (SMP) 150 cm suction coupled with application of vermicompost @ 6t ha^{-1} resulted in significant increase in paddy grain and straw yield, number of tillers per m^{-2}, grain weight panicle^{-1}, 1000-grain weight. Water expense was maximum(101.29 cm and 132.36 cm) where irrigation was applied at 2 Days after disappearance of ponded water (DADPW) during both the years, while Water Expense Efficiency (WEE) was higher (61.45 kg ha^{-1}cm^{-1}) at irrigation scheduling at SMP at 150 cm suction rather than irrigation at 2 and 4 DADPW during both the years. However, among nutrient sources application of inorganic fertilizer showed maximum water expense of 81.5cm and 118.16cm during both the years with WEE of 53.54 kg ha^{-1}cm^{-1} in first year but in 2nd year WEE was recorded higher (39.05 kg ha^{-1}cm^{-1}) in vermicompost application @ 6t ha^{-1}. Puddling 3 times in rice also showed higher WEE as compared to normal practice and 2 times puddling . Nutrient (NPK) availability to rice crop was significantly more when nutrient source like vermicompost, FYM+Inorganic applied with irrigation scheduling at SPM at 150 cm suction. However, level of puddling and irrigation schedule had no residual effect on wheat yield but the vermicompost as nutrient sources had significant residual effect on grain and straw yield of succeeding wheat crop. Irrigation schedulingbased on SMP at 150 suction recorded maximum Net Return of Rs 33816 in first year with B:C ratio of 2.61 and 2.91 in 1st and 2nd year respectively. However application of vermicompost @ 6t ha^{-1} recorded maximum net return of ₹ 37499 in 2nd year of study.

Key words: Soil matric potential, puddling, rice, irrigation scheduling, water efficiency

INTRODUCTION

Rice-wheat is a major cropping system in India and is practiced on 42 million hectares of land and is widely followed in Indo-Gangetic plains of North-West India and plays a significant role in food security contributing 76% of the total food grain production of the country. In Jammu province alone, rice and wheat covers an area of about 1.16 and 2.47 lakh ha, respectively with an average productivity of 1.60 t ha^{-1}and 1.83 t ha^{-1}, respectively which is far less as compared to national average of rice, i.e. 2.02 and 2.57 t ha^{-1} (Anonymous, 2007). It happens due to application of imbalanced use of chemical fertilizer as well as faulty management of irrigation practices specially in rice crop. Application of organic materials in conjunction with inorganic fertilizers in the crops leads to increased productivity and soil health thereby leading to sustainability of the ecosystem besides benefiting the succeeding crop owing to the build up of soil organic carbon content (Luikham *et al.*, 2004; Thakur *et al.*, 2010). Optimum

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water management in rice on the basis of appropriate irrigation scheduling and puddling intensities are of practical relevance and need of hour. Henceforth, the present study was conducted with a view to find out the optimum combination of organic and inorganic sources of nutrients such as vermicompost and FYM in rice under different puddling and irrigation levels and its residual effects of succeeding wheat crop under sub-tropical conditions of Jammu region.

MATERIALS AND METHODS

A field experiment was conducted during the *kharif and rabi* season of 2005-06 and 2006-07 at the Research Farm, Main Campus, Chatha of SKUAST-Jammu. The soil of the experimental field was sandy loam in texture, neutral to slightly alkaline in reaction (pH 7.4), low in organic carbon (0.46%) and available N (212 kg ha^{-1}) and medium in available P (15.90 kg ha^{-1}) and K (139.00 kg ha^{-1}). The experiment was laid out in split-split plot design with 3 replications. The treatments consisted of 3 levels of puddling i.e. normal practice (1 time), 2 times puddling and puddling thrice and 3 level of irrigation schedules i.e. 2 days after disappearance of ponded water (DADPW), 4 DADPW and irrigation at soil matric potential (SMP) at 150 cm suction besides 4 levels of nutrient sources i.e. application of vermicompost @ 3 t ha^{-1} + 75% recommenced dose (RD) through inorganic fertilizers, application of vermicompost @ 6 t ha^{-1}, application of 50% N through FYM + 50% NPK through inorganic fertilizers and recommended N, P, K doses through inorganic fertilizer). Rice 'PC-19' was transplanted with seedlings of 25 days old at a spacing of 20 cm x 15 cm. The organic sources like vermicompost (N-3 %, P-0.6 % and K-1.3 %) and FYM (N-0.61 %, P-0.22 % and K-0.72 %) were incorporated on dry weight basis 5 days before transplanting in the respective treatments. Recommended dose of N:P:K @ 100:60:60 kg ha^{-1} wherein full dose of recommended P through DAP and K through MOP besides half dose of N through Urea were applied as basal dose at the time of sowing whereas rest of the N was given in two equal splits as top dressing at mid tillering and before panicle emergence stage during both the years of experimentation. With the help of permanently fixed scales on Parshall flume, water depth before and after each irrigation was recorded and the difference was taken as the amount of applied irrigation. After harvest of rice, the succeeding wheat cv. PBW-343 was sown during first week of November in the same layout to asses the residual effect of the treatments during both the years of experimentation. In wheat, full dose of P (60 kg ha^{-1}) and K (60 kg ha^{-1}) besides half dose of N (50 kg ha^{-1}) were applied as basal dose at the time of sowing whereas rest of the N (50%) was given in two equal splits as top dressing at 22 days after sowing at crown root initiation stage and 105 days after sowing at booting stage during both the years of experimentation. Irrigation scheduling in rice was carried out mainly on the basis of disappearance of ponded water at an interval of 2-6 days after complete infiltration of water besides on the basis of soil matric potential at 150 $\pm$ 20 cm suction through the use of permanently fitted tensiometers during the crop growing season. The water expense and water expense efficiency was calculated as the ratio of yield (grain and straw yield) to the total amount of water expense measured through applied water through parshall flume and expressed as in kg $ha^{-1}cm^{-1}$. Plant samples (grain and straw) of rice crop were collected from each plot during both study period while composte surface soil sample(0-15cm) were also collected after comletion of study period of two years and analyzed for nutrient uptake and available nutrient status (Jackson, 1964).

RESULTS AND DISCUSSION

Yield of rice

All the growth and yield parameters improved significantly due to different treatments (Table 1). The level of puddling, puddling 3 times were found to increase the number of tillers sq m^{-1}, grain and straw yield significantly as compared to normal practice of puddling and 2 times puddling. The increase in the grain yield may be due to better water retention capacity of the soil as due to better puddling the soil became impervious to water besides soft bed for easy establishment of the rice seedlings. Thereby resulting in reduction of vegetative lag phase resulting in better growth and favorable environment for root prolification thereby increasing the nutrient uptake by the crop as a result of increased in water use efficiency (Mohanty *et al.* 2004) who also reported significantly increased grain yield in puddled soil (more than four times) than unpuddled soil to an extent of 50 %.

Similarly, significant variation in grain yield was recorded with variable irrigation schedules with application of irrigation at Soil Matric Potential (SMP) of 150 cm suction giving significantly increased the number of tillers sq m^{-1}, grain weight panicle^{-1}, 1000-grain weight, grain and straw yield of rice significantly than irrigation at 2 and 4 DADPW respectively during 2005-06. However, both were at par with the irrigation applied at 2 DADPW during 2006-07 which may be attributed to the increased water infiltration and water retention owing to use of vermicompost as a nutrient source due to which the increased organic matter during the second year of experimentation may have shown better water retention capacity and water use efficiency (Parihar, 2004). Moreover, the irrigation applied through SMP at 150 cm suction provided the constant and proper water required for mobilizing the constant nutrient supply which in turn might have helped to promote the metabolic activity of the plant. reported similar effects of irrigation schedule on crop yield. The results corroborates to the findings of Parihar (2004).

Application of N, P and K at recommended levels brought significant increase in number of tillers sq m^{-1}, grain weight panicle^{-1}, 1000-grain weight, grain and straw yield of rice than vermicompost @ 3t ha^{-1}+inorganic fertilizers, vermicompost alone @ 6t ha^{-1}and FYM + inorganic fertilizers (50% each) at harvest in the first year (2005-06) of experimentation (Table 1). However, during second year (2006-07) application of vermicompost @ 6t ha^{-1}increased the number of tillers sq m^{-1}, grain panicle^{-1}, 1000-grain weight, grain and straw yield significantly over vermicompost @ 3t ha^{-1}+ inorganic fertilizer, FYM + inorganic fertilizers (50% each) and N, P and K applied through inorganic fertilizers (Singh. *et al.* 2006). This may be due to the mineralization of the applied vermicompost during previous and subsequent year which may have added essential micronutrients like manganese, zinc and iron so as to improve the soil's physico-chemical properties besides releasing macro nutrients such as N, P and K in optimum doses besides other growth promoting substances, which influenced the availability of major and minor nutrients, there by resulting in higher grain yield and yield attributes of rice. The results corroborates to the findings of Singh (2006).

Interaction effect

Interaction between different intensities of puddling and irrigation scheduling on grain and straw yield of rice was found significantly during both the years of experimentation (Table 2). Soil matric potential at 150 cm suction coupled with 3 times puddling intensity increased the grain yield (45.63 q ha^{-1}) and straw yield(67.71 q ha^{-1}) of rice in 1st year and 47.26 q ha^{-1} and 69.77 q ha^{-1} grain and straw of rice in 2nd year over normal practice and 2 times puddling intensity respectively.

Table 1. Yield and yield attributes as influenced by various treatments in rice.

Treatments	No. of tillers sq m^{-1}		Grain weight panicle^{-1} (g)		1000-grain weight (g)		Grain yield (q ha^{-1})		Straw yield (qha^{-1})	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Puddling intensity										
Normal practice	314.72	324.97	1.94	1.96	21.59	21.77	41.94	43.60	60.76	62.83
2-times puddling	315.83	326.08	1.95	1.97	21.69	21.87	42.52	44.15	61.80	63.88
3-times puddling	322.50	334.39	1.96	1.98	21.81	21.99	43.72	45.34	64.01	66.09
C.D. (p=0.05)	2.53	2.82	N.S	N.S	N.S	N.S	0.44	0.41	0.67	0.60
Irrigation scheduling										
2 DADPW*	317.69	328.47	1.95	1.97	21.37	21.96	42.39	44.04	61.27	63.67
4 DADPW	314.97	325.78	1.92	1.94	21.12	21.42	42.07	43.69	61..21	62.96
SMP** at 150 cm suction	320.39	331.19	1.99	2.00	22.61	22.25	43.73	45.35	64.10	66.17
C.D. (p=0.05)	2.53	2.82	0.06	0.10	0.63	0.69	0.44	0.41	0.67	0.60
Nutrient sources										
Vermicompost 3t ha^{-1}+ inorganic fertilizer	314.00	325.93	1.94	1.94	21.52	21.83	42.51	44.06	61.45	63.53
Vermicompost @ 6t ha^{-1}	311.04	336.41	1.92	2.01	21.34	22.31	41.75	45.56	59.91	66.57
FYM+In-organic fertilizer (50% each)	321.04	334.00	1.97	1.99	21.90	21.85	43.02	44.77	62.91	64.98
N.P.K Recommended	324..66	317.59	1.98	1.93	22.02	21.54	43.64	43.05	64.50	61.99
C.D. (p=0.05)	3.86	4.87	0.04	0.09	0.59	0.63	0.43	0.46	1.20	0.88

*Days after disappearance of ponded water, ** Soil matric potential

Table 2. Interaction effect of puddling intensity and irrigation scheduling on yield of rice during 2005-06 and 2006-07

Treatments	2005-06			2006-07		
	Irrigation scheduling					
	2 DADPW*	4 DADPW	SMP** 150	2 DADPW	4 DADPW	SMP 150
Puddling intensity	Grain yield (q ha^{-1})					
Normal practice	41.91	41.48	42.45	43.62	43.10	44.07
2 times puddling	42.33	42.10	43.10	43.99	43.72	44.73
3 times puddling	42.90	42.62	45.63	44.51	44.25	47.26
CD at 0.5%		0.71			0.63	
	Straw yield (q ha^{-1})					
Normal practice	59.81	60.79	61.67	62.87	61.89	63.74
2 times puddling	61.50	61.00	62.91	63.58	63.08	64.99
3 times puddling	62.50	61.83	67.71	64.57	63.91	69.79
CD at 0.5%		1.17			1.05	

* Days after disappearance of ponded water (DADPW) ** Soil matric potential (SMP)

Whereas application of vermicompost @ 6 tonnes had positive intraction with 3 times puddling coupled with irrigation scheduling at SMP of 150 cm suction.

Water expense efficiency

Water expense was maximum where irrigation was applied at 2 DADPW over 4 DADPW and SMP at 150 cm suction during both the years (Table 3). Irrigation scheduling with SMP at 150 cm suction resulted in higher water expense efficiency of 61.45 kg $ha^{-1}cm^{-1}$ in 1st year and 42.26 kg $ha^{-1}cm^{-1}$ in 2nd year, respectively than irrigation at 2 and 4 DADPW. Maximum water expense of 81.51 cm and 118.61 cm was recorded at recommended dose of N, P, and K applied through fertilizers over the application of vermicompost @ 3t ha^{-1}+inorganic fertilizer followed by FYM+inorganic fertilizer

Table 3. Amount of irrigation water, water expense ,water expense efficiency , net return and B:C ratio of rice as influenced by irrigation schedules

Treatments	Amount of irrigation water (cm)		Water expense (cm)		Water expense efficiency (Kg ha^{-1} cm^{-1}) Grain		Net Return (₹ ha^{-1})		B:C Ratio	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Puddling intensity										
Normal practice	60.00	50.00	81.69	117.59	51.34	37.08	32396	35842	2.50	2.77
2-times puddling	60.00	50.00	81.29	117.34	52.31	37.62	32854	36307	2.38	2.63
3-times puddling	60.00	50.00	80.98	117.17	53.99	38.70	32405	37310	2.22	2.56
Irrigation scheduling										
2 DADPW*	80.00 (16)	65.00 (13)	101.29	132.36	41.85	33.27	32737	36214	2.45	2.75
4 DADPW	50.00 (10)	45.00 (9)	71.31	112.40	59.00	38.87	32510	35916	2.51	2.79
SMP ** at 150 cm suction	50.00 (10)	40.00 (8)	71.16	107.32	61.45	42.26	33816	37321	2.61	2.91
Nutrient sources										
Vermicompost 3t ha^{-1}+ inorganic fertilizer	60.00	50.00	81.39	117.68	52.23	37.44	32830	36222	2.26	2.49
Vermicompost @ 6t ha^{-1}	60.00	50.00	80.99	116.67	51.55	39.05	32221	37499	2.00	2.32
FYM+In-organic fertilizer (50% each)	60.00	50.00	81.18	117.06	52.99	38.25	33260	36827	2.17	2.41
N.P.K Recommended	60.00	50.00	81.51	118.16	53.54	36.44	33773	35387	2.61	2.73
Effective Rainfall(cm) 2005-06 -	31.98									
Effective Rainfall(cm) 2006-07 -	78.35									

*Days after disappearance of ponded water, ** Soil matric potential.Figures in parenthesis are number of irrigations applied

(50% each) and vermicompost @ 6t ha^{-1} alone during 2005-06 and 2006-07. Similar findings were reported by Parihar, 2004. However, during second cropping season (2006-07), application of vermicompost @ 6 t ha^{-1} resulted in higher water expense efficiency (39.05 kg $ha^{-1}cm^{-1}$) than FYM + inorganic fertilizers (50% each) 38.25 kg $ha^{-1}cm^{-1}$, vermicompost @ 3t ha^{-1} + inorganic fertilizers (37.44 kg $ha^{-1}cm^{-1}$), and application of N, P and K (recommended) through fertilizer (36.44 kg $ha^{-1}cm^{-1}$) (Table 3). This may be due to higher water holding capacity as a result of incorporation of organics which during the second season onwards might have released the nutrients in required quantity with high intensity of puddling and varying irrigation schedule. These results are close conformity with that of Singh *et al.* (1990).

Similarly, puddling 3 times in rice resulted in higher water expense efficiency of 53.99 kg $ha^{-1}cm^{-1}$ in 1st year and 38.70 kg $ha^{-1}cm^{-1}$ in 2nd year as compared to normal practice and 2 times puddling due to decreased unproductive water losses viz. percolation and infiltration thereby increasing the water use efficiency resulting in higher grain yield and its attributes. Combination of soil with high intensity of puddling with various scheduling of irrigation resulted in the highest water expense efficiency (Singh *et al.*, 1990).

Economics

The maximum net return of ₹ 32,854 in 2 times puddling, and ₹ 33,773 in recommended dose of NPK through inorganic fertilizer was recorded in 1st year of study, however irrigation scheduling at SPM 150 cm recorded maximum net return of 33816 and 37321 with B.C ratio of 2.61 and 2.91 in 1st and 2nd year of study (Table 3).

Nutrient uptake of rice

Irrigation scheduling and nutrient sources significantly increased the N, P and K uptake of rice crop, but no significant difference was observed with different levels of puddling (Table 4) on the uptake of nutrients in rice. Nutrient (NPK) uptake by rice crop increased significantly with application of irrigation SMP at 150 cm suction though at par with irrigation at 2 DADPW. Irrigation scheduling did not show significant effect on available nutrient status of soil after 2 year study period.

Application of recommended dose of N, P and K through fertilizers N, P, and K uptake of 50.81

Table 4. Total uptake by paddy and available nutrient status (kg ha^{-1}) as influenced by various treatments

Treatments	Nutrient Uptake (kg ha^{-1})						Soil fertility status after completion of 2 year study period (kg ha^{-1})			
	2005-06			2006-07						
	N	P	K	N	P	K	O.C%	N	P	K
Puddling intensity										
Normal practice	50.14	9.32	53.24	50.86	9.53	54.18	0.45	189	15.70	142
2-times puddling	50.21	9.34	53.61	50.93	9.55	54.25	0.46	192	14.72	144
3-times puddling	50.40	9.35	53.67	51.13	9.57	54.29	0.45	194	14.66	141
C.D. (p=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Irrigation scheduling										
2 DADPW*	50.52	9.37	53.73	51.24	9.58	54.36	0.46	191	15.02	147
4 DADPW	49.62	9.24	53.23	50.35	9.45	53.86	0.47	184	14.90	142
SMP** at 150 cm suction	50.69	9.40	53.86	51.33	9.61	54.48	0.47	185	14.87	144
C.D. (p=0.05)	0.495	0.08	0.165	0.67	0.12	0.24	N.S	N.S	N.S	N.S
Nutrient sources										
Vermicompost 3t ha^{-1}+ inorganic fertilizer	50.07	9.32	53.46	50.37	9.43	53.77	0.47	216	16.20	148
Vermicompost @ 6t ha^{-1}	49.72	9.26	53.19	51.98	9.72	54.90	0.50	214	15.80	148
FYM+In-organic fertilizer (50% each)	50.40	9.37	53.72	51.23	9.61	54.49	0.47	220	16.11	146
N.P.K Recommended	50.81	9.40	54.07	50.31	9.43	53.79	0.45	205	15.30	138
C.D. (p=0.05)	0.40	0.06	0.47	0.50	0.10	0.54	0.04	19.8	0.50	6.11
Initial status							0.46	212	15.9	139

*Days after disappearance of ponded water, ** Soil matric potential

kg ha^{-1}, 9.40 kg ha^{-1} and 54.07 kg ha^{-1} in rice during the first year (2005-06) whereas significant increase in nutrients uptake N (51.98 kg ha^{-1}), P (9.72 kg ha^{-1}) and K (54.90 kg ha^{-1}) was observed during 2nd year (2006-07) with application of vermicompost @ 6t ha^{-1} when compared with FYM+inorganic fertilizer (50% each) and Vermicompost@ 3t ha^{-1}+ inorganic fertilizer (Table 4) which may be attributed to enhanced availability of nitrogen in vermicompost and inorganic nutrients in the irrigation regimes whereas increase in P uptake, because of conversion of ferric phosphate to ferrous phosphate and by forming the phospho-humic complexes which are easily assimilated by the crop. These results corroborate to the findings given by Balasubramanian and Krishnarajan (2000). Soil nutrient status also influenced with the application of organic source of nutrient like vermicompost coupled with inorganic fertilizer (Table 4). The highest NPK content in soil was found under application of vermicompost coupled with inorganic fertilizer which was significantly higher over recommended dose of NPK through fertilizer. However soil organic carbon content was recorded higher in those treatments where organic sources of nutrient was applied Thakur *et al.* (2010) also reported that integrated use of fertilizer with manure seems to increase soil organic carbon content where as sub-optimal levels of fertilizer application, reduce the organic carbon content under continuous rotational rice-wheat cropping system in sub-tropical conditions.

Residual effect on succeeding wheat crop

The experiment revealed that puddling intensity and irrigation scheduling treatments did not exhibit any significant influence on the grain and straw yield of succeeding wheat crop (Table 5). Since the experiment was conducted for 2 years only that might not have developed a hard layer even under the high density puddling. However, lower yielded trends were observed in high puddling intensities than lower puddling intensity, which may be owing to restricted root growth and improper soil aeration (Kukal and Aggarwal, 2003).

Application of vermicompost @ 6t ha^{-1} applied to rice crop brought about significant increase in the grain and straw yield of wheat as compared with vermicompost @ 3t ha^{-1}+inorganic fertilizers, FYM + inorganic fertilizers (50% each) and N, P and K applied through inorganic fertilizers at recommended doses. This may be due to increased mineralization of nutrients thereby resulting in higher grain yield and straw yield of wheat as a result of improvement in soil organic matter, physio-chemical and biological properties of soil

Table 5. Residual effect of various treatments on grain and straw yield (q ha^{-1}) of wheat in rice-wheat cropping system

Treatments	Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
	2005-06	2006-07	2005-06	2006-07
Puddling Intensity				
Normal puddling (Single puddling)	46.70	48.18	75.56	78.72
2-times puddling	46.41	47.83	74.98	77.72
3-times puddling	46.29	47.67	74.74	77.71
C.D. (p=0.05)	N.S	N.S	N.S	N.S
Irrigation Scheduling				
2 DADPW*	46.40	47.84	74.96	78.05
4 DADPW	46.38	47.80	74.92	77.96
SMP** 150 suction	46.61	48.04	75.39	78.44
C.D. (p=0.05)	N.S	N.S	N.S	N.S
Nutrient sources				
Vermicompost 3t ha^{-1}+ inorganic fertilizer	46.61	48.14	75.38	78.64
Vermicompost @ 6t ha^{-1}	46.74	48.15	75.64	78.67
FYM+In-organic fertilizer(50% each)	46.35	47.74	74.87	77.86
N.P.K Recommended	46.15	47.54	74.47	77.44
C.D. (p=0.05)	0.50	0.54	1.01	1.08

*Days after disappearance of ponded water, ** Soil matric potential

with incorporation of enriched organic sources such as vermicompost in the soil. These results corroborate the findings of (Patidar and Mali, 2002; Thakur *et al.* (2010).

Based on two years of experimentation it may be safely concluded that maximum grain and straw yield can be obtained with puddling the field thrice coupled with application of irrigation at soil matric potential at 150 cm suction using tensiometers or applying irrigation at 2 days after disappearance of ponded water using recommended levels of N, P and K or alone use of vermicompost @ 6 t ha^{-1} per hectare were found to be economical and best treatments for use in paddy fields for sustained and increased production besides increasing the water use efficiency of rice in rice-wheat cropping system through increased soil fertility and soil health. Significant residual effect of different nutrient sources on succeeding wheat grain and straw yield was observed and maximum grain and straw yield was recorded in plots applied with vermicompost @ 6t ha^{-1} than recommended doses of N, P and K after two years of experimentation.

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An interactive multi-objective linear programming approach for watershed planning-a case study

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ABSTRACT

A watershed management planning study is carried out with the help of multi-objective programming approach and analysed with interactive technique (STEP method). The selected watershed is Mandakini Balinala watershed No-1 in Begunia block of Khurda district, Odisha. The total geographical area of the watershed is 506.67 ha, out of which the area treatable is 457 ha. The land allocation plan is done considering the major crops grown in the area i.e. paddy, maize, pigeonpea, mustard and green gram along with one fodder and fuel wood crop i.e. hybrid napier bajra and subabool. In the multi-objective approach, a compromise solution is obtained from the optimal solutions by the preference of Decision Maker (planner) by using interactive step method. The objective function taken for the maximisation are food, fodder, fuel wood, net income, labour employment generation and runoff water augmentation considering constraints of land, water and human resources. From the proposed plan the benefit-cost ratio was found to be 1.33:1 and the cropping intensity and the cropping intensity was found to be 163.37% (*Kharif* 85.83% and Rabi 77.54%). The benefit for the proposed planning is ₹ 34782.59 × 10^3 as compared to ₹ 12234.25 × 10^3 for the existing practice, which is 184% higher than the existing one.

Key words: Linear programming, step method, watershed planning, land allocation

INTRODUCTION

Agriculture is a term hard to imagine without two basic natural resources. The two natural resources are namely land and water. In this context, rural people may be considered as the third resource because they are responsible for effective and sustained use of the resources of a particular area. So proper planning, management practices and efficient use of these resources are very much necessary, at present scenario. Agriculture plays an important role not only by feeding to each person but also contributing towards the country's growth.

The question in front of us today is how to increase the production with such limited resources. Solution may be in different ways but their ultimate aim is to increase the productivity. That is to grow more crop per ha of land and also with per drop of water. Watershed management is a multi disciplinary activity in which several goals is to be achieved. Watershed management programme constitutes of several objectives but we have to consider only those which are critical for the watershed. As there are multiple objectives in the watershed management programme, so it comes under multi objective programming. The objectives taken for the present study are maximisation of food production, maximisation of fodder production, maximisation of fuel wood production, maximisation of net income generation, maximisation of labour employment generation and maximisation of runoff water augmentation. These objectives are to be treated against a set of resource and nutritional constraints. The solution of these programming is done by interactive step method, which will give rise to the land allocated for different crops. All the objective functions cannot be optimised simultaneously. So the decision maker (DM) has to find a compromise solution rather than an optimal solution.

Multi-objective programming (MOP) has a wide range of applications in the field of Agriculture, Business, Industry and Management. Because at present scenario, optimal utilization of resources

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as well as maximisation of profit are trending issues. It has undergone a rapid development during the last few decades. Mohan and Jothiprakash (2000) used fuzzy linear programming to determine the optimal crop plans for an irrigated condition. Kaur *et al.* (2004) conducted a study to estimate the sediment yield from the Nagwan watershed and to develop a land use plan by using linear programming (LP) for soil loss reduction. Interactive method has been widely used in watershed planning. Jha and Singh (2008) proposed a multi-objective model for the optimal allocation of resources like land, crop and water of Kosi irrigation system in Nepal. Rejani *et al.* (2011) proposed an optimal cropping pattern and ground water management plan for three blocks of Balasore district, Odisha. A few notable reviews in watershed management include Shirgure (1998) and Paul *et al.* (2004) used interactive STEP method for watershed planning and found out, this method is the best suited one. Some multi-objective strategies were also discussed in the field of watershed management by Wang *et al.* (2006) and Honghai and Altinakar (2013).

Keeping the above facts in view, In the present study an attempt has been made to analyse the watershed planning problem using STEP method and to prepare a comprehensive watershed workplan for Mandakini Balinala watershed No-1 in Begunia block of Khurda district, Odisha.

MATERIALS AND METHODS

The general description of a multi-objective programming problem involving, p objectives, n decision variables and m constraints can be expressed as:

Max Z(X) = [Z_k(x), for k= 1, 2,......p] 1

Subjected to: g_i(x) (d"=e") b, for i=1, 2,....m 2

And x e≥ 0 3

Where Z and X are the vectors of the objective functions and decision variables, Equation (2) and (3) are constraint equations. If all the equations are linear, then the formulation is known as multi objective linear programming (MOLP).

In multi objective programming, the concept of compromise solution is more important rather than the optimal solution. Because it is not possible to maximize each objective at the same time, so it is important to get a solution which would take care, all the objectives. Therefore, a non inferior compromise solution is derived by making trade-offs between different objectives by taking into consideration of the Decision Maker's preferences.

Step method

The step method is an interactive technique that converges to the best compromise solution, in no more than p iterations, where p is the number of objectives. The method is based on a geometric notation of the best fit, i.e. the minimum distance from an ideal solution with modifications to a generated solution. The method begins with the construction of pay-off table. This is done by solving each objective individually and the solution of each objective is put under different objective functions. Each column will correspond to an objective, while rows will correspond to optimal solution set. From each column the maximum value of the objective function i.e. M_k and minimum value n_k is found out. These values are used to find the scaling term and the expression is given by

$$\frac{M_k\text{-}n_k}{M_k} = \text{Scaling term}$$

Another term i.e. Normalising term is calculated by the expression given in equation

$$\left[\sum (Cj^k)^2\right]^{\frac{-1}{2}} = \text{Normalising term}$$

Where, Cj^K is the coefficient of objective functions. The expression for Cj^K is clear from the linear equation given in equation (5).

Z_k (x) = ($C_1{}^k$) + ($C_2{}^k$) + ...+ ($C_n{}^k$) 4

K = 1,2, ...p

$(C_j^k)^2 = C_1^2 + C_2^2 + ...+ C_n^2$ 5

For K = 1,2, ...p

The product of the scaling term and normalising term will give the value of

$$\alpha_k(\text{alpha}) = \frac{M_k - n_k}{M_k}\left[\sum (Cj^k)^2\right]^{\frac{-1}{2}} \quad ....6$$

From the value of α_k,W_k (weights assigned to different objective functions) are calculated.

$$W_k = \frac{\alpha_k}{\sum \alpha_k} \quad ....7$$

The value of W_k is used to derive the first compromise solution. The objective functions whose weights are zero or nearer to zero has already attained the maximum value and no need to find out the compromise solution for such objectives. The variable of the compromise solution will be obtained by solving the following linear programming.

Minimise'd' 8

Subjected to Wk [M_k – Z_k(x)] – d d≤ 0 9

For k= 1, 2, ...p

d e" 0 10

Where,'d' is the deviation of the objective function from the optimal value. The solution of this equation will give first compromise solution. If the percentage of difference of first compromise solution from the optimal solution is within 5%, then the DM is satisfied with the solution, otherwise has to go for second compromise solution by adopting the same procedure and so on.

About the watershed

The watershed selected for this study is Mandakini Balinala watershed No-1 which lies in the Begunia block of Khurda district (Odisha). The latitude of the area is 20^0 18′ to 20^0 20′ N and longitude 85^0 62′ to 85^0 64′E. The total watershed area is 506.67 ha, out of which the net treatable area is 457 ha. The rest area comes under homestead, nallah roads and for other uses. Out of the total area, 282.22 ha come under agricultural land. The forest land, culturable wasteland and gochar land can be brought under fodder and fuel wood cultivation. Mainly the slope of the watershed is mild varies between 0-5%. The climate of the watershed area is hot and dry sub humid with mean average annual rainfall is 1499.29 mm. The main crop grown in the area is paddy. However, crops like maize, pigeonpea are grown in some areas in *kharif* season. Due to lack of irrigation facility most of the areas remain barren in *rabi* season. Most of the farmers inside the watershed are small and marginal farmers. The economic condition of the farmers is not good inside the watershed. The present study made an attempt to provide food security to the population, employment generation and also to generate some income from field crops.

Multi-objective Linear Programming Model

A multi-objective programming is done to find out the land allocated to different crops and plantation activities in Mandakini Balinala watershed No-1. The following crops and plantation activities are considered.

x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16} and x_{17} are area under upland paddy, medium land paddy, low land paddy, maize, pigeonpea, hybrid napier bajra grass and subabool plantation in *kharif* (ha) season.

x_{21}, x_{22}, x_{23}, x_{24} and x_{25} are area under low land paddy, mustard, greengram, hybrid napier, bajra grass and subabool plantation in *rabi* (ha) season.

x_8 is area required for construction of ponds (ha).

Data and data source

The data pertaining to existing crop area were collected from Soil Conservation Officer, Khurda, Odisha. The cost of cultivation were calculated as Annonymous, 1998. The multi-objective programming was solved using WIN-QSB software.

Objective function

The following objective functions are formulated which are important for improving the socio-economic status of the habitants of the watershed. The objective functions also take into account the optimal utilization of the land, water and human resources of the watershed. The details of the objective function and constraints are given in Table 1 and 2.

Table 1: Objective functions

a. Food production maximisation (tons)	
Max. $Z_1(x) = 2.6x_{11}+3.2x_{12}+3.7x_{13}+4x_{14}+1.8x_{15}+4.3x_{21}+1.5x_{22}+x_{23}$	11
b. Fodder production maximisation (tons)	
Max. $Z_2(x) = 6.5x_{11}+7.1x_{12}+8x_{13}+2x_{14}+30x_{16}+7x_{17}+8.5x_{21}+20x_{24}+3x_{25}$	12
c. Fuel wood production maximisation (tons)	
Max. $Z_3(x) =10x_{17} + 10x_{25}$	13
d. Maximisation of net income generation from field crops(Rs.)	
Max. $Z_4(x) =9671x_{11}+11202x_{12}+11838x_{13}+15618x_{14}+48673x_{15}+10800x_{16}$	
$+6980x_{17}+16916x_{21}+15213 x_{22}+24740 x_{23}+7200 x_{24}+4980 x_{25}$	14
e. Maximisation of labour employment generation	
Max. $Z_5(x) =102x_{11}+132x_{12}+165x_{13}+160x_{14}+93x_{15}+60x_{16}+185x_{17}$	
$+165x_{21}+100x_{22}+65x_{23}+90 x_{24}+ 185x_{25}$	15
f. Maximisation of runoff water augmentation (ha-m)	
Max. $Z_6(x) = 3x_8$	16

Table 2: The constraint equations for the objectives

1.	Land constraints	
	$x_{11}+ x_{12}+ x_{13}+ x_{14}+ x_{15}+ x_{16}+ x_{17}+ x_8 \leq 457$	17
	$x_{21}+ x_{22}+ x_{23}+ x_{24}+ x_{25}+ x_8 \leq 457$	18
	$x_{11}+ x_{12}+ x_{13}+ x_{14}+ x_{15} \leq 282.22$	19
	$x_{21}+ x_{22}+ x_{23} \leq 219.97$	20
	$x_{11}+ x_{14}+ x_{15} \leq 62.25$	21
	$x_{12}+ x_{15} \leq 199.85$	22
	$x_{13} \leq 20.12$	23
	$x_{22}+x_{23} \leq 199.85$	24
	$x_{21} \leq 20.12$	25
	$x_{16}+ x_{17}+ x_8 \leq 174.78$	26
	$x_{24}+ x_{25}+ x_8 \leq 174.78$	27
	$x_{16}- x_{24} = 0$	28
	$x_{17}- x_{25} = 0$	29
2.	Water constraints	
	$1.2x_{11}+1.2x_{12}+x_{13}+0.45x_{14}+0.35x_{15}+0.4x_{16}+0.35x_{17} \leq 306$ ha-m	30
	$x_{21}+0.4x_{22}+0.4x_{23}+0.2x_{24}+0.1x_{25} \leq 127$ ha-m	31
3.	Nutritional constraints	
a.	Protein	
	$177x_{11}+218x_{12}+252x_{13}+340x_{14}+441x_{15}+292x_{21}+300x_{22}+240x_{23} \geq 25{,}556$	32
b.	Calorie	
	$8970x_{11}+11040x_{12}+12765x_{13}+13720x_{14}+6264x_{15}+14835x_{21}$	
	$+4376x_{22}+3240x_{23} \geq 1119378$	33
4.	Labour Constraints	
	$30x_{11}+30x_{12}+30x_{13}+35x_{14}+15x_{15}+25x_{16}+20x_{17} \leq 17160$ $20x_{11}+35x_{12}+35x_{13}+30x_{14}+20x_{15}+10x_{16}+10x_{17} \leq 17160$	....34 35
	$15x_{11}+20x_{12}+30x_{13}+15x_{14}+10x_{15}+10x_{16}+30x_{17} \leq 17160$ $7x_{11}+12x_{12}+30x_{13}+20x_{14}+23x_{15}+5x_{16}+25x_{17} \leq 17160$ $30x_{11}+35x_{12}+40x_{13}+60x_{14}+25x_{15}+10x_{17} \leq 17160$ $10x_{16}+110x_{17} \leq 17160$ $30x_{21}+20x_{22}+10x_{23}+10x_{24}+20x_{25} \leq 17160$ $35x_{21}+15x_{22}+10x_{23}+10x_{24}+20x_{25} \leq 17160$ $30x_{21}+10x_{22}+10x_{23}+15x_{24}+15x_{25} \leq 17160$ $30x_{21}+25x_{22}+10x_{23}+15x_{24}+10x_{25} \leq 17160$	....36 ....37 ....38 ....39 ....40 ....41 ....42 43
	$40x_{21}+30x_{22}+25x_{23}+10x_{24}+10x_{25} \leq 17160$ $30x_{24}+90x_{25} \leq 17160$	....44 45
5.	Bulk constraints	
a.	fodder	
	$6.5x_{11}+7.1x_{12}+8x_{13}+2x_{14}+8.5x_{21} \geq 970$	46
	$30x_{16}+7x_{17}+20x_{24}+3x_{25} \geq 970$	47
b.	fuel wood	
	$10x_{17}+10x_{25} \geq 1755$	48
c.	Paddy	
	$2.6x_{11}+3.2x_{12}+3.7x_{13}+4.3x_{21} \geq 174$	49
d.	Maize	
	$4x_{14} \geq 71.3$	50
e.	Pigeonpea	
	$1.8x_{15} \geq 18$	51
f.	Mustard	
	$1.5x_{22} \geq 17.2$	52
g.	Greengram	
	$x_{23} \geq 15.14$	53
6.	Area required for ponds	
	$x_8 \geq 40.39$	54
7.	Non negative constraints	
	$x_{11} \geq 0, x_{12} \geq 0, x_{13} \geq 0, x_{14} \geq 0, x_{15} \geq 0, x_{16} \geq 0, x_{17} \geq 0,$	
	$x_{21} \geq 0, x_{22}$ e″0, $x_{23} \geq 0, x_{24} \geq 0, x_{25} \geq 0, x_8 \geq 0$	55

RESULTS AND DISCUSSIONS

The six objective functions are solved individually along with 38 constraints (using WIN-QSB software). The pay off table is constructed using the values of variable (Table 3). From the pay off table initial set of weights are determined by using equation 6 and 7. The weights are used to calculate the first compromise solution, which is given Table 4. If the change in value of the objectives is within the 5% of maximum value, then the objective is optimised. In the following case six objectives are optimised during first compromise solution. The decision maker is satisfied with the solution. The land allocation plan is given in Table 5.

The resource utilization pattern for different natural resources was calculated. The land utilization is 86 %, water utilization is 86 %, labour utilization is 67 %. The cost economics of the proposed planning is 1.33 compared to 1.08 of the existing one. The figure showing food grain requirement and food grain production under optimal plan is shown in Fig. 1. The figure showing calorie and protein requirement vs. production under optimal plan is shown in Fig. 2. The figure showing fodder and fuel wood requirement vs. production under optimal plan is shown in Fig. 3. The cropping intensity of the proposed plan is 163.37% compared to 108.81% of the existing one.

Table 3: Pay-off table

Objective function	$Z_1(x)$ ton	$Z_2(x)$ ton	$Z_3(x)$ ton	$Z_4(x)$ in Rs	$Z_5(x)$ Man-days	$Z_6(x)$ ha-m
Optimal solution						
X_1 (0, 182.04, 20.12, 52.25, 10, 24.25, 87.75, 20.12, 184.71, 15.14, 24.25, 87.75, 40.39)	1262	3819	1755	8591125	95520	121.17
X_2 (0, 187.49, 20.12, 17.82, 10, 24.25,110.14, 20.12, 11.46, 15.14, 24.25, 110.14, 40.39)	882	4012	2202	5746614	81690	121.17
X_3(0, 100.08, 20.12, 17.82, 10, 24.25, 110.14, 20.12, 11.46, 15.14, 24.25, 110.14, 40.39)	602	3392	2202	4767348	70151	121.17
X_4(0, 155.43, 20.12, 17.83, 10, 24.25, 110.14, 20.12, 11.47, 15.14, 24.25, 110.14, 40.39)	779	3785	2202	5387503	77457	121.17
X_5(0, 175.52, 20.12, 52.25, 10, 24.25, 110.14, 20.12, 184.71, 15.14, 24.25, 110.14, 40.39)	1241	3996	2202	8785756	102942	121.17
X_6(0, 100.08, 20.12, 17.82, 10, 24.25, 87.75, 20.12, 11.46, 15.14, 24.25, 87.75, 40.39)	602	3168	1755	4499564	61866	121.17

Table 4: Compromise solution

Objective function	Maximum value	First compromise solution	% difference from maximum value
$Z_1(x)$	1262	1241*	1.66
$Z_2(x)$	4012	3996*	0.39
$Z_3(x)$	2202	2202*	0
$Z_4(x)$	8785756	8785756*	0
$Z_5(x)$	102942	102942*	0
$Z_6(x)$	121.17	121.17*	0

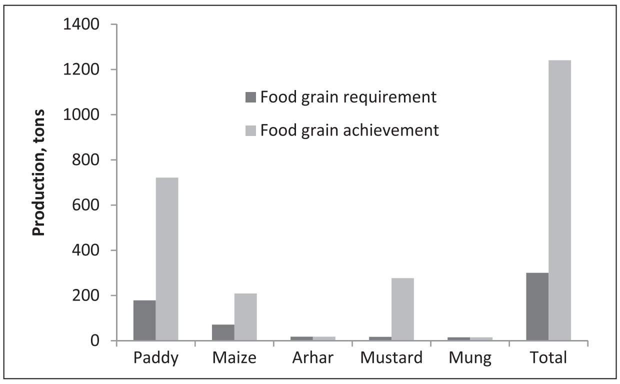

Fig 1. Food grain requirement vs. Food grain achievement

Table 5: Land allocation plan for the watershed

Kharif		Rabi	
1. Paddy (medium land)	175.52 ha	1.Paddy (low land)	20.12 ha
2. Paddy(low land)	20.12 ha	2.Mustard	184.71 ha
3. Maize	52.25 ha	3.Greengram	15.14 ha
4. Pigeonpea	10.00 ha	4.Hybrid napier bajra grass	24.25 ha
5. Hybrid napier bajra grass	24.25 ha	5.Subabool	110.14 ha
6. Subabool	110.14 ha		
Total	392.28 ha	Total	354.36 ha

Table 6: Achievement level of different objectives

I.	Food production	= 1241 ton
II.	Fodder production	= 4012 ton
III.	Fuel wood production	= 2202 ton
IV.	Net income from field crops	= ₹ 87,85,756
V.	Labour employment generation	= 102942 Mandays
VI.	Run off volume augmentation	= 121.17 ha-m

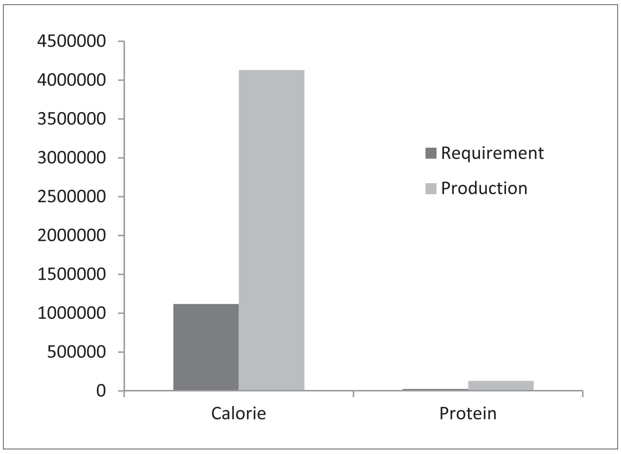

Fig 2. Calorie and protein requirement vs. Production

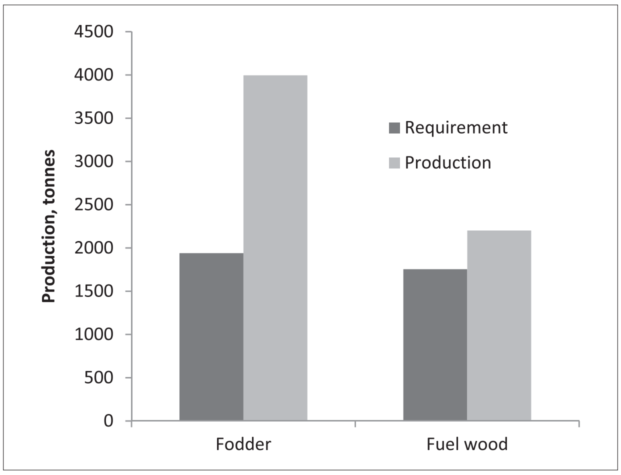

Fig 3. Fodder and Fuel wood requirement vs. Production

The benefit-cost ratio of 1.33 indicates the economic viability of the programme besides meeting the food, fodder and fuel wood production of the area with ecological advantage. Besides this area under ponds are 40.39 ha.

CONCLUSION

The multi objective analysis with six objectives and thirty eight constraints are solved using interactive STEP method. The land allocated to different crops and plantation gives satisfactory achievement level objectives. The STEP method is found suitable for the watershed planning for its simplicity and capacity to handle the size of the problems encountered. The cost economics of the proposed planning is 1.33 compared to 1.08 of the existing one. The cropping intensity of the proposed plan is 163.37% compared to 108.81% of the existing one. The benefit-cost ratio of 1.33 indicates the economic viability of the programme.

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Nitrate reductase activity in different moisture tolerant genotypes of maize (*Zea mays* L.) in flooding and non-flooding regimes

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ABSTRACT

Influence of water logging on the nitrate reductase activity in different moisture tolerant varieties of maize (*Zea mays* L.) in flooding and non-flooding regimes under Varanasi conditions of different cultivars MT-981, MT-982, MT-983, MT-984, VC-2, MT-991 and MT-992 were estimated. Experiment was performed under field conditions. The flooding of the maize varieties is not the factor to increase or decrease the nitrate reductase activity (NRA) in leaves but it is varietal response to the flooding condition is the deciding factor. At the age of 72 days of the plants prolonged days after flooding i.e. 29 days nitrate reductase activity significantly decreases in all the varieties except MT-991, and MT-992 where no significant change. In normal condition i.e. non flooding condition the nitrate reductase activity in leaves of the maize varieties was observed, increases with the age of the plants and it is highest at 89 days age among the age group studied. The flooding condition significantly decreases the NRA in leaves of the maize varieties and this effect is not even annotated with the prolonged period of flooding treatment. This minimizing effect on the flooding nitrate reductase activity in all the varieties begins with flooding is enable to regain the normal activity an increase it again.

Key words: *Zea mays* L., Nitrate reductase activity, flooding, non-flooding

INTRODUCTION

Nitrogen is taken up by maize (*Zea mays* L.) plant throughout its growth period. Nitrate reductase is the key enzyme for most of the higher plants (Chempbell, 1999). Measurement of leaf NR activity provided reasonable estimates for ability of maize hybrids to accumulate reduced N in shoots during vegetative growth, and higher levels of NR activity during grain development led to higher levels of nitrate (Reed *et al.* 1980). Supplemental N treatments significantly increase in NR activity in several crop species (Srivasatava 1992) and NR can be used as an environmental biotechnology tool (Chempbell 1999).In tropical and subtropical regions, severe crop losses are caused by prolonged seasonal rainfall excess water produces anoxic soil conditions within few hours (Gambrell, 1978). Plants roots, consequently, suffer hypoxia or anoxia. In flood tolerant plants, the formation of arenchyma and adventitious roots in the vicinity of cotyledonary nodes is an indicator of the presence of adaptive mechanisms (Kawase, 1981).

Maize (*Zea mays* L.) is an important C_4 cereal crop. It is grown in diverse environmental and geographical range than any other cereal crop. In India maize is the forth most important food crop after rice, wheat and sorghum. For nitrogen assimilation, NR is considered to be the most important enzyme, because nitrate is the major N source for most of the higher plants and a lot of attention has been focused on nitrate reductase for several reasons as it appears to limit nitrate assimilation due to small amounts of it present in plants, it has been focus of efforts to enhance nitrogen and protein content in agronomically important plants like maize (Beevers and Hageman, 1983). The regulation of nitrate assimilation has been the focus of intense research activity because of the potential for improving the efficiency of the process and enhancing agricultural productivity through intervention in this growth limiting process. Substantial understanding has been achieved regulation of nitrate assimilation mechanism particularly nitrate reductase.

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However, a detail understanding of how nitrate reductase is regulated under various environmental conditions is still lacking and it is likely that there is no single mode of regulation of the enzyme rather several different modes of regulation may act simultaneously or sequentially in response to different signals of changing environmental conditions. The knowledge about these facts may provide means the improving the efficiency of nitrate utilization and enhance agricultural productivity (Solomonson and Barber, 1990) and the genotypic and nutritional factors in relation to climatic factors should be kept in consideration while planning for crop improvement program.

The activity of NR in higher plants is influenced by many external factors, most important being light and temperature regimes. Higher NR activity reflected in higher yields and total reduced N at the end of the season (Srivastava, 1980). NR activity has been shown to be higher in rainy season than during winter in *Lolium* (Bergareche and Simon, 1988). It is important to understand the influence of flooding and non-flooding (normal) conditions and their interaction on NR activity as this is one of important traits used for crop improvement in India where the crop seasons vary significantly for temperature, rainfall, etc. Thus, the present experiment was carried out with the objective to study the effect on nitrate reductase activity in water logging condition and normal conditions and its relation with flowering and vegetative maize plants.

MATERIALS AND METHODS

Experiments were conducted on sandy loam soils (7.32 pH) with an available N of 125 kg^{-1} soil (125 kg ha^{-1}) at Agricultural Research Farm, Varanasi, India, during monsoon (June to Sept) Seasons. Environment plays a determining role in crop productivity. It is important to know about the implication of environment on crop growth in Indian conditions, particularly due to complex agro-climatic conditions prevailing in this vast country. In India, the crop growing periods are strikingly different with Kharif, Rabi and Zaid seasons. The present investigation was aimed at to know about the eco-physiological interactions with particular reference to rainfall, one of the most important factors that determine the plant growth and yield. Kharif season was selected for study as this is the major, strikingly different and important crop growing season in India.

Selection of crop

Maize is one of the most important food and fodder crops which can be grown in both Kharif and Rabi seasons as it has wide adaptability to various environmental conditions. It is an important crop the physiological point of view, being a C_4 plant, and has a high yield potential.

Climatic conditions

Maize is a warm weather plant. It grows from sea level to 3000 meter altitudes. It can be grown under diverse conditions. It is grown in many parts of the country through the year. Varanasi city is situated in the North Indian belt of semi arid to sub-humid climate and lies between 25° 18'N latitude and 83° 03' E longitude at an altitude 128°.93 m from the sea level. The annual mean precipitation, ranging approximately from 75 to 100 cm, is mostly confined to kharif season, but light and intermittent showers are also received during winter. Normally, the maximum and minimum temperature varied from 23.2° C to 41°C and 5.0°C to 25.5°C, respectively.

Experimental site

The present study was carried out at the vegetable garden of Agricultural farm, Institute of Agricultural Sciences, Banaras Hindu University. A rectangular field with a uniform fertility and even topography, with an assured irrigation facility was selected for layout of the experiment.

Soil conditions

Soil analyses were done prior to sowing after taking samples randomly throughout the field. The physico-chemical properties of soil given in the table 1.

Table 1. The physico-chemical properties of soil prior to sowing

Properties	Values
pH (1:2.5)	7.32
F.C	12.1
PW.P	3.5
EC (dsm^{-1})	0.165
O.C (%)	0.375
$CaCO_3$ (%)	0.72
Ca++	3.75
Mg++	2.97
Na++	0.09
K++	0.17
Textural class	Sandy loam
Av. N.	125
Av. P.	8.6
Av. K.	67.0

Irrigation regime

Irrigation was given prior to sowing because there was lack of masture for germination. First irrigation was given 15 days after germination otherwise no need of irrigation in Kharif maize season crop.

Irrigation for flooding

After the sixth week of germination water logged condition was created by irrigation in the half of the portion of cropping field. This flooding given for two weeks when the plants height about 3 m long and 7 or 8 leaves were comes.

Effect of season on two growing conditions of different verities of maize

As the emphasis now focused on the sustainability of agriculture, the importance of genotype and environment interaction was realized. The knowledge about genotype x environment interaction with reference to physiological implications on plant growth and yield is very essential in crop improvement programme. Thus, this experiment was designed to study the nitrate reductase activity of *Kharif* season crop at two different growing conditions *viz* flooding and normal condition of seven different genotypes of maize.

Choice of genotypes

Seven different genotypes of maize were studied. All the seven genotypes are moisture tolerant viz. MT-981, 982, 983, 984, VC-2, MT-991 and MT-992 chosen as all were relatively new and widely under cultivation. The germplasm of lines were collected from various neighboring flood prone lines which showed the tolerance were identified and intercross to develop excess moisture tolerant.

Experimental units

The experiment was carried out in randomized block design. The total number of plots for this experiment were- 21 (varieties = 7 replications = 3)

Two growing condition viz flooding and normal condition (Total combinations = 7 x 3 x 2 = 42) viz. 21 plots for flooded condition and 21 plots for normal condition.

The observations were taken in flowering as well as non-flowering plants at different three stages beginning from anthesis. The first stage for observation were- anthesis 6 days after flooding, 2^{nd} stage was 29 days after flooding and 3^{rd} stage was 46 days after flooding.

Fertilizer applications

Nitrogen was applied as diammonium phosphate (DAP); urea and ammonium nitrate @ 0, 80,120 and 160 kg ha^{-1}. Applications of nitrogen at the time of sowing, 10-leaf stage and tassel emergence stage were done in the 2:1:1 ratio of total N dose in each treatment, respectively. Single super phosphate and muriate of potash were applied at the rate of 60 P and 40K kg ha^{-1}, respectively at the time of sowing. In DAP treatments, it was applied as per requirement for P (60 kg ha^{-1}) and the remaining N as urea to provide appropriate nitrogen for the treatment.

Selection of leaves for estimation of N.R. activity

Leaf sample from the Maize varieties was collected in the month of 2^{nd} week of August. The sixth or seventh leaf from apex of each fully sun light exposed plant was selected 5 mg of the leaf was used for each sample for assaying *in vivo* NR activity at three different dates were provided for the age of the plant from germination along with their sowing date to find out the age of the plant at which the nitrate reductase activity was estimated using the method of Hageman and Flescher (1960) and Nicholas *et al.* (1976).leaf samples from three plants in the middle rows from each replication and treatment were collected between 8 and 9 am at each sampling time. Data were statistically analyzed for analysis of variance and CD values were used to compare means at P = 0.05.

Extraction of enzyme

The leaf samples in each replication of each treatment were collected in separate labeled polythene bags in the early morning. They were cleaned thoroughly with filter paper. The chopped leaf material weighing 0.5 g was taken into the tubes containing 8 ml of 0.1 M phosphate buffer, 1 ml of 0.1M KNO_3 and 1 ml of 5% n-propanol. The test tubes were equated to achieve complete infiltration of the medium into the sample. These tubes were incubated at 30 ^{0}C in dark for 45 min in each an incubator. After the incubator period, the reaction was stopped by placing the tubes. Then they were cooled and 1 ml extract from test tube taken in fresh test tube. To this 1 ml 1% sulphanilamide and 1 ml of 0.02% NEDD was added. The pink color was allowed to develop for 20 min. and after that the intensity of color was recorded at 540 nm in terms of O.D (absorbance).

RESULTS AND DISCUSSION

The *in vivo* activity in leaf at seven growth stages of crop development had strikingly different trends during monsoon seasons of maize. The nitrate reductase activity (NRA) in µmol/500 mg fresh weight/45 min leaves of different genotypes of maize. The results have been observed on the plants having 50 days age and 6 days of flooding. The non-flooded crop was taken as control. At this stage approximately 40% of the plants have flowered. That's why we have taken the observations on the two types of the plants those flowered and the plants still did not flowered. Fig. 1 presents nitrate reductase activity in leaves of non-flowering plants at 6 days, 29 days, and 46 days of flooding at 50 days, 72 days and 89 days from germination of plants respectively. In the genotypes MT-983 and MT- 984 at 6 days of flooding maximum nitrate reductase activity followed by MT-982 and VC-2 was observed as compared to (Fig. 2) control conditions. Other four genotypes minimum nitrate reductase activity was observed. In case of 29 days of flooding i.e. 72 (Fig. 1) days from germination minimum NRA in all the genotypes except VC-2 genotype as compared to (Fig. 2) controlled conditions. Likewise 46 days of flooding i.e. 89 days from germination (Fig. 1) very less NRA was observed as compared to (Fig. 2) controlled conditions. The result presented in the Fig 3 and 4, the nitrate reductsae activity in leaves of the varieties studied at this stage all the plants flowered therefore no data can be taken on the non-flowered plants. Nitrate reductase activity in flowering plants there was no significantly difference in 6 days of flooding and non-flooding condition but in 29 days of flooding NRA increased in MT-982 and VC-2 followed by MT-991 and MT-984. NRA in 46 days of flooding VC-2 and MT-992 was recorded maximum followed by MT-981 and MT-982. The result indicate that in flowering plants prolonged flooding increased the NRA in maize genotypes

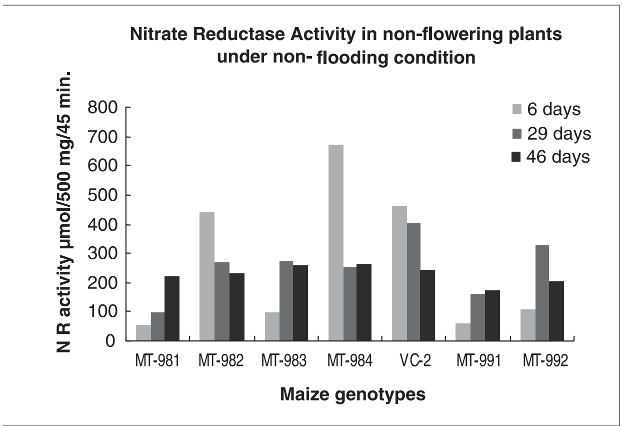

Fig. 1. Nitrate Reductase Activity in non-flowering plants under non-flooding conditions

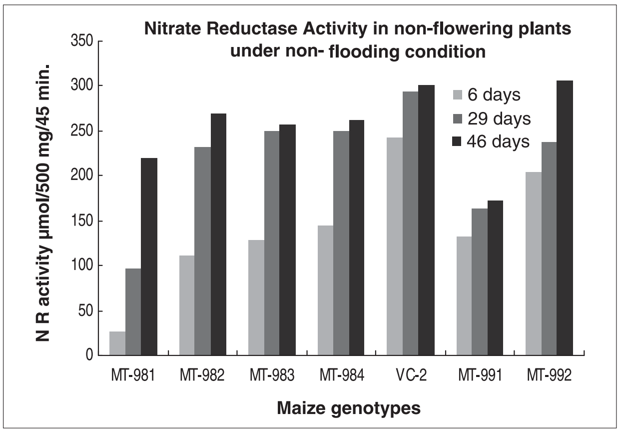

Fig. 3. Nitrate Reductase Activity in flowering plants under non- flooding conditions

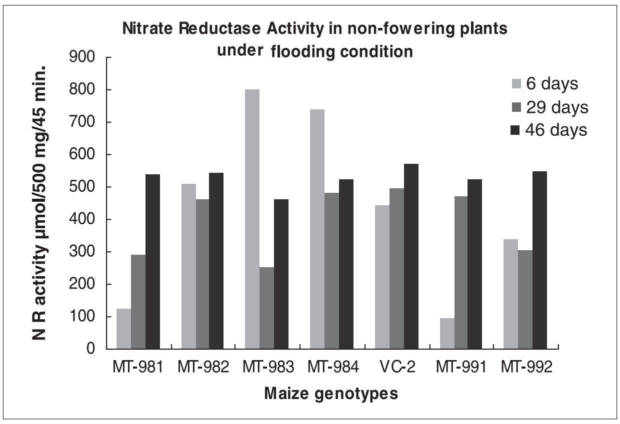

Fig. 2. Nitrate Reductase Activity in non-flowering plants under flooding conditions

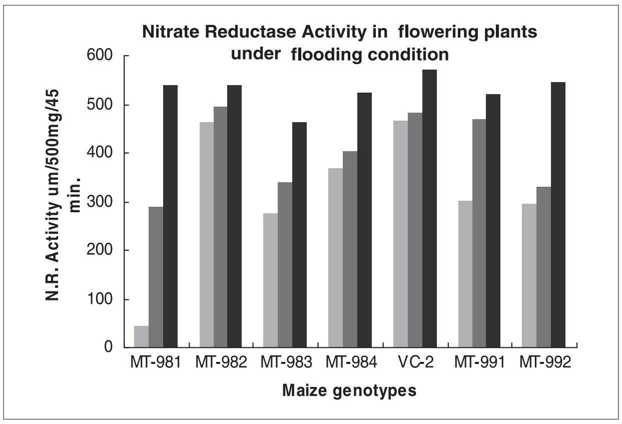

Fig. 4. Nitrate Reductase Activity in flowering plants under flooding conditions

so, it was clear that the NRA increased in leaves with the age of the plants up to this stage. In our experiment the flowering plants in flooded and non- flooded condition as control. Clearly indicates that the variation achieved for nitrate reductase activity (NRA) in leaves is dependent varietals characteristics to react with the flooded condition. The results clearly indicates that the variety i.e. having the maximum nitrate reductase activity in flooding and specially in prolonged flooding condition was not the variety that have the maximum NRA in noon-flooded condition. The other varieties also showed the same type of trend for increase or decrease nitrate reductase activity. At least we can be certain on a point that increase or decrease NRA was not directly correlated with the flooding condition. Though flooding certainly effect NRA in positive or negative terms in all the varieties studied here as the values have been changed in all the cases with control. It required more repetitions before recommending it to farmers at least we can see that variety like MT-982, VC-2 followed by MT-984 and MT-991 can be preferred for use cultivation in the flooded as well as prolonged flooded condition the nitrate reductase activity in leaves these varieties had significantly increased.

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Crop growth indices of wheat-Japanese mint intercropping as influenced by land configurations and nutrition levels

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ABSTRACT

A field experiment was conducted during winter to summer seasons of 2006-07 and 2007-08 at Gurdaspur (Punjab) on silty clay loam soil to study the crop growth rate (CGR) and relative growth rate (RGR) of wheat-Japanese mint (J. mint) intercropping system under different planting methods and nitrogen levels. The experiment was laid out in randomized block design having two planting methods viz. two rows of wheat (November sown) with 20 cm row spacing and two rows of J. mint (intercropping in February) on outer sides of wheat rows under flat and bed (37.5 cm top + 30 cm furrow) methods covering a total width of 67.5 cm and five levels of nitrogen i.e. 0+0 (control), 90+75, 120+75, 150+75 and 180+75 kg N ha^{-1} to wheat and J. mint, respectively. In wheat, the bed method gave significantly higher CGR over flat and it was higher by 8.9, 12.4 and 24.4 per cent during 2006-07 and 11.9, 16.6 and 40.4 per cent during 2007-08 at 60-90 DAS, 90-120 DAS and 120 DAS-harvest stage, respectively. In J. mint, during both the years from 60-90 DAS, the flat recorded significantly higher CGR than the bed. However, at 120 DAS-harvest stage during 2007-08, the bed produced significantly higher CGR than the flat, possibly due to variable rainfall pattern between the years. Between 120 DAS-harvest stage, the CGR of wheat decreased from 0 to 90 kg ha^{-1} and then increased upto 150 kg N ha^{-1} during 2006-07 and it enhanced upto 180 kg ha^{-1} during 2007-08. The impact of higher rate of N application to wheat remained effective for wheat only and it was not shifted on the CGR of J. mint. During both the years at all the stages, the RGR of wheat did not differ significantly due to both the planting methods except at 120 DAS-harvest stage during 2007-08. In J. mint, at almost all the crop growth intervals, both the planting methods differed significantly in RGR. The RGR of wheat at N_{120} over control showed an increment of 71 and 39 per cent at 60-90 DAS and 9 and 35 per cent at 90-120 DAS during 2006-07 and 2007-08, respectively but, reversely, at 120 DAS-harvest stage, the respective increase in control over N_{120} was 109 and 276 per cent. Interactive impact of planting method and nitrogen levels on CGR of wheat was significant between 120 DAS-harvest stage during 2007-08.

Key words: Wheat, mint, intercropping, crop growth rate, relative growth rate, planting method, nitrogen

INTRODUCTION

In the present scenario, increase in the productivity of wheat per unit area per unit time is a challenging task under Punjab conditions. However, the possibility of higher productivity can be explored by adopting better alternative techniques like intercropping of a high value crop J. mint in standing wheat and altering the management practices especially land configurations and nitrogen application. Common characteristics of different forms of intercropping are that they have the advantage of exploiting environmental resources more efficiently (Francis, 1989; Li *et al.*, 2003; Zhang and Li, 2003; Li *et al.*, 2006), improving soil fertility (Shen and Chu, 2004; Dahmardeh *et al.*, 2010) and increasing crop yield and quality (Javanmard *et al.*, 2009; Dahmardeh *et al.*, 2010). In an intercropping situation where two or more crops are associated, their fertilizer requirement may vary widely and hence, fertilization becomes more complex (Singh *et al.*, 1996).

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Growth analysis is an important tool in the prediction of yield and to assess the events that occurs during plant growth. It is a suitable method for plant response to different environmental conditions during plant life (Teaser, 1984). Crop growth rate and relative growth rate are the most important traits in plant growth analysis and are useful for interpreting plant reaction to environmental factors. Crop growth rate indicates the rate at which a crop is growing and expressed as kg ha^{-1} day^{-1}. Relative growth rate indicates the rate of growth per unit dry matter. It is expressed as milligram of dry matter produced by a gram of existing dry matter in a day.

As per the packages of practices of Punjab, the sowing of wheat is recommended on flat as well as bed planting with the help of seed-cum-fertilizer drill and bed planter, respectively. Reports from India and Pakistan revealed many advantages of bed planting in rice-wheat systems (Hobbs and Gupta, 2003; Connor *et al.*, 2003). Bed planting may improve the resource use efficiency and increase the yield potential of wheat. Bed planting offers many benefits like opportunity for mechanical weed control, reduced crop lodging, lowering of the seeding rates and reduced water logging (Humpreys *et al.*, 2005). Beds also provide additional advantages like reduced germination of *Phalaris minor*, reduced irrigation water requirement by 30-50%, reduced water logging (Sharma and Swarup, 1988; Gill *et al.*, 1993) and reduced seed rate requirement by 25-30% (Dhillon *et al.*, 2004). Owing to its positive results, it has also been recommended and included in the package of practices of Punjab Agricultural University, Ludhiana in 2002-03 (PAU, 2002). Therefore, studies of wheat-mint intercropping under flat and bed planting methods is very significant.

In wheat-mint intercropping system, whole of nitrogen to wheat was applied within one month of sowing and to J. mint, half nitrogen was applied at the time of planting in the mid season of wheat and the remaining half nitrogen was top dressed after harvesting of wheat crop. The possibility was there that J. mint crop might use the residual nitrogen applied to wheat. Therefore, suitable rate of nitrogen application under different planting methods for the growth of both the component crops in an intercropping system needs to be evaluated.

Considering these facts, a two year study was conducted to study the crop growth rate and relative growth rate of wheat-mint intercropping system under flat and bed planting methods with various rates of nitrogen application.

MATERIALS AND METHODS

A field experiment was conducted during winter (*rabi*) to summer seasons of 2006-07 and 2007-08 at Village Dalla in the Gurdaspur district of Punjab. Chemical analysis of the experimental soil indicated that it was normal in reaction and non-saline, high in organic carbon, low in available nitrogen, high in available phosphorous and potassium at 0-15 cm depth whereas it was low in available nitrogen and medium in organic carbon (OC), available phosphorus (P) and potassium (K) at 15-30 cm depth.

The treatments comprising of two planting methods and five levels of nitrogen were tested in randomized block design with three replications. Two rows of wheat (W) with 20 cm spacing and planting of two rows of J. mint (M) in close vicinity on outer sides of wheat rows (2:2) were sown under flat (FP) and bed planting (BP) covering a total width of 67.5 cm and designated as FP-W+M (2:2) 67.5 cm (Fig. 1) and BP-W+M (2:2) 67.5 cm (Fig. 2), respectively. Five levels of nitrogen i.e. 0+0 (control), 90+75, 120+75, 150+75 and 180+75 kg N

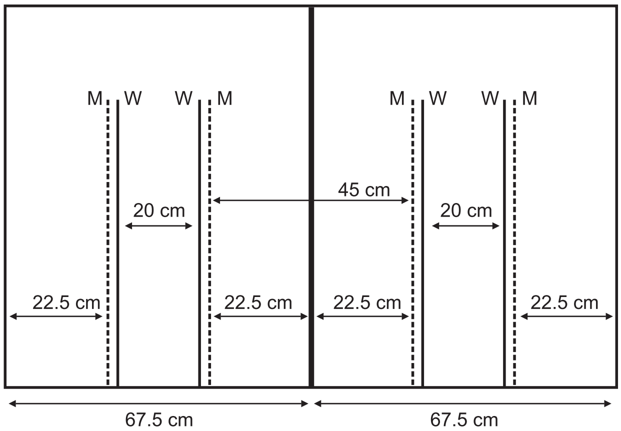

Fig. 1. Flat method: FP-W+M (2:2) 67.5 cm

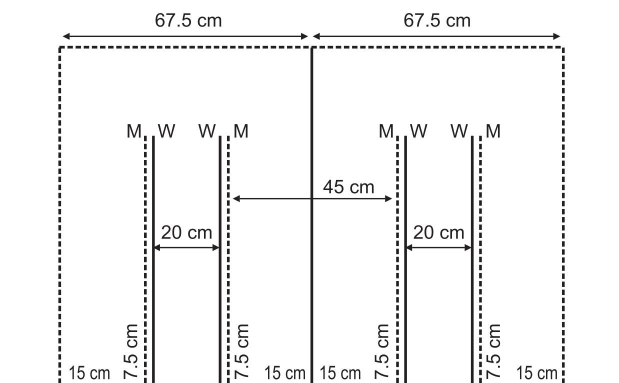

Fig. 2. Bed planting: BP-W+M (2:2) 67.5 cm

ha^{-1} to wheat and J. mint, respectively, were abbreviated as WN_0+MN_0, $WN_{90}+MN_{75}$, $WN_{120}+MN_{75}$, $WN_{150}+MN_{75}$, $WN_{180}+MN_{75}$ in similar order.

The wheat variety 'PBW 502' was sown on November 3 and 5 during 2006-07 and 2007-08, respectively, using 75 kg seed ha^{-1}. In a single operation, with the help of bed maker-cum-planter, the raised beds of 67.5 cm were prepared by keeping 37.5 cm as the top of the bed with furrows of 30 cm and two rows of wheat were drilled at 20 cm spacing on the top of the 37.5 cm raised beds. Irrigation water was applied in the furrows between the beds and water was not allowed to reach at the top of the bed by applying 5 cm irrigation on the plot area basis. Bed sown row arrangements were exactly followed in the flat situation and crop was sown in solid rows with the help of seed drill and irrigated with 7.5 cm of depth. In Punjab, the row to row spacing of wheat has been recommended as 20 cm on bed top and it is 20-22 cm for flat. To make the uniformity of treatments, the row spacing in both the methods was kept 20 cm.

Planting of J. mint was done in the standing wheat on February, 7 and 10 during 2006-07 and 2007-08, respectively. In bed planting, two rows of J. mint were planted on the bed-top on outer sides of wheat rows. In flat situation, similar row pattern was followed. The wheat and J. mint were harvested manually on April 13 and June 26 during 2006-07 and on April 19 and July 10 during 2007-08, respectively.

Nitrogen fertilizer was applied through urea to wheat and J. mint as per treatment. In wheat, half dose of N was broadcast just before sowing of wheat and the remaining N was top dressed after first irrigation. In J. mint crop, half of the N was applied along the J. mint rows at the time of planting and remaining half N applied as top dressing after harvesting of wheat crop. In flat, fertilizer was broadcast uniformly but in bed treatment it was applied carefully on the top 37.5 cm width for both wheat and J. mint crops. Recommended dose of phosphorus i.e. 61.8 kg P_2O_5 ha^{-1} was applied to wheat at sowing through diammonium phosphate but it was skipped at the time of planting of J. mint. All the recommended cultural operations were followed as per packages of practices for *rabi* and *kharif* crops of Punjab (PAU, 2006 and PAU, 2007).

Crop growth indices i.e. crop growth rate and relative growth rate of wheat and J. mint were calculated at 60-90 DAS, 90-120 DAS and 120 DAS-harvest stages by using the following formulae and expressed in kg ha^{-1} day^{-1} and mg g^{-1} day^{-1}, respectively.

$$CGR = \frac{(W_2-W_1)}{(t_2-t_1)}$$

$$RGR = \frac{(Log_e W_2 - Log_e W_1)}{(t_2-t_1)}$$

where, W_1 and W_2 referred to dry matter weight of plants at time t_1 and t_2, respectively.

RESULTS AND DISCUSSION

Crop growth rate of wheat and J. mint

Planting method

The crop growth rate of wheat and J. mint indicated that as both the crops progressed from 60 DAS-120 DAS, it showed an increasing trend under flat and bed planting methods during 2006-07 and 2007-08 (Table 1). In the subsequent stage i.e. 120 DAS-harvest, the CGR of wheat during both the years and J. mint during 2006-07 decreased under both the planting methods. However, in the year 2007-08, the CGR of J. mint under flat planting decreased marginally but it increased in bed planting. In wheat, the 'Bed Planted Wheat + J. mint (2:2 rows) on 67.5 cm width' gave significantly higher crop growth rate of wheat over 'Flat Planted Wheat + J. mint (2:2 rows) on 67.5 cm width' and it was higher by 8.9, 12.4 and 24.4 per cent during 2006-07 and 11.9, 16.6 and 40.4 per cent during 2007-08 at 60-90 DAS, 90-120 DAS and 120 DAS-harvest stage, respectively. Favourable environment of the bed which contained loose soil and better aeration (West and Black, 1969), possibly enhanced the mineralization of nutrients which increased root growth and consequently the higher CGR. Rasheed *et al*. (2003) reported that crop growth rate of hybrid maize at 30-75 DAS was significantly higher in the crop planted on 70 cm spaced ridges (31.1 g m^{-2} day^{-1}) than 70 cm spaced single-rows (28.0 g m^{-2} day^{-1}). In J. mint, during both the years from 60-90 DAS, the flat method recorded significantly higher crop growth rate than the bed planting. At 90-120 DAS during both the years and 120 DAS-harvest stage during 2006-07, both the planting methods were on par. However, at 120 DAS-harvest stage during 2007-08, the bed produced significantly higher CGR than the flat. The possible reason for variation in CGR of J. mint

Table 1: Effect of planting methods and nitrogen levels on the crop growth rate of wheat and J. mint

Treatment	Crop growth rate (kg $ha^{-1}day^{-1}$)											
	60-90 DAS				90-120 DAS				120 DAS-harvest			
	Wheat		J. Mint		Wheat		J. Mint		Wheat		J. Mint	
	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08
Planting Methods (P)												
FP-W+M (2:2) 67.5 cm	107.3	99.2	24.0	28.8	146.2	141.5	71.7	73.7	44.3	44.6	66.1	72.7
BP-W+M (2:2) 67.5 cm	116.8	111.1	19.8	25.1	164.4	165.0	68.0	70.9	55.1	62.6	67.5	90.8
CD (5%)	4.58	5.20	1.70	1.85	9.44	9.49	NS	NS	7.12	3.09	NS	5.25
Nitrogen (Kg ha^{-1})												
WN_0+MN_0	36.9	44.7	17.9	22.3	61.9	53.2	54.2	53.8	49.2	73.9	43.7	55.5
WN_{90}+MN_{75}	124.6	115.0	22.8	28.1	169.6	163.8	74.4	75.9	28.1	33.1	74.2	89.9
WN_{120}+MN_{75}	131.4	120.7	22.8	28.0	176.9	178.0	72.9	76.5	60.0	44.5	71.9	87.2
WN_{150}+MN_{75}	133.8	122.0	23.3	27.8	184.0	185.4	73.6	77.5	69.0	56.7	71.5	89.4
WN_{180}+MN_{75}	133.7	123.4	22.7	28.6	184.3	186.0	74.2	77.7	42.2	60.1	72.6	86.6
CD (5%)	7.24	8.22	2.69	2.93	14.93	15.01	6.33	8.17	12.92	4.89	9.34	8.31

between the planting methods was related to variable rainfall pattern between the two years. During first year, due to comparatively low rainfall (70.4 mm) between 120 DAS-harvest stage, the crop on beds came under water stress which affected the crop growth. In the second year, higher rainfall (314.7 mm) during this period caused excess moisture content and poor aeration under flat planting owing to heavy texture of the soil which suppressed the plant growth. While, the bed sown J. mint escaped from submergence/water logged like situation and, infact, the rainfall favoured the crop growth rate due to optimization of soil moisture under the bed. Sweeney and Sisson (1988) reported improved drainage in root zone in case of poorly drained soil.

At 90-120 DAS, the CGR of J. mint on beds was less than flat whereas in case of wheat it was opposite. It is mentioned that all the growth stages of both the crops were observed at different times, and environmental conditions were also not similar in the same number of days after sowing. Because, wheat was sown in the month of November and J. Mint was planted in the month of February. In J. mint, the crop on beds came under water stress due to high temperature of 36.1^0 C and 33.4^0 C during 2006-07 and 2007-08, respectively, prevailing at that stage and it resulted into less accumulation of dry matter on the beds. Moreover, irrigation water was applied in the furrows only and it could reach to mint plants owing to seepage. Further, Yadav *et al.* (2002) reported rapid drying of soil surface in bed planting. This might be the reason for low CGR in mint at this stage. On the contrary, wheat recorded maximum temperature of 17.7^0 C during 2006-07 and 17.0^0 C during 2007-08 at 90-120 DAS and it remained favourable for more accumulation of dry matter accumulation in wheat and consequently higher CGR on beds. West and Black (1969) also confirmed that favourable environment of the bed which contained loose soil and better aeration, possibly enhanced the mineralization of nutrients which increased the root growth and finally the higher CGR.

Nitrogen

During both the years, between 60-120 DAS, CGR of wheat was generally enhanced as the N application increased from 0 to 180 kg ha^{-1}. Between 120 DAS-harvest stage, it decreased from 0 to 90 kg ha^{-1} and then increased upto 150 kg N ha^{-1} during 2006-07 and enhanced upto 180 kg ha^{-1} during 2007-08. When comparison was made between no application and highest rate of N application to wheat (N_{180}), it was observed that N_{180} recorded an increase of 262 and 176 per cent at 60-90 DAS and 198 and 250 per cent at 90-120 DAS during first and second year, respectively but reversely, at 120 DAS-harvest stage, the respective increase in control was 17 and 23 per cent over N_{180}. Higher CGR was also observed at 160 kg N ha^{-1} in wheat (Kakar, 2003) and at 250 kg N ha^{-1} in hybrid maize (Rasheed *et al.*, 2003) than unfertilized crop. Bennett *et al.* (1989), Ahmad *et al.* (1993) and Mohsan (1999) also reported an increase in CGR of maize with the application of N over control. No application of nitrogen (control) recorded significantly less CGR of wheat than all the N fertilized treatments between 60-120 DAS during both the years. During 2006-07, between 120 DAS-harvest stage, the crop growth rate under control was maximum and on par with N_{120} and N_{180}.

Interestingly, during 2007-08 between 120 DAS-harvest stage, the control recorded significantly higher crop growth rate over all the N fertilized treatments indicating that crop mechanism tried to accumulate maximum dry matter at the last phase even with no application of fertilizer.

At all the growth stages, N application to wheat at all the levels had no visible impact on the CGR of J. mint but application of N at 75 kg ha^{-1} to J. mint gave significantly higher increase in crop growth rate than the control (N_0). Therefore, it indicated that the impact of higher rate of N application to wheat remained effective for wheat only and it was not shifted on the growth of J. mint.

Relative growth rate of wheat and J. mint

Irrespective of planting methods and nitrogen levels, the trend in Table 2 revealed that the relative growth rate of wheat and J. mint was decreased as the crop advanced from 60 DAS-harvest stage.

Planting method

During both the years at all the stages, the RGR of wheat did not differ significantly due to both the planting methods except at 120 DAS-harvest stage during 2007-08 where the bed sown wheat recorded 16 per cent higher RGR than flat method and the differences were significant (Table 2). In J. mint, at almost all the crop growth intervals, both the planting methods differed significantly with respect to RGR. At the initial growth stage i.e. 60-90 DAS during both the years, flat recorded higher RGR than bed. At 90-120 DAS and 120 DAS-harvest, bed produced significantly higher RGR than the flat method and it was higher by 7.9 and 8.3 per cent in 2006-07 and 5.4 and 24.3 per cent in 2007-08 per cent, respectively.

Nitrogen

The two year experiment on the RGR of wheat portrayed that the impact of N application was significant except at 90-120 DAS during 2006-07. While comparing N_{120} with no application of N, it was noticed that N_{120} gave an increment of 71 and 39 per cent at 60-90 DAS and 9 and 35 per cent at 90-120 DAS during 2006-07 and 2007-08, respectively but reversely, at 120 DAS-harvest stage, in similar order, the control was higher by 109 and 276 per cent over N_{120}. In the initial stages of crop growth, no application of nitrogen (control) recorded low RGR but at 120 DAS-harvest stage, it was significantly higher than all the N levels. It clearly indicated that in the late phase, the plant mechanism tried to recover the initial set back in RGR under no application of N. In J. mint, at 60-90 DAS and 120 DAS-harvest stage during 2006-07 and 90-120 DAS during both the years, all the N levels (N_{75} to J. mint) recorded significantly higher RGR than the control. During both the years, at all the growth intervals, the RGR of J. mint was on par irrespective of variable N levels except WN_0+MN_0 to accompanied wheat crop, showing thereby, that applied level of N_{75} to J. mint was sufficient enough to meet the N requirement of the crop under the wheat+mint intercropping system at these configurations of planting.

Planting method x Nitrogen

Interactive impact of planting method and nitrogen levels on CGR of wheat was significant at 120 DAS-harvest stage during 2007-08. At the same level of N, bed recorded significantly higher CGR than flat planting (Table 3). In both the methods, as the N application increased from 0 to

Table 2: Effect of planting methods and nitrogen levels on the relative growth rate of wheat and J. mint

Treatment	Relative crop growth rate (mg $g^{-1}day^{-1}$)											
	60-90 DAS				90-120 DAS				120 DAS-harvest			
	Wheat		J. Mint		Wheat		J. Mint		Wheat		J. Mint	
	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08
Planting Methods (P)												
FP-W+M (2:2) 67.5 cm	16.6	15.4	23.7	26.6	9.5	9.4	17.7	16.6	2.4	2.5	7.2	7.4
BP-W+M (2:2) 67.5 cm	16.4	15.2	23.2	26.2	9.9	9.6	19.1	17.5	2.4	2.9	7.8	9.2
CD (5%)	NS	NS	0.45	NS	NS	NS	0.39	0.30	NS	0.14	0.48	0.65
Nitrogen (Kg ha^{-1})												
WN_0+MN_0	10.6	11.7	22.5	25.8	9.0	7.4	17.7	15.9	4.6	6.4	6.5	7.7
$WN_{90}+MN_{75}$	18.5	16.3	23.6	26.4	9.8	9.8	18.7	17.2	1.1	1.3	7.9	8.7
$WN_{120}+MN_{75}$	18.1	16.3	23.6	26.6	9.8	10.0	18.5	17.3	2.2	1.7	7.8	8.5
$WN_{150}+MN_{75}$	17.9	16.1	24.0	26.5	9.9	10.2	18.4	17.5	2.5	2.1	7.7	8.6
$WN_{180}+MN_{75}$	17.6	16.1	23.6	26.7	9.8	10.1	18.7	17.2	1.5	2.2	7.8	8.3
CD (5%)	1.00	0.62	0.72	NS	NS	0.61	0.61	0.47	0.79	0.23	0.76	NS

Table 3: Interactive impact of planting methods and nitrogen levels on crop growth rate (CGR) and relative growth rate (RGR) of wheat

Treatment	Nitrogen (Kg ha^{-1})					
	WN_0+ MN_0	WN_{90}+ MN_{75}	WN_{120}+ MN_{75}	WN_{150}+ MN_{75}	WN_{180}+ MN_{75}	Mean
CGR (kg ha^{-1}day^{-1}), 2007-08 at 120 DAS to harvest						
Planting Methods (P)						
FP-W+M (2:2) 67.5 cm	69.9	21.1	32.0	47.2	53.0	44.6
BP-W+M (2:2) 67.5 cm	77.8	45.1	57.0	66.2	67.1	62.6
Mean	73.9	33.1	44.5	56.7	60.1	
CD (5%) : P= 3.09, N= 4.89, P x N= 6.91						
RGR (mg g^{-1} day^{-1}), 2006-07 at 90-120 DAS						
FP-W+M (2:2) 67.5 cm	8.2	9.4	9.7	10.1	10.0	9.5
BP-W+M (2:2) 67.5 cm	9.8	10.3	9.8	9.7	9.7	9.9
Mean	9.0	9.8	9.8	9.9	9.8	
CD (5%) : P= NS , N= NS, P x N= 1.01						
RGR (mg g^{-1} day^{-1}), 2007-08 at 120 DAS-harvest stage						
FP-W+M (2:2) 67.5 cm	6.5	0.9	1.3	1.9	2.1	2.5
BP-W+M (2:2) 67.5 cm	6.3	1.7	2.0	2.3	2.3	2.9
Mean	6.4	1.3	1.7	2.1	2.2	
CD (5%) : P= 0.14, N= 0.23, P x N= 0.32						

90 kg ha^{-1}, the CGR of wheat decreased significantly and thereafter, it increased significantly upto 150 N kg ha^{-1}. The interaction occurred due to variation in magnitude of increase or decrease with N levels under both the planting methods.

The Interaction between planting methods and nitrogen levels was also significant on the RGR of wheat at 90-120 DAS during 2006-07 and at 120 DAS-harvest stage during 2007-08 (Table 3). During 2006-07 at 90 to 120 DAS, bed sown wheat recorded significantly higher RGR over the flat when no N was applied. In the remaining N levels, both the planting methods did not differ significantly. In flat method, increasing levels of nitrogen enhanced the RGR of wheat significantly upto N_{90} but in the bed, all the N levels did not differ significantly. During 2007-08 at 120 DAS-harvest stage, both the planting methods were on par at the same levels of N i.e. N_0 and N_{180}, whereas, in the remaining N levels, the bed system was significantly higher than the flat. No application of N (control) to wheat under both the methods was significantly higher than all the combinations of N levels and planting methods. The RGR in both the planting methods was decreased as the N application to wheat increased from control to N_{90}, and thereafter enhanced significantly upto N_{150}.

Irrigation water used

During both the years, the bed system showed a saving of irrigation water applied from the sowing of wheat in November till harvesting of J. mint in the month of June/July (Fig. 3). It was observed that bed planting saved 33.3% irrigation water than the flat. In the bed system, as the irrigation water was applied only in the furrows and it covered less area than flat which resulted into less amount of irrigation water applied.

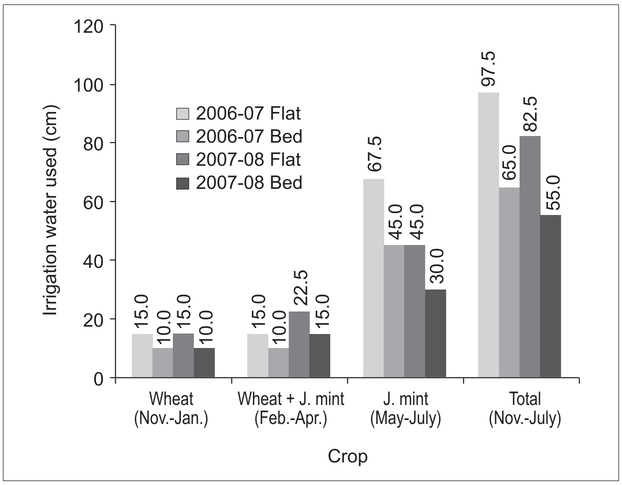

Fig. 3. Irrigation water used in wheat-J.mint intercropping during the season

CONCLUSION

Considering the CGR and RGR of both wheat and J. mint, the promising option was to adopt the intercropping on beds alongwith application of 120 and 75 kg N/ha to the crops, respectively.

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Performance of Bt and non-Bt cotton cultivars under conservation agriculture practices in a cotton-wheat system

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ABSTRACT

Development of Bt cotton in recent years represents a significant technical change for cotton production and has proved to be a boon for cotton-wheat cropping system. This breakthrough has the potential to expand the production frontier of cotton and improve producers' benefits. The direct benefits from use of Bt cotton is to control insect pests with reduced use of broad-spectrum insecticides, lower farming risks and production costs, better yields and profitability, expanded opportunities to grow cotton and a brighter economic output for the cotton industry. Field experiments were conducted during 2006 and 2007 at the Indian Agricultural Research Institute, New Delhi to evaluate the performance of Bt and Non-Bt cotton cultivars under conservation agriculture practices vis-à-vis conventional tillage practices. The experiment was conducted in split plot design with five replications in a fixed lay out. The main plot treatments consisted of two tillage practices, viz. conventional tillage and conservation tillage, while the sub plot treatments were 8 cultivars of cotton (4 cultivars were Bt and 4 cultivars were non-Bt). The performance of Bt cotton was significantly higher than non-Bt cotton cultivars. The seed cotton yield was similar between the two tillage practices, thus, conservation agriculture practice was found potential to enhance the productivity and resource use efficiency. The pest populations were less in Bt cultivars than non-Bt cultivars.

Key words: Conventional tillage, crop residues, Bt cotton, yield, pest, transgenic

INTRODUCTION

Cotton is an important fibre crop of India being cultivated over an area of about 9.5 million hectares (m ha) representing approximately one quarter of the global area of 35 million hectares under this crop. After China, India is the largest producer and consumer of cotton, the country accounting for a little over 21% of the global cotton production. Much of this success owes itself to the introduction of Bt cotton in 2002 prior to which cotton production suffered huge losses due to its susceptibility to insect pests (CICR, 2009). Among the insects, cotton bollworms are the most serious pests of cotton in India causing annual losses of at least US$300 million. The cotton bollworm complex comprises, American bollworm, also called 'false America bollworm' or 'old world bollworm', *Helicoverpa armigera*; pink bollworm, *Pectinophora gossypiella*; spiny bollworm, *Earias insulana* and spotted bollworm, *Earias vittella*. *Spodoptera litura*, the leaf worm, is mainly a foliage feeder but it also damages cotton bolls. Insecticides valued at US$660 million are used annually on all crops in India, of which about half are used on cotton alone (Manjunath, 2004; Rai *et al.*, 2009). Bt or *Bacillus thuringiensis* is a ubiquitous soil bacterium first discovered in 1901 by Ishiwata, a Japanese microbiologist (Kumar *et al.*, 1996). Later it was found that some Bt strains (Cry+) were highly toxic to larvae of certain insect species which are also plant pests. Gandhi and Namboodiri (2006) surveyed 694 cotton growing farmers from Gujarat, Maharashtra, Andhra Pradesh and Tamil Nadu and reported that the yields of Bt cotton were significantly higher than that of non-Bt cotton under both irrigated and non-irrigated conditions. Karihaloo and Kumar (2009) reported that farmers' earnings and profitability from Bt cultivation have been significantly higher than those from cultivation of non-Bt cotton. Cotton is the most

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important foreign exchange earner through export of raw cotton, garments and cotton seed by-products in the form of edible oils and oilcakes. Wheat is the second most important cereal after rice and meets the nutritional requirement of the majority of people. These crops contribute significantly towards the economy of large number of people engaged in their cultivation, trade, processing etc. Development of short-duration early-maturing varieties of cotton and expansion of irrigation facilities have led to cultivation of these crops in sequence. Accordingly, cotton – wheat cropping system now occupies an important pace in the agricultural economy of north India, covering 1.7 million ha in the states of Punjab, Haryana and Rajasthan. Productivity of cotton showed a decline since mid-1990s with wide fluctuations in area and productivity for almost a decade. The major biophysical constraints were: poor plant stand due to poor emergence owing to crust formation after sowing, seedling burning due to high temperature at emergence, alkalinity and salinity problems, and increased incidence of pests and diseases. Likewise in wheat, delay in sowing due to late harvest of cotton results in reduction of yield due to prevalence of hot winds during March-April which coincide with grain filling stage. Development of Bt cotton in recent years represents a significant technical change for cotton production and has proved to be a boon for cotton-wheat cropping system. This breakthrough has the potential to expand the production frontier of cotton and improve producers' benefits, lower farming risks and production costs, better yields and profitability, expanded opportunities to grow cotton and a brighter economic output for the cotton industry (Edge *et. al*., 2001). The downside is the high cost of seeds and apprehension on the part of environmentalists about gene flow. The Bt cotton varieties mature early and vacate the field for timely sowing of wheat. Based on a study conducted in central India Ramasundaram *et al.* (2007) reported that Bt cotton hybrid reduced plant protection cost by Rs. 1268/ha, raised crop yield by 2.01 q/ha, worth Rs 6394/ha and reduced the time spent by the crop in the field by 15-20 days.

Major research and development efforts in the green revolution era focused on enhancing productivity of selected food grains and a few other crops. In the post-green revolution era, the issues of conservation have assumed greater importance in view of widespread resource degradation problems and the need to reduce production costs, increase profitability and make agriculture more competitive. Resource degradation problems are manifesting in several ways. Declining water tables in many agriculturally important regions imply increasing pumping costs, replacement of shallow gravity tube wells with submersible pumps at huge cost, adverse effects on water quality and overall ecology of the region. Declining soil carbon and fertility are reflecting in declining soil biodiversity, multiple nutrient deficiencies, need for increasing inputs use to maintain yields, and implications for quality of produce and environment. Conservation technologies involve minimum soil disturbance, providing a soil cover through crop residues or other cover crops and crop rotations for achieving higher productivity. This has emerged as way for transition to the sustainability of intensive cropping systems. Considering the above, an experiment was conducted to evaluate the performance of Bt and Non-Bt cotton cultivars under conservation agriculture practices vis-à-vis conventional tillage practices and their reactions to different insect pests.

MATERIALS AND METHODS

Field experiments were conducted during 2006 and 2007 at the Indian Agricultural Research Institute, New Delhi, situated at 28352 N latitude and 77°122 E longitude and at an altitude of 228.6 m above mean sea level (Arabian sea). Soil of the experimental site was sandy loam (Typic Haplustept, Inceptisol) with pH 7.6 and 3.8 g C kg^{-1} at 0-15 cm depth of soil. Field experiments were conducted during summer/rainy season (June-November) during 2006 and 2007 in split plot design with six replications in a fixed lay out. The main plot treatments consisted of two tillage practices viz. conventional tillage and conservation tillage, while the sub plot treatments were 8 cultivars (Table 1) of cotton (4 cultivars were Bt and 4 cultivars were non-Bt) i.e. four varieties of transgenic cotton were taken having Bt genes while other was not having the Bt genes. The previous wheat crop residues were applied @ 3.0 t/ha to cotton crop in a cotton-wheat rotation only in conservation tillage treatment plots. In conventional tillage: after the harvest of previous crop, the plots were ploughed with a disc harrow twice and cultivator was run twice followed by planking before sowing of cotton seed. In conservation tillage: no tillage operation was carried out after harvest of previous crop, cotton was sown manually.

Fertilizer dose of N:P:K ::160:35:66 kg ha^{-1} was applied to cotton. Half dose of N and full dose of P and K were applied as basal, whereas the remaining N was top-dressed. Urea, diammonium phosphate (DAP) and muriate of potash (MOP) were used as source of N, P and K, respectively. The population of Jassids (*Amrasca biguttalla biguttalla*), white fly (*Bemesia tabaci*) and thrips (*Thrips tabaci*) were determined from three leaves of cotton crop. Similarly population of American bollworm (*Helicoverpa armigera) and* spotted bollworm *(Earias spp) (Earias vittella* and other species*)* were determined per plant from each from each treatment. The observations were taken on seed cotton yield, number of bolls/plant, plant biomass at opening, plant height and duration to maturity from each treatment. The data recorded for different parameters were analysed with the help of analysis of various (ANOVA) technique for a split plot design using MSTAT-C software. The result are presented at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Performance of Transgenic cotton under different tillage practices

The seed cotton yield, number of bolls/plant, plant biomass, number of bolls/plant, plant height and duration to maturity for eight commercially available transgenic cotton cultivars under two tillage practices are presented in Table 1. The seed cotton yield of transgenic cotton cultivars were similar under both the tillage practices. Yield attributes, viz. plant biomass, bolls/plant, plant height and duration to maturity were also similar under both the tillage practices. The performance of cotton cultivars were statically similar under both conservation and conventional tillage practices (Table 1). The cotton yields, bolls/plant and bio-mass production were non-significant due to tillage practices. The performance of Bt and non-Bt cultivars differed significantly with respect to seed cotton yield and number of bolls/plant. The biomass yield among the eight transgenic cultivars was similar, though the biomass yield was comparatively higher in non-Bt than Bt cultivars. The Bt cotton cultivars produced significantly higher seed cotton yield and bolls/plant than non-Bt cultivars. Among the BT cotton cultivars, RCH-134 recorded maximum cotton yield (3.266) followed by MRC 6301 (2.873), RCH-317(2.832) and MRC 6304 (2.753). The latter 3 cultivars produced statistically similar cotton yield. Among the non-BT cotton cultivars, RCH 317 gave highest cotton yield (2.486 t/ha) followed by RCH 134, MRC 6301

Table 1: Yield and yield attributes of different transgenic cotton under conservation and conventional tillage practices (pooled mean of two years)

Treatment	Yield/ha (t ha^{-1})	No.of bolls/plant	Biomass at boll formation (t ha^{-1})	Biomass at boll opening (t ha^{-1})	Plant height (cm)	Duration to maturity (days)
Tillage practices						
Conservation Tillage	2.464	23.40	8.18	10.06	68.71	140
Conventional Tillage	2.477	22.58	8.12	10.71	65.47	143
SEm ±	0.051	1.774	0.284	0.185	0.70	
CD (P=0.05)	NS	NS		NS		
BT Cultivars						
RCH-134	3.266	27.52	8.40	8.40	73.20	130
RCH-317	2.832	28.17	7.78	9.54	63.07	145
MRC-6301	2.873	23.05	6.20	9.73	69.03	139
MRC-6304	2.753	22.12	7.59	8.61	69.33	139
Mean	2.931	25.3		9.07	68.5	
NBT cultivars			11.28			
RCH-134	2.102	24.00	8.67	11.03	70.00	145
RCH-317	2.486	23.00	7.78	11.87	66.00	145
RCH-6301	1.960	15.65	7.50	12.19	65.05	145
MRC-6304	1.890	20.35		11.70	61.12	145
Mean	**2.109**	**20.7**	1.728	**11.70**	**65.5**	
SEm ±	0.028	2.523		1.53		
CD (P=0.05)	0.058	7.2		NS		

and MRC 6304. The plant height in Bt cotton cultivars was marginally higher than non-Bt cultivars. There was variation in duration to maturity among Bt cultivars. However the duration to maturity for non-Bt cultivars was the same (145 days). From the above it is revealed that though the seed cotton yield between conventional and conservation tillage are similar, but due to less production cost (Malik *et al.*, 2005) in the latter, the profit margin will be more in Conservation tillage. It is also reported that the soil health under conservation tillage with respect to physical, chemical and biological parameters are better in conservation tillage than conventional tillage (Abrol and Sangar, 2006). Similarly the performance of Bt cotton was significantly higher than non-Bt cotton, which offers an opportunity for enhancing productivity in the region through cultivation of Bt cotton.

The incidence of pest in Bt and non-Bt cultivars of cotton

With respect to tillage practices, conservation tillage practice invariably harboured more number of sucking pests like jassids, whitefly and thrips, as well as both the bollworm species compared to the conventional tillage. Since in conventional tillage the field remained more weed free and cleaner compared to conservation tillage, the population of insects was relatively low. However, as both the tillage practices showed non-significant response to incidence of pests, conservation tillage practice was more economical/cost saving than conventional tillage and is more suitable economic point of view.

The pest populations were relatively higher in non-Bt cotton than the Bt cotton (Table 2). Continuous cultivation of Bt-cotton has at some places led to increased incidence of sucking and other pests such as mired bugs, mealy bugs, thrips and leaf eating caterpillar, and appearance of leaf reddening and Para wilt (Nagrare *et al.*, 2009). In the present study the bollworm incidence in both the Bt and non-Bt cotton was non-significant. However, the population of both American bollworm and spotted bollworm were relatively more in non-Bt cotton compared to Bt. As regards to the sucking pests, the incidence in Bt and non-Bt was non-significant. However, the population of jassids was relatively higher on Bt cotton compared to non-Bt. The incidence of bollworm in general during the period of study was less prevalent, which may be the reason for non-significant reaction of the varieties to the bollworm pest. In contrary, the population of whitefly and thrips recorded to be more in non-Bt compared to Bt. This clearly indicates that Bt and non-Bt cotton did not show any definite preference for the sucking pest in general. However, other reports also show a similar reaction to sucking pest. The plant characters might be the reason for differential incidence of Jassids in Bt in compared to non-Bt.

Table 2. Pest population in Bt and non-Bt cultivaras of transgenic cotton under different tillage practices (pooled mean of 2 years).

Treatment	Average population/three leaves			Average population/plant (Larvae)	
Tillage practices	Jassids	White fly	Thrips	*Helicoverpa armigera*	*Erias Spp*
Conservation Tillage	0.63	1.0	1.76	0.175	0.283
Conventional Tillage	0.53	0.82	0.38	0.171	0.208
SEm ±	0.064	0.06	0.152	0.018	0.014
CD (P=0.05)	NS	NS		NS	NS
Cultivars					
BT/RCH-134	0.50	0.37	1.43	0.1	0.133
BT/RCH-317	0.63	0.63	1.40	0.1	0.167
BT/MRC-6301	0.87	0.93	0.95	0.2	0.133
BT/MRC-6304	0.70	1.63	0.43	0.1	0.100
Mean	0.675	0.875		0.125	0.125
NBT/RCH-134	0.73	2.52	1.23	0.2	0.383
NBT/RCH-317	0.45	1.68	0.62	0.1	0.350
NBT/RCH-6301	0.30	1.48	1.72	0.2	0.30.267
NBT/MRC-6304	0.43	2.03	0.75	0.3	0.40.433
Mean	0.475	1.93		0.2	0.375
SEm ±	0.259	0.54	0.423	0.1	0.098
CD (P=0.05)	NS	NS	NS	NS	NS

CONCLUSION

The performance of Bt and non-Bt cultivars of cotton were similar under both conventional and conservation the tillage practices. The seed cotton yield of Bt cotton was significantly higher than non-Bt cotton cultivars. The bollworm and sucking pest incidence in both Bt and non-Bt cultivars were non-significant. However, the incidence was comparatively higher in non-Bt than Bt cotton cultivars.

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SOIL CONSERVATION SOCIETY OF INDIA (SCSI)
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DEV PRAKASH SHASRI MARG, NEW DELHI-110012

INCOME AND EXPENDITURE STATEMENT FOR THE YEAR ENDING 31ST MARCH, 2014

	Schedule Reference	Year ended 31st March 2014 (Rupees)	Year ended 31st March 2013 (Rupees)
INCOME			
Admission Fee		4,770	1,330
Membership Subscription	**H**	65,480	47,542
Interest on Deposit/Bank Transfer		648,289	352,474
Sale of Society's Other Publications		510,000	1,148,500
Admin. Cost/Overheads of IWMP, Rajasthan		196,650	-
Overheads/Instituitional Training of SCSI Receipt		126,700	107,300
Miscellaneous Receipt		11,609	19,000
Financial Assistance for Journals by the ICAR		150,000	107,638
TA Cost of Prof. J S Bali Received		-	7,682
National Conerence Lucknow, UP	**I**	990,199	26,500
IWMP Preparatary Phase Eva. Study of Rajasthan - I		361,732	-
IWMP Preparatary Phase Eva. Study of Rajasthan - II		483,000	-
		3,548,429	**1,817,966**
EXPENDITURE			
Payments to and Provisions for Employees	**J**	241,497	95,100
Printing Expenses	**K**	371,803	417,920
Administration and Other Expenses	**L**	672,310	434,634
Bank Charges		264	502
Depreciation	**B**	53,376	76,411
National Conerence Lucknow, UP	**M**	1,069,758	
IWMP Preparatary Phase Eva. Study of Rajasthan - I	**N**	340,411	
IWMP Preparatary Phase Eva. Study of Rajasthan - II	**O**	434,700	
Rates and Taxes	**P**	122,346	
		3,306,465	**1,024,567**
EXCESS OF INCOME OVER EXPENDITURE		241,964	793,399
Significant accounting policies and notes to the accounts	**G**		

The schedules referred to above form an integral part of the Income and Expenditure Account.
As per our report attached to the Balance Sheet.

Place : New Delhi
Dated : 16.09.2014

Verified and found correct

For **Rajesh K. Sachdeva & Associates**
Chartered Accountants
Firm Registration No.: 019200N

For and on behalf of **Soil Conservation Society of India**

For **Rajesh Sachdeva**
Partner
Membership No.: 083757

Sd/-
(SURAJ BHAN)
President

Sd/-
(JAGATVEER SINGH)
Secretary General

Sd/-
(R.A.S. PATEL)
Treasurer

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Types of contribution

Papers should mainly be based on original works/experience or ideology on any aspect of soil and water conservation including the generation and interpretation of basic data for these programmes.

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The text should suitably be subdivided; the main heading has to be in capital letters, secondary heading also in capitals but in side position and tertiary heading should be normal typescript in side position. Underline only those words that should be in italics. Use the metric system. The abstract should not be exceed 200 words; it should highlight only techniques ans significant finding and thus be more concise than a regular 'Summary'. References should be written in the form as given below:

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