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Yield and Economic Performance of Hybrid and Inbred Rice under System of Rice Intensification

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ABSTRACT

An experiment was conducted under All India Co-ordinated Rice Improvement Project at J.N.K.V.V., College of Agriculture Rewa (M.P.) during *kharif* season, 2008. The experiment was aimed to assess the performance of different hybrids and inbred varieties of rice under system of rice intensification. Amongst the rice varieties including both inbred and hybrids, PRH 10 proved its suitability for *Rewa* region which performed best in respect of number of effective tillers/hill, roots length, root shoot ratio, number of grains/panicle, number of sound grains/panicle, grain yield (99.33 q/ha) and straw yield (122.39 q/ha). Economic analysis suggested that the maximum net return of Rs. 50484/ha was accrued from PRH 10 hybrid and the minimum of Rs. 12936/ha from HMT inbred variety.

Keywords: Hybrid and inbred rice, Biomass yield, Harvest index, economics, B:C ratio.

Rice (*Oryza sativa* L.) is the staple food of India and popularly grown in north eastern, southern and central part of the country. Presently, rice is grown in an area of 43.6 million hectares with a production of about 90 million tons in India. In Madhya Pradesh, about 17.0 lakh ha area is under rice cultivation, out of which around 5000 ha is under hybrid rice particular under irrigated eco- system. A large number of hybrids have been released for cultivation from both private and government sector to enhance its productivity. Hence, it is essential to compare the productivity of these high yield hybrids and inbreds under different agro-climatic regions of the state. Meanwhile, suitable production technology of these varieties also needs to be developed. The development of high yielding rice hybrids have shown better yield potential than high yielding inbred varieties mainly due to presence of larger sink. Hybrid rice has unique advantage of better physiological efficiency and thus hybrid rice has ability of produce about 15-20% higher grain yield than in bred cultivars (Virmani *et al.*, 1991). According to Siddiq (1993), hybrid vigour in rice can be profitably used to increase its productivity by 14 to 28% over the available best varieties in India. The System of Rice Intensification (SRI) is a method of increasing the yield of rice produced in farming. The beneficial effect of transplanting very young seedlings, less than 15 days old, was discovered serendipitously. Subsequently, when fertilizer prices increased, compost made from any decomposed biomass turned out to give even better results than chemical fertilizer. The system of rice intensification (SRI) a set of cultivation practice based upon a number of insights into how to create the best growing environments for rice plants under limited water resources and therefore a study was conducted to assess the performance of different hybrids and inbreds rice under system of rice intensification.

MATERIALS AND METHODS

The experiment was conducted at All India Co-ordinate Rice Improvement Project, J.N.K.V.V., College of Agriculture Farm, Rewa (M.P.) during *kharif* season, 2008. Rewa is situated in the North-eastern part of Madhya Pradesh at latitude $24^0$31'N, longitude $81^0$15'E and altitude of 365.7 m above the mean sea level. It has subtropical climate, hot and dry summer and cold winter are the main characteristic features of the region. The weather conditions throughout the crop season were quite favourable for better growth and development of rice. The minimum and maximum temperature occasionally reaches 10^0C and 43.4 ^{0}C, respectively. The average annual rainfall of the region ranges from 90 to 120 cm which mostly occurs during July to September months and occasionally showers are received in winter months also. The textural class of soil was clay loam containing sand-30.3, silt-32.3 and clay-37.5%, respectively. And soil was medium in available nitrogen (0.765 kg/ha), low in available phosphorus(12.54 kg/ha), medium in available potash (207.20 kg/ha).The soil was almost neutral in reaction (6.95). The treatments consisted of 11 varieties (6 hybrids and 5 inbred) i.e. T1:JRH-4, T2:JRH-5, T3:JRH-8, T4:JRH-10, T5:JRH-11, T6:PRH-10, T7:HMT, T8:WGL-32100, T9:WGL-3844, T10:Jagtilal Sanali T11:MR-219. The experiment was laid out in randomized block design with 3 replications. The recommended dose of nutrients i.e. 120 kg N, 60 kg P_20_5 and 40 kg K_2O + 10 kg BGA /ha was given. One seedling per hill was transplanted manually at the spacing of 25 cm apart between rows and plant. Morphological, growth and yield analytical observation were recorded at 30days interval. Performance indicators on yield and yield attributing characters were recorded after harvest.

RESULTS AND DISCUSSION

Effect on growth

The findings of the present experiment clearly indicated that the plant height of rice hybrid JRH 11 was maximum 123.67 cm followed by JRH 4 and JRH 8 (122.33 and121.67.00 cm) at 90 days after transplanting (DAT). However, the rice hybrid PRH 10 produced the maximum number of tillers per plant at 90 DAT (15.67) as well as tillers/m^2 (391.75/m^2) this was followed by JRH-11(14.33) hybrid and MR 219 (13.80) inbred **(Table 1)**. On the other hand, JRH 10 hybrid produced significantly the lowest tillers/plant (8.87) followed by WGL 32100 inbred (10.33). The superiority of PRH 10 in respect of growth parameters might be due to variation in hybrid vigour and more nutrient uptake right from the initial growth stage. The results obtained for the number of tillers per hill by these hybrids and inbreds is in agreement with the findings of Surekha *et al.* (1999) and Bhabor (2008). The roots length was highest in hybrid JRH (30.00 cm) followed by JRH 4 (28.13) and minimum 18.00 cm in JGL 3844. However, the maximum root shoot ratio was in hybrid PRH 10 (1:9.13) and the lowest in inbred HMT (1:6.73).The maximum dry matter production/plant (89.03 g) was noted in JRH 11 and minimum in Jagtial Sonali (66.87 g). The higher dry matter in JRH 11 at 60 DAT is associated with superior active photosynthetic surface area which is mainly responsible for production of dry matter and yield in plants (Swain *et al*., 2006).

Effect on yield

The maximum number of sound grains per panicle was recorded in PRH 10 (285.00/panicle) hybrid and the lowest sound grains (142.67/panicle) were produced in case of HMT inbred variety **(Table 2)**. The higher number of sound grains recorded in case of PRH 10 might be due to better grain filling character inherited in these hybrids and inbred varieties. These results are in conformity with Rao *et al.* (1985) and Swain *et al*. (2006). The maximum test weight (29.97 g) was recorded in case of JRH 4 followed by JRH 8 (29.69 g) and JRH 5 (28.51 g). The lowest test weight (15.19 g) was recorded in case of WGL 32100. In respect of grain yield, the rice hybrids PRH 10 maintained their significant superiority by producing the highest grain yield (99.33 q/ha), being significantly higher to rest of the inbred and hybrids. The inbred variety HMT produced the lowest grain yield (55.00 q/ha), thus gave the poor performance. The rice hybrid PRH 10 also produced significantly higher straw yields (122.39 q/ha) over rest of the hybrids and inbred varieties. The lowest straw yield (74.80 q/ha) was recorded from HMT inbred. Grain yield is the end result of all the vegetative and reproductive growth characters and genetic yield potential which further lead to produce higher grain. Rao *et al.* (1985) also reported the similar results from their study. Similarly, the harvest index also differed significantly among the varieties. The maximum harvest index (44.80 %) was recorded by PRH 10, followed by JRH 8 (43.23%) and JRH 10 (43.20%) and the lowest (41.50%) in case of JGL 3844 inbred rice.

Economics

The highest net returns (Rs.50484/ha) was accrued from rice hybrids PRH 10 followed by JRH 10 (Rs.36805/ha) and Jagtial Sanali (Rs.35949/ha). The lowest net returns (Rs.12936/ha) was obtained from inbred HMT. Similar trend was also noticed for the benefit: cost ratio and it was highest (2.47) with PRH 10 while the lowest (1.40) in case of HMT. These findings are collaborative with Barrett *et al.* (2003)

Table1. Growth parameters of rice hybrid and inbred varieties

Rice hybrids and improved inbred	Plant height (cm)	Number of tillers/ hill	Length of roots (cm) (90 DAT)	Roots shoot ratio (90 DAT)	Dry matter production/m^2 (g)
JRH 4	122.33	10.20	28.13	1:8.27	1991.67
JRH 5	120.00	11.60	26.00	1:7.77	1950.00
JRH 8	121.67	10.17	23.67	1:7.40	1791.67
JRH 10	119.00	8.87	23.00	1:7.10	1950.00
JRH 11	123.67	14.33	30.00	1:7.53	2216.67
PRH 10	119.33	15.67	24.33	1:9.13	2125.00
MR 219	94.33	13.80	21.33	1:7.27	1875.00
Jagtial Sonali	102.43	12.60	20.67	1:7.00	1666.67
JGL 3844	103.63	11.40	18.00	1:7.27	1716.67
WGL32100	91.27	10.33	21.67	1:7.63	1883.33
HMT	90.00	11.00	21.30	1:6.73	1850.00
SEm±	0.857	1.235	0.436	1.145	79.423
C.D. (5%)	2.530	3.573	1.260	0.419	229.698

Table 2. Yield, yield contributing characters and economics of rice hybrid and inbred varieties

Rice hybrids and improved inbred	Number of effective tillers/m^2 panicle	Number of sound grains/	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)	Net income (Rs/ha)	B: C ratio
JRH 4	255.00	235.33	78.33	103.40	42.73	32840	1.95
JRH 5	290.00	230.47	75.33	100.19	42.90	30301	1.88
JRH 8	254.00	239.00	82.00	107.42	43.23	35949	2.05
JRH 10	221.75	243.33	83.00	108.73	43.20	36805	2.07
JRH 11	358.25	236.33	79.33	106.27	42.70	33766	1.99
PRH 10	391.75	285.67	99.33	122.39	44.80	50484	2.47
MR 219	345.00	219.33	65.00	87.75	42.50	21498	1.63
Jagtial Sonali	315.00	214.33	62.33	84.76	42.30	19233	1.56
JGL 3844	285.00	220.33	65.33	86.24	41.50	21693	1.63
WGL32100	258.25	162.33	58.33	78.75	42.50	15770	1.46
HMT	275.00	142.67	55.00	74.80	42.30	12936	1.40
SEm±	8.107	2.052	0.739	0.982	0.261	—	—
C.D. (5%)	23.447	5.935	2.139	2.840	0.756	—	—

who also reported results on similar line in his economic studies.

CONCLUSIONS

Amongst the rice inbred and hybrids studied, PRH 10 found to be suitable for Rewa region of Madhya Pradesh with respect to overall performance and producing higher biomass and economic yield. The maximum net return of Rs.50484/ha was also accrued from PRH 10 hybrid followed by JRH 10 (Rs. 36805/ ha). The minimum net returns was obtained from HMT (Rs.12936/ha).

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Water Production Functions for Chick pea under Different Irrigation Scheduling and Planting Layouts

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ABSTRACT

Water production function is a quantitative expression which relates the output of the system to the inputs which are controlled by decision variables. A field experiment was laid out for development of water production functions for chickpea (cv. Phule Digvijay) in sandy clay loam soil in factorial randomized block design under surface method of irrigation. The treatments comprised of combination of five different irrigation schedule viz. 0.6, 0.8, 1.0, 1.2 IW/CPE ratio and at critical growth stages and two planting layouts viz. flat bed and ridges and furrows. The linear, quadratic, power, exponential and logarithmic functions were tried to establish relationship between biological and grain yield of chick with irrigation water applied and consumptive use of crop. The second order quadratic water production functions were found best fit for irrigation water applied and consumptive use of chickpea with biological and grain yield for flat bed and ridges & furrow layout. The estimated yield was determined by using obtained water productions function and variations with actual values were observed less than 1 %. The study also revealed that chickpea showed significantly higher yield (24.74 q ha^{-1}) for irrigation scheduling at 1.0 IW/CPE ratio which is found to be the best proposition for chickpea crop. The field water was efficiency was also maximum i.e. 12.37 kg ha^{-1} mm^{-1} at 1.0 IW/CPE ratio with ridges and furrows planting layout as compared to other treatments.

Key words: IW/CPE ratio, water production function, planting layout, chick pea.

Water scarcity is a real threat to food production as population continues to grow and the arable land area per capita is decreasing. Water is the major factor limiting crop production in many regions of the country and thus, improved water productivity is urgently needed in water scarce dry areas. It is estimated that almost two-third of the increase in crop production needed in the upcoming decades must come from an increased yield per unit land areas (FAO 1988). Higher water use efficiency in agriculture can be achieved by producing more agriculture output with the limited amount of water applied to crops. Deficit irrigation can be considered as a key strategy for increasing on-farm water use efficiency and water productivity in water scarce dry areas. Many irrigation experiments involving different irrigation amo unt of water resources compared with full irrigation and therefore has higher levels showed that deficit irrigation produces higher overall grain yield with the same water productivity (Singh H. *et al*., 2002). The risk with deficit irrigation can be minimized through proper irrigation scheduling (when and how much to irrigate) and avoiding water stress in water-stress sensitive stages. Thus, improving water productivity with less water for producing more food is essential for future food production. In order to maximize total production of crop, the information about crop yield response to the quantity of water applied is important. The use of production functions as tools for analyzing agronomic relationships and crop growth is gaining importance the world over. The effect of each irrigation schedule on the yield of a crop is usually quantified through water production function which is a functional relationship between variable quantity of the water as input and crop yield as output. The established crop production functions make it possible to solve the problem of allocation of limited water resources between crops where crops compete for

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limited available water in dry areas. The predictive values of yield from water production functions for specific agro-ecological sites particularly in semi arid lands is of special interest (Kibe and Onyari 2007), but little work is being done with this regard in India. Generally, liner or quadratic type of functions are found best fit for developing relationship between crop yield and seasonal evapotranspiration or irrigation water (Pratap Singh *et al.,* 1985). The linear relationships are simple and more practical, but the quadratic functions more descriptive and are more useful (Vijay Kumar et.al. 2001; Zhang and Oweis, 1999 Zhang, H. *et al.,* 1999; English and Nakamura, 1989).

Cultivation of pulses in the Maharashtra is mostly done as rainfed sole crop. Chickpea is one of important pulse of state cultivated as rainfed, drought tolerant crop and is grown on residual soil moisture in areas having an annual rainfall of about 625 to 750 mm. Due to limited soil moisture availability in Rabi season it experiences moisture stress which results into low productivity. Chickpea is very sensitive to water availability in root zone, since it has got relatively shallow root zone and requires more frequent drainage; therefore, many times crop water yield relationship is quite complex. This is because the economic yield of chick pea not only depends upon total water supplied during growing season but also on its allocation throughout the period. Most of the time, low yields of such a valued crop could also be attributed to improper irrigation quantity applied by farmers. However, information is needed to guide farmers when and how much to irrigate with controlled deficit irrigation practices in order to reduce the unwanted effect of water stress on crop yield. Thus, water production functions need to be derived for the crop so that, the available water resources can be used more effectively producing more yields.

In Maharashtra, chickpea is generally grown on flat bed resulting into low yields due to temporary water logged condition coupled with compaction, especially in clay soil. Thus, when grown on ridges and furrows yield can be enhanced substantially than flat bed (Shaikh and Mungse, 1998). The ridges and furrows provide good aeration and seedbed for better irrigation and drainage of excess water. Therefore, irrigation scheduling in combination with planting layout forms an important aspect in managing the irrigation water.

MATERIAL AND METHODS

An experiment on development of water production function for chick pea under different irrigation layouts was carried out at research farm of Mahatma Phule Krishi Vidyapeeth, Rahuri, Distt. Ahmednagar (M.S.). Geographically, the study area is located at 19° 24' N latitude, 74° 39' E longitude and at an altitude of 500 m. Agro climatically the area falls under scarcity zone of Maharashtra with annual rainfall varying from 307 to 619 mm. The average annual rainfall is 520 mm, which is mostly concentrated during the monsoon months from June to September.

The soil of the experiment field was sandy clay loam having sand, silt and clay percentage as 14.77, 22.86, and 23.56 respectively. The moisture content at field capacity and permanent wilting point were 27.07 and 12.09 per cent, respectively. The bulk density of experimental site was 1.37 g cm^{-3}. The soil was slightly alkaline in reaction (pH 8.10). The water table was more than 3 m below soil surface hence; there was no contribution to soil moisture from the underground water table.

In the present investigation, ten treatment combinations with five different irrigation schedules viz. 0.6, 0.8, 1.0, 1.2 IW/CPE ratios and irrigation at critical growth stages and two planting layout viz. flat bed and ridge and furrows were studied in factorial randomized block design (FRBD) with three replications. The irrigations were scheduled at cumulative pan evaporation (CPE) as 50 mm. The recommended dose of fertilizer (25:50:0 N P_2O_5 kg ha^{-1}) was applied as basal dose for all the treatments. The quantity of water to be applied per irrigation and seasonal water requirement of crop was worked out. The consumptive use of water was determined for each treatment from the depth of moisture depleted in each layer viz., 0, 15 and 30 cm during an irrigation cycle taking into account effective rainfall (Michael, A.M. 1978).

The water production functions were established between biological and grain yield of chickpea with actual water applied and consumptive use of water for each treatment. Mathematically the function may be expressed as:

Y = F(X) .... (1)

Where, Y is the yield of crop and X is represented by:

i) The actual depth of irrigation water applied (IR)

ii) The consumptive use of water.

When first option is chosen to represent water use, their adoptability to other sites and seasons is not feasible as the water used by the crop may vary with location specific parameters such as climate, soil, field condition etc. Further some of the irrigation water may be lost as drainage or runoff or to be stored in the soil and is not accounted. Such difficulties are not encountered when consumptive use is chosen as independent variable. In this study the water production functions based on both consumptive use and irrigation water applied have been derived.

RESULTS AND DISCUSSION

Yield

The yield data obtained for various treatments are presented in **Table 1**. The significantly superior seed yield over all other treatments (24.74 q ha^{-1}) was recorded when irrigation applied at 1.0 IW/CPE whereas, lowest mean seed yield as 18.95 q ha^{-1} was recorded for irrigation at 0.6 IW/CPE ratio. The continuous stress of moisture at the lower regimes caused reduction in the yield. When irrigation applied at 1.2 IW/CPE ratio, the crop might have experienced adverse effect of higher moisture regime for which chick pea is very susceptible and produced 24.05 q ha^{-1} of yield which was slightly lower than yield obtained at 1.0 IW/CPE ratio.

Among two planting layouts, the ridges and furrows recorded significantly superior mean grain yield (22.09 q ha^{-1}) over flat bed (21.09 q ha^{-1}). It showed that ridges and furrows improved the favorable environment for optimum soil-water-air equilibrium in the root zone which proved beneficial for chickpea.

In case of biological yield, the significantly higher yield (47.05 q/ha) was observed in 1.0 IW/CPE application of irrigation however, it was at par with biological yield obtained at 1.2 IW/CPE (46.48 q/ha). This indicates that higher moisture availability at root zone beyond 1.0 IW/CPE does not increased biological as well as grain yield of chick pea. In case

Table 1. Yield and water applied to chickpea as influenced by different irrigation layouts

Treatment	Irrigation water applied (cm)	Effective rainfall (cm)	Seasonal water requirement (cm)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Consu-mptive use of water (cm)	Water use efficiency (kg ha^{-1} mm^{-1})
A. Irrigation scheduling								
0.6	17.0	13.2	18.32	18.95	12.72	31.67	16.8	1.127
0.8	21.0	13.2	22.32	20.07	15.62	35.69	17.29	1.161
1.0	25.0	13.2	26.32	24.74	22.32	47.05	20.0	1.237
1.2	29.0	13.2	30.32	24.05	22.42	46.48	22.0	1.093
At critical growth stages	20.0	13.2	21.32	20.15	19.47	39.62	17.95	1.123
S.E ±	—	—	—	0.017	0.013	0.028	—	—
CD at 5 %	—	—	—	0.051	0.038	0.082	—	—
B. Planting layouts								
Flat bed	22.4	13.2	21.72	21.09	17.81	38.90	17.44	1.209
Ridges and furrows	22.4	13.2	21.72	22.09	19.21	41.30	17.74	1.245
S.E ±	—	—	—	0.011	0.008	0.017	—	—
CD at 5 %	—	—	—	0.032	0.024	0.052	—	—

of straw yield, significantly higher straw yield was observed when irrigation was applied at 1.2 IW/CPE ratio (22.42 q ha^{-1}) than those registered in rest of the treatments. It indicated that excess moisture availability might have resulted into more vegetative growth.

Water use

The data pertaining to irrigation water applied, effective rainfall, consumptive use of water, seasonal water requirement and water use efficiency under different irrigation scheduling and planting layouts are given in **Table 1**. The quantity of irrigation water applied for different irrigation scheduling varied considerably from 17 to 29 cm. The consumptive use of water increased with the increasing depth of irrigations. The maximum total consumptive use of water was 22 cm when irrigation was applied at 1.2 IW/CPE ratio. The seasonal water requirement was also found maximum (30.32 cm) when irrigation provided at 1.2 IW/CPE ratio as compared to other treatments. The seasonal water requirement was not affected by planting layouts. However, the water use efficiency was found highest (1.237 q/ha-cm) when irrigation was given at 1.0 IW/CPE ratio. The minimum water use efficiency was observed at 1.2 IW/CPE ratio (1.093 kg ha^{-1} cm^{-1}). It was observed that water use efficiency for flat bed and ridges & furrow was found almost equal.

Water production function

Water production function for chickpea under surface method of irrigation was developed using data on yield and biological yield versus depth of water applied and consumptive use of crop for two different layouts. The linear, second order polynomial, power, exponential, and logarithmic relationships were tried, out of which second order quadratic relationship was found best fit for all the combinations. The second order quadratic crop water production functions developed for different combinations are listed below.

Ridges & furrow irrigation layout:

$y = -0.027x^2 + 1.763x - 3.136$ R2 = 0.85

$y = -0.0706x^2 + 4.774x - 25.73$ R2 = 0.86

$y = -0.306x^2 + 12.91x - 111.4$ R2 = 0.91

Flat bed irrigation layout:

$y = -0.02x^2 + 1.451x - 1.033$ R2 = 0.84

$y = -0.107x^2 + 6.341x - 47.89$ R2 = 0.87

$y = -0.299x^2 + 12.77x - 112$ R2 = 0.94

$y = -1.076x^2 + 44.76x - 418.0$ R2 = 0.99

The various water production functions developed are depicted graphically in **Fig 1** to **Fig 8**. It is indicated from water production function that increasing water application and consumptive use the biological as well as grain yield of chick pea is increased upto some extent but diminished with further increase in water quantum. It revealed that irrigation quantity beyond a certain amount exerted a reverse effect on growth and yield of chick pea.

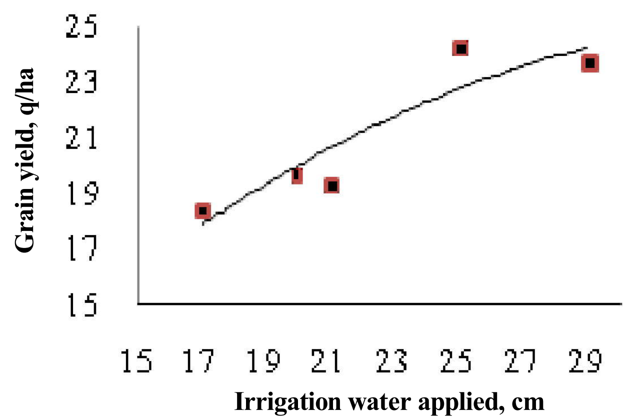

Fig. 1. WPF for chick pea again yield using irrigation water applied in flat bed

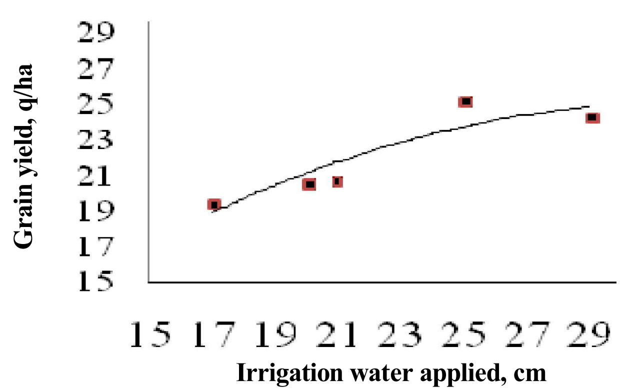

Fig. 2. WPF for chick pea again yield using irrigation water applied in ridges and furrows

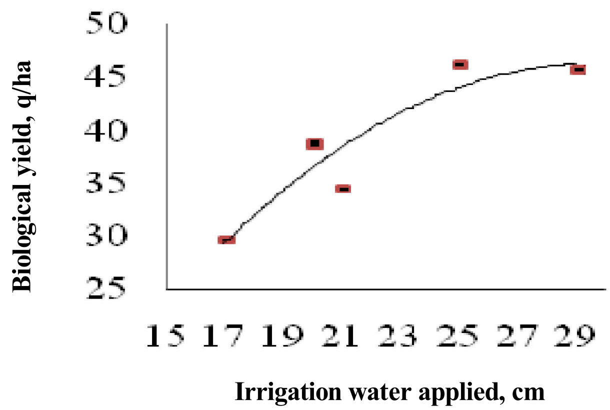

Fig. 3. WPF for chick pea biological yield using irrigation water applied in flat bed

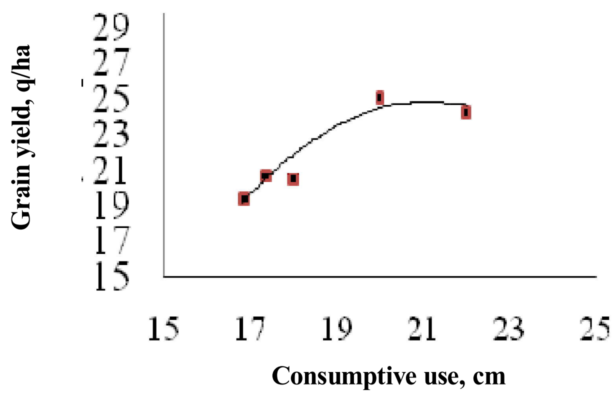

Fig. 6. WPF for chick pea grain yield using cunsumptive use in ridges and furrows

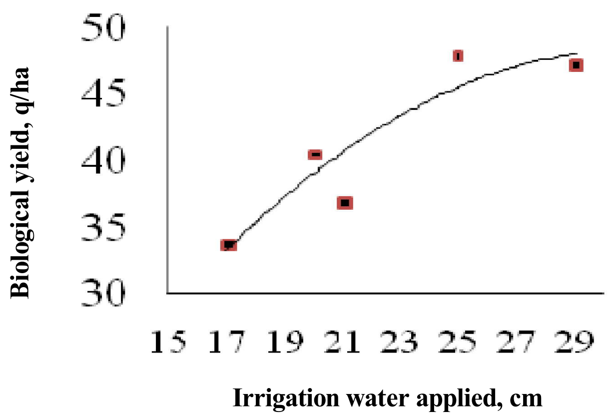

Fig. 4. WPF for chick pea biological yield using irrigation water applied in ridges and furrows

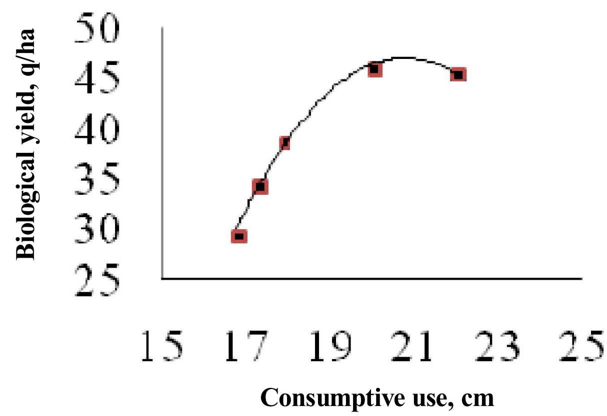

Fig. 7. WPF for chickpea biological yield using consumptive use in flat bed

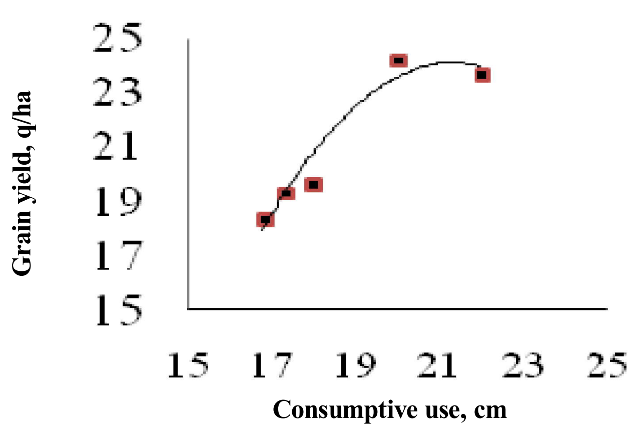

Fig. 5. WPF for chick pea grain yield using cunsumptive use in flat bed

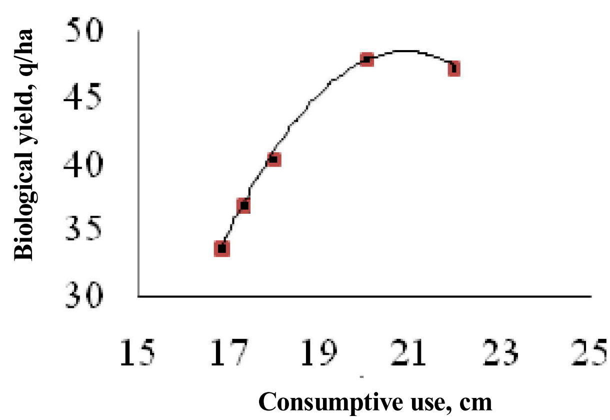

Fig. 8. WPF for chickpea biological yield using consumptive use in ridges and furrows

Table 2. Relationship between observed and estimated yield of chick pea with irrigation water applied

Treatment	Water applied (cm)	Observed Biological yield, q/ha	Estimated Biological yield, q/ha	% variation	Observed Grain yield, q/ha	Estimated Grain yield, q/ha	% variation
Flat bed planting layout							
0.6	17.0	29.57	29.57	0.00	18.4	17.85	0.09
0.8	21.0	34.387	34.387	1.42	19.4	20.62	0.43
1.0	25.0	46.083	46.083	0.17	24.3	22.74	0.39
1.2	29.0	45.657	45.657	0.03	23.7	24.23	0.04
At critical growth stages	20.0	38.81	38.81	0.35	19.7	19.99	0.02
Ridges and furrow planting layout							
0.6	17.0	33.763	33.46	0.01	19.487	19.03	0.05
0.8	21.0	36.983	41.01	1.18	20.783	21.98	0.33
1.0	25.0	48.027	46.12	0.16	25.22	24.06	0.21
9.0	29.0	47.307	48.80	0.10	24.377	25.28	0.14
At critical growth stages	20.0	40.43	39.35	0.07	20.587	21.32	0.13

Table 3. Relationship between observed and estimated yield of chick pea with consumptive use

Treatment	Consum-ptive use	Observed Biological yield, q/ha	Estimated Biological yield, q/ha	% variation	Observed Grain yield, q/ha	Estimated Grain yield, q/ha	% variation
Flat bed planting layout							
0.6	16.8	29.57	30.28	0.06	18.41	18.15	0.02
0.8	17.29	34.387	34.24	0.00	19.35	19.41	0.00
1.0	20.0	46.083	46.80	0.02	24.253	23.80	0.03
1.2	22.0	45.657	45.94	0.00	23.723	24.22	0.04
At critical growth stages	17.95	38.81	38.75	0.00	19.713	20.88	0.35
Ridges and furrow planting layout							
0.6	16.8	33.763	33.02	0.05	19.49	19.12	0.03
0.8	17.29	36.983	34.09	0.61	20.78	20.34	0.05
1.0	20.0	48.027	39.35	3.26	25.22	24.40	0.11
1.2	22.0	47.307	42.51	1.03	24.38	24.52	0.00
At critical growth stages	17.95	40.43	35.48	1.50	20.59	21.74	0.31

The estimated biological and grain yield of chickpea were obtained using water production functions for two different layouts and compared with actual observed values of yields **(Table 2 & 3)**. The results indicated that, the deviation between observed and estimated chickpea yields are less than 1 % indicating that this relationship can be used to predict biological and grain yield of chickpea under surface method of irrigation if depth of irrigation water applied or consumptive use is known.

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Irrigation Scheduling of Summer Groundnut through Microsprinkler under Different Moisture Regimes in Western Maharashtra

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ABSTRACT

Microsprinkler irrigation method is getting popularity rapidly as a result of higher irrigation efficiency and water use for close growing crops. In order to evaluate the different irrigation regimes a field experiment was undertaken on summer groundnut cv. TAG-24 in sandy clay loam soil. The experiment was laid out in split plot design of ten treatments with three replications comprises of two irrigation methods viz., surface irrigation and microsprinkler irrigation combined with five irrigation regimes viz., 0.6, 0.75, 0.90, 1.05 and 1.20 IW/CPE ratio. The yield contributing characters viz. dry pod (33.52 q/ha) haulm (26.05 q/ha) and kernel yield (28.00 q/ha) were observed significantly superior over the rest of the treatments in micro-sprinkler at 1.05 IW/CPE ratio as compared to other treatments. The study clearly indicated that the proportion of air, soil and water was maintained at optimum level throughout the period of crop in microsprinkler method which enhanced the yield of summer groundnut. The water use efficiency was found more for all irrigation regimes in microsprinkler irrigation as compared to surface method of irrigation and it was found highest (4.43 kg $ha^{-1}mm^{-1}$) in microsprinkler with 0.90 IW/CPE ratio. The net seasonal income was found less in surface than microsprinkler (Rs. 67531) whereas, B:C ratio was found higher in microsprinkler with 0.9 IW/CPE ratio. The maximum net extra income over surface irrigation and maximum water productivity was also found in microsprinkler with 0.90 IW/CPE ratio.

Key words: Microsprinkler, summer groundnut, IW/CPE ratio, Irrigation scheduling

In Maharashtra, water is becoming limiting factor for agricultural sector as large water quantity is diverted for non-agricultural uses like industry, domestic use, power etc. Out of 225 lakh ha area under cultivation in state, only about 40 lakh ha area is under irrigation. It means against national average of 35 per cent, only 17 per cent of the sown area in the state is presently under irrigation. Higher cultivation intensities of water loving crops like sugarcane, banana, increasing urbanization and environmental concerns have all combined to put pressure on state water resources. The dominant methods of irrigation practiced in state from time consist of furrows and borders irrigation which have low application efficiency. It has therefore, emphasis to shift towards efficient method of irrigation which can play an important role in achieving higher water use efficiency by producing more agriculture output with the limited amount of water applied.

Groundnut is one of important oilseed of state which holds a significant share in water resources available for cultivation. It has been observed that during past one decade the growth in area of groundnut has shown continuously decrease in the State except very few years. Causes for low productivity are improper soil and water management. The droughts or insufficient monsoon rains during the pods formation stage of crop badly affects the production level of the crop. Hence, groundnut yield in general is higher during summer season as compared to kharif season and farmers prefer cultivation of groundnut in summer season. However, summer groundnut requires large quantity of water especially during the water scarce months from February to May. Further, pod formation can be affected by stagnation of water, when surface irrigation or flood irrigation practice is implemented. Adoption of efficient water management practices through advance methods of irrigation like micro-sprinkler can be a better alternative in enhancing production. Research studies conducted suggest that micro sprinkler is one such method, which not only produce higher yield but also gives quality produce (Khalil Ajdary *et. al.,* 2004).

Micro sprinkler is often preferred over drip irrigation and other methods when irrigation water is to be given to close growing crops which require frequent irrigations of light intensity. The microsprinkler can maintain aeration in root zone of crop which can help in increasing the pod formation in groundnut. Moreover, microsprinkler usually installed at 45 cm above the soil surface improves the microclimate required for flowering and interception of pod in the soil. The irrigation scheduling through micro-sprinkler irrigation has showed favourable effects on growth and yield attributes of groundnut. The seasonal water requirement of groundnut is higher in surface irrigation than micro-sprinkler irrigation methods (Kabra, 1994; Husen 1995; Firake and Shinde 2000; Kadam *et al.*, 2006). However, information is needed to guide farmers when and how much to irrigate with controlled irrigation practices like micro sprinkler in order to reduce the unwanted effect of water stress on crop yield. Thus, investigation was carried out to determine the optimum irrigation schedule through microsprinkler for summer groundnut.

MATERIAL AND METHODS

The field experiment was conducted to study the yield of summer groundnut as influenced by irrigation methods and regimes at Mahatma Phule Krishi Vidyapeeth, Rahuri during summer season. Agroclimatically, the area falls under the scarcity zone of Maharashtra with annual average rainfall of 520 mm which is mostly erratic and uncertain in nature. The topography of the experimental field was uniform and leveled. The soil was 30 cm deep and water table was more than 3 m below soil surface there was no contribution to soil moisture from the underground water table. The soil texture was sandy clay loam having 6.40 % coarse sand, 16.95 % fine sand, 26.15 % silt and 49.40 % clay. The soil was alkaline in nature with pH of 8.37 and electrical conductivity of 0.79 dSm^{-1}. The bulk density of soil was 1.34 g/cm^3 and having organic carbon 0.65 %. The soil was low in available N (172 kg/ha), and P (12.78kg/ha) and high in available K (302.4 kg/ha) content. The soil was having good drainage with infiltration rate 3.14 cm/hr. The moisture contents at field capacity, permanent wilting point and available soil moisture was 28.36, 14.17 and 14.19 %, respectively.

The experiment was laid down in with 2 main levels and 5 sub levels with three replications. The ten treatment combinations with five different irrigation schedules viz. 0.6, 0.75, 0.9, 1.05 and 1.20 IW/CPE ratios and two irrigation methods viz. micro-sprinker and surface were studied in split plot design. The sowing of summer groundnut variety TAG-24 which is high yielding, has early maturity and suitable for summer season was done at the spacing of 30 cm x 10 cm. The recommended dose of fertilizer (25:50:0 N P_2O_5 kg ha^{-1}) was applied as basal dose for all the treatments. The quantity of water to be applied per irrigation and seasonal water requirement of crop was worked out.

Design and layout of microsprinkler irrigation

The microsprinkler irrigation system was installed to meet out crop water requirement. The PVC pipe of 90 mm diameter was used for main and PVC pipe of 63 mm size for submain with a valve was provided for each plot. To avoid the clogging of nozzles due to physical impurities in irrigation water, screen filter was used with back flushing arrangement. The duration of delivery of irrigation was controlled with the help of control valve provided at the inlet of each manifold for each plot. The rotating microsprinklers were placed on laterals of diameter 16 mm. The spacing between two adjacent lateral and microsprinkler within plot was 1.80 m and 1.5 m, respectively. The rotating nozzles of 140 lph capacity at a riser height 22.5 cm were provided on lateral with application rate of 11.75 mm/hr. The system was operated at a constant pressure of 1.5 kg/cm^2 which was maintained with the help of control valve. As the water source was a tube well and the problem of organic residues was nominal, the back flushing of screen filter was carried out at regular interval of 15 days. To ensure the minimum quantities of essential water was applied from each microsprinkler, uniformity coefficient of the system was worked out. The average coefficient of uniformity for microsprinkler irrigation system was estimated as 82.5 per cent for all treatments.

Table 1. Influence of irrigation methods and regimes on yield and its contributing characters

Treatments	Dry pod yield (q/ha)	Haulm yield (q/ha)	Pod to haulm ratio	Kernel yield (q/ha)	Oil content (%)	Oil yield (q/ha)
A. Irrigation methods						
I_1 : Microsprinkler	27.45	21.49	1.28	21.83	49.33	10.81
I_2 : Surface	20.38	16.30	1.25	15.21	48.35	7.35
'F' test result	Sig.	Sig.	N.S.	Sig.	Sig.	Sig.
S.E. ±	0.227	0.306	-	0.172	0.023	0.085
CD at 5 %	1.380	1.859	-	1.046	0.139	0.519
B. Irrigation regimes						
L_1 : IW/CPE = 0.6	17.89	14.21	1.26	14.22	48.47	6.89
L_2 : IW/CPE = 0.75	21.18	16.53	1.28	15.97	48.56	7.75
L_3 : IW/CPE = 0.90	26.94	21.56	1.25	21.51	49.66	10.77
L_4 : IW/CPE = 1.05	28.21	21.91	1.29	22.21	49.02	10.90
L_5 : IW/CPE = 1.20	25.36	20.25	1.25	18.69	48.51	9.07
'F' test result	Sig.	Sig.	N.S.	Sig.	Sig.	Sig.
S.E. ±	0.580	0.539	-	0.509	0.047	0.248
CD at 5 %	1.739	1.616	-	1.524	0.140	0.744
C. Interaction						
'F' test result	Sig.	Sig.	N.S.	Sig.	N.S.	Sig.
S.E. ±	0.821	0.763	-	0.719	-	0.351
CD at 5 %	2.459	2.286	-	2.155	-	1.053
General Mean	23.92	18.90	1.27	18.52	48.84	9.08

In micro-sprinkler system of irrigation, the irrigation was scheduled on the basis of pan evaporation rate. The irrigation was applied twice in a week through micro sprinkler method. The depth of irrigation to be applied was estimated using CPE for three consecutive days. The subsequent irrigations were scheduled as per the treatments. In surface irrigation 5 cm depth of irrigation was applied at 50 mm cumulative of pan evaporation. The quantity of water applied was measured by using replogal flume. The daily pan evaporation data was recorded from USWB class A Pan from Demonstration Farm of M.P.K.V. Rahuri.

RESULTS AND DISCUSSION:

Yield

The observations regarding to dry pod yield, haulm yield, pod to haulm ratio, kernel yield, oil content and oil yield as influenced by irrigation methods under different regimes presented in **Table 2**.

Irrigation methods

The yield contributing characters was found improved in microsprinkler than surface irrigation method. The dry pod yield and haulm yield was recorded maximum (27.45 q/ha & 21.49 q/ha) with microsprinkler irrigation system which were significantly superior over surface irrigation method (20.38 q/ha & 16.30 q/ha). The crop received sufficient moisture from frequent irrigations with microsprinkler during pegging and pod formation from early to maturity stages. The frequent irrigations through microsprinkler during these stages maintained the soil moisture content almost near to the field capacity and crop did not experienced moisture stress during the crop growth hence produced more yields. Similarly, values of kernel yield (21.83

q/ha), oil content of groundnut kernel (49.33 %) and oil yield (10.81 q/ha) were significantly superior in microsprinkler as compared to respective values obtained in surface method of irrigation (15.21 q/ha), (48.35 %) and (7.35 q/ha.).

Irrigation regimes

Application of irrigation at 1.05 IW/CPE ratio produced significantly higher dry pod yield (28.21 q/ha) than those registered in rest of the treatments. The treatment 0.9 IW/CPE (26.94 q/ha) was at par with the treatment 1.05 IW/CPE ratio. Significant decrease in dry pod yield was recorded (17.89 q/ha) when irrigation given at 0.6 IW/CPE ratio. The combined effect of irrigation methods and irrigation regimes used water judiciously and maintenance proper moisture in soil. Optimum soil water-air balance in root zone resulted into good physiological activity and enhanced the yield. In case of haulm yield, highest values (21.91 q/ha) at application of irrigation at 1.05 IW/CPE ratio was obtained than rest of the treatments. However, it was at par with that of 0.9 IW/CPE ratio i.e. 21.56 q/ha. However, pod to haulm ratio was not differed significantly with difference in irrigation method or irrigation regimes.

In case of kernel yield, the irrigations applied at 1.05 IW/CPE ratio produced significantly higher kernel yield (22.21 q/ha) followed by irrigation applied at 1.20 IW/CPE ratio (18.69 q/ha). This indicated higher moisture regime exerted adverse effect on yield of crop. Continuous stress of moisture at lower moisture regimes (0.6 IW/CPE ratio) observed with significant decrease in kernel yield (14.22 q/ha). The maximum oil content was recorded under 0.9 IW/CPE ratio (49.66 %) followed by 1.05 IW/CPE (49.66 %). The lowest values of all yield contributing characters were recorded at irrigation applied lower regimes i. e. 0.6 IW/CPE. This is revealed that moisture stress in summer groundnut resulted in less vegetative growth and hence reduced yield characters drastically.

Table 2. Water used and water use efficiency of summer groundnut as influenced by irrigation methods and regimes.

Treatment	Irrigation water applied (cm)	Effective rainfall (cm)	Seasonal water requirement (cm)	Dry pod yield (q ha^{-1})	Water use efficiency kg ha^{-1} cm^{-1}
A. Irrigation methods					
i. Surface	68	8.69	76.69	20.38	26.6
B. Irrigation regimes					
i. 0.6 IW/CPE	47	6.87	53.87	15.88	29.5
ii. 0.75 IW/CPE	57.5	7.78	65.28	18.34	28.1
iii. 0.90 IW/CPE	68	8.69	76.69	20.35	26.5
iv. 1.05 IW/CPE	78.5	9.60	88.10	26.06	29.6
v. 1.20 IW/CPE	89	10.51	99.51	21.26	21.4
B. Irrigation methods					
i. Microsprinkler	66.92	8.74	75.66	27.45	36.3
B. Irrigation regimes					
i. 0.6 IW/CPE	45.23	6.59	51.82	19.91	38.4
ii. 0.75 IW/CPE	55.75	8.05	63.80	24.02	37.6
iii. 0.90 IW/CPE	66.67	9.07	75.74	33.52	44.3
iv. 1.05 IW/CPE	77.91	9.69	87.60	30.36	34.7
v. 1.20 IW/CPE	89.05	10.31	99.36	29.46	29.7

Effect of interaction

The interaction effect between irrigation methods and irrigation regimes for all yield contributing characters were found significant for microsprinkler with 1.05 IW/CPE ratio as compared to other treatments/ interactions. However, oil content of kernels was not influenced significantly by the interaction of different irrigation methods and irrigation regimes. The combined effect of irrigation methods and irrigation regimes resulted into good physiological activity and increase in yield contributing characters.

Water use

The data pertaining to the water applied, effective rainfall, seasonal water requirement and field water use efficiency as influenced by different treatments are given in **Table 2**. This is indicated from **Table 2** that total irrigation water applied in surface as well as microsprinkler irrigation varied from 452.3 mm to 890 mm under different irrigation regimes whereas; in system it varied from 452.3 to 890.5 mm in different irrigation regimes. As similar quantity of water was applied in both the irrigation methods hence water saving due to microsprinkler observed to be negligible. However, when yield obtained in both the systems, it was revealed that the yield levels in 0.6 IW/CPE in microsprinkler were on par with yield levels in 0.9 IW/ CPE in surface method. Similarly, yield levels in 0.75 IW/CPE under microsprinkler were on par with 1.05 IW/CPE ratio under surface method and so on. Considering this fact, it indicated that, microsprinkler resulted into water saving to the extent of 29.22 per cent as compared to surface method of irrigation.

In microsprinkler, the range of water use efficiency was observed much higher than surface irrigation (29.7 to 44.3 kg $ha^{-1}mm^{-1}$). The highest water use efficiency was observed when irrigation applied at 0.90 IW/CPE ratio (44.3 kg $ha^{-1}mm^{-1}$) which is 1.5 times more than when irrigation applied with same regime in surface irrigation. The minimum water use efficiency was observed at 1.20 IW/CPE in both the micro sprinkler and surface irrigation as 29.7 kg $ha^{-1}mm^{-1}$ and 21.4 kg/ha-mm respectively.

Cost and economics

The cost of cultivation and economics of groundnut under different methods of irrigation and regimes are given in **Table 3**. This is clear from **Table 3** that cost

Table 3. Cost economics of summer groundnut as influenced by different treatments

Irrigation regimes	Cost of cultivation (Rs/ha) system (Rs/ha)	Seasonal cost of irrigation (Rs/ha)	Total seasonal cost (Rs.)	Net seasonal income	Benefit cost ratio irrigation (Rs.)	Net extra income over surface (Rs./ha)	Water productivity
Surface							
L_1 : 0.6 IW/CPE	26887.95	647.5	27535.45	16137.55	1.59	–	299.62
L_2 : 0.75 IW/CPE	26887.95	647.5	27535.45	22047.55	1.80	–	337.74
L_3 : 0.90 IW/CPE	26887.95	647.5	27535.45	27595.05	2.00	–	359.83
L_4 : 1.05 IW/CPE	26887.95	647.5	27535.45	45430.05	2.65	–	515.66
L_5 : 1.20 IW/CPE	26887.95	647.5	27535.45	29401.55	2.07	–	295.46
Microsprinkler							
L_1 : 0.6 IW/CPE	24040.35	10334.48	34374.83	25717.17	1.75	10608.31	516.23
L_2 : 0.75 IW/CPE	24040.35	10334.48	34374.83	32756.17	1.95	11462.01	525.31
L_3 : 0.90 IW/CPE	24040.35	10334.48	34374.83	67531.17	2.96	40814.03	903.21
L_4 : 1.05 IW/CPE	24040.35	10334.48	34374.83	54702.67	2.59	9584.42	628.02
L_5 : 1.20 IW/CPE	24040.35	10334.48	34374.83	45523.17	2.32	16194.47	458.94

of cultivation per hectare was higher (Rs. 26887.95) in surface treatment. In case of microsprinkler irrigation with all treatments from 0.6 to 1.20 IW/CPE ratio, the cost of cultivation was Rs. 24040.35. The seasonal total cost per hectare for all treatments in microsprinkler was higher (Rs. 34374.83) than surface (Rs. 27535.45). The higher initial cost of microsprinkler system is the key reason for high total seasonal cost. Considering the life of microsprinkler system as 10 years, the seasonal cost will not be more than surface irrigation if estimated so. However, net seasonal income per hectare was maximum (Rs. 67531.17) in microsprinkler with 0.90 IW/CPE ratio which is more than 3 times than net seasonal income obtained in surface irrigation with 0.6 IW/CPE ratio. This stressed upon the utility of micro sprinkler system in term of economics for groundnut crop. It is also clear from **Table 3** that maximum B:C ratio was observed in microsprinkler with 0.90 IW/CPE ratio (2.96). The lower values of B:C ratios were observed in surface irrigation when respective regimes in both the irrigation methods were compared. The maximum net extra income over surface irrigation and maximum water productivity was also found in microsprinkler with 0.90 IW/CPE ratio. However, comparatively minimum net extra income was found in 1.05 IW/CPE ratio i.e. Rs. 9584.42 with microsprinkler irrigation.

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Post Eco-restoration Changing Environmental Dynamics in Chilika Lagoon

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ABSTRACT

The unique and fragile ecosystem of Chilika lagoon with estuarine characters gradually started losing its ecological characters due to changing coastal processes, decrease in salinity regime, explosive spread of invasive weeds, degraded drainage basin, and rapid siltation. Further, the lagoon had turned more towards a freshwater eco-system resulting in substantial changes in species composition. Keeping this in view, an artificial lagoon mouth was opened on 23rd September 2000. After opening of the new lagoon mouth, the salinity in different stations ranged between 0.04 to 36.50 PSU with clear sectoral and seasonal variation. The annual average salinity for the whole lagoon during pre-intervention period (8.9 PSU) and post-intervention period (12.8 PSU) showed an increase of 43.8%. The annual average water depth for the whole lagoon during pre-intervention period (1.8 m) and post-intervention period (2.05 m) showed an increase of 13.9%. The pH of Chilika in general is alkaline in nature and varied between a minimum of 6.92 and a maximum of 10.07. Opening of the new lagoon mouth enhanced the annual average alkalinity by 7.5% during the post-intervention period (98.5 ppm) in comparision to the pre-intervention period (91.7 ppm). The overall dissolved oxygen status of Chilika lagoon (7.07±1.57 mg l^{-1}) after hydrological intervention appears to be better than the overall dissolved oxygen level (6.7 mg l^{-1}) during 1957-1961. The estimated annual mean biomass of bottom vegetation was 4365 g m^{-2} in northern sector, followed by southern sector (1200.75 g m^{-2}), central sector (983 .08 g m^{-2}) and outer channel sector (235.5 g m^{-2}). In terms of annual mean standing crop (wet weight) of bottom fauna, the outer channel sector is comparatively richer (159.20 kg ha^{-1}) while, the value for whole lagoon was 99.3 kg ha^{-1}. The annual average primary productivity for the whole lagoon was 196.2 mg C m^{-3} h^{-1}, showing an increase of 51.6% as compared to pre-intervention phase, an indicative of encouraging biological productivity. This historic hydrological intervention in Chilika lagoon has significantly improved the water quality, aquatic biodiversity and finally restored the unique coastal wetland ecosystem.

Key words: Biological productivity, Chilika lagoon, Fisheries, Hydrobiology, Water quality.

Chilika lagoon, a Ramsar site since 1981, is an assemblage of marine, brackish and fresh water ecosystem with amazing bio-diversity. The lagoon fluctuates in area from a monsoon maximum of 1165 km^2 to a dry season minimum of 906 km^2 (annual average of 923 km^2) while the linear axis is 64.3 km having average mean width of 20.1 km (Ghosh and Pattnaik, 2005). The unique and fragile ecosystem of Chilika lagoon with estuarine characters, gradually started losing its ecological characters due to changing coastal processes, significant decrease in salinity regime, explosive spread of invasive weeds, degraded drainage basin, and rapid siltation at the rate of 7.53 lakh Cu. m annually (World Bank, 2005). These natural changes distinctively contributed to the eco-degradation in the lagoon which was further aggravated by incessant anthropogenic activities ie., un-abated expansion of eco-inimical and illegal shrimp pen culture inside the lagoon (11% of lagoon area) and excessive fishing activity including destructive fishing (Mohanty *et al.*, 2004a, b). The fishery resources of the lagoon suffered serious setback since the later part of 1980s when invasive weeds began to take hold and the salinity level sharply decreased to 9.6 PSU which was more than 22.0 PSU in the 1960s (Banarjee and Roychoudhury, 1966 and Siddiqi and RamaRao, 1995). Further, the lagoon had turned more towards a freshwater eco-system resulting in substantial changes in species composition with significant increase in freshwater forms. Keeping this in view, an artificial mouth was opened on 23rd September 2000. In this backdrop, attempt was made to analyze/evaluate the environmental scenario of Chilika lagoon in conjunction with hydrobiological factors during pre- and post-intervention phases.

MATERIALS AND METHODS

Study Site

The present study area was the entire Chilika lagoon ($19^0$28' and $19^0$54' N and $85^0$05' and $85^0$38'E) and the study duration was from 2001-07. The newly opened artificial mouth under hydrological intervention has recently reduced the distance between the lagoon proper and the lagoon mouth from 30 km to 12 km. Hydrologically, Chilika is influenced by three hydrologic sub-systems, the Mahanadi distributaries, 52 streams from western catchments draining into the lagoon and the sea (Bay of Bengal). The lagoon is broadly divided into four ecological sectors based on differences in ecological features. These sectors are called northern sector, central, southern and outer channel sectors while, Magarmukh acts as the gateway between the main lagoon and the outer channel.

Physico-chemical Parameters

Water samples for the study of environmental variables, both *in-situ* and in the laboratories were collected (between 08.00-10.00 h) monthly from sixteen sampling stations. The *in-situ* observations were carried out on environmental variables such as water depth (using graduated tide gauge), water temperature (using digital electronic thermometer), transparency (using standard secchi disc), pH (using portable Multi-parameter Water Analyzer (YK-611, Yeo-Kal Electronics Pty. Ltd., Australia), Salinity and turbidity (WQC-22A, TOK, Japan) and dissolved oxygen (using DO meter, model-YSI-55, USA). Salinity analysis was cross checked with Mohr-Kundsen $AgNO_3$ titration method (APHA, 1998 and expressed in PSU). Primary productivity, chlorophyll-a, total suspended solids (TSS) and total alkalinity of the water samples were determined by standard method (APHA, 1998). The other environmental variables were measured as per the standard methodology *ie.*, biochemical oxygen demand (Trivedy and Goel, 1984), nitrate (Strickland and Parson, 1972 and Grasshoff *et al.*, 1999), nitrite (Strickland and Parson, 1972 and Grasshoff *et al.,* 1999), ammonia (Grasshoff *et al.*, 1999), dissolved inorganic nitrogen and phosphate (Grasshoff *et al.*, 1999). Estimation of phyto and zooplankton, bottom vegetation and benthic fauna were carried out as described by Mohanty *et al.*, 2009. Correlation and principal component analysis (PCA) between various water quality parameters were undertaken by using computer software "SPSS (11.0 version)".

RESULTS AND DISCUSSION

Salinity

Salinity, plays a vital role in influencing the biodiversity, its succession pattern and species distribution, recruitment, migration, maturation, spawning and natural food availability. In Chilika lagoon during the study period, the salinity in different stations ranged between 0.04 to 36.50 PSU **(Table 1)** with clear sectoral and seasonal variations. The northern sector exhibited the lowest salinity among all the sectors throughout all the seasons probably due to massive freshwater influx into this sector by major rivers and rivulets. The lagoon exhibited higher salinity during the pre-monsoon except southern sector; mainly due to high temperature, low precipitation, high evaporation and minimum dilution of freshwater (Mohanty and Mohanty, 2002). The higher salinity in the southern sector during monsoon could be due to the pushing of saline water mass from northern and central sectors towards south during inflow of monsoon and enclosed nature of the sector. The mean monthly salinity variation pattern of the whole lagoon exhibited single oscillation having the peak during April-June and minimum during July-December. The annual average salinity for the whole lagoon during pre-intervention period (8.9 PSU) and post-intervention period (12.8 PSU) however, showed an increase of 43.8%.

Water depth

The sectoral depth of the lagoon during the study period **(Table 1)** varied between 86 ± 34 cm (northern sector) to 217 ± 32 cm (southern sector). The average depth was observed to be the highest during all three seasons in southern sector and this sector exhibited comparatively stable depth. The lower depth was in pre-monsoon followed by post monsoon due to lack of freshwater influx. The annual average water

Table 1. Sectoral variation in environmental variables in Chilika lagoon during 2001-07

Parameter		Northern sector	Central sector	Southern sector	Outer Channel	Whole lagoon
Salinity (PSU)	Mean± SD	3.39±3.71	12.05±7.4	14.8±4.85	17.47±9.34	11.75±9.08
	Range	0.04-21.80	0.05-34.9	5.90-26.9	0.2±36.50	0.04-36.50
pH	Mean± SD	8.43±0.43	8.32±0.36	8.34±0.26	8.17±0.26	8.24±0.36
	Range	7.14 -10.07	6.92-9.29	7.30-9.21	7.30-8.91	6.92-10.07
Dissolved oxygen (ppm)	Mean± SD	6.05±2.47	7.25±1.25	7.41±0.76	7.62±0.78	7.07±1.57
	Range	0.30-9.76	4.90-10.98	5.08-9.04	6.00-9.86	0.3-10.98
Temperature (^{0}C)	Mean± SD	27.7±2.2	28.2±2.1	28.8±1.8	28.6±2.0	28.3±2.1
	Range	18.9-32.8	20.6-33.1	22.0-33.6	22.0-33.0	18.9-33.6
Transparency (cm)	Mean± SD	32±19	67±34	127±49	67±32	69±45
	Range	10-112	12-164	37-240	17-155	10-240
Alkalinity (ppm)	Mean± SD	85.5±40.8	97.0±19.7	110.8±21.3	93.4±20.1	95.6±29.3
	Range	28.0-266.0	48.0-138.0	70.0-326.0	22.0-127.0	22.0-326.0
chlorophyll-a (mg m^{-3})	Mean± SD	8.69±7.32	9.42±8.97	4.84±3.36	7.65±6.15	7.83±9.68
	Range	1.83-26.53	1.03-33.36	0.88-12.92	1.03-20.78	0.88-33.36
BOD (mg l^{-1})	Mean± SD	4.09±3.88	2.28±1.18	1.85±0.80	2.03±0.87	2.56±1.83
	Range	0.53-13.68	0.10-8.30	0.35-4.47	0.47-6.00	0.10-13.68
Depth (cm)	Mean± SD	86±34	135±41	217±32	216±68	158±70
	Range	30-202	61-262	133-309	73-365	30-363

depth for the whole lagoon during pre-intervention period (1.8 m) and post-intervention period (2.05 m) showed an increase of 13.9%.

Water temperature and transparency

Water temperature did not exhibit marked sectoral variations; rather there was clear seasonal variation. The water temperature during the study varied between 18.9 and 33.6^{0}C **(Table 1)**. The water temperature had higher values during pre-monsoon followed by monsoon and winter in all the sectors. The transparency in Chilika lagoon exhibited a clear sectoral as well as seasonal variation and varied between the range of 10 and 240 cm **(Table 1)**. The whole lagoon except the southern sector exhibited lower transparency in monsoon due to silt-loaded floodwater influx through northern sector. The southern sector exhibited high transparency in all the seasons as the sector is less affected by the floodwater among all the four sectors.

pH and alkalinity

The pH of Chilika in general is alkaline in nature and varied between a minimum of 6.92 and a maximum of 10.07 **(Table 1)**. The pH of the lagoon was higher in northern sector in comparison to outer channel sector, southern and central sectors, probably due to higher photosynthesis of weeds in northern sector. The overall pH (8.24 ± 0.36) observed in Chilika lagoon was well with in the favourable range for the ichthyofauna. The annual mean value (95.6±29.3 mg l^{-1}) of total alkalinity for the whole lagoon as observed during the study **(Table 1)** indicated productive status of the lagoon. The average alkalinity of the lagoon was highest during the pre-monsoon and lowest during the monsoon probably due to the low carbonate and bicarbonate content in the river discharged freshwater. Opening of the new lagoon mouth enhanced the annual average alkalinity by 7.5% during the post-intervention period (98.5 ppm) in comparision to the pre-intervention period (91.7 ppm).

Dissolved oxygen

During the present study, seasonal mean dissolved oxygen for the whole lagoon ranged between 6.55 ± 1.56 – 7.60 ± 1.54 mg l^{-1}, an indicative of improved habitat condition for fish, prawn and crabs after opening of new mouth. Due to proper water exchange through the new mouth, outer channel sector registered the highest overall mean dissolved oxygen values (7.62 ± 0.78 mg l^{-1}) followed by southern sector (7.41 ± 0.76 mg l^{-1}), central sector (7.25 ± 1.25 mg l^{-1}) and northern sector (6.05 ± 2.47 mg l^{-1}). The overall dissolved oxygen status of Chilika lagoon (7.07 ±1.57 mg l^{-1}) after hydrological intervention as recorded during the present study **(Table 1)** appears to be better than the overall dissolved oxygen level (6.7 mg l^{-1}) during 1957-1961 (Banerjee and Roychaudhury, 1966). The higher dissolved oxygen values in all the 4 sectors were recorded during the post-monsoon and the lower during the monsoon.

Nutrients

The dissolved inorganic nitrogen and inorganic phosphate did not exceed the upper limits of pollution level in the lagoon and exhibited similar pattern of distribution on a spatial and temporal scale. The NO_2 and NO_3 concentrations during the monsoon and NH_4 concentration during the post-monsoon were observed to be higher in the northern sector. The NO_3 concentration was higher in the monsoon season in all the sectors except the southern sector where the concentration was higher in Pre-monsoon. The NO_2 concentration was higher during the monsoon in outer channel sector and in pre-monsoon in central and southern sectors. The low concentration of DIN during the post-monsoon might be due to sufficient utilization of nutrients by the phytoplanktons. The concentration of dissolved inorganic phosphate (DIP) never exceeded the upper limits of pollution level except the northern sector. Ketchun (1967) observed that 2.55 μ mol l^{-1} of PO_4 is the maximum limit to access the eutrophication of lagoon/lake. The maximum concentration of PO_4 in the lagoon as a whole was observed during pre-monsoon (0.92 μ mol l^{-1}) followed by post-monsoon (0.81 μ mol l^{-1}) and monsoon (0.76 μ mol l^{-1}). Among the sectors, northern sector registered the highest concentration during the whole year (1.44 μ mol l^{-1}) probably due to decomposition of large quantity of freshwater weeds.

Principal Component Aanalysis

The principal component analysis for the whole lagoon exhibited a complete different pattern of factors. In total, four PCs were extracted having Eigen values more than 1 and represented 62.524 % of the total variables. The PC-1 represented 25.899% of the total variance and the positively loaded ammonia, BOD, nitrate are negatively loaded with depth, transparency and alkalinity. This factor explains that in the low depth areas of the lagoon during the high saline phases, there is decomposition of the freshwater weeds, which resulted in higher BOD, nitrate and ammonia. PC-2 explained 13.458% of the total variables and the positively loaded chl-a and water temperature are negatively loaded with the DO. This factor explains higher temperature facilitated higher growth of phytoplankton and produced blooming condition and thus resulting in depletion of DO. PC-3 explained 12.309% of the total variables and loaded positively with the phosphate, nitrate and DO. PC-4 represented 10.859% of the total variables and loaded positively with the salinity and pH, which is a natural phenomenon.

Bottom Vegetation and Benthic Fauna

The estimated annual mean biomass of bottom vegetation was 4365 gm m^{-2} in northern sector, followed by southern sector (1200.75 gm m^{-2}), central sector (983 .08 gm m^{-2}) and outer channel sector (235.5 gm m^{-2}). Seagrass meadows, comprising of *Halophila* and *Halodule* spp. provides favourable habitat for crabs and prawns were almost lost during eco-degradation phase, remarkably reappeared in central, southern and outer channel sectors after enhancement in the salinity regime during post-new mouth period. Northern sector was devoid of seagrass due to prevalence of low salinity for about six mouths in a year. The annual mean biomass of seagrass was highest in central sector (1078.8 gm m^{-2}) followed by southern sector (853.9 gm m^{-2}) and outer channel sector (618.5 gm m^{-2}). During the present investigation, gastropods and bivalves were found to be two major groups, which regulated the community structure both in terms of qualitative texture and quantitative abundance, both sector and season-wise. The abundance of macrobenthic community in Chilika lagoon fluctuated between 827 (northern sector) – 3040 nos. m^{-2} (central sector). In terms of annual

Table 2. Abundance of macro-benthic fauna (g m^{-2}) in Chilika lagoon during 2001-07

Parameter	Northern sector	Central sector	Southern sector	Outer Channel Sector	Whole lagoon
			Total Biomass (g m^{-2})		
Pre-monsoon	5.69	14.83	4.21	10.69	8.86
Monsoon	3.62	13.62	3.69	12.32	8.31
Post-monsoon	8.65	19.32	4.55	17.96	12.62
Annual avg.	5.99	15.92	4.15	13.66	9.93

Table 3. Abundance of phytoplankton (cells l^{-1}) in Chilika lagoon during 2001-07 (figures in parentheses indicate percentage composition)

Group	Northern sector	Central sector	Southern sector	Outer channel sector	Whole lagoon
			Annual average		
Diatom	15840 (39.01)	41400 (76.98)	37300	42833 (83.74)	35843 (71.38)
Dionoflagellates	4707 (9.74)	5140 (9.56)	3420	5067 (9.90)	4583 (9.32)
Blue-green algae	26640 (48.90)	6147 (11.43)	1643	2267 (4.43)	7669 (17.12)
Green algae	1133 (2.35)	1093 (2.03)	1070	987 (1.93)	1071 (2.18)
Total	48320	53780	43433	51153	49167

Table 4. Seasonal zooplankton biomass (g m^{-2}) in Chilika lagoon during 2001-07

Parameter	Northern sector	Central sector	Southern sector	Outer Channel Sector	Whole lagoon
			Total biomass (g m^{-2})		
Summer	0.69	4.21	1.96	6.29	3.29
Monsoon	0.92	0.99	1.01	3.95	1.72
Winter	1.21	2.11	2.39	3.12	2.21
Annual avg.	0.94	2.44	1.79	4.45	2.41

mean standing crop (wet weight) of bottom fauna, the outer channel sector is comparatively richer (159.20 kg ha^{-1}) while, the value for whole lagoon was 99.3 kg ha^{-1} **(Table 2)**.

Plankton Density and Biological Productivity

The abundance of phytoplankton in different sectors (Central sector > outer channel > northern sector > southern sector) and their dominance pattern (Diatoms > blue green > dinoflagellates > green algae) exhibited a good correlation with the chlorophyll-a. Phytoplankton abundance assumes greater importance in the context of lagoon fishery, as it constitutes one of the major food items for the fish, prawn and crab juvenile, during their recruitment from the sea into the lagoon. The percentage composition of various groups of zooplankton in the lagoon as a whole showed the dominance of copepods (79.04%) followed by rotifers

(5.11%), protozoa (4.08%), cladocera (3.98%), mysids (2.38%) and crustacean larvae (2.03%). The biomass of the total zooplankton in the lagoon ranged from 0.69-6.29 g m^{-3} during the whole year and the annual mean value for the whole lagoon was 2.41 g m^{-3}. Season-wise annual average biomass was highest during the pre-monsoon (3.29 g m^{-3}) followed by winter (2.21 g m^{-3}) and monsoon (1.72 g m^{-3}) as furnished in **Table 4**.

The average sectoral values of chlorophyll-a fluctuated between 4.84±3.36 mg m^{-3} (southern sector) and 9.42±8.97 mg m^{-3} (northern sector) during the study period **(Table 1)**. The lagoonal higher chl-a was recorded during the pre-monsoon season. Northern sector registered higher chl-a during post-monsoon due to more phytoplankton growth as a result of inflow of enormous quantity of nutrient-rich flood water during monsoon. The average values of chlorophyll-a for the whole lagoon (7.83 ± 9.68 mg m^{-3}) indicated healthy phytoplankton availability and hence productive nature of the habitant so far as fisheries in general in concerned. The overall low BOD value (2.56 ± 1.83 mg l^{-1}) for the whole lagoon **(Table 1)** was within the safe limit for its fisheries resources (NACA, 1994). The BOD was always higher in the northern sector in all the seasons. Among the seasonal samplings, higher BOD value was recorded during pre-monsoon season in all the sectors except the southern sector which recorded lowest value in post-monsoon. The decomposition of weeds during the pre-monsoon months favours the growth of microorganisms and thus the BOD registered higher values in the pre-monsoon. In 1995-96, the annual average primary productivity for the whole lagoon was 131.21 mg C m^{-3} h^{-1} (Banerjee *et al.*, 1998). This situation was an indicative of poor phytoplankton production during pre-intervention phase. However, an improved situation was observed, during 2001-07, where the annual average primary productivity for the whole lagoon was 196.2 mg C m^{-3} h^{-1}, showing an increase of 51.6% as compared to pre-intervention phase.

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Water Productivity and Groundwater Pricing in Central Plain Zone of Uttar Pradesh

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ABSTRACT

Irrigation development has always been the priority sector for the policy makers to ensure food security of India. The present paper is an attempt to measure the groundwater extraction by sellers, productivity of groundwater at micro level and examine the pricing mechanism of groundwater in Central Plain Zone (CPZ) of Uttar Pradesh which has evolving groundwater market. In the groundwater market, farmers in the buyer's category emerged as more productive in groundwater use as compared to other categories in production of wheat and sugarcane crops. In the price determination (equilibrium) of the groundwater use, total water extracted and gross irrigated area of buyer were found to be key explanatory variables and total water extracted by seller gave greater bargaining power to the seller in price determination than gross irrigated area of buyer and gross irrigated area of seller.

Key words: Groundwater, Price equilibrium, Sugarcane, Water market, Water productivity, Wheat.

Irrigation development has always been the priority sector for the policy makers for assuring food security in India. Currently, about 60 percent of the irrigated food grain production depends on groundwater irrigation. Besides, with passage of time, dependency of modern agriculture on groundwater irrigation has increased many folds, due to its well established comparative advantages over canal irrigation and lackluster efficiency of the latter. In fact, the number of shallow tube wells roughly doubled every 3.7 years between 1951 and 1991. Development of groundwater took a major stride through private modern water extraction mechanisms (WEMs), ownership of which are highly skewed towards large farmers due to huge capital investment needed and relatively better consolidation of land holdings among them (Dhawan, 1982 and Shah, 1993). Thus, small and marginal farmers and even large farmers with fragmented holdings have to depend on WEM owners to irrigate their crops, which led to emergence of an informal groundwater market with varied ramifications (Patel and Patel, 1970; Shah, 1985; Kolavalli *et al.,* 1993; Pant, 2004, Singh and Singh, 2003; 2006).

Many researchers have assessed the value of extra crop yield attributable to irrigation. These "marginal value products" for water vary widely in value from near zero to more than $100 per acre-foot in United States, depending on the crop and the geography of the area. The wide range of values clearly shows that water is not marketed and transported easily to the point of its highest valued use. Rather it is used in activities of very different productivity and these "inefficient" uses are protected by legal and institutional barriers. As water markets mature, we can expect to see strategic shift of water use towards higher-valued uses as well as the price reflecting a more uniform marginal value. In rural India, there always remain few sellers of groundwater, thus creating a situation of oligopoly market, where producers/ sellers have better bargaining power. However, due to underdeveloped groundwater market and pre-dominant inter-personal relationship among rural people, the prices of groundwater for irrigation are not decided on the basis of economic factors. Under such circumstances, irrigation charge seems to be low for the water seller while small water buyers feel it too high to motivate crop cultivation as more than three-fourth of the farmers in the state as well as in the region have less than one hectare land.

The present paper therefore, is an attempt to measure the groundwater extraction by sellers, productivity of groundwater at micro level and examine the pricing mechanism of groundwater use in Central Plain Zone (CPZ) of Uttar Pradesh which has evolving groundwater market and exclusively engaged in growing water intensive crops.

MATERIAL AND METHODS

Study domain and data sources

Uttar Pradesh state ranks fourth (after separation of Uttarakhand) with respect to geographical area among the Indian states but have the largest (17% of total) population. Average rainfall in the state ranges from 100-200 cm in the east to 60-100 cm in the west, with about 90 percent of it occurring during July to September. The Central Plain Zone comprises 13 districts (Farrukhabad, Fatehpur, Hardoi, Kanpur Dehat, Kanpur Nagar, Kheri, Lucknow, Kannauj, Sitapur, Rae Bareli, Pratapgarh, Allahabad and Etawah) and falls between these two regions, where more than two-third of area is irrigated by shallow tube wells.

The study is primarily based on primary data collected during 2006-07 using multi-stage simple random sampling technique from randomly selected two representative districts- Lucknow and Sitapur- of Central Plain Zone of Uttar Pradesh. From both the districts, two blocks were selected randomly. Finally, from each of the selected blocks, a cluster of two to three villages were selected randomly out of which 25 sample farmers were drawn randomly from each block. Thus, total sample size from two selected districts was hundred. All the sample farms were irrigated by diesel operated tube wells, as electricity supply was erratic. Canal, in some cases provided water only during rainy season.

Conceptual framework and methodology

Water market

Water markets exist where there is considerable water scarcity. Berbel and Gomez-Limon (2000) concluded that water pricing reduces the range of crops that can be irrigated profitably, thus increasing economic vulnerability in the farming sector due to the limited number of alternative strategies available. Groundwater markets in India are informal institutions, in which private tube well owners sell surplus irrigation water after their own use to the farmers who don't have their own tube wells in the vicinity of their land. The water markets are very crucial, where state machinery for (groundwater/canal) irrigation are non-existing or has failed to deliver the promises to the resource poor farmers, as they cannot afford to invest to construct water extraction structure for irrigating their small land holding.

In the present study, four kinds of water regimes/ markets have been studied *viz.* (a) self-users, under which farmers have their own water extraction structures for irrigating their own land only and do not participate in water market; (b) large farmers with fragmented land holdings which necessitates them to buy water in addition to their own sources (tube well), who can be termed as self-user + buyer; (c) only buyer, primarily small and marginal farmers with poor resource base, who depend on others to buy water for irrigating their lands and; (d) self-user + seller, includes those farmers who sell groundwater after meeting their own irrigation requirement. Buying and selling of water occurs across the farmers, which means all the water-sellers sell the surplus water to many buyers, similarly, a buyer with fragmented holding may buy from different sellers depending on the location of their plots. In the study area, there was not a single household who was only seller.

Groundwater extraction and productivity

The volume of ground water extracted (in liters) was estimated as (Eyhorn *et al*., 2005):

$$Q = t*129574.1 * BHP / (d + ((255.5998 * BHP^2) / d^2 * D^4)) \quad (1)$$

here,

Q = Quantity of groundwater extracted (L)

t = Total duration of irrigation (h)

BHP = Engine power of pump (HP)

d = Average depth of the well (m)

D = Diameter of the suction pipe (in)

(The equation is dimensionally non-homogeneous and hence could be depeted. Q in liters is not understandable. It is not used even in data collection and hence delete)

Productivity of the groundwater can be understood at different levels. For a farmer, it means getting more crop per drop of irrigation water. But, for a society as a whole, this means getting more value per unit of water resource used. Increasing water productivity is then the function of several factors working in harmony at field, irrigation-system and river basin level (Kijne *et al.*, 2003). In the present study, water productivity has been measured by estimating the quantity of irrigation water applied using eq. (1) to produce a unit quantity of grain yield. It is worth to note that amount of water applied to produce one kilogram of output is a part of irrigation requirement of crop and it does not include rain water.

Price equilibrium for groundwater use

Price equilibrium for groundwater use was examined in terms of bargaining power of the buyers and sellers for which Nash equilibrium framework was used to model the bargaining power of water sellers and buyers. The model assumes that water buyers and sellers are highly rational with equal bargaining skills, each has full knowledge of the water market, and each individual wishes to maximize his utility. Bargaining power of seller is assumed in terms of gross irrigated area (GIA) of sellers and total water extracted by them, while bargaining power of buyer is assumed in terms of GIA of buyers. Water price per unit tends to remain uniform, which was standardized by amortized cost incurred by sellers for extracting every unit of water and was chosen as the dependent variable.

Amortized cost of irrigation

The amortized cost represents the annual fixed cost component of irrigation water. The amortized cost varies with the type of well, status of the well, year of construction, average age of well and interest rate chosen. The amortized cost of pump-set, bore-well and over-ground structures was calculated separately as fallows (Kumar *et al.*, 1997):

$$A = \frac{CB*(1 + i)^{n}*i}{(1 + i)} \qquad (1)$$

where,

A = Amortized cost

CB = Cost of respective asset at current price

I = Interest rate

n = Average life of the asset.

Average life of the pump-set and bore-well was assumed to be 15 and 10 years, respectively. Compound interest rate of 2 per cent had been used to amortize the irrigation cost as it is a close approximation to the growth of investment in well irrigation (Diwakara and Chandrakanth, 2007). Total amortized cost was the sum of the amortized cost of pump-set, bore-well, over ground structures and annual maintenance cost. After standardization with amortized cost, price-cost ratio (margin ratio) was assumed as a surrogate for bargaining power.

Nash's bilateral bargaining model

For regression analysis, the variation in groundwater price was reduced considering the margin ratio equal to irrigation charge (per hectare-cm of groundwater) charged by sellers divided by the amortized cost per hectare-cm of groundwater of the seller (Deepak *et al.*, 2003). Nash bargaining model is thus constructed as,

$$Y = f\,(X_1, X_2, X_3) \qquad (2)$$

where,

Y = Margin ratio

X_1 = Gross irrigated area of seller

X_2 = Total water extracted by seller

X_3 = Gross irrigated area of buyer.

Empirically, the Nash Bargaining model followed the quadratic function;

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + C_1X_1^2 + C_2X_2^2 + C_3X_3^2 + u_i \qquad (3)$$

The elasticity of price-cost ratio with respect to each of the explanatory variables was considered as,

$$(bi + 2C_iX_i\,)*X_i / Y_i \qquad (4)$$

This elasticity shows that for one per cent increase in GIA of seller or buyer or total water extracted by seller, how much increase will be there in price–cost ratio. The ratio thus, explored bargaining power of seller.

(Explain parameters of equations e and 4 which have not been explained earlier)

RESULTS AND DISCUSSION

Groundwater status in the study region

According to Irrigation department of Uttar Pradesh state, total replenishable ground water resource in Central Plain Zone (CPZ) for future development is only 8.5 BCM. Out of 819 blocks, there are 85 " Dark" blocks, 214 "Grey" blocks in the state, of which 15 dark & 38 grey blocks fall in CPZ. The yield of tube wells ranges between 35 to 70 m^3/hr. (Delete this para not needed)

Distribution of land holding under different groundwater markets

The study region was found to be characterized by relatively high magnitude of inequality in land distribution. Overall, in Central Plain Zone, more than 80 per cent of land belonged to less than 20% of farmers, who were also the large farmers. Land distribution in the zone was highly skewed towards big farmers. Overall average size of land holding in the study domain varied between 0.82 ha for water buyer category to 2.75 ha for self-user + buyer category **(Table 1)**.

Few studies have discussed the possibility of increasing the productivity of sugarcane and wheat by reducing the excessive water use on self-users' farms, which in turn would increase the availability of water on the buyers' farms (Singh and Singh, 2006). Groundwater markets have facilitated in mitigating inequality in terms of providing physical access to the irrigation water, particularly among the resource- poor small farmers in many cases (Sharma and Sharma, 2006). In the study area, farmers under buyer category having uneconomic land holding (0.82 ha) became an important agent of water market. On the other hand, farmers under self-user + seller category were having 2 hectares of land holding and were the net sellers of groundwater. (Delete mostly repetition)

Table 1. Spread of farmers' fields according to groundwater market in study area

(ha)

Category of water market regimes	Farm category			Overall
	Marginal (0-1 ha)	Small (1-2 ha)	Others (> 2 ha)	
Buyer	0.46	1.29	4.11	0.82
Self-user	0.67	1.42	4.02	1.64
Self-user + Buyer	0.80	1.47	4.19	2.75
Self-user + Seller	0.78	1.73	4.56	2.00
Total	0.55	1.47	4.22	1.46

Data source: Field survey, 2007

Groundwater productivity at farmers' fields

Rosegrant *et al.* (2002) estimated water (irrigation plus net or effective precipitation) productivity of rice in India in the range of 0.14 to 0.20 kg/m^3 of water during 1995, while for other cereals, it ranged between 0.2 to 0.7 kg/m^3 of water. It has been projected that water productivities for other cereals will increase from 0.6 to 1.0 kg/m^3 in developing countries between 1995 and 2025. (Delete we are discussing only wheat and sugarcane in this paper as per abstract) It can be observed from **Table 4** that farmers belonging to buyer category were more efficient user of irrigation water in wheat and sugarcane crops, which were major water consuming crops, as they applied less amount of water to produce one unit of output (Is rice not a major water consuming crop). In case of wheat crop, buyers used lowest quantity of water *i.e.* 760 litres to produce one kilogram of wheat, while in case

Table 2. Crop productivity in terms of water use under different water market regimes

(Litres of water/ Kg of output)

Category	Wheat	Paddy	Sugarcane	Potato
Buyer	759.66	1000.58	40.27	161.02
Self user	1081.60	929.45	87.66	185.70
Self-user + Buyer	1087.52	1030.56	82.54	132.55
Self-user + Seller	933.33	781.39	72.55	160.54

Table 3. Trends in irrigation charges

(Rs/hr)

Type of tube-well	2003	2004	2005	2006
Diesel operated	66.44	71.82	78.03	84.55
Electric operated	50.00	51.79	55.71	58.57

of self-user + buyer and self-user, ratio was 1087.52 and 1081.60, respectively showing injudicious utilization of water as compared to buyer and self-user + seller. The reason for the low ratio in case of buyers in wheat and sugarcane may be the fact that buyers were predominantly small and marginal farmers with small land holding size and thus they were engaged in intensive cultivation with proper utilization of resources.

In case of paddy, self-user + seller applied least irrigation water for producing each kg of paddy. This was mainly due to the fact that there were only few farmers (3) under this category growing paddy and most of them had low land area, where rainfall water stagnated for longer period. Besides, with balanced use of fertilizer, they could harvest better crop yield (5 t/ha) as compared to other farmers. Similarly, in case of potato, although self-user + buyer emerged to be more water-use efficient, but the number of observations under such categories being very small, it was difficult to reach to such conclusion. Again self-users with assured irrigation facilities were found to be using irrigation water injudiciously with 185.7 litres of water to produce one kilogram of potato.

(If you yourself are not sure about your results probably you should include as the sample size is too small, restrict to wheat and sugarcane)

Trends in irrigation charges

In the study domain, both diesel and electric operated tube wells were observed but due to irregularity of electricity and administrative bottlenecks of government operated electric tube wells, majority of the sample households were found to be using diesel operated tube wells. During last four years, irrigation charges of diesel operated tube wells have increased from about Rs. 65/h to Rs. 85/h **(Table 3)**. When further enquired, respondents confirmed that irrigation charges was decided by seller and varied mainly according to the cost of diesel and to some extent, plot size of buyer as well as personal relations between the buyers and the sellers. In case of electric operated tube wells, irrigation charges increased from Rs. 50/h to Rs. 59/h during the same period.

(Delete text information is sufficient to convey the information)

Price equilibrium for the groundwater use

To examine the price equilibrium of the irrigation water in the study domain, Nash Bilateral Bargaining model was used, as bargaining power is the most important factor for the price equilibrium in oligopolistic kind of market, where few buyers and few sellers exist. Details of the findings regarding pricing mechanism of irrigation water are presented in the following sub sections:

Amortized cost of water extraction structure for seller

Amortized cost of pump-set and bore-well plus over ground structures were estimated as Rs. 1936.66 and Rs. 424.40 per annum, respectively **(Table 4)** making a total of Rs. 3403.92 per annum as the annual amortized cost of irrigation including maintenance cost.

Nash bilateral bargaining power estimates

Nash Bilateral Bargaining Power model was fitted with price-amortized cost ratio as dependent variable and total water extracted (ha-cm), gross irrigated area of seller (ha), and gross irrigated area of buyer (ha) as explanatory variables. From **Table 5**, it is evident that water extracted, gross irrigated area of seller and gross irrigated area of buyer were found to be significant at 1 per cent level of significance with the coefficients 0.042, 0.136 and 1.173, respectively. R^2 value was 0.86 showing that 86% variation in dependent variable, price-cost ratio (margin ratio) is explained by these three explanatory variables.

Table 4. Amortized cost of irrigation water extraction structure for seller

Particulars	Cost (Rs)	Average life (years)
Amortized cost of pump-set*	1936.66	15
Amortized cost of bore-well and over ground structures	424.40	10
Annual maintenance cost	1042.86	–
Total annual amortized cost	3403.92	–

*Amortized cost of conveyance is included in pump-set

Table 5. Nash bilateral bargaining power estimates

Variables	Coefficient
Intercept	-1.889 (0.508)
Water extracted (ha cm)	0.042* (0.012)
Gross irrigated area of seller (ha)	0.136* (0..086)
Gross irrigated area of buyer(ha)	1.173* (0.188)
Sq. of water extracted (ha cm) (What is this)	-0.0002* (0.00006)
Sq. of gross irrigated area of seller (ha)	-0.052* (0.035)
Sq. of gross irrigated area of buyer (ha)	-0.154* (0.025)
R square	0.86
No. of observations	15
Dependent variable: Price-cost ratio per litre of irrigation	

* Indicates significant at 1 per cent significance level

Elasticity coefficients for pricing of irrigation water

Using the coefficients of the Nash bilateral Bargaining model, elasticity coefficients for all the three explanatory variables were estimated which explains the bargaining power of sellers and Buyers. The results given in **Table 6** showed that for one percent increase in water extracted by seller, price-cost ratio increased by 1.243 percent. Similarly, with one percent increase in gross irrigated area of the seller, price-cost ratio increased by only 0.019 percent, while one per cent increase in gross irrigated area of buyer, the price-cost ratio increased by 0.971 percent.

Thus, it can be interpreted that water extracted and gross irrigated area of buyer were the key explanatory variables in price determination in a groundwater market. Total water extracted by seller or in other words, the high capacity water extraction mechanism gave greater bargaining power to the seller in price determination than gross irrigated area of buyer and gross irrigated area of seller. On the other hand, gross irrigated area of the seller was not found to be a major factor for price determination as explained by small value (0.019) of elasticity coefficient. Therefore, in a region where groundwater is extracted largely by resourceful farmers, their financial power which gets reflected in terms of high volume of groundwater extraction through high power diesel engine coupled with deep tube well, dictates the pricing of irrigation.

CONCLUSIONS

The acute shortage of electricity supply in the region forces the farmers to depend on diesel operated private tube wells for providing minimum irrigations to their crops. Thus, groundwater market emerged as an informal institution providing the resource-poor small and marginal farmers physical access to irrigation water. Farmers under buyer category emerged as more productive in groundwater use as compared to other categories in production of wheat and sugarcane crops. In the price determination (equilibrium) of the groundwater, total water extracted by seller gave greater bargaining power to the seller.

These are text book issues which are not emerging from the paper and hence may be deleted. Leave potato and paddy from the paper)

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Table 6. Elasticity coefficients for pricing of irrigation water

Variables	Elasticity coefficient	Remark
Total water extracted (ha cm)	1.243	Most influencing factor
Gross irrigated area of seller (ha)	0.019	Least influencing factor
Gross irrigated area of buyer (ha)	0.971	Less influencing factor

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Irrigation, Agriculture, Livelihood and Poverty Linkages in Orissa

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ABSTRACT

Odisha (Change everywhere the new spelling) is endowed with plentiful surface and groundwater resources, which have not been exploited adequately for income generation activities. As per the latest estimates of the Modified Expert Group of Planning Commission, Orissa has the highest proportion of population living below the poverty line (BPL). It is therefore, important to examine irrigation resources and agricultural scenario vis-à-vis the poverty and living condition of the people to formulate a strategy to improve the living conditions of the poor. In this context, an analysis of irrigation, agriculture, livelihood and poverty linkages in the districts of Orissa was carried out to understand the issues through various indices developed for the study. Groundwater development varied from 6% (Malkangiri) to 47% (Balasore) with index values varying from very low to very high. Created irrigation potential out of total potential ranged from 19% (Nawarangpur) to 93% (Puri) in *kharif* and 8% (Bolangir) to 61% (Puri) in *rabi* season. Half of the districts had medium agricultural development index values; while 6 and 8 districts indicated low and high agricultural development, respectively. Level of living in 9 districts was found to be low. Sambalpur and Bargarh are only two districts with high index value while rest of the districts showed medium values. About 60% of BPL rural families comprised of agricultural labourers, marginal and small farmers. It ranged from 25% (Ganjam) to 94% (Nawarangpur). Balasore, Bargarh, Bhadrak, Cuttack, Ganjam, Jajpur and Puri districts showed higher irrigation and agriculture development. While Deogarh, Dhenkanal, Kandhamal, Malkangiri, Nawapara, Raygary and Sundargarh districts showed lower irrigation and agriculture development. The links are more in case of poorer condition of other sectors; while betterment in one sector has not linked to other sectors in many of the districts. Thus, the study has unveiled the links and/or missing links between irrigation resources, agriculture development, poverty and level of living.

Key words: Irrigation, agriculture, livelihood, poverty, indices.

Over the last four decades the policy agenda of agriculture has evolved significantly from an initial focus on increasing food production to concerns for the environment, poverty and diversified livelihood options. It has been recognized that irrigation resources have played a major role historically in poverty alleviation by ensuring agricultural development, expanding livelihood opportunities and employment both on and off the farm. Development of irrigated agriculture has been a major engine for economic growth and poverty reduction. But the growing scarcity and competition for water are putting the poor in irrigated areas at great risk (Barker *et al.*, 2000). An important factor to poverty alleviation was the growth in public sector funded canal irrigation and in largely private sector-funded tube well irrigation. Identification of analytical, methodological and policy issues are crucial for understanding and promoting the overall poverty alleviation impacts of irrigation (Saleth *et al.,* 2003). during the 3rd annual partners meet of the International Water Management Institute (IWMI) – Tata Water Policy Research Programme on February 2004 it was mentioned that (a) irrigation development promotes non-farm employment (b) the impact of irrigation was relatively higher in temporal and spatial variations in rural poverty (c) groundwater irrigation explained variations in rural poverty even better than canal irrigation and (d) irrigation availability (measured as irrigated area per worker) has a positive impact on real farm wage rates. If irrigation has the potential to produce such profound impacts on agrarian dynamism, why such impacts are not visible in eastern India, where it is needed and has the water resources to sustain intensive irrigation (Shah, 2004). Delineation of the missing links between growth of irrigation and agriculture sector and poverty scenario holds significance. The state of Orissa is still poverty stricken (about 47% population below poverty line) with narrow livelihood options in spite of plentiful water resources. To study this kind of mismatch an analysis of irrigation, agriculture, livelihood and poverty linkages in the state of Orissa was carried out.

Poverty alleviation has always been an important aim of the governments of developing countries when investing in the construction of irrigation infrastructure (van Koppen, 2002). Between the mid 1970s and 1990, the number of people below the poverty line in India fell from over 50 per cent to approximately 35 percent (Datt, 1998); however, the absolute number of people below the poverty line increased. (Delete)

MATERIALS AND METHODS

Various indexes were constructed for assessment of district wise scenario of irrigation, agriculture, livelihood and poverty. These are Irrigation Potential Development Index (IPDI), Groundwater Development Index (GWDI), Irrigation Potential Utilisation Index (IPUI), Irrigation Coverage Index (ICI), Composite Irrigation Index (CII), Agricultural Development Index (ADI), Poverty Ration Index (PRI) and Level of Living Index (LLI). Brief account of these indexes are given below:

- (Please change all as in this case) IPDI is the ratio of the created irrigation potential for both *kharif* and *rabi* season to the ultimate projected potential.
- GWDI is the ratio of the gross annual draft (ha-m) to the utilizable groundwater resource of the respective district (ha-m).
- IPUI takes into consideration of utilised irrigation potential for both *kharif* and *rabi* season out of the created potential.
- ICI is calculated as annual gross irrigated area out of gross cultivated area. (Already a index irrigation intensity is available why to coin new terms when understandable terms exist, It may be Changed accordingly here as well as in the whole paper)
- CII is the arithmetic average of IPDI, GWDI, IPUI, and ICI. (This suffices instead of making it complex)
- ADI includes eight indicators *viz.* % of cultivable land to total land area, % of net sown area to total cultivable area, % of gross irrigated area to gross cropped area, cropping intensity, % of area under HYV (full form and than bracket) of major crops, yield of major crop, food grain production and per ha fertilizer consumption. (How eight are included, units are not same, give how the index was framed)
- PRI is calculated as the % rural families below poverty line to total number of rural families.
- LLI includes 14 indicators *viz.* % of rural families above poverty line, literacy rate, per capita food grain production, yield of major crop, % of gross irrigated area to gross cropped area, % of village electrification, women work participation rate, % of agril. laborers to total main workers,% of cultivators to total main workers, % of industrial workers to total main workers, % of main workers to total population, percentage of urban population to total population, agricultural productivity per worker, and SC/ST population. (Give here how it is calculated)

District-wise data on selected variables were taken from Economic Survey (2004-05, 2005-06, 2006-07), Agricultural Statistics of Orissa (2004-05, 2005-06, 2006-07), 2001 Census, Orissa BPL Survey 1997 and other published sources. District wise values of different indices were calculated. Each index ranges from 0.0 to 1.0. The districts are classified under each index into five categories *viz.* very low (0.0 to 0.2), low (>0.2 to 0.4), medium (>0.4 to 0.6), high (>0.6 to 0.8) and very high (>0.8 to 1.0).

RESULTS AND DISCUSSION

Variations in Indices

District wise values of different indices are mentioned in **Table 1** and frequency of districts under five categories of each index is given in **Table 2**.

Apprising district wise irrigation scenario at the end of tenth five year plan (March 2007) in Orissa revealed that the created irrigation potential out of total potential varied amongst the districts ranging from 19% (Nawarangpur) to 93% (Puri) in *kharif* and 8% (Bolangir) to 61% (Puri) in *rabi* season. Irrigation potential development is more than 50% in 11 districts out of which 6 districts were having 50% of cultivated area irrigated. 30% of GCA is irrigated in 15 districts. The IPDI values of 12 and 6 districts are very low (0-0.2) and low (>0.2-0.4), respectively.

Table 1. Different indices in the districts of Orissa

	District	GWDI	IPDI	IPUI	ICI	CII	ADI	LLI	PRI
1.	Balasore	1.00	0.39	0.72	0.64	0.69	0.72	0.49	0.33
2.	Bhadrak	0.95	0.53	0.81	0.95	0.81	0.76	0.58	0.52
3.	Bolangir	0.26	0.03	0.82	0.13	0.31	0.45	0.42	0.67
4.	Sonepur	0.13	0.77	0.80	0.85	0.64	0.66	0.57	0.35
5.	Cuttack	0.30	0.73	0.59	0.85	0.62	0.67	0.60	0.91
6.	Jajpur	0.72	0.85	0.48	1.00	0.76	0.61	0.43	0.69
7.	Jagatsingpur	0.21	0.13	0.57	0.27	0.30	0.48	0.53	0.90
8.	Kendrapara	0.62	0.62	0.27	0.41	0.48	0.58	0.53	0.70
9.	Dhenkanal	0.24	0.14	0.53	0.30	0.30	0.39	0.43	0.63
10.	Angul	0.28	0.09	0.70	0.24	0.33	0.41	0.46	0.72
11.	Ganjam	0.47	0.45	0.88	0.67	0.62	0.71	0.50	0.84
12.	Gajpati	0.29	0.20	0.61	0.18	0.32	0.50	0.40	0.66
13.	Kalahandi	0.20	0.48	0.91	0.51	0.52	0.56	0.39	0.63
14.	Nawapara	0.24	0.17	0.76	0.16	0.33	0.35	0.27	0.00
15.	Keonjhar	0.18	0.21	0.73	0.27	0.35	0.46	0.39	0.24
16.	Koraput	0.02	0.31	0.85	0.49	0.41	0.47	0.35	0.05
17.	Malkangiri	0.00	0.58	0.19	0.29	0.27	0.39	0.41	0.10
18.	Nawarangpur	0.26	0.01	0.58	0.00	0.21	0.41	0.30	0.33
19.	Rayagarh	0.16	0.19	0.71	0.29	0.34	0.35	0.30	0.37
20.	Mayurbhanj	0.38	0.13	0.74	0.42	0.42	0.43	0.43	0.22
21.	Kandhamal	0.11	0.08	0.61	0.08	0.22	0.19	0.31	0.20
22.	Boudh	0.26	0.44	0.89	0.57	0.54	0.44	0.45	0.15
23.	Puri	0.11	1.00	0.65	0.90	0.67	0.68	0.55	0.45
24.	Khurda	0.19	0.44	0.62	0.51	0.44	0.54	0.56	0.72
25.	Nayagarh	0.11	0.22	0.66	0.27	0.31	0.41	0.40	0.49
26.	Sambalpur	0.10	0.26	0.85	0.48	0.42	0.56	0.61	0.71
27.	Bargarh	0.20	0.35	0.91	0.79	0.56	0.77	0.61	0.69
28.	Deogarh	0.13	0.16	0.92	0.32	0.38	0.32	0.28	0.19
29.	Jharsuguda	0.40	0.02	0.97	0.23	0.41	0.43	0.53	1.00
30.	Sundargarh	0.23	0.16	0.73	0.29	0.35	0.31	0.41	0.56
	Max. Value	1.00	1.00	0.97	1.00	0.81	0.77	0.61	1.00
	Min. Value	0.00	0.01	0.19	0.00	0.21	0.19	0.27	0.00
	Mean	0.29	0.34	0.70	0.45	0.44	0.50	0.45	0.50
	Standard deviation	0.24	0.26	0.18	0.28	0.16	0.15	0.10	0.28

Table 2. Classification of districts under each index

Categories	Frequency of the districts							
	GWDI	IPDI	IPUI	ICI	CII	ADI	LLI	PRI
Very low (0.0-0.20)	13	13	1	5	0	1	0	6
Low (>0.2-0.4)	12	6	1	10	14	6	9	6
Medium (>0.4-0.6)	1	6	5	7	9	15	19	4
High (>0.6-0.8)	2	3	13	3	6	8	2	10
Very high (>0.8-1.0)	2	2	10	5	1	0	0	4

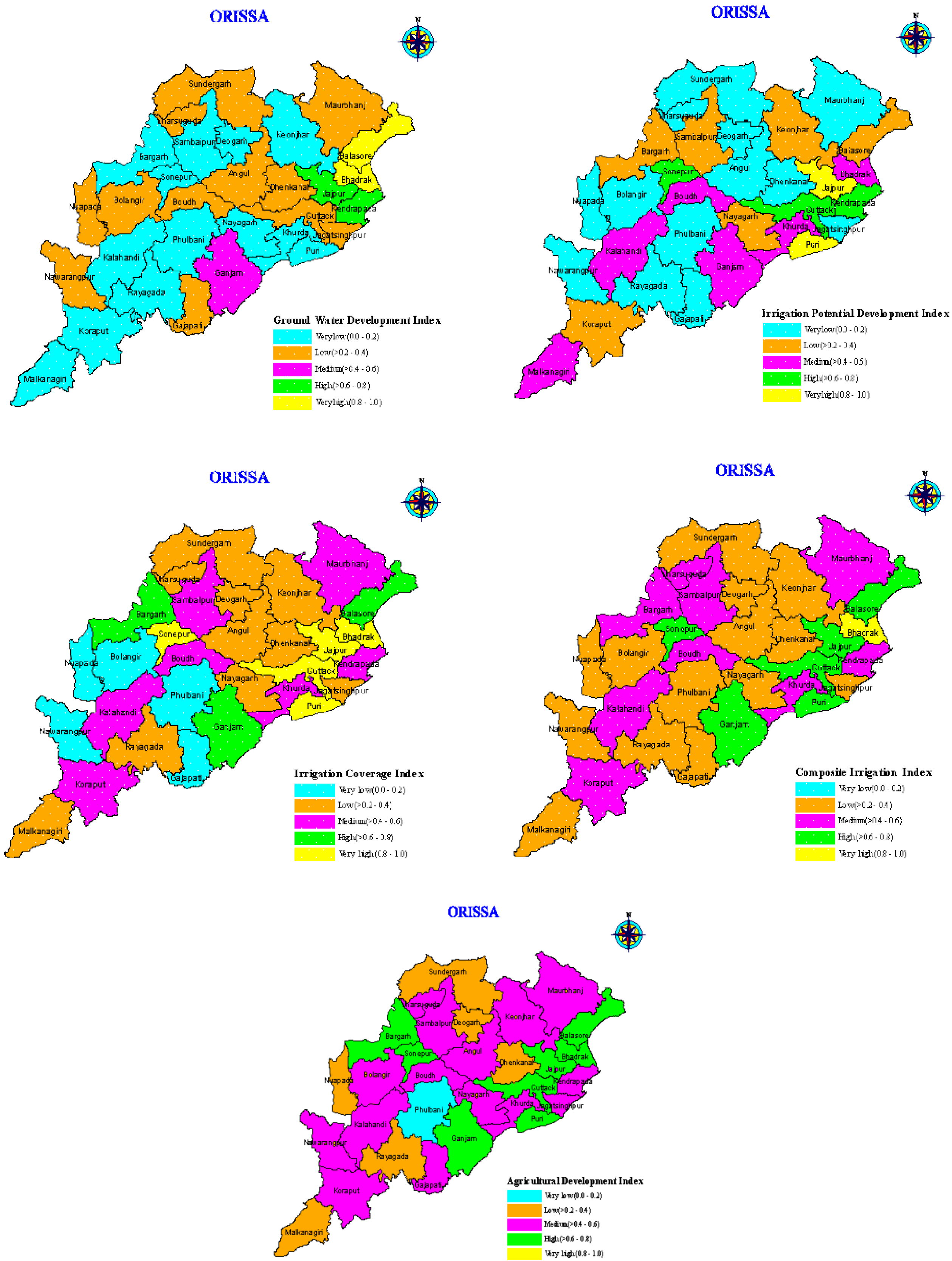


Fig. 1. District maps of different indices in Orissa

Groundwater development varies from 6% (Malkangiri) to 47 % (Balasore). Groundwater development is less than 20% in 23 districts with state average of about 18%. Only 4 districts value is >0.6 (high to very high). The irrigation utilization varied from 23 to 96% and 25 to 98% of the created potential in *kharif* and *rabi* seasons, respectively. IPUI values of 11 and 12 districts fell under very high (>0.8 to 1.0) and high (>0.6 to 0.8) category, respectively. Irrigation intensity varied from 14% (Nawarangpur) to 125% (Puri) with a state average 52%. (Use irrigation intensity as the index)

The gross irrigated area ranged from 9% (Nawarangpur) to 62% (Jajpur) of gross cultivated area with a state average of 33%. ICI values of 15 districts were very low to low, while those of 8 districts were high to very high. CII value varied from 0.21(Nawarangpur) to 0.81 (Bhadrak) . CII value varied from 0.21(Nawarangpur) to 0.81 (Bhadrak). CII of 14 districts was low, while 6 districts fell under high category.

District wise agricultural development is assessed on the basis of data on selected indicators for the year 2004-05, 2005-06 and 2006-07 and the data are screened for the year categorized as a normal year without any flood, drought or other natural calamities affecting agricultural performance (How for only three years data you could do so. As such you might have only one year data for each case and that may not represent the long-term). ADI values of 30 districts ranged from 0.77 (Bargarh) to 0.19 (Kandhamal). Half of the districts show medium ADI values (>0.4-0.6); while 6 and 8 districts indicate low (>0.2-0.4) and high (>0.6-0.8) agricultural development, respectively.

Rural poverty was explored through PRI. About 60% of BPL rural families comprised of the agricultural labourers, marginal and small farmers families; it ranged from 25% (Ganjam) to 94% (Nawarangpur). PRI values of 10 districts are in high range while 12 districts show very high to high poverty level with PRI values in the range of 0.0 to 0.2 and >0.2 to 0.4, respectively (How confusion).

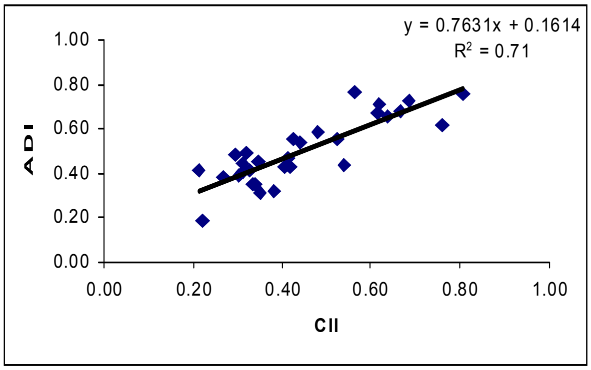
Level of living of 19 and 9 districts was found as medium and low respectively. Sambalpur and Bargarh are only two districts with high LLI value.

Links between irrigation, agriculture, livelihood and poverty could be understood through a correlation matrix **(Table 3)**. Correlation matrix reveals that ADI is significantly related with GWDI, IPDI, ICI and CII, while LLI is significantly related with IPDI, ICI, CII, ADI and PRI. Correlation coefficient value between PRI and ADI is significant. However, the regression analyses revealed that 71% variation in ADI is explained by CII **(Fig. 2)**. It is relevant to note that IPDI, ICI and CII values are lowest in Nawarangpur district showing very poor irrigation scenario with highest % of agricultural labourers, marginal and small farmers families below poverty line in rural areas to total number of rural families. In contrast, Balasore and Bhadrak districts are agriculturally developed with highest groundwater development. The marginal impact of groundwater irrigation on poverty reduction is larger than that of canal irrigation, which is due to

Table 3. Correlation matrix of different indicators

	GWDI	IPDI	IPUI	ICI	CII	ADI	LLI	PRI
GWDI	1.000							
IPDI	0.207	1.000						
IPUI	-0.044	-0.270	1.000					
ICI	0.399*	0.834**	0.121	1.000				
CII	0.615**	0.762**	0.206	0.947**	1.000			
ADI	0.513**	0.657**	0.116	0.827**	0.843**	1.000		
LLI	0.271	0.478**	0.043	0.641**	0.580**	0.751**	1.000	
PRI	0.238	0.065	0.011	0.191	0.200	0.400*	0.619**	1.000

** significant at 0.01 level (r > 0.463) and * significant at 0.05 level (r > 0.361)



Regression Summary between ADI and CII:

Multiple R	=	0.843**
R^2	=	0.710
F value	=	68.55**
Reg. Coefficient	=	0.763
t - test	=	8.280**

Fig. 2. Relationship between ADI and CII

greater control in the application and wide spread use of groundwater irrigation than of canal irrigation (Bhattarai and Narayanmoorthy, 2003). In recent years investments made by the private farmers in groundwater irrigation may have had a larger impact on livelihoods for poor people than the public investments in large-scale surface water irrigation systems (Rijsberman, 2003). In this context, lower groundwater exploitation for irrigation in Orissa has bearing on the lower impact of irrigation development on the poverty and livelihood scenario in the state. (it is not clear how it has emerged from your study. I know it otherwise also that groundwater irrigation is better than canal irrigation)

A linkage matrix is prepared showing frequency of districts under various combinations of links between Irrigation, Agriculture, Livelihood and Poverty **(Table 4)**. Irrigation – Agriculture link is found in 23 districts; however, it is narrowed down to 14 and 13 districts in case of Agriculture – Livelihood and Irrigation – Livelihood link, respectively. Irrigation – Poverty and Agriculture – Poverty link is visible in 11 and 9 districts, respectively. Irrigation – Agriculture – Livelihood – Poverty link is seen only in 5 districts. (How the linkage matrix is prepared should be included in the materials and methods)

CONCLUSION

Balasore, Bargarh, Bhadrak, Cuttack, Ganjam, Jajpur and Puri districts show higher irrigation and agriculture

Table 4. Linkage matrix showing frequency of districts under various combinations of links between Irrigation, Agriculture, Livelihood and Poverty

Types of Links	No. of Districts			
	Index: High to Very high	Index: Medium	Index: Low to Very low	Total
Irrigation - Agriculture	8	8	7	23
Agriculture – Livelihood	1	9	4	14
Irrigation – Livelihood	1	5	7	13
Livelihood - Poverty	2	3	7	12
Irrigation - Poverty	4	0	7	11
Irrigation – Agriculture – Livelihood	1	4	5	10
Irrigation – Agriculture – Poverty	4	0	5	9
Agriculture - Poverty	4	0	5	9
Irrigation – Livelihood - Poverty	1	0	6	7
Agriculture – Livelihood – Poverty	1	0	4	5
Irrigation – Agriculture – Livelihood - Poverty	1	0	4	5

development. While Deogarh, Dhenkanal, Kandhamal, Malkangiri, Nawapara, Raygary and Sundargarh districts show lower irrigation and agriculture development. The links are more in case of poorer condition of different sectors; while betterment in one sector has not linked to other sectors in many of the districts. Thus, the study has unveiled the links and/ or missing links between irrigation resources, agriculture development, poverty and level of living. (needs to be rewritten. It is not emerging from the study but seems to have been based upon general observations)

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Seasonal Variation in Gas Exchange in Pineapple Plants (*Ananas comosus L. -Merill.*) for Fitting in Rice Based Cropping System

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ABSTRACT

When the pineapple has to fit in a rice-based cropping system in rain fed areas, it is imperative to confirm the existence of crassulacean acid metabolism (CAM), a water use efficient metabolism in the pineapple crop during post monsoon scenario to fit in rice based cropping system. The changes in CO_2 fixation pattern and simultaneous changes in trend of assimilatory nitrate reductase activity in pineapple plant were studied from January to April. Study was designed to understand the effect of seasonal change on CO_2 fixation pattern over the period of these four months. In general from 9.00 h up to the early part of the afternoon (until 15.00 hrs), CO_2 fixation was observed to be negligible. However, from 15.00 hrs there was increase in net CO_2 fixation rate, the increase being significant at 18.00 hrs during January and at 19.00 hrs in February. In March and April, the significant increase was evident only at 20.00 hrs. The identical trends of net CO_2 fixation rate and stomatal conductance over the period of a day in all these four months strongly suggested that net exogenous CO_2 fixation rate in pineapple was predominantly under stomatal control. However higher net CO_2 fixation rate in March-April than January-February, suggested that metabolic environment for growth of pineapple would be better in warmer months (March-April) rather than cooler season of January or February. Increased net CO_2 fixation rate with onset of darkness confirmed the existence of CAM in pineapple plants in present scenario. Higher WUE during warmer months (March-April) suggested suitability of the crop in post monsoon rain fed scenario in rice based cropping system.

Key words: CAM metabolism, CO_2 fixation, photosynthetic gas exchange, rain fed cultivation.

Crassulacean Acid Metabolism (CAM) is normally found in the Crassulacean family of succulents. The CAM plants adapt to life in arid climates by conserving water and shows extreme level of plasticity from absolutely no CO_2 uptake (known as CAM – idling) to CO_2 uptake continuously throughout 24 h period with very less water requirement (Dodds *et al.*, 2002). But few members of CAM plants have economic importance *e.g.* pineapple, sisal etc. Nevertheless they have high water use efficiency (WUE) compared to other plants. For example: In C_3 plants like rice, wheat, etc. the water use efficiency ranges from 0.6-1.3 x 10^{-3} mol. CO_2 fixed per mol. H_2O transpired where as in C_4 plants like sugarcane, maize, etc. it ranges from 1.7-2.4 x 10^{-3} . But in comparison to C_3 or C_4 species, CAM plants like pineapple, sisal, cactus etc., water use efficiency ranges from 6-30 x 10^{-3} in night and 1-4 x 10^{-3} during day (Dodds *et al.*, 2002). Such a high level of water use efficiency in CAM plants is mainly because of CO_2 fixation during night and later part of afternoon (phase-I and phase-IV, Osmond, 1978) respectively when evaporative demand is relatively low. As there is no CO_2 assimilation from morning until initial hour of afternoon due to closed stomata, water loss through transpiration is avoided resulting into high water use efficiency in comparison to C_3 and C_4 plants. The temperature has been reported to influence the gas-exchange and CO_2 fixation rate in pineapple (Bartholomew and Maleziéux, 1994). Therefore, if pineapple is to be cultivated under rain fed conditions, the crop is likely to experience seasonal changes in temperature, day length and moisture regime before harvest in June/July (before paddy cultivation), if the crop has to fit in a rice-based cropping system. Therefore, an attempt is made to study the changes in CO_2 fixation pattern and simultaneous changes in trend of assimilatory nitrate reductase activity in pineapple plant. The study was designed to underpin the effect of seasonal change on CO_2 fixation pattern over the period of four months from January to April. The diurnal pattern of CO_2 fixation was monitored for better understanding of impact of seasonal changes on periodicity of CO_2 fixation over a period of day. The resultant effect on water use efficiency was also studied to understand strategic response of the crop.

MATERIALS AND METHODS

Plant Material

Pineapple plants (*Ananas comosus (L) -Merrill*) were grown in polythene bags containing 5 kg soil: compost mixture @ 2:1 ratio. The top crown was used as planting material. The plants were grown in natural day length with day and night temperature ranging between 25/15°C to 42/25°C. Plants were irrigated at regular interval to avoid moisture stress during the experimental period. Leaves for observations were selected by length. Only longest on the plant which is known as 'D' leaf was selected for photosynthetic observation

Photosynthetic Gas Exchange Measurement

The photosynthetic rate, stomatal conductance, and environmental parameters like photosynthetically active radiation, leaf temperature, and substomatal CO_2 concentration were measured on "D" leaf of plants using a CIRAS2 portable photosynthetic system (M/S PP Systems, UK). There was no drift for calibration curve for water vapor and CO_2 calibration curve. A universal leaf chamber with broad leaf attachment with 18 cm^2 area was used for all the gas exchange measurements. The data were collected at different times of the day.

RESULTS AND DISCUSSIONS

Changes in temperature and day length at the experimental site during January to April 2010 are shown in **Table 1**. The data suggest that distinct temperature regime existed during the four months. The temperature regime in the experimental period in January was 28.3/14.1 which reached up to 39.1/25.8 in the month of April. Therefore, the plants passed through a wide range of temperature regime during the four month period. Temperature is one of the most important factors for pineapple cultivation and practically determined area distribution for cultivation best being 28-32°C (Nievola *et al.*, 2005).

Table 1. The mean maximum, minimum temperature, sunset time and total day length period

Months	Max T T (°C)	Min T (°C)	Sun set (hrs)	Day length (h, min)
Januray, 2010	28.3	14.1	1727	11 h 02 min
February, 2010	33.4	18.4	1745	11 h 29 min
March, 2010	37.3	24.3	1756	12 h 00 min
April, 2010	39.1	25.8	1810	12 h 36 min

www.time&date.com, and OUAT Bhubaneswar observatory

In addition to changes in temperature, the day length and appearance of dark period also showed significant change in this period. The difference in day length was almost one and half hours between January and April.

The changes in net CO_2 fixation at different periods of the day revealed negligible CO_2 fixation from 9.00 hrs up to the early part of the afternoon i.e. till 15.00 hrs **(Fig. 1)**. However from 1500 hrs onwards, there has been increment in net CO_2 fixation rate. This increase was significant at 1800 hrs during January and at 1900 hrs in February. But in the month of March and April, the significant increase was evident at 2000 hrs. Therefore, it was clear that consistently there has been quantum jump in net CO_2 fixation rate in late afternoons. This was the reason to achieve the sufficient elevation in net CO_2 fixation rate from 1800 hrs in Jan to up to 2000 hrs in March and April as the time for onset of dark period shifted from 1725 hrs in January to 1840 hrs in April.

The stomatal conductance of the leaves also showed a characteristic pattern **(Fig. 2)**. Like net photosynthesis rate, in January, quick increase in stomatal conductance was evident with onset of the dark period. Until1500 hrs, stomatal conductance remained low. However, beginning 1500 hrs, a

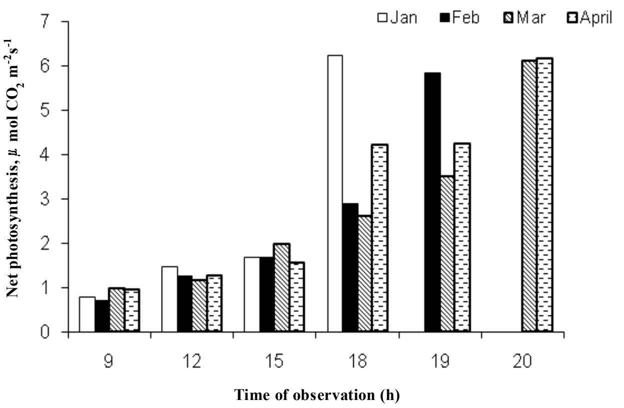

Fig. 1. Changes in net CO_2 fixation rate in different period of the day in pineapple in different months. The symbols are as in figures

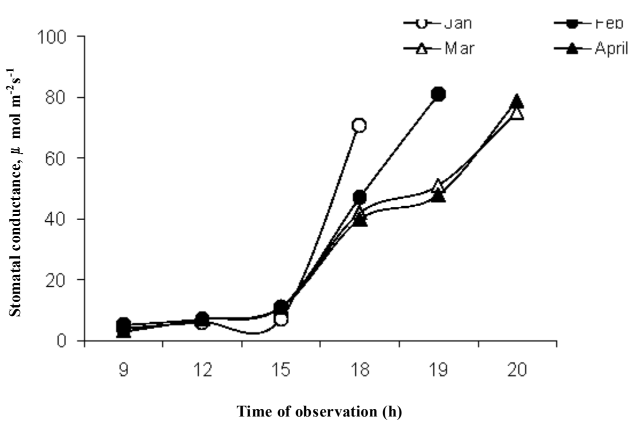

Fig. 2. The changes in stomatal conductance of pineapple leaves at different periods of a day. The symbols are as in figures

significant increase in stomatal conductance was observed. The pattern remained same in all the four months. Except for the fact that, the elevated CO_2 fixation rate reached steeply in January and February, whereas in later months such elevation was evident later between 1900 and 2000 hrs. This was presumably due to extended day length during later month. These data suggest that, throughout light period of the day (from 0900 hrs onwards) net photosynthesis remained low and surged up in the late afternoon in all the months, i.e. from January to April. However, the rise in net CO_2 fixation rate was dependent on onset of dark period in the evening. The identical trends of net CO_2 fixation rate and stomatal conductance over the period of a day in all these four months period strongly suggested that net exogenous

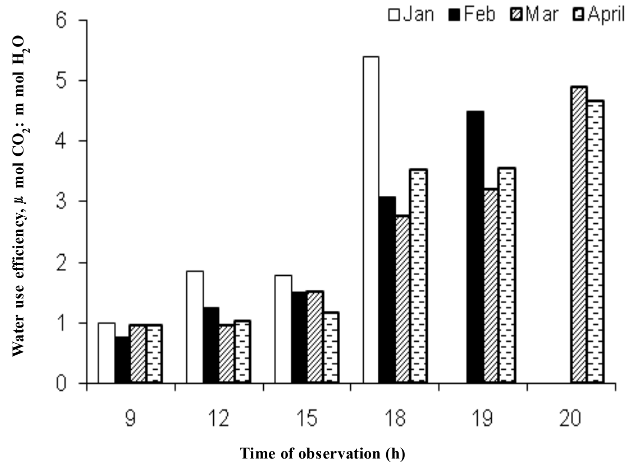

Fig. 3. The changes in water use efficiency of pineapple leaves at different periods of a day. The symbols are as in figures

CO_2 fixation rate was predominantly under stomatal control. Similar diurnal rhythm of net CO_2 fixation rate in pineapple was reported in literature, which clearly suggested four phase pattern of CO_2 fixation (Osmond, 1978, Dodds *et al.*, 1999). The main point evident in our data has been temporal shifting of the surge of net CO_2 fixation which paralleled with onset of dark period. Interestingly, even though there has been increase in day temperature, maximum recorded values of net CO_2 fixation rate did not show significant change over different month, particularly from Feb-April period, and suggested that the phenomenon is less sensitive to rise in temperature. Therefore, with rise in temperature also, primary productivity (at least at leaf level) did not change appreciably in these months.

Moreover, in a CAM plant with high water use efficiency, it was imperative to study the quantum of water lost for fixing a unit amount of CO_2. The water use efficiency (WUE) remained fairly low, till early afternoon*, i.e.* till 1500 hrs and ranged between 0.96 to 1.78 µmol CO_2 fixed per mmol H_2O transpired during the said period. However, from then onwards, WUE increased up to 5.39 in January to 4.86 to 4.89 in March-April. The higher WUE in January was presumably due to more net photosynthesis rate and simultaneous less transpiration than in the warmer month of March-April when evaporative demand is relatively high. However high WUE level (4.66-4.89 µmol CO_2 fixed per m mol H_2O transpired) achieved at initial phase of evening in warmer March-April suggested suitability of cultivation of pineapple crop in rainfed rice fallows in post monsoon period.

CONCLUSION

Irrespective of seasonal variation, the diurnal rhythm of photosynthetic CO_2 fixation showed a rhythmic change, *i.e.* low net photosynthesis over period of day which showed an increasing trend at the end of the day. However overall mean higher net CO_2 fixation rate suggested better growth of pineapple in warmer months (March-April) rather than in cooler January or February. Increased net CO_2 fixation rate with onset of darkness confirmed the existence of CAM in pineapple plants. At later part of the day the WUE was maintained at high level even during warmers months (March-April), when evaporative demand is higher. This suggested scope of the pineapple crop for cultivation rainfed rice fallows in post monsoon season.

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Water use Studies under Different Scheduling Through Drip on Onion Seed Production

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ABSTRACT

An experiment conducted to assess drip method of irrigation in combination of three irrigation regimes viz. 75 %, 100 % and 125 % of cumulative pan evaporation (CPE) with four irrigation intervals viz. 1, 3, 7, and 10 days and conventional irrigation at 50 mm CPE as an control treatment. The field experiment was laid out in randomized block design with thirteen treatments replicated thrice for two consecutive years 2008-2009. The study revealed that when drip irrigation applied daily or 3 days with amount equal to 100 per cent of CPE all yield contributing characters were improved as compared to other longer irrigation intervals and surface irrigation. These results were on par with drip irrigation applied daily or at 3 days with 75 per cent of cumulative pan evaporation (CPE). The total quantity of water applied through drip was less as compared to surface irrigation treatment indicating 41 to 65 per cent water saving with 2 to 40 % increase in the productivity of onion seed production. The economics of study also revealed that highest best benefit: cost ratio was obtained under drip irrigation at 100% CPE, daily application (3.79). The application of water through drip at daily basis irrigation interval was found to be effective for growth yield, quality and economically viable for onion seed production with saving of water.

Key words: Cumulative pan evaporation, Irrigation interval, Onion seed, Drip irrigation.

Onion is grown worldwide over an area of 34.21 lakh hectares with 637.87 lakh tons production and having an average productivity 18.64 t/ha. The latest global review of area and production shows that among the major vegetables, onion rank second in area, and third in production. India ranks second in area for onion production next to China (55 lakh tons). In India, onion is grown over an area of 0.58 M ha, producing about 7.16 M tonnes of bulbs. The average yield of onion in India is about 11 t/ha which is utilized for local consumption as well as export purpose (Anonymous, 2006). Onion export has increased by three times, over the decade. Besides feeding huge domestic population, India exports 7.0 to 8.0 lakh tons of onion annually which worth of Rs.700 to 800 crores. During last 10 years, the area, production and productivity of onion have increased by 11, 40 and 27 percent, respectively. In spite of large area under cultivation per hectare productivity of onion in India is only 11 t/ha, which is very low when compared to USA (49 t/ha), Netherlands (35 t/ha) and China (22 t/ha). Onion is also the second most widely grown vegetable in the country. Among the major onion producing states, Maharashtra is the leading state with annual cultivation accounting for 23 % of total area (92600 ha) and 27.5 % of the production with the average yield 12.1 t/ha. (Anonymous, 2006).

With increase in area under onion cultivation in the country, the demand for seed has also been increased tremendously. Quality seed of high yielding varieties in onion and has revolutionized yield over last three decades. But still availability of pure seed of such a cash crop is big constraint faced by entire agriculture sector in the country. Nearly 60-70% production comes from local types maintained by farmers themselves. Traditional practice of farmers to cultivate seed in a corner plot does not succeed, for the quality degenerates over generations of the seed. These local types suffer from variation in size, shape, colour and maturity. Besides this impediment, poor seed viability of carryover stock does not make onion seed production a lucrative business as compared to other vegetables. Therefore, there is a wide gap between demand and production of onion seed. As per the estimates of National Seed Corporation, India needs about 4000 tonnes of certified seed of onion per year while the yearly production of onion seed is about 600 tonnes only (Singh, 2003). Therefore, it is essential to boost up the good quality seed production to meet the production and demand gap.

The seed yield of onion is influenced by many factors *viz*., variety, bulb weight, spacing, nutrition and quantity of irrigation. Amongst them irrigation quantity and method of irrigation plays a pivotal role. Onion crop is very sensitive to irrigation, since it has got relatively shallow root zone and requires more frequent irrigation. The low yields of such a valued crop could also be attributed to surface irrigation method predominantly adopted by farmers. Several extensive studies have been reported from India and a broad in respect of cultivation of onion bulb. Micro irrigation with stressed water application seems to be better alternative to improve onion seed production with reduced water commodity (Bekele and Tilahub, 2007). However, the research work on the irrigation aspect of onion seed production is very meager. Thus it was attempt to assess the effect of irrigation scheduling through drip on onion crop grown for seed purpose.

MATERIAL AND METHODS

Details of experiment

The field experiment was conducted to study the different irrigation scheduling through drip irrigation for onion seed production at Mahatma Phule Krishi Vidyapeeth, Rahuri, during two consecutive *Rabi* seasons of 2008 and 2009. Agroclimatically, the area falls under the scarcity zone of Maharashtra with annual average rainfall of 520 mm which is mostly erratic and uncertain in nature. The experimental plot had plain topography. The soil texture was sandy clay loam having 17.28 % coarse sand, 38.57 % fine sand, 22.14 % silt and 23.54 % clay with medium depth. The soil was alkaline in nature with pH of 7.93 and electrical conductivity of 0.06 dSm^{-1}. The bulk density of soil was 1.47 g/cm^3. The soil was low in available N (143 kg/ha), and P (11.82 kg/ha) and high in available K (255.34 kg/ha) content. The soil was having good drainage with moisture contents at field capacity, permanent wilting point and available soil moisture as 30.32, 13.37 and 16.95 %, respectively.

The planting of onion bulb (var. N-2-4-1) was done on raised beds spaced at 1.50 m. A raised bed of 1.20 m top width & 1.50 bottom width was prepared and on each bed four rows of onion bulbs were planted at spacing of 30 cm. The spacing between two bulbs on a raised bed was kept as 30 cm. The recommended fertilizer dose 100:50:50 NPK, kg/ha was applied through fertigation in form of water soluble fertilizers viz. urea (46 % N), urea phosphate (17:44) and muriate of potash (60 % K_2O). The basal dose of phosphorous, potassium and half dose of nitrogen (through soil) were applied at the time of planting. Remaining half dose of nitrogen was applied one month after planting. The field experiment was conducted in Randomized Block Design (RBD) with thirteen treatments combinations replicated thrice. The main plot treatments were comprises of three depths of irrigation viz. 75, 100 and 125 per cent of cumulative pan evaporation values. The sub plot treatments were comprised of different irrigation intervals viz. daily, 3 days, 7 days 10 days respectively. The surface irrigation was also included in the experiment as control.

Estimation of water requirement

The irrigation was applied as per treatment on the basis of climatological approach. The daily pan evaporation data was recorded from USWB class A Pan from Demonstration Farm of M.P.K.V. Rahuri. The quantity of water applied through drip irrigation as per treatment was calculated by the following formulae (Doorenbous *et al.*,1976)

$$ETc = Ep \times Kp \times Kc \quad \text{.................................(1)}$$

$$V = \frac{ETc \times Wa}{E} \quad \text{.........................(2)}$$

Where,

ETc = Evapotranspiration of onion (seed)

Ep = Cumulative pan evaporation (mm)

Kp = Pan coefficient (0.7)

Kc = Crop coefficient (Allen et.al. 1994)

V = Crop water requirement of onion seed/ emitter

Wa = Wetted area (Ðr2)

r = Radius of wetting front of dripper (35 cm)

E = Efficiency of the system (91 %)

Design and layout of drip irrigation:

The drip irrigation system was installed to meet out crop water requirement of onion seed. The PVC pipe of 75 mm diameter was used for main, 63 mm diameter was used for sub main and PVC manifold of 40 mm size with a valve was provided for each plot. To avoid the clogging of emitters due to physical impurities in irrigation water, both sand and screen filters were used with back flushing arrangement. The duration of irrigation was controlled with the help of control valve provided at the inlet of each manifold for each plot. Each manifold was consisted of 3 laterals. The LDPE lateral lines of 12 mm diameter were laid along the crop rows at 1.5 m spacing and each lateral with inbuilt dripper spaced at 0.5 m was laid in between two rows of planted bulb. The system was operated at a constant pressure of 1.25 kg/cm^2 which was maintained with the help of control valve. As the water source was a tube well and the problem of organic residues was nominal, the back flushing of sand filter was carried out at regular interval of 15 days. The average emission uniformity of drip irrigation system were estimated as 91 per cent by standard methodology (Kermaili & Keller, 1974). The emission uniformity was calculated by using following formula.

$$EU = 100 \left(\frac{q_{min}}{q_{av.}} + \frac{q_{av.}}{q_x} \right) \times \frac{1}{2}$$

Where,

EU = Emission uniformity in per cent

q_{min} = Minimum discharge rate of emitter from all emitters selected for observation, lph.

q_{av} = Average emitter flow rate of all emitters selected for observation, lph.

q_x = Average of the highest 1/8th emitter discharge rate, lph.

In surface irrigation 5 cm depth of irrigation was applied at 50 mm cumulative of pan evaporation. The quantity of water applied was measured by using replogal flume. In order to evaluate the effectiveness of each treatment the data on yield and its attributing characters, total water applied, water use efficiency, seasonal water requirement, total cost of cultivation, total income from produce total net income and other relevant parameters of onion for seed were recorded.

RESULTS AND DISCUSSION

Yield

The data presented in **Table 1** regarding number of seed per umbel, seed yield per umbel revealed that different treatments of irrigation scheduled statistically influenced the number of seeds per umbel. The maximum number of seeds per umbel was recorded in treatment T_5 (DI at 100 % PE, at daily application), which was at par with treatment T_1 (DI, at 75 % PE, daily application) and T_6 (DI, at 100 % PE at 3 days interval) followed treatments at 7 days interval of irrigation application through drip.

The irrigation application at daily basis, 3 days interval and 7 days interval show higher number of seeds per umbel than surface irrigation at 50 mm CPE. The irrigation application through drip at 3 days interval at 75, 100 and 125 per cent PE, and 7 days interval at 75 and 100 per cent PE, showed maximum yield of onion seeds per umbel than surface irrigation. The minimum number of seed per umbel was recorded in treatment T_4 (DI at 75 % PE, at 10 days interval) which was at par with treatments T_{12} and T_8, irrigation application through drip at 125 and 100 per cent PE, at 10 days interval.

The results revealed that drip irrigation gave the higher yield as compared to conventional method of irrigation. The drip irrigation with 100 % of cumulative pan evaporation daily application showed maximum yield of onion seed of 478 Kg/ha, which was on par to yield obtained from drip irrigation with 75 % of cumulative pan evaporation for daily and 3 days interval i. e. 470.3 Kg/ha and 457.0 Kg/ha, respectively. This indicates that slight increase in irrigation interval with reduced depth of application can be optimal for onion seed production.

The yield characters showed decreasing trend with increase in irrigation interval. The application of water at 3 days interval in 75, 100 and 125 % of cumulative pan evaporation showed more yield as compared to seed yield obtained from surface irrigation at 50 mm CPE. However, the yield at 7 days interval in all 75 %, 100 % and 125% of cumulative pan evaporation application through drip was at par with surface method of irrigation. The seed yield at 10 days interval in all the application through drip at 75 %, 100 % and 125% of cumulative pan evaporation was quite lower

Table 1. Yield contributing characters of onion for seed as influenced by different treatments

	Treatments	Seed yield/umbel	Seed yield/plant	No. of seed/umbel	Thousand seed weight (g)
T_1	D.I. at 75 % PE daily application	1.87	11.00	549.00	3.88
T_2	D.I. at 75 % PE, once in 3 day	1.80	10.66	489.33	3.74
T_3	D.I. at 75 % PE, once in 7 days	1.67	9.66	476.66	3.59
T_4	D.I. at 75 % PE, once in 10 days	1.53	8.33	407.00	3.18
T_5	D.I. at 100 % PE, daily application	2.05	11.33	578.00	3.91
T_6	D.I. at 100 % PE, once in 3 days	1.87	11.00	534.66	3.80
T_7	D.I. at 100 % PE, once in 7 days	1.73	9.66	480.33	3.69
T_8	D.I. at 100 % PE, once in 10 days	1.55	8.66	437.33	3.28
T_9	D.I. at 125 % PE, daily application	1.64	9.33	476.66	3.50
T_{10}	D.I. at 125 % PE, once in 3 days	1.63	9.33	472.00	3.45
T_{11}	D.I. at 125 % PE, once in 7 days	1.57	9.00	445.66	3.34
T_{12}	D.I. at 125 % PE, once in 10 days	1.55	8.33	415.66	3.25
T_{13}	S.I. at 50 mm CPE	1.63	9.00	446.00	3.39
	S.E. ±	0.09	0.52	29.3	0.02
	C.D. at 5 %	0.28	1.52	85.80	0.05

than surface irrigation yield. This revealed that severe moisture stress resulted in less vegetative growth as well as reduced the yield drastically. Hence the irrigation at higher intervals is not advisable for onion seed production through drip.

The daily application of water increased the biomass in onion seed. The straw yield was observed higher in daily irrigation with 100 % and 75 % of cumulative pan evaporation as compared to other treatments of drip and surface irrigation at 50 mm CPE.

Water use

The seasonal water requirement was higher in surface irrigation at 50 mm of cumulative pan evaporation (77.5 cm) as compared to irrigation applied by drip irrigation treatments **(Table 2)**. The overall water saving in drip irrigation ranged from 41 to 65 %. From the water saved, about 1.83 ha additional area can be brought under onion seed production and additional economical benefits can be derived. The water use efficiency was highest (17.12 Kg ha-cm^{-1}) when drip irrigation was applied daily with 75 % of cumulative pan evaporation, which is closer to water use efficiency obtained when irrigation applied at 3 days interval with 75 % of CPE. The water use efficiency was found lowest as 4.90 kg ha-cm^{-1} in surface irrigation at 50 mm CPE.

The irrigation applied at 7 days interval does not increases yield significantly over surface irrigation even the water use efficiency is higher. An overall decrease in yield is observed when irrigation was applied at 10 days interval as compared to surface irrigation at 50 mm cumulative pan evaporation level. On the basis of these results and in view of water saving the irrigation at 3 days interval with 75 % of cumulative pan evaporation can be promoted for onion seed production.

Economic aspects

The data regarding the cost of cultivation, gross and net returns and benefit: cost ratio from cultivation of onion seed as influenced by different treatments are presented in **Table 3**. Among the different treatments, the cost of cultivation was higher (Rs.54843.9 per ha) in treatment of surface irrigation at 50 mm CPE as compared to drip irrigated treatments. The maximum gross monetary returns (Rs.259200 per ha), net

Table 2. Water used by onion seed production under different irrigation scheduling of drip (pooled data of 2 years)

Details	Water applied (cm)	Field water use efficiency (Kg/ ha-cm^{-1})	Water saving (%)	Increase in yield (%)
75 % CPE at daily	27.46	17.12	65	24
75% CPE at 3 days interval	27.09	16.87	65	20
75 % CPE at 7 days interval	26.44	15.17	66	06
75% CPE at 10 days interval	25.24	12.90	67	-14
100 % CPE at daily	36.66	13.04	53	26
100 % CPE at 3 days interval	36.14	11.60	53	10
100 % CPE at 7 days interval	35.26	11.24	55	04
100 % CPE at 10 days interval	33.66	9.92	57	-12
125 % CPE at daily	45.83	8.23	41	-1
125% CPE at 3 days interval	45.18	8.34	42	-1
125 % CPE at 7days interval	44.08	7.73	43	-10
125% CPE at 10 days interval	42.08	7.12	46	-21
Surface irrigation at 50 mm CPE	77.50	4.90	—	—

*saving of water over T_{13}; ** Increase in yield over T_{13}; *** -ve sign shows decrease in yield over T_{13}

Table 3. Cost economics of onion for seed as influenced by different treatments

	Treatment	Total cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	Benefit: cost ratio	Net extra income over control (Rs/ha)
T_1	D.I. at 75 % PE daily application	51114.86	239796	175824.6	3.75	370013.25
T_2	D.I. at 75 % PE, once in 3 days	51108.36	206598	142626.6	3.23	285956.2
T_3	D.I. at 75 % PE, once in 7 days	51109.93	195600	131628.6	3.06	254590.85
T_4	D.I. at 75 % PE, once in 10 days	51096.94	108798	44826.6	1.70	16369.73
T_5	D.I. at 100 % PE, daily application	51244.56	259200	178428.6	3.79	310977.31
T_6	D.I. at 100 % PE, once in 3 days	51234.86	228600	164628.6	3.57	232241.87
T_7	D.I. at 100 % PE, once in 7 days	51224.81	199596	135624.6	3.12	171028.78
T_8	D.I. at 100 % PE, once in 10 days	51220.25	136200	72228.6	2.13	43258.41
T_9	D.I. at 125 % PE, daily application	51372.72	190200	126228.6	2.97	94894.41
T_{10}	D.I. at 125 % PE, once in 3 days	51361.36	188598	124626.6	2.95	96168.28
T_{11}	D.I. at 125 % PE, once in 7 days	51361.26	153996	90024.6	2.41	37929.41
T_{12}	D.I. at 125 % PE, once in 10 days	51341.88	133596	69624.6	2.09	7588.43
T_{13}	S.I. at 50 mm CPE	54843.60	108798	55811.40	2.05	0.00

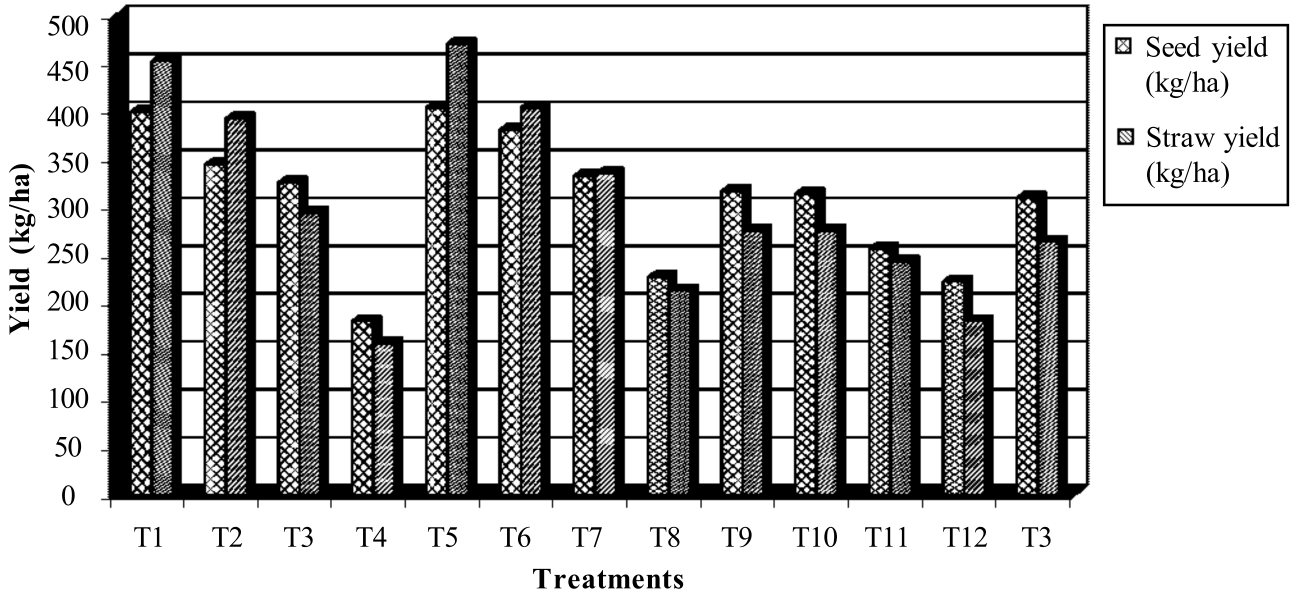

Fig. 1. Seed and straw yield per ha (kg) of onion for seed as influenced by different treatments

income ((Rs.178428.66 per ha) were observed in T_5 (DI at 100 % PE, daily application) treatment as more yield of seeds obtained. The minimum monetary returns (Rs.108798 per ha) and net income (Rs.55811.40 per ha) were obtained from T_4 (DI at 75 % PE, 10 days interval) and surface irrigation at 50 mm CPE, which was due to lower yield.

The computed values of B:C ratio in various treatments were in the range of 1.7 to 3.79. Amongst all the treatments the highest B : C ratio was obtained in the treatments T_5 (DI at 100 % PE, daily application), followed by treatment T_1 (DI at 75 % PE, daily application). Thus, it was seen that treatment T_5 was best as far as B:C ratio is concerned amongst the drip irrigation treatments. In all the treatmtments, T_{13} (SI at 50 mm CPE) the B:C ratio was lowest (2.05) which may be attributed to the lower yields recorded. However, maximum net extra income (Rs.370013) was obtained in treatment T_1 (DI, at 75 % PE, daily application), followed by treatment T_5 (DI at 100 % PE, daily application) (Rs. 310977.31).

CONCLUSIONS

The drip irrigation treatments were found suitable for onion seed cultivation as it resulted into 41 to 65 per cent water saving with 4 to 26 per cent increase in the seed yield. All the growth characters and seed yield of onion was increased in drip irrigation applied daily or once in 3 days than other longer intervals. The irrigation application once in 3 days interval with 75 % cumulative pan evaporation was found optimum scheduling criteria for onion seed production. The application at higher interval of irrigation viz. 7 and 10 days was resulted into inferior growth, yield and quality of onion seed. The highest best benefit: cost ratio was obtained in treatment T_5 (DI at 100% PE, daily application (3.79), as drip irrigation not only increases the yield but also saved sizable quantum of water. Hence, treatment T_5 (DI at 100 % PE, daily application) was superior over the rest of treatments as far as the B: C ratio was concerned.It can be concluded that, for onion (var. N-2-4-1) cultivated for seed purpose in sandy clay loam soil, the drip irrigation application with 75 % of cumulative pan evaporation at once in 3 days interval was best to obtain better growth, improve yield and quality of onion seed.

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Rice-fish Farming System as Micro-water Resource and Income Generation under Rainfed Lowland Situations

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ABSTRACT

Integrated rice-fish farming was studied to find out it's utility as micro-water resource and income generation under rainfed lowland situation. During the period from 2002-03 to 2004-05, mean grain yield of 3.96 t/ha was recorded from *Kharif* rice and 4.37 t/ha from *Boro* rice with the total of 8.33 t/ha from the cropping sequence. In the year 2007-08, short duration vegetable crops were grown in the dry season using the harvested water from the system. Highest yield of 57 q/ha was obtained from radish, followed by potato (47.2 q/ha). Economics of the integrated rice-fish farming system during 2002-03 to 2006-07 revealed that mean gross returns were Rs 68962/ha. The mean rice equivalent yield of the system for 2002-03 to 2006-07 was 11.5 t/ha, which was higher than sole rice cropping (3 to 4 t/ha) and rice - rice cropping (7 to 8 t/ha) recorded from nearby farmers field.

Key words: Rainfed farming, Lowlandss, rice-fish farming, Rice equivalent yield, Water harvesting.

Northeast India receives high amount of rainfall distributed over a long period. In Assam, average rainfall is 1742 mm of which 66 to 85% occurs from June to September followed by 20 to 30% of pre-monsoon rainfall in April-May. Some times, low rainfall during rainy season or delay in the onset in monsoon delays transplanting of rice. Occasionally, transplanted crop is affected due to water deficit at critical growth stages like seedling establishment, tillering, primordial initiation, flowering and milking. Short drought like situation is common after flash floods (Rautaray, 2007). In Assam, around one million ha of rainfed lowlands are available for rice-fish farming in the ecologies of medium deep (up to 50 cm water depth), deep water areas (up to 100 cm water depth) and coastal wetlands (Sinhababu, 2001). Extent of flood prone area is 39% in North Bank Plain Zone, 32% in Lower Brahmaputra Valley Zone and 17% in Upper Brahmaputra Valley Zone of Assam (Pathak *et al.*, 2004). Rice-fish system may act as a risk minimizing measure for rainfed lowlands affected by short season drought and moderate flood. High rainfall, extended river valley, high organic matter content in soil and preference of people for rice and fish may favour rice-fish system in this region. Information is meager on integrated rice-fish farming system as water and nutrient harvesting structure and source of income to farmers and hence, the present study was undertaken.

MATERIALS AND METHODS

A low lying rice field (125m x 40m) holding 20 to 60 cm water in *Sali* season but free from floods was selected for construction of the rice-fish farm. Adjacent to the rice-fish field, 3 sole rice fields each measuring 40 m x 40 m were selected. The bund heights of sole rice fields were 15, 30, and 45 cm, respectively. For comparing with the rice-fish system, rice yields were recorded from well managed farmers field (10 nos.) under rice-fallow and rice-rice cropping sequence. In case of rice-fish field, height of the dykes was 0.9 m after settling. The components of rice-fish farming system were *Kharif* rice (winter rice grown during June-July to November-December), and *Boro* rice (spring-summer rice grown during November-December to May-June) or winter vegetables in the dry season in the main field. Fishes were grown in the refuge pond, trenches and also in

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the rice fields (at appropriate water level) and vegetables, fruit crops, ornamental crops and agro-forestry on dykes. Spatial cropping intensity was possible by growing creeper/climbing vegetables on platforms hanging over the trench. Rice yields recorded from 2835 m^2 area were converted into t/ha. For computing the economics of integrated rice-fish farming system on one hectare area basis, actual income from rice, fish and horticultural crops were multiplied by 2 as the area under the system was 5000 m^2.

Field Design

Field design of rice-fish system included wide dykes all around, a pond refuge connected to two side trenches (micro-watershed-cum-fish refuge) and one guarded outlet (Rautaray *et al*., 2005). Main field occupied 2835 m^2 area for growing *Kharif* rice in wet season while *Boro* rice or winter vegetables in dry season. Dykes occupied 1256 m^2 area for growing horticulture and agro-forestry plants. The pond refuge (30 m x 12 m x 2m) was constructed at the lower end (down slope) of the field occupying 7.2% (360 m^2) area. The two trenches of 2.5 m width occupying 10% (500 m^2) of the total area were constructed adjacent to the dykes along the longitudinal side of the field and those connected to the pond refuge at one end. The trench bottom had a gentle slope of 0.75% towards the pond refuge. The dug-out soil from the pond refuge and side trenches was used for construction of wide dykes all around with bottom and top width of 4 m and 2 m, respectively. The average height of the dykes was 0.9 m, which was 0.3 m higher than the usual maximum water level in the field. Six platforms of 4mx 3.5 m size were constructed from the inner side of the dyke hanging over the trenches for planting the creeper vegetables at the inner side of the dyke and allowing the plants to creep over it.

Production Technologies

Main field

A crop sequence of rice-rice was followed in the main field for 3 years (2002-03 to 2004-05). *Sali* rice variety 'Joymati' was bulk planted in 2002 while Ranjit in 2003 and 2004. Rice variety 'Rupsundari' was used in the *Boro* season. In *Sali* season, 35 days old seedlings were transplanted during June last week to July first week while during *Boro* season, 50 days old seedlings were transplanted in last week of December. *Sali* rice received organic nutrition at 20 kg N ha^{-1} through decomposed paddy straw or farmyard manure, except the year 2003 in which the crop was grown in native fertility. During *Boro* season, the first crop was grown with chemical fertilizer at 60-17-33 kg N-P-K ha^{-1}. The second and third crop received farmyard manure at 20 and 40 kg N ha^{-1}, respectively. Land preparation was not done for *Boro* rice as soft mud was maintained due to constant water logging under rice-fish farming system. *Boro* rice seedlings were transplanted between two rows of the previous crop. Rice-winter vegetable crop sequence was followed in the main field in 2007-08. Short season winter vegetables tested in the system include snap bean, amaranthus, spinach, coriander, radish and potato and plant nutrition was met from composts generated within the system. Data relating to yield and net return were analysed statistically by applying analysis of variance for Randomized Block Design.

Fish

Fingerlings of catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), bata (*Labeo bata*), common carp (*Cyprinus carpio communis*), silver carp (*Hypophthalmichthys molitrix*) and China punti (*Puntius gonionatus*) were released in the pond during May to first week of June. A total of 6,250 fingerlings consisting of catla (24%), silver carp (8%), rohu (12%), bata (12%), mriga1 (24%), common carp (16%), and China-punti (4%) were released. The body weight of fingerlings varied from 17-82 g at the time of release. Manuring of pond with cow dung was done at the rate of 100 kg per month applied in weekly splits. Supplementary feed through rice bran and mustard oil cake at 1:1 ratio was provided per annum (160 kg). Live *Azolla* was also provided for feeding of fish by releasing within a bamboo quadrat (3.0x1.5m) floating in pond refuge. *Azolla* feeding was done at an interval of three weeks by releasing a layer of this water fern inside the quadrat. Thus, the fish nutrition was met from organic sources.

Dyke (Horticulture and Agro-forestry)

Vegetables on dyke included snap bean, radish, brinjal, okra, pumpkin, tomato, poi, spinach, coriander and lai sag. Climbing and creeper vegetables like country bean, bottle gourd, squash gourd and ridge gourd were grown over the platforms for crop intensification over space. Banana, papaya, coconut, arecanut, guava and lemon were grown on dykes. Marigold and tuberose were grown on the dyke adjacent to pond refuge. Teak (15 plants) as agro-forestry component was planted only on the dyke opposite to that at the pond refuge.

RESULTS AND DISCUSSION

Rice in Main Field

Water level for the year 2002 in main field resulted in continuous water logging of rice field **(Fig. 1)**. Water level was low (1-3 cm) till mid-April but subsequently it was around 10 cm in mid-April to mid-May. *Sali* rice was transplanted at a water level of 13 cm and it was maintained till the establishment of seedlings. Maximum water level of 51 cm was recorded on 15th August. Drainage was provided by natural gradient to contain the water level below the canopy of rice plant. *Sali* rice was harvested at a water level of 24 cm at the end of November. The amount of water harvested was 2080 m^3. Boro rice was transplanted after one-month with a residual standing water of 16 cm **(Fig. 2)** with the volume of harvested water as 1780.5 m^3. Mean rice grain yield of 3.96 t/ha was recorded with the fine grain variety Joymati or Ranjit in *Sali* season during the period from 2002-03 to 2004-05 **(Table 1)**. But higher yield of 4.37 t/ha was recorded in *Boro* season. Higher yield during *Boro* season might be due to longer duration and more sunshine hours available in this season (Singh *et al.*, 2003). A sum total of 8.33 t/ha of rice grain was harvested under rice-rice cropping sequence. Compared to this, yields from farmers practice of sole rice cropping in *Sali* season using high yielding variety varied from 3 to 4 t/ha.

Bund and water harvesting

A short season water deficit is common after flood. In the flood year 2004, deficit rainfall was received in August (90 mm) and September (72 mm). Harvested water under integrated rice-fish system was useful in meeting the water requirement. Bund height of 45 cm was also useful in this regard **(Table 2)**. But lower bund height of 15 cm required irrigation water of 165 mm. Mishra (1999) reported that bund height of 22 to 26 cm was optimum for conserving sediment and nutrient and minimizing irrigation requirement for non-flooded situation in

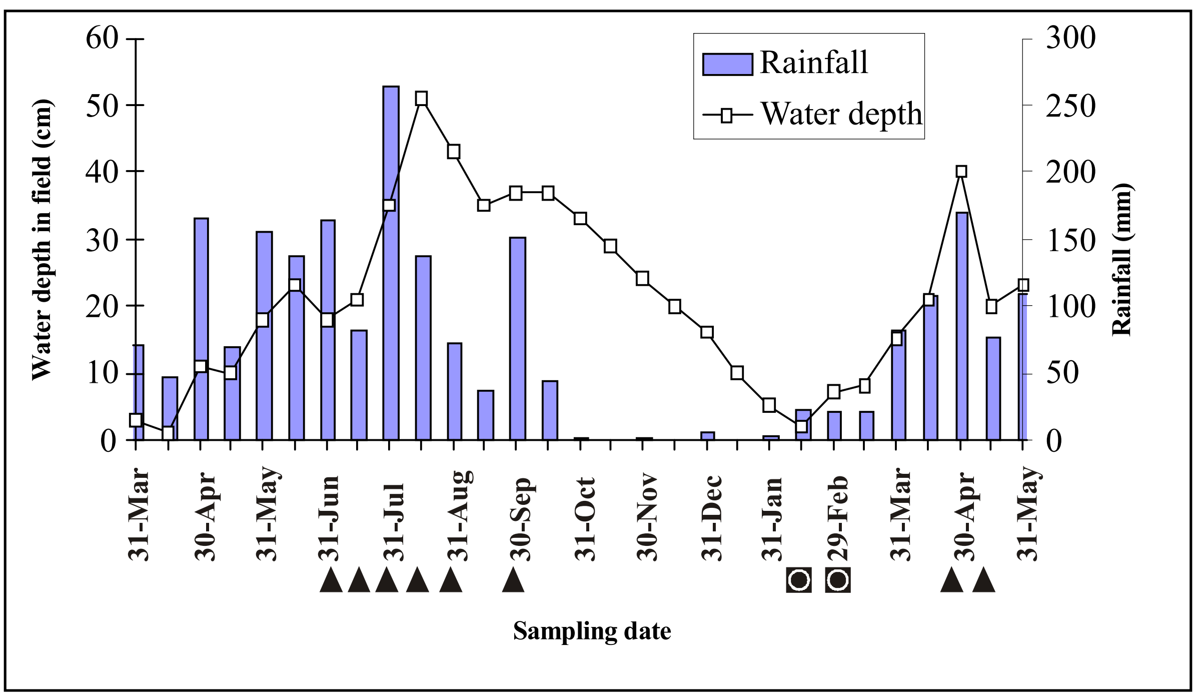

Fig. 1. Rain fall and water depth in the rice field of the rice-fish farm in 2002 (March)-03 (May) (▲ - water drained from field, ◙- irrigation given)

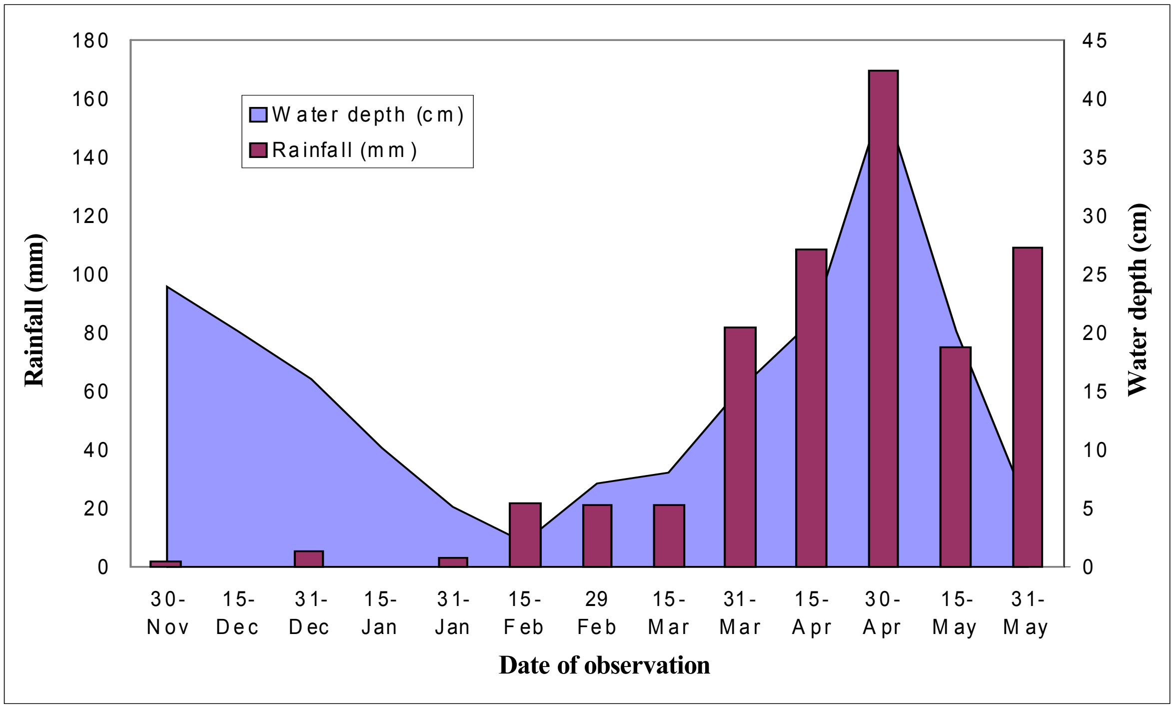

Fig. 2. Depth of water and rainfall in *Boro* 2002-03 (November - May) in rice-fish field

Table 1. Yield of rice (t/ha) in rice-fish farming system under rice-rice cropping sequence in bulk plot (2002-03 to 2004-05)

Year	2002-03		2003-04		2004-05		Mean	
Rice season	Grain yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)
Sali	3.70	4.85	2.94	3.52	5.25	7.10	3.96	5.16
Boro	5.47	7.56	2.89	3.34	4.73	5.62	4.37	5.51
Total	9.17	12.41	5.83	6.86	9.98	12.72	8.33	10.66

medium lands of Bhubaneswar. In *Boro* season, residual water was maintained in rice-fish system and rice seedlings were transplanted into the soft mud between the two rows of previous rice crop. For the bund heights of 15 to 45 cm, dry ploughing and puddling was done before rice transplanting. Irrigation water requirement was 1590 mm for this situation as compared to 272 mm under rice-fish system. Considering *Kharif* rice-*Boro* rice sequence, water harvesting could save irrigation water by 85% under integrated rice-fish system. Even for a deficit rainfall year like 2006, mean precipitation for the growing period (July to November) was 466 mm and it was 51% of the normal. Farmers could not puddle and transplant paddy. As a result, a large chunk of farmer's field remained fallow. In this situation, rice-fish system with a strong dyke (90 cm) all around could act as a water harvesting structure. Thus, promotion of large number of rice-fish systems may act as a series of miniature water harvesting structures for harvesting the costly plant nutrients, organic matter, soil and water. With these benefits, the system has potential in stabilizing crop productivity in fragile rainfed lowlands with uncertain weather conditions.

Table 2. Effect of bund height on saving irrigation water and grain yield during flood affected 2004 *Kharif* and 2004-05 *Boro*

Bund height (cm)	Irrigation water (mm)		Total (mm)	Grain yield (t/ha)		Total (t/ha)
	Kharif	*Boro*		*Kharif*	*Boro*	
15	165	1590	1755	5.42	4.85	10.27
30	70	1590	1660	5.30	4.91	10.21
45	0	1590	1590	5.26	4.80	10.06
Rice-fish (90)	0	272	272	5.25	4.78	10.03

Table 3. Performnce of short duration vegetable crops using harvested water

Crops	Yield (t/ha)	Gross returns (Rs.)	Gross expen-diture (Rs.)	Net returns (Rs.)
Spinach	2.30	13800	10618	3182
Amaranthus	2.41	14460	10618	3842
Coriander	0.85	17000	10918	6082
Potato	4.72	33040	30882	2158
Toria	0.47	15040	12500	2540
Radish	5.70	19950	15242	4708
Snap bean	2.00	20000	18982	1018
CD (P=0.05)	0.161	-	-	1487

*Price of green spinach or amaranthus Rs 6000/t, green coriander Rs 20000/t, potato Rs 7000/t, radish, Rs 3500/t, Snap bean pods Rs 10000/t, toria seed Rs 32000/t.

Table 4. Gross Income (Rs/ha) and rice equivalent yield (t/ha) from different components and, economics of integrated rice-fish system (2002-03 to 2006-07)

Year	Gross Income (Rs./ha)			
	Rice	Fish	Horticulture	Total
2002-03	48880	24000	1804	74684
2003-04	22752	25200	14996	62948
2004-05	39078	28320	25430	92828
2005-06	15582	31650	19398	66540
2006-07	14112	8040	25658	47810
Mean	28081	23424	17457	68962
%	41	34	25	100
Rice equivalent yield (t/ha)	4.68	3.90	2.92	11.5

Performance of short duration vegetable crops using harvested water

Short duration vegetable crops with low water requirement were attempted using the harvested water from the rice-fish farming system **(Table 3)**. Highest yield of 5.7 t/ha was obtained from radish, followed by potato (4.72 t/ha), amaranthus, spinach, and French bean. Highest net returns were accrued from green coriander followed by radish and amaranthus.

Economics of integrated rice-fish farming system

Gross income generated from different components of rice-fish integrated farming system during the period from 2002-03 to 2006-07 is presented in **Table 4**. The system as a whole generated Rs 47810 in deficit rainfall year 2006 to Rs 92828 in flash flood affected year 2004 with a mean of Rs 68962/ha. This is high compared to generation of Rs 12496/ha from traditional practice of growing high yielding rice variety in *Kharif* season. Rice accounted 41% of the income followed by fish (34%), and horticulture (25%). The mean rice equivalent yield for the period from 2002-03 to 2006-07 was 11.5 t/ha, which is higher than sole rice cropping 3 to 4 t/ha and double rice cropping 7 to 8 t/ha. Income is again expected to increase in the subsequent years from the produce of coconut, areca nut, and teak crops.

CONCLUSIONS

Promotion of large number of rice-fish systems may act as a series of miniature water and nutrient harvesting structures for harvesting the costly plant nutrients, organic matter, soil and water, which would otherwise be dumped into the sea. With the global warming and climate change, a more departure in frequency, intensity and amount of rainfall is expected and thus, utility of these miniature structures may assume greater importance in future, especially in tropical climatic regions.

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Performance of Wheat Based Intercropping as Influenced by Row Proportions under Rainfed Condition of Kaymore Plateau in Madhya Pradesh

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ABSTRACT

A field experiment was conducted on various wheat based intercropping system in different row proportions under rainfed condition of Kaymore plateau at Krishi Vigyan Kendra, Deendayal Research Institute, Majhagawan, Satna, Madhya Pradesh in *rabi* seasons 2005 and 2006. The intercropping of wheat was done with chickpea, linseed and mustard with row proportions of 2:2, 4:2 and 6:2.The intercropping of wheat with chickpea proved to be superior in terms of wheat equivalent yield and economics.

Key words: Wheat, chickpea, linseed, mustard, wheat equivalent yield, economics, intercropping and row proportion.

Wheat is a major staple food crop of India and is of paramount importance for food security of the country. The current production of wheat in India is approximately 74 million tonnes, out of which about 91 percent is produced in six states viz. Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan and Bihar (Mishra, 2007). The productivity of wheat in irrigated conditions is plateauing out due to problems related nutrient exhaustion, salinity build up and raising water table. Therefore, attempts are needed for increasing the productivity and production of rain fed wheat in the country in general and in the state of Madhya Pradesh in particular as this state has sufficient wheat area under rain fed conditions. Pulses and oilseeds are the main crops of rain fed area. Among pulses chickpea is grown on 2.56 million hectare with 925 Kg/ha productivity (Ali and Shiv Kumar, 2007). Among oilseeds, rapeseed and mustard has a great significance and contributed a lot in increasing the total oilseed production in the country during last two decades. Madhya Pradesh is a major oilseed producing state in the country.

The ways of increasing production are either expansion in area or improvement in productivity. In general, there is hardly any scope to bring additional area exclusively under pulses or oilseeds or even wheat as the demand of land for other crops will continue to rise. Thus there is only way to left is improvement in productivity of crops. Besides, other techniques, intercropping systems of growing two or more crops together on the same piece of land simultaneously may play an important role particularly under rain fed situation, where risk is more in mono cropping system. Hegde (2007) also suggested that there is considerable scope to bring large area under oilseed through intercropping system. Therefore, a study was carried out to assess the wheat productivity as well as economics with different oilseeds and pulses as inter crops.

MATERIALS AND METHODS

The field experiments were conducted on sandy loam soil at research farm of Krishi Vigyan Kendra Majhagawan, Satna, Madhya Pradesh in two consecutive *rabi* seasons (2005 to 2007). The location has subtropical climate characterized by hot dry summer and cool winter. The mean annual rainfall in the region varies from 600 mm to 850 mm. The treatments consisted 3 intercropping systems viz. wheat + chick pea, wheat + linseed, wheat + mustard and three row proportions of wheat+ intercrop 2:2, 4:2,6:2 plus one control of sole wheat. Three extra treatments of sole chickpea, sole mustard and sole linseed were also included for comparison. Thus the 10 treatments of wheat based intercropping were tried in randomized block design with 3 replications. The crop was sown on 19 November 2005 and 14 November 2006. The seed rate of intercrops was decided according to row proportions. Weeding was done to conserve soil moisture through dust mulch created by hand weeding after one month of sowing during both years. The recommended doses of fertilizers for each crop were given as band placement. The yields obtained in different intercrops were converted to wheat equivalent yield for statistical analysis to work out the variations on significance level amongst the treatments under study.

RESULTS AND DISCUSSION

Yield

Among intercropping, chickpea produced significantly highest and mustard produced lowest grain and straw yields of wheat **(Table1)**, these yields are attributed to yield attributes and growth characters of wheat which also behaved in a similar manner under different intercropping system. Chickpea being dwarf statured did not cause much competition for space and solar radiation, and being legume provided some of the symbiotic N for wheat utilization, which ultimately produced higher wheat yield than other intercroppings (Tomar *et al.*, 1997). Under row proportions lowest wheat yield recorded in 2:2 row ratio with mustard intercrop **(Table 1)**. The lower yield of wheat with linseed than chickpea intercropping might be due to allelopathic effect of chickpea. Reddy (2004) mentioned that allelopathic compounds can have important effects on other crop plants, when planted in association or mixtures. These results are in conformity with the findings of Tomar *et al.* (1997).

As regards row ratio of wheat + intercrops 6:2 row ratio produced significantly highest wheat yields, while 2:2 row ratio produced significantly lowest yields **(Table1)**.These yields are attributed directly to plant population of wheat under different row ratios and whereas under intercrops 2:2 wheat +chickpea produced maximum yield over other treatments **(Table 2)** it might be due to greater competition exerted by dominant mustard crop for light, space and nutrients. Greater canopy of mustard had shaded effect on wheat resulting in adverse effect on plant canopy (Srivastav and Bohra, 2006). Similar results have been reported by Sharma *et al.* (1987).

Table 1. Grain and straw yield of wheat (q/ha) under different treatments (Pooled data for 2 years)

Treatment	Number of grains/ spike	1000 grain weight (gm)	Grain yield (q/ha)	Straw yield (q/ha)
Intercropping	Pooled	Pooled	Pooled	Pooled
Wheat+chickpea	36.19	39.64	32.58	45.24
Wheat+linseed	33.64	40.91	28.36	40.05
Wheat+mustard	31.77	42.23	23.07	34.95
S.Ed.±	0.79	0.33	0.71	0.97
C.D.(P=0.05)	1.58	0.66	1.44	1.97
Row ratios				
2:2	34.11	40.97	21.89	33.76
4:2	33.9	41.08	29.19	41.8
6:2	33.59	40.73	32.93	44.69
S.Ed.±	0.79	0.33	0.71	0.97
C.D.(P=0.05)	NS	NS	1.44	1.97
Sole v/s intercropping				
Sole crop	32.96	41.61	39.94	50.95
Intercrop wheat	33.87	40.93	28	40.08
S.Ed.±	1.01	0.42	0.92	1.26
C.D.(P=0.05)	NS	NS	1.86	2.54

Wheat equivalent yield

Wheat equivalent yield was also computed significantly higher under the treatments of wheat+chickpea intercropping than sole wheat and other intercropping treatments **(Table 3)**. These are attributed to higher yield of both component crops because of better compatibility for resource utilization. These results confirm the findings of Singh *et al* (1992), Wheat equivalent yield increased with each wider row ratio in wheat, linseed or mustard intercropping but reduced in wheat + chickpea intercropping numerically. These findings are in collaboration with Mallik *et al.* (1993),

Table 2. Yield parameters of intercrops under different treatments (Pooled data for 2 years)

Yield parameter	Intercroping Rows proportion				S.Ed.±	C.D. (P=0.05)
	Sole crop	2:2	4:2	6:2		
			Chickpea			
No. of pods	22.67	26.22	27.1	26.94	0.82	1.79
Weight of 1000-seeds (g)	158.0	160.25	160.9	160.63	2.21	NS
Grain yield, q/ha	19.73	12.67	8.52	6.56	0.56	1.22
Straw yield, q/ha	27.26	17.1	11.38	8.83	0.65	1.41
			Linseed			
No. ofcapsule	28.27	31.13	30.39	29.94	0.83	1.8
Weight of 1000-seeds (g)	6.46	6.65	6.73	6.65	0.13	NS
Grain yield, q/ha	12.19	6.66	4.63	3.41	0.29	0.64
Straw yield, q/ha	19.71	10.3	7.08	5.28	0.45	0.97
			Mustard			
No. of siliquae	115.77	131.78	135.65	136.51	3.72	8.11
Weight of 1000-seeds (g)	4.41	4.49	4.52	4.51	0.06	NS
Grain yield, q/ha	14.11	10.54	7.11	5.39	0.32	0.69
Straw yield, q/ha	29.06	20.22	13.84	10.9	0.63	1.38

Table 3. Wheat equivalent yield (q/ha) and Land equivalent ratio under different treatments (Pooled data for 2 years)

Treatments	Wheat equivalent yield (q/ha)	Land equivalent ratio	Net income (000 Rs/ha)	B:C ratio
Sole wheat	39.94	1	36.882	3.45
Wheat + chickpea (2:2)	46.04	1.36	42.429	3.64
Wheat + linseed (2:2)	35.86	1.08	30.52	2.84
Wheat + mustard (2:2)	35.14	1.16	30.203	2.79
Wheat + chickpea (4:2)	44.61	1.27	41.232	3.59
Wheat + linseed (4:2)	39.83	1.12	35.687	3.31
Wheat + mustard (4:2)	37.04	1.11	33.119	3.06
Wheat + chickpea (6:2)	44.16	1.23	40.718	3.59
Wheat + linseed (6:2)	41.76	1.14	37.952	3.5
Wheat + mustard (6:2)	38.5	1.1	25.07	3.24
S.Ed.±	1.92	0.06	1.914	0.17
C.D.(P=0.05)	3.76	0.11	3.752	0.33
Sole intercrop				
Chickpea	27.62	1	19.146	1.71
Linseed	26.82	1	19.366	2.09
Mustard	25.4	1	19.589	2.15

Land equivalent ratio was recorded higher in intercropping treatments of wheat+chickpea as compared to other intercropping and sole cropping treatm ents **(Table3)**. All intercropping treatments attained higher values of LER than sole crops. Higher LER in intercropping system in general and in wheat + pulses in particular has also been reported by Singh *et al* (1992). Barik *et a.l* (2006) reported that land equivalent yield increased with each wider row ratio in wheat, linseed or mustard intercropping but reduced in wheat + chickpea and wheat +mustard intercropping numerically.

Economics

Net income was also computed significantly higher in the intercropping treatments of wheat +chickpea than all other treatments **(Table 3)**. These results may very well supported by the findings Singh *et al.* (1992.The intercropping treatment of wheat + chickpea being at par with wheat + linseed in 6:2 row ratio and with sole wheat, attained higher values of B:C ratios than all other treatments. These are attributed to higher net income in wheat + chickpea intercroppings and to combined effects of lower cost and higher income in case of wheat + linseed in 6:2 row ratio and sole wheat treatments. Findings of Singh *et al*. (1992) and Srivastav and Bohra (2006) are in agreement to the findings of the present investigation.

CONCLUSIONS

It could be concluded from the findings that the intercropping and row proportions of wheat + chickpea with 2:2 was found to be suitable for higher production, wheat equivalent yield and economics for rain-fed areas. The maximum yield of wheat was observed in wheat + chickpea whereas, maximum wheat equivalent yield, land equivalent ratio, net return and B: C ratio recorded under wheat + chickpea with 2:2 rows ratio.

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