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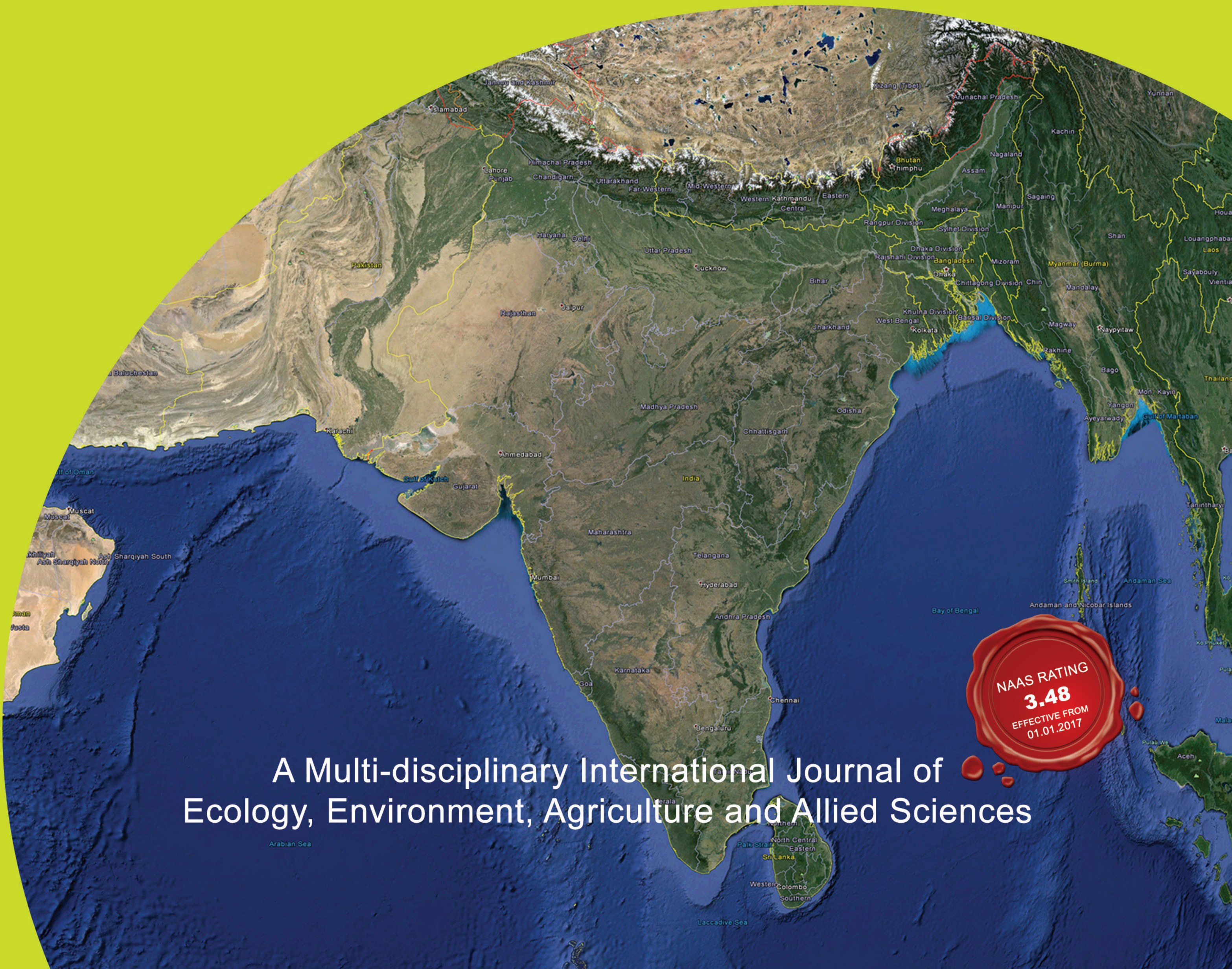

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Assessment of a sustainable rice based integrated farming system in rainfed conditions of Odisha

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ABSTRACT

The present investigation on economic viability and sustainability of crop-fish-poultry-mushroom integration against conventional farming in rainfed rice farms were carried out for three consecutive years from *kharif* 2010 to *rabi* 2013 at Khajuripada cluster villages of Kandhamal district, Dhenkanal Sadar and Odapada cluster villages of Dhenkanal district and Golamunda and Narla cluster villages of Kalahandi district of Odisha. The treatments of study consisted of two factors *viz.* sources of water i.e. P_0: without water harvesting structure (rainfed, no pond), P_1: with water harvesting structure (irrigated, with pond) and size of farm i.e. marginal: 0.8 ha, small: 1.6 ha. The treatments were in factorial randomized block design with five replications. The 1.6 ha integrated farming system (IFS) model gave rice equivalent yield (REY) of 44.93 t, net return of ₹ 2,27,521 and B: C of 1.83 as compared to REY of 6.70 t, net return of ₹ 15,235 and B:C of 1.26 in conventional rice-greengram cropping system. Sustainable yield and value index in 0.8 ha IFS model increased to 0.84 and 0.47 as compared to 0.10 and 0.03 in rice-greengram conventional pair cropping and in 1.6 ha IFS model increased to 0.82 and 0.44 over 0.13 and 0.03 in conventional cropping. The labour employment in both IFS models increased to 588 and 942 as compared to 204 and 400 in respective conventional rice farms. The land use efficiency had also increased over conventional system. Thus, this recommended model proved to be sustainable over the conventional practice in rainfed rice cropping situations of Odisha.

Key words : Land use efficiency, rainfed, rice equivalent yield, sustainable yield index

INTRODUCTION

Rice, the major crop of India, is cultivated in about 44 mha (Anon., 2019). Increasing production and productivity of rice is essential to feed the evergrowing population. However, considering its poor cost-benefit ratio and negative impact on the environment, alternatives options in rice farming need to be thought off (Theodore, 2004). Mamun et al. (2011) found that single crop production enterprises are vulnerable to high degree of risk and uncertainty due to seasonal, irregular and uncertain income and employment to the farmers. Jayanthi et al. (1997) in their studies also revealed that with a view to mitigate risks and uncertainties of income from crop enterprises and to reduce the time lag between investment and returns, it is essential that the farmers include such of those enterprises in their production programme that yield regularly and evenly distribute income throughout the year and are not subjected to vagaries of nature. Also, there is a need to produce more from these existing arable lands through proper management of basic agricultural resources such as soil, water and biological inputs (Saha et al., 2012).

Farming system is a complex inter-related set of elements containing crops, dairy, poultry, fish, sericulture, vermi-compost, sheep and goats etc. which interact among themselves. The judicious mix of the crops and animal enterprises must be based on the principle of minimizing the competition for resources and maximizing the complementarities of returns among the enterprises (Sachinkumar et al., 2012).

Babalad and Hundekar (1999) in their studies opined integrated farming system (IFS) model is not only the need of the time but also better alternative for optimization of resources available with small farmers. It is assumed to be the best possible solution to the continuous increase in demand for food production, stability of income and improvement of nutrition (Korikanthimath and Manjunath, 2009).

The practice of farming system varies from place to place depending on the agro-climatic condition, suitability of enterprise to the location, availability of inputs and marketing facilities (Chinnusamy, 1994; Veerabhadran, 1994; Basavaraja, 1999). Hence, IFS should include livestock, poultry, fishery, duckery, mushroom production, apiculture and sericulture along with crop components through which total biomass production per unit area can be increased. Backyard poultry and vermicomposting can be added to IFS to increase farm income and strengthen livelihoods of farmers (Nath and Barik, 2010). The farming system approach of land use through integration of agri-horti crops, fishery and livestock has been found most suitable for livelihood security (Rathore and Bhatt, 2008). Diversification of enterprises and especially inclusion of vegetables, livestock and other activities in the farming system not only helps to increase farm income but also generates employment (Sachinkumar et al., 2012). Integrated farming system provides an opportunity to increase the economic yield per unit area per unit time due to intensification and diversification of cropping and integration of allied enterprises, and thereby efficient use of resources (Singh et al*.,* 2007). Under the above circumstances, this research study was undertaken to find out a suitable rice based IFS model for the small and marginal farmers against their conventional rice-greengram cropping system which is economically viable and remains sustainable over the years.

MATERIALS AND METHODS

Field experiments were carried out for three consecutive years from *kharif* 2010 to *rabi* 2013 in five clusters of villages belonging to Kandhamal, Dhenkanal and Kalahandi district of Odisha. The experiments were conducted at Khajuripada cluster of Kandhamal district, Dhenkanal Sadar and Odapada cluster of Dhenkanal district and Golamunda and Narla cluster of Kalahandi district. Khajuripada is situated at 84°24' E Longitude, 20°26' N Latitude and 476 m above mean sea level (msl), Dhenkanal Sadar is situated at 85° 38' E Longitude, 20°40' N Latitude and 56 m amsl, Odapada is situated at 85° 26' E Longitude, 20° 45' N Latitude and 56 m amsl, Golamunda situated at 83° 01' E Longitude, 19° 49' N Latitude and 254 m amsl and Narla is situated at 83°22' E Longitude, 20° 03' N Latitude and 254 m amsl. The soils of Khajuripada were well-drained, light textured with sandy clay loam texture and mostly acidic in reaction. In Dhenkanal Sadar and Odapada, soils were clay loam in texture with slightly acidic to slightly alkaline soil reaction. The soils of Golamunda and Narla were heavy textured with textural class of clay and slightly acidic to slightly alkaline in reaction. The normal annual rainfall of Kandhamal, Dhenkanal and Kalahandi districts are 1427.9 mm, 1428.8 mm and 1330.5 mm respectively. Of the total annual rainfall 1102.9 (77 %), 1109.0 mm (78%) and 1128.1 mm (85%) are received during rainy season (June to September).

The investigation was carried out with marginal and small land holding of 0.8 (S_1) and 1.6 ha (S_2) size, two sources of water i.e. no pond or rainfed (P_0) and pond or irrigated (P_1) and five replications(clusters) located in five different blocks, *viz.* Khajuripada (Kpd) of Kandhamal district (North Eastern Ghat Zone), Dhenkanal Sadar (Dsr) and Odapada (Opd) of Dhenkanal district (Mid Central Table Land Zone), Golamunda (Gld) and Narla (Nrl) of Kalahandi district (Western Undulating Zone) of Odisha with rainfed medium land situations. The experiment aimed at comparing performance of pond based IFS model comprising rice-onion sequence cropping system, pisciculture and on dyke plantation, poultry and mushroom with rainfed rice.

In all the IFS models, high yielding rice cv. '*Lalat*' was taken during *kharif* season and onion cv. 'N - 53' during *rabi* in all the years i.e. 2010-11, 2011-12 and 2012-13. Under rainfed condition without pond, rice (cv. *Lalat*) - greengram (cv. Local) cropping system was followed except Khajuripada cluster where rice- fallow system was followed. In IFS 0.8 ha models, cropping area was 7110 m^2 where as in control (no pond) the cropping area was 8,000 m^2. But in 1.6 ha IFS models, the cropping area was 14310 m^2 where as in control (no pond) the cropping area was 1.6 ha.

The components were selected basing on the popularity and suitability to rain-fed rice lands in Odisha. Pond was excavated to provide assured irrigation to rice crop in *kharif* season during dry spell as well as to take up a second profitable crop of onion during *rabi* season after the harvest of rice crop along with composite fish farming. Pond dyke was used for planting of papaya, banana and drumstick. Selection of profitable rice based cropping system and further their linkage with allied enterprises like fish, poultry and mushroom cultivation using the available by-products or wastes from cropping was envisaged.

From each block, two villages were selected randomly. The farmers were selected through the process of stratified random sampling. The farmers in each village were first grouped into small and marginal on the basis of size of land holdings and twenty farmers per cluster were selected from which 10 were marginal and 10 were small farmers. Thus, the total sample consisted of 100 farmers. All the sample farmers were interviewed with a structured questionnaire to get the necessary information. The data were collected from the farmers through the personal interviews. Data on different indicators *viz.* bio-physical indicators, economic indicators and land use indicators were collected. Economics of the farming was calculated and total information on labour use was recorded. Different statistical tools were used as per their suitability for better interpretation. The following computations were done to evaluate the sustainability of the proposed models.

Rice grain equivalent yield

Rice grain equivalent yield was worked out by converting the economic yield of onion and green gram on basis of marketable price ratio for each crop and rice and expressed in t ha^{-1}.

Rice grain equivalent yield (t ha^{-1}) =

$$\frac{\text{Productivity of component (t)} \times \text{Price of component (₹/t)}}{\text{Price of rice (₹/t)}}$$

Land use efficiency

Land use efficiency (LUE) computed by using formula (Usadadiya and Patel, 2013), expressed as %.

$$\text{LUE} = \frac{\text{Total duration of crops in individual crop sequence (Rice-onion or rice-green gram or rice-fallow)}}{365} \times 100$$

Sustainable yield index

The sustainable yield index (SYI) was computed by using the formula (Vittal et al*.,* 2002)

$$\text{SYI} = \frac{Y_{mean} - \sigma}{Y_{max}}$$

Y_{mean} = mean yield, σ = Standard deviation

Y_{max} = maximum yield from all treatment

Sustainable value index

Sustainable value index (SVI) was calculated like SYI in terms of monetary value.

$$\text{SVI} = \frac{Y_{mean} - \sigma}{Y_{max}}$$

Y_{mean} = mean net return, σ = Standard deviation

Y_{max} = maximum net return from all treatments

RESULTS AND DISCUSSION

Rice crop was taken up in all the twenty units. In five marginal rainfed units rice was taken up in 0.8 ha of land, whereas in five small rainfed units rice was taken up in 1.6 ha of land. In case of marginal IFS units, the rice crop was taken up in an area of 0.711 ha and in small IFS unit, the crop was grown in 1.431 ha.

Table 1. Rice equivalent yield (t ha^{-1}) from conventional rice- greengram cropping system

Size of farm (ha)	Kpd	Dsr	Opd	Gmd	Nrl	Mean
2010-11						
0.8	2.52	4.2	4.12	4.07	4.37	3.86
1.6	4.45	7.86	7.38	7.06	7.49	6.85
2011-12						
0.8	2.44	3.97	3.74	3.85	4.24	3.65
1.6	4.30	7.55	6.68	6.63	6.96	6.42
2012-13						
0.8	2.54	4.27	4.01	3.93	4.42	3.83
1.6	4.36	8.09	7.35	6.86	7.51	6.83
Pooled						
0.8	2.50	4.15	3.96	3.95	4.34	3.78
1.6	4.37	7.83	7.14	6.85	7.32	6.70

The conventional rice-greengram cropping system was followed in four out of five cluster villages. It was observed from the above table that the highest rice equivalent yield (REY) was recorded 4.34 t ha^{-1} (Narla), whereas the lowest was 2.50 t ha^{-1} (Khajuriapada) in 0.8 ha marginal farming category. Among the 1.6 ha category, the highest REY was obtained 7.83 t $ha^{-1}$and the lowest was 4.37 t ha^{-1}. In both the cases Khajuriapada remained at the lowest REY because rice-fallow cropping system was followed in those cluster villages. Rice-pulses (greengram) gave more REY, increased cropping intensity and also affected other factors. Table 2 indicates that the factors related to sustainability of farming is better in both the cases of small and marginal category in case of the recommended IFS model than the conventional practice. In economical terms, the BC ratio increased from 1.38 to 1.83 in 0.8 ha farm and in 1.6 ha it increased from 1.26 to 1.83. In 1.6 ha category of farms, the mean cost of cultivation in all clusters, increased from ₹ 59194 to ₹ 27400 but the gross return increased to ₹ 501523 from ₹ 74429.

Labour requirement for IFS model crop - pisciculture - mushroom - poultry enterprises remained more or less same over years. Among the clusters, labour requirement varied from 585 in Khajuripada and Narla to 594 in Odapada in 0.8 ha IFS model and 927 in Khajuripada to 948 in Narla in 1.6 ha IFS models (Table 2). The IFS model with 0.8 ha size required a total labour of 588 human days per annum constituting 54.4, 24.0, 11.7 and 9.9 per cent in crop, mushroom, fish and poultry, respectively. In case of 1.6 ha model, the total labour was 942 with share of 67.2, 15.0, 11.7 and 6.1 per cent for respective enterprises.

Table 2. Rice equivalent yield (t ha^{-1}), economics and labour employment (man days) in IFS models

Particulars	Khajuripada	Dhenkanal Sadar	Odapada	Golamunda	Narla	Mean
IFS models- 0.8 ha						
Rice equivalent yield	28.60	33.37	32.12	32.29	33.23	31.92
Cost of cultivation(₹)	194668	194879	195698	195211	194786	195048
Gross return(₹)	319188	372468	358455	360239	370630	356196
Net return(₹)	124520	177589	162757	165028	175844	161148
B: C	1.64	1.91	1.83	1.85	1.90	1.83
Labour employment	585	587	594	590	585	588
Conventional cropping system- 0.8 ha						
Rice equivalent yield	2.50	4.15	3.96	3.95	4.34	3.78
Cost of cultivation(₹)	22128	32790	32512	31955	32218	30321
Gross return(₹)	27754	46046	43881	43847	48231	41952
Net return(₹)	5626	13256	11369	11891	16013	11631
B: C	1.25	1.40	1.35	1.37	1.50	1.38
Labour employment	146	209	206	201	203	204
IFS models- 1.6 ha						
Rice equivalent yield	39.75	46.68	45.17	45.58	47.45	44.93
Cost of cultivation(₹)	272409	274586	274191	275018	273798	274000
Gross return(₹)	443705	521340	504494	508692	529381	501523
Net return(₹)	171295	246754	230303	233674	255583	227521
B: C	1.63	1.90	1.84	1.85	1.93	1.83
Labour employment	927	942	946	952	948	942
Conventional cropping system- 1.6 ha						
Rice equivalent yield	4.37	7.83	7.14	6.85	7.32	6.70
Cost of cultivation(₹)	43243	63924	63748	62227	62827	59194
Gross return(₹)	48481	87112	79227	75971	81354	74429
Net return(₹)	5238	23188	15478	13743	18527	15235
B: C	1.12	1.36	1.24	1.22	1.29	1.26
Labour employment	283	412	406	389	400	400

During all the years of experimentation, LUE was not influenced significantly by sizes of farm and clusters. Both 0.8 and 1.6 ha farm gave nearly equal LUE. The mean LUE varied from the lowest of 56.52 % in Khajuripada to the highest of 65.63% in Odapada cluster .Sources of water influences LUE significantly. Creation of pond increased LUE significantly compared to no pond. In absence of pond, the LUE was 51.48, 51.45 and 51.35 per cent during 2010-11, 2011-12 and 2012-13, respectively with mean of 51.43 %. Construction of pond enhanced LUE to 75.58, 75.44 and 75.73 per cent, respectively with mean of 75.66 %. Averaged over years, the construction of pond enhanced LUE by 47.11%.

Table 3. Land use efficiency (%) of different IFS during 2010-11 to 2012-13

Treatments	Kpd	Dsr	Opd	Gmd	Nrl	Mean
2010-11						
0.8 ha	55.92	64.67	66.10	65.04	65.83	63.51
1.6 ha	56.56	64.88	65.54	64.99	65.79	63.55
Mean	56.24	64.78	65.82	65.01	65.81	63.53
S R	NS NS					
No pond	36.40	54.54	55.77	55.22	55.49	51.48
Pond	76.08	75.02	75.87	74.81	76.12	75.58
SE(m)± for P 1.59 CD (P=0.05) for P 4.91			P × S NS			
2011-12						
0.8 ha	56.46	64.71	65.39	65.38	65.53	63.49
1.6 ha	56.69	64.42	65.09	65.33	65.49	63.40
Mean	56.57	64.56	65.24	65.35	65.51	63.45
S R	NS NS					
No pond	37.13	54.25	55.48	55.34	55.07	51.45
Pond	76.02	74.87	75.00	75.37	75.95	75.44
SE(m)± for P 1.53 CD (P=0.05) for P 4.70			P × S NS			
2012-13						
0.8 ha	56.69	64.48	65.47	65.91	65.45	63.60
1.6 ha	56.80	64.19	65.03	65.86	65.53	63.48
Mean	56.74	64.33	65.25	65.88	65.49	63.54
S R	NS NS					
No pond	36.68	53.85	55.50	55.49	55.22	51.35
Pond	76.81	74.81	75.00	76.28	75.76	75.73
SE(m)± for P 1.61 CD (P=0.05) for P 4.97			P × S NS			
Pooled for 3 years						
0.8 ha	56.36	64.62	65.89	65.44	65.60	63.58
1.6 ha	56.68	64.50	65.37	65.40	65.60	63.51
Mean	56.52	64.56	65.63	65.42	65.60	63.55
S R	NS NS					
No pond	36.74	54.22	55.58	55.35	55.26	51.43
Pond	76.30	74.90	75.67	75.49	75.94	75.66
SE(m)± for P 0.91 CD (P=0.05) for P 2.61			P × S NS			

The productivity of the farming system in absence of on-farm water harvesting pond was very unsustainable as indicated by SYI values ranging from 0.07 in Khajuripada 0.12 in Narla cluster with 0.8 ha model and 0.08 in Khajuripada to 0.15 in Dhenkanal Sadar cluster in 1.6 ha model (Table 4). The trend was more or less similar for SVI values also. The construction of on-farm water harvesting pond enhanced both SYI and SVI values. The SYI values increased to 0.75 in Khajuripada and 0.88 in Narla cluster in 0.8 ha IFS model and 0.73 in Khajuripada to 0.87 in Narla cluster with 1.6 ha IFS model. Similarly, the SVI values increased from 0.03 to 0.47 in 0.8 ha model and 0.03 to 0.44 in 1.6 ha IFS model.

Table 4. Sustainable yield index (SYI) and Sustainable value index (SVI) of different models

Clusters	Sustainable yield index		Sustainable value index	
	No pond	Pond	No pond	Pond
0.8 ha IFS model				
Kpd	0.07	0.75	0.01	0.34
Dsr	0.11	0.88	0.04	0.52
Opd	0.11	0.84	0.03	0.47
Gmd	0.11	0.85	0.04	0.48
Nrl	0.12	0.88	0.05	0.52
Mean	0.10	0.84	0.03	0.47
1.6 ha IFS model				
Kpd	0.08	0.73	0.01	0.31
Dsr	0.15	0.85	0.04	0.48
Opd	0.13	0.82	0.02	0.44
Gmd	0.13	0.83	0.03	0.46
Nrl	0.14	0.87	0.03	0.52
Mean	0.13	0.82	0.03	0.44

SYI and SVI values were lower in rainfed systems as compared to pond based systems. In rainfed systems, the SYI values varied from 0.07 to 0.12 in 0.8 ha and 0.08 to 0.15 in 1.6 ha model (Table 4). The SYI values in 0.8 ha pond based model varied from 0.75 to 0.88 and 0.73 to 0.87 in 1.6 ha pond based model. Solaiappan et al. (2007) reported higher sustainability index for combination of enterprises compared to cropping alone for net returns. The SVI values varied from 0.01 to 0.05 in 0.8 ha rainfed farm and 0.01 to 0.04 in 1.6 ha rainfed farm. The SVI values in 0.8 ha pond based model varied from 0.34 to 0.52 and in 1.6 ha model from 0.31 to 0.52. Thus, on-farm water harvesting pond converted unsustainable rainfed farm to sustainable IFS model. In aberrant weather years, pond provided life saving irrigation during the period of partial dry spell and helped in growing of the second crop of onion during *rabi* and ancillary enterprises throughout the year. This study corroborates the findings of Nath et al. (2016).

The study indicates that instead of traditional cropping practices, adoption of water harvesting based IFS by the resource-poor farmers could be of immense helpful in creating jobs and enhancing farm income if easy credit arrangement can be made. It would also help to conserve soil erosion and ground water recharge through deep percolation by reducing runoff during heavy shower.

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Comparative study of yield gaps and economics in soybean (*Glycine max* L.) through frontline demonstrations in Dhar district, Madhya Pradesh

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ABSTRACT

A study was carried out to analyze the yield gaps and economics in soybean (*Glycine max* L.) through frontline demonstrations by Krishi Vigyan Kendra Dhar, Madhya Pradesh at tribal farmers' fields of Dhar district. The highest yield (1876 kg ha^{-1}) of soybean was recorded in recommended practice whereas the minimum yield (1340 kg ha^{-1}) was recorded in farmers' practice under rainfed conditions during the year 2018-19. An increase of 43.2% in yield with demonstration over farmer's practice was recorded. The technological gap (324 kg ha^{-1}), extension gap (536 kg ha^{-1}) and technological index (17.72%) were recorded under frontline demonstrations. The maximum gross monetary return (₹ 56280 ha^{-1}) was recorded in recommended practice, while the minimum gross monetary return (₹ 40200 ha^{-1}) was observed in farmer's practice. Moreover, the maximum net monetary returns (₹ 28780 ha^{-1}) was recorded in recommended practice and the minimum net monetary returns was observed in farmers' practice (₹ 13950 ha^{-1}) while the highest B:C ratio (2.04) was also found in recommended practice as compared to farmers' existing practice (1.53).

Key words: Economics, extension gap, technology index, technology transfer, yield

INTRODUCTION

Soybean [*Glycine max* (L.) Merill] is one of the important rainfed leguminous oilseed crops of central India particularly in Madhya Pradesh (FAO, 1982; Singh et al., 2014; Nainwal et al., 2019). Soybean ranks first amongst oilseed crops in India as well as in the world. It is also widely grown in Maharashtra and Rajasthan as a sole or intercrop with pigeon pea, maize and cotton (Singh et al., 2014; Singh, 2018). In India, it is cultivated on an area of about 10.96 million hectares, which is likely to produce more than 13.46 million tonnes with productivity 1228 kg ha^{-1} during the year 2018-19 (Anon., 2019). Madhya Pradesh (5.24 m hectare), Maharashtra (3.93 m hectare) and Rajasthan (0.93 m hectare) constitute the major niche for the cultivation of soybean crop. Soybean, a major legume crop known as 'miracle bean', is rich in protein (40%) and moderate in oil (18-22%). It is popular because of its wider adaptability for soil, climate and food composition value (FAO, 1982; Sharma et al., 2016). Madhya Pradesh is known as "Soya State of India". It has the potential to bridge the gap between the supply and demand of edible oil and protein. The crop has shown enormous growth in area and production in India during recent past and has come out as one of the noteworthy *kharif* crop in Central India (Sharma and Sharma, 2004; Sharma et al., 2016).

Soybean is a major *kharif* oilseed crop for income generation and livelihood of tribal farmers in Dhar district of Madhya Pradesh. Majority of soybean area *i.e.* 2.90 lakh hectares which is about 75% of the total cultivable area of Dhar district mostly grown under rainfed conditions but due to non-availability of quality seed of improved varieties and poor adoption of scientific cultivation practices in the district, productivity (1230 kg ha^{-1}) of soybean is far below the potential yield (2000 kg ha^{-1}). To boost the production and productivity of soybean with implementation of latest and specific technologies in tribal areas of the state, Krishi Vigyan Kendra, Dhar has promoted and extended improved technologies with quality seed, balance use of fertilizers, nutrient management, integrated pest management, land configuration along with capacity building of tribal farmers.

MATERIALS AND METHODS

A study was carried out in *kharif* during 2018-19 by the KVK Dhar of Madhya Pradesh. The demonstrations were conducted in farmers' fields of six different tribal villages of Nalcha and Sardarpur blocks of Dhar district. Farmers were trained to follow the package and practices for soybean cultivation as recommended by the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh. Need based critical inputs and technical support were provided to the beneficiaries by KVK (Table 2). In case of local check, the traditional practices were kept by using existing variety (JS 335). An area of 10 hectares was covered with plot size 0.4 ha under frontline demonstration with active participation of 25 farmers during 2018-19. High yielding improved variety RVS 2001-4 (duration 95-105 days) which has two to three bold seeds in a pod and resistant to yellow mosaic virus (YMV) depending on the environmental condition were grown with recommended practice. Before conducting trials, a baseline survey was conducted to know the basic needs of farmers and a list of farmers was prepared through group meeting and interface. As per the needs, specific skill training was imparted to the targeted farmers.

Table 1. Comparison of practices between demonstration and local control (farmers' practice) in soybean

Particulars	Demonstration	Farmers' Practice
Farming situation	Rainfed	Rainfed
Variety	RVS 2001-4	JS-335
Time of sowing	17 June to 05 July	17 June to 05 July
Method of sowing	Line sowing	Line sowing
Seed rate	80 kg ha^{-1}	120 kg ha^{-1}
Fertilizer as per STV	NPK 25:60:40:20 kg ha^{-1}	NPK 18:46:00 kg ha^{-1}
Seed treatment and inoculation	With Carboxin 17.5 + Thiram 17.5 @ 2.5 ml kg^{-1} of seed and inoculation with Rhizobium and PSB @ 5 g kg^{-1} of seed	Nil
Weed management	Post-emergence herbicide (Imazethapyr 10% SL)	Hand weeding
Plant protection	Need based application of insecticide (Betacyfluthrin + Imidacloprid, Thiacloprid)	Profenofos + cypermethrin
Time of harvesting	02-08 October	02-10 October

Table 2. Critical inputs and technological packages distributed under front line demonstrations of soybean in 2018-19

No. of demonstrations	Variety	Technology demonstrated	Need based input distributed
25	RVS 2001-4	Improved variety, seed treatment, inoculation, NM, WM and IPM	Improved seed (80 kg ha^{-1}), soil testing, seed treatment with Carboxin 17.5 + Thiram 17.5 @ 2.5 mL kg^{-1} of seed and inoculation with Rhizobium and PSB @ 5 g kg^{-1} of seed, Imazethapyr 10 % SL @ 1 L ha^{-1}, Betacyfluthrin + Imidacloprid for white fly and caterpillar, Thiacloprid for girdle beetle, on and off campus trainings, field day and exposure visits

Frequent visits to farmers' fields with the extension functionaries was arranged at demonstration plots to disseminate the message at large scale. The beneficiaries were timely facilitated by KVK scientists to perform field operations during the course of training and visits. The traditional practices were carried out as farmers used to do earlier. The yield obtained from demonstrations and potential yield of the crop was compared to estimate the yield gaps which were further categorized into technology index and technology gap. The data were recorded from both FLD plots as well as control plots. Finally, the extension gap, technology gap, technology index along with the benefit cost ratio were worked out with the help of formula as given by Samui et al. (2000) as described below:

$$\text{Technology gap} = \text{Potential yield} - \text{Demonstration yield}$$

$$\text{Extension gap} = \text{Demonstration yield} - \text{Farmer's yield}$$

$$\text{Technology index (\%)} = \frac{\text{Potential yield} - \text{Demonstration yield}}{\text{Potential yield}} \times 100$$

RESULTS AND DISCUSSION

Results pertaining to the demonstrations indicated that the improved cultivation practices comprised with the use of improved variety (RVS 2001-4), line sowing, balanced application of fertilizers and control of pest at economic threshold level following integrated pest management practices increased the yield and profitability. The maximum number of branches (4.8) and pods per plant (56) were recorded in demonstrations as compared to farmers' practice (branches 3.25) and pods (44) during the study, respectively (Table 5). Yield parameters enhanced with inclusion of improved package of practices under demonstrations over existing farmers practice as shown in Table 3. Results revealed that performance of soybean productivity was comparatively much higher in the demonstrated plots than the farmers' practice. The demonstration plot with high yielding variety recorded an average yield of 1876 kg ha^{-1} whereas plots with local variety produced average yield of 1310 kg ha^{-1}. The demonstration plots registered 43.2% more yield over local practices. Similarly, yield enhancement in different crops in front line demonstrations were documented by Singh et al. (2019) and Yadav et al. (2020). The results clearly indicated the positive effects of FLDs over the existing practices toward enhancing the productivity of soybean (Table 3).

Table 3. Productivity, technology gap, extension gap and technology index under recommended and farmer practices

Variety	No. of demonstrations	Seed yield (kg ha^{-1})			% increase over control	Technology gap (kg ha^{-1})	Extension gap (kg ha^{-1})	Technical index (%)
		Potential	FLD	FP				FLD
RVS 2001-4	25	2200	1876	1340	43.20	324	536	14.72

Table 4. Comparative study of economics of demonstrations and farmer practices

Village covered	Block	No. of farmers	Area (ha)	Cost of cultivation (₹ ha^{-1})		Gross monetary return (₹ ha^{-1})		Net return (₹)		B:C ratio	
				Demo.	FP	Demo.	FP	Demo.	FP	Demo.	FP
Sodpur, Ruparel, Undeli, Bodgaon, Moregaon, Hatod	Nalcha and Sardarpur	25	10	27500	26250	56280	40200	28780	13950	2.04	1.53

* Rate of soybean in the Mandi of Dhar was ₹ 3000 per quintal during 2018-19

Table 5. Yield attributing characters of soybean in 2018-19

Yield attributing characters					
Pods per plant		Branches per plant		Seed weight (100 seed)	
Demonstration	FP	Demonstration	FP	Demonstration	FP
56	44	4.8	3.25	11.90	10.60

The extension gap was also recorded in an increasing trend. The extension gap 536 kg ha^{-1} of study also emphasizes that there is need to educate the farmers through various means for adoption of improved practices to reverse the trend of wide extension gap. The trend in technology gap (324 kg ha^{-1}) reflects the farmers' cooperation in carrying out such demonstrations with encouraging results in subsequent years. The performance study of the technology demonstrated was found to be better than the farmers' practice under the same environment (Nainwal et al., 2019; Singh et al., 2019). The farmers were trained and motivated by seeing the results in terms of productivity and income. They are now embracing the climate resilient soybean variety *i.e.* RVS 2001-4 by adopting good agricultural practices. The feasibility of technology is confirmed by the lower value of technology index. As such fluctuation in technology index (14.72 %) may be attributed to the dissimilarity in soil fertility status, weather conditions, non-availability of water and insect pest attack in the crop during the study period in certain region (Singh et al., 2014).

The maximum gross monetary returns (₹ 56280 ha^{-1}) was recorded in recommended practice while minimum gross monetary returns (₹ 40200 ha^{-1}) was recorded in farmers' practice. Moreover, the maximum net monetary returns (₹ 28780 ha^{-1}) was recorded in recommended practice while minimum net monetary returns was observed in farmers' practice (₹ 13950ha^{-1}). The highest B:C ratio (2.04) was noted in recommended practice as compared to farmers' existing practice (1.53). Hence, favourable benefit cost ratio proved the economic viability of the interventions and convinced the farmers on the utility of interventions. These results are in conformity with Saikia et al. (2018), Singh et al. (2019) and Yadav et al. (2020).

CONCLUSION

The technology gap can be reduced to a considerable extent by sowing of high yielding climate resilient soybean variety *viz.* RVS 2001-4 and adoption of scientific methods of cultivation to increase productivity of soybean. It can be achieved by imparting scientific knowledge to the tribal farmers, providing the quality seed material, timely availability of critical inputs and their proper utilization. Extension institutes like Krishi Vigyan Kendra in the district may play the lead role in providing proper technical support for welfare of the farming community through organizing different educational and extension activities and also may reduce the extension gap for better oilseed production and productivity in the district.

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Evaluation of some rice hybrids and high yielding varieties for their resistance to major insect pests and diseases in coastal plain of Odisha

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ABSTRACT

Biotic stress in the form of insect pest infestation and disease incidence is a major production constraint in rice contributing lower productivity and profitability. Though pesticide application continues to be the most preferred pest control strategy, its injudicious application has many undesirable effects on the human health and surrounding environment. Host plant resistance mechanism with the development of resistant and tolerant varieties against the targeted pests is gaining importance over the years to reduce the pest damage and minimize the load of harmful pesticides in the agro-ecosystem. Experiments carried out at the Regional Research and Technology Transfer Station, Ranital in 2018 and 2019 revealed that among the test hybrids and high yielding varieties of rice a significantly lower plant hopper and leaf hopper population was recorded in the hybrid BS 144 and the high yielding variety MTU-1010. The test hybrid BS 133 though had little higher population of plant and leaf hoppers, produced higher grain yield in comparison to other hybrids and varieties indicating the presence of some tolerance mechanism in this hybrid against the sucking pest complex of rice. The lowest sheath blight and BLB incidence was recorded in the variety MTU 1010, whereas among the hybrids, BS 144 and BS 133 had comparatively lower disease incidence. The hybrids Sahadri and Arize bold were found to be highly susceptible to the major insect pest and diseases of rice. The hybrids BS 144 and BS 133 and the high yielding variety MTU-1010 were found to have higher yield potential during the wet season at the coastal plain zone of Odisha and their yield performance may further increase if timely and need based plant protection measures will be adopted.

Key words : Disease resistance, HYV, pest resistance, rice varieties, screening

INTRODUCTION

Rice is the staple food of more than 50% of world's population and its sustainable production is critically essential for the global food security. Over 90 per cent of rice is grown in Asian countries with China and India being the major producing nations. Approximately 52% of the global production of rice is lost annually owing to the damage caused by biotic stress factors, of which 25% is attributed to the attack of insect pests (Yarasi et al., 2008). Similarly, around 10 to 30 per cent of the annual rice harvest is lost due to infection by many diseases (Skamnioti and Gurr, 2009). Nearly 300 species of insect pests attack the rice crop at different stages and among them 23 species cause notable damage (Pasalu and Katti, 2006) causing 30-35 % yield loss (Prakash et al., 2007). Insect pest infestation is accounting for 50 % damage in vegetative, 30 % in reproductive and 20 % in the ripening stage of rice (Gupta and

Raghuraman, 2003). There has been a changing pest scenario in the rice eco-system with the appearance of some new arthropod pests, attainment of major pest status by minor pests with higher incidence and damage potential, regular infestation of sporadic pests, development of insecticide resistance in major pests and appearance of insect biotypes to infest the resistant crop varieties. Though stem borer, gall midge and leaf folder are the major insect pest of rice, plant hoppers (brown plant hopper and white backed plant hopper) assumed serious significance in the recent years and cause widespread damage particularly to the wet season rice of coastal areas due to favourable ecological niche and injudicious use of chemical insecticides resulting in insecticide resistance and resurgence. Generally, the yield losses due to hoppers ranges from 10 to 90%, but if timely control measures are not taken up, there may be possibility of total crop loss within a very short period (Seni and Naik, 2017). A recent report from Directorate of Rice Research estimated that plant hoppers cause losses ranging from 1-2 million tons of rice annually in India. Besides, the direct damage through hopper burn, brown plant hopper (BPH) transmits viral diseases like grassy stunt, ragged stunt and wilted stunt (Bhanu et al., 2014) and therefore often considered as the most destructive insect pest of wet season rice.

The white backed plant hopper (WBPH), *Sogatella furcifera* (Horváth) (Homoptera: Delphacidae),which was earlier recognized as a minor pest of rice is emerging as a serious pest in many rice growing countries (Khan and Saxena, 1986) and the extent of yield losses ranges from 54.4 to 79.8 per cent in different rice varieties (Khan and Kushwaha, 1991). Though Green Leaf Hopper (GLH) is known for its ability to transmit rice tungro virus, its direct damage through plant sap sucking has been inconspicuous. However, in the recent years the direct damage of GLH trough sap sucking and honey dew secretion cause stunted plant growth and considerable yield loss of 15-20 % (Prakash and Rao, 1998) and the extent of damage is more serious in the susceptible varieties. The increased economic importance of these sucking insect pests of rice and less efficacy of conventional insecticide based management strategies necessitates the development of some resistance varieties by incorporating the natural resistance mechanisms in the crops. Similarly, diseases like BLB, sheath blight, brown spot, sheath rot and blast have been causing sizable yield loss in rice. Rice sheath blight, caused by the soil-borne fungal pathogen Rhizoctonia solani, is an economically important disease in rice and depending upon the severity of the disease, it may cause 25–100% yield losses (Yadav et al., 2018). Bacterial leaf blight (BLB) disease caused by *Xanthomonas oryzae pv. oryzae* Ish. is one of the serious diseases of rice worldwide and is particularly destructive in Asian countries with a yield loss potential of 30 per cent in India (Chahal, 2005).

Application of chemical pesticides is the most preferred plant protection strategy adopted by the farmers to reduce pest infestation. However, injudicious and excessive use of insecticides not only cause undesirable consequences in the agro-ecosystem but has serious adverse effect on human health. Further, indiscriminate application of pesticides leads to other undesirable consequences like resistance development, resurgence, residue deposits and environment pollution besides, most of these chemicals are expensive and there by increases the cost of production for the resource poor farmers. Host plant resistance has been increasingly recognized as one of the important components of integrated pest management as it largely minimizes the adverse impact of reckless use of pesticides. Among the three mechanisms of resistance *viz.* antixenosis, antibiosis and tolerance, the tolerance varieties have great future prospects as this mechanism does not exert any selection pressure on the pest and prevent the development of biotypes. Improving the yield potential of rice is through the introduction of hybrids is gaining prominence in many countries of the world. Hybrid rice is extensively commercialized in China where over 50% of the total land area for rice is planted to hybrids (Cheng et al., 2007). Other Asian countries like India, Philippines, Thailand, Vietnam, Indonesia, and Bangladesh have also commercialized hybrid rice (Virmani et al., 1996). Hybrid rice is a promising and sustainable technology for increasing rice production and productivity (IRRI, 1997). It has been proven practically that hybrid varieties could out-yield their inbred counterparts grown under similar conditions by 15–20% (Virmani, 1994). However, Research findings suggests that hybrid rice has been highly vulnerable to damage from a wide range of insect pests due to favourable crop phenology, higher nutrient requirement and absence of natural resistance mechanism. Therefore, a renewed focus has been initiated to develop rice hybrids with some resistance and tolerance mechanism against the biotic stresses. Keeping this in view, some medium duration high yielding varieties and hybrids (110 to 130 days) were evaluated for their productivity and resistance or tolerance to the sucking insect pest and major diseases.

MATERIALS AND METHODS

The experiments were carried out to evaluate some hybrids and high yielding varieties of rice for their yield and pest resistance during kharif seasons of the year 2018 and 2019 at the experimental plots of the Regional Research and Technology Transfer Station (RRTTS), Ranital, OUAT. The experimental plots were laid out in randomized block design with nine treatments (five hybrids and four high yielding varieties) and three replications. The seeds were sown in the nursery during the month of July (6th July, 2018 and 21st July, 2019) and the seedlings were transplanted in the experimental plots during 3rd August 2018 and 19th August 2019, respectively for both the years of investigation with a closer spacing of 15 × 10 cm to ensure higher population build up of plant hoppers and leaf hoppers. The fertilizer dose of 80 :40 : 40 kg N, P_2O_5, K_2O ha^{-1} and 120:60:60 NPK kg N, P_2O_5, K_2O ha^{-1} was applied for the HYV and hybrids, respectively with the application of nitrogen in three split doses. A boarder strip of susceptible variety Swarna with closer spacing and higher dose application of nitrogen fertilizer was maintained around the experimental plot to harbor more insect pests and disease inoculums. The crop in the experimental plot was maintained with recommended agronomic package of practices and standard intercultural operations without any plant protection measures. Observations on the population of plant hoppers (BPH and WBPH per hill), green leaf hoppers (GLH per hill) and the incidence of BLB and sheath blight were recorded at weekly interval from ten randomly selected hills from each plot starting from the appearance of insect pest and disease symptoms. Disease scoring was done by using the 0-9 rating scale recommended by the International Rice Research Institute (IRRI, 1988) and the recorded infection scores were then used for calculation of per cent disease index (PDI) as suggested by McKinny (1923).

$$PDI = \frac{\text{Sum of numerical rating} \times 100}{\text{Total no. of leaves observed} \times \text{Maximum disease grade in the score chart}}$$

The mean insect population and disease incidence were worked out by considering the cumulative pest data over the entire period of observation. The mean insect population per hill was subjected to logarithm transformation and percent disease incidence was subjected to angular transformation for statistical analysis. The plot wise grain yield (kg per plot) was recorded after the harvest of crop and the total yield was calculated by converting it into q ha^{-1} for further statistical analysis.

RESULTS AND DISCUSSION

Reaction of the test hybrids and HYVs to insect pests

The lowest plant hopper population (was recorded in the hybrid BS 144 (16.34 and 19.12 per hill, during 2018 and 2019, respectively with a mean hopper population of 17.73 per hill) which was found to be statistically superior to the rest of the varieties and hybrids (Table 1). Comparatively lower plant hopper population was also recorded in MTU 1010 (20.86 and 23.46 per hill during 2018 and 2019, respectively with a mean of 22.16 hoppers per hill), BS 133 (22.82 and 24.12 per hill during 2018 and 2019, respectively with a mean of 23.47 hoppers per hill), Gobinda (23.34 and 27.07 per hill during 2018 and 2019, respectively with a mean of 25.20 hoppers per hill), MTU 1001 (25.95 and 25.13 per hill 2018 and 2019, respectively with a mean of 25.54 hoppers per hill), Lalat (27.36 and

Table 1. Population of sucking insect pests in some HYVs and Hybrid of rice (*kharif* 2018 and 2019)

Treatments	Plant hopper* (BPH and WBPH) no. per hill			Green leaf hopper* no. per hill		
	2018	2019	Mean	2018	2019	Mean
T_1: Arize Bold	39.79 (1.6)	34.12 (1.53)	36.96 (1.57)	42.17 (1.62)	39.23 (1.59)	40.7 (1.61)
T_2: BS 144 (AZ 6453ST)	16.34 (1.21)	19.12 (1.28)	17.73 (1.25)	20.61 (1.31)	21.27 (1.32)	20.94 (1.32)
T_3: BS-133 (AZ-8433 DT)	22.82 (1.36)	24.12 (1.38)	23.47 (1.37)	30.82 (1.49)	26.67 (1.42)	28.75 (1.46)
T_4: Ajaya	30.22 (1.48)	30.04 (1.48)	30.13 (1.48)	32.13 (1.51)	33.72 (1.53)	32.93 (1.52)
T_5: KJ RTH-2 (Sahadri)	42.14 (1.62)	36.46 (1.56)	39.3 (1.59)	43.73 (1.64)	40.84 (1.61)	42.29 (1.63)
T_6: Lalat	27.36 (1.44)	24.55 (1.39)	25.96 (1.41)	30.08 (1.48)	28.06 (1.45)	29.07 (1.46)
T_7: MTU-1001	25.95 (1.41)	25.13 (1.4)	25.54 (1.41)	27.86 (1.44)	30.04 (1.48)	28.95 (1.46)
T_8: MTU-1010	20.86 (1.32)	23.46 (1.37)	22.16 (1.35)	23.84 (1.38)	25.89 (1.41)	24.87 (1.4)
T_9: Gobind	23.34 (1.37)	27.07 (1.43)	25.2 (1.4)	25.16 (1.4)	32.03 (1.5)	28.6 (1.46)
SEm (±)	0.028	0.027	0.02	0.028	0.023	0.017
CD (0.05)	0.09	0.08	0.06	0.08	0.07	0.05

*Values in the parentheses are log10 (x) transformed values

24.55 per hill during 2018 and 2019, respectively with a mean of 25.96 hoppers per hill) and all these treatments were statistically comparable with each other. However, a higher plant hopper population was observed in the hybrids Ajaya (30.22 and 30.04 per hill during both the years of investigation, respectively with a mean value of 30.13 plant hopper per hill), Arize Bold (39.79 and 34.12 per hill during 2018 and 2019, respectively with a mean hopper population of 36.96 per hill) and KJ RTH-2 (42.14 and 36.46 per hill during 2018 and 2019, respectively with a mean hopper population of 39.30 per hill).

A similar trend was observed in the GLH population among the test hybrids and varieties. The minimum GLH population was recorded in the hybrid BS 144 (20.61 and 21.27 per hill during 2018 and 2019, respectively with a mean value of 20.94 GLH per hill) which was considered to be superior to the rest of the varieties and hybrids. The high yielding variety MTU 1010 with an average 23.84 and 25.89 GLH per hill during 2018 and 2019, respectively with a mean value of 24.87 insects per hill was found to be the next best treatment. The other varieties and hybrids follow the order as Gobinda (28.60 mean GLH per hill), BS 133 (28.75 mean GLH per hill), MTU 1001 (28.95 mean GLH per hill), Lalat (29.07 mean GLH per hill). In contrast the higher GLH population was observed in the hybrids Ajaya (32.93 mean GLH per hill), Arize Bold (40.70 mean GLH per hill) and KJ RTH-2 (42.29 mean GLH per hill).

Table 2. Incidence level of Sheath blight and BLB in some HYVs and Hybrid of Rice and their yield performance

Treatments	Sheath Blight			Bacterial Leaf Blight			Yield (q ha^{-1})		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
T1: Arize Bold	15.1 (22.86)	21.24 (27.43)	18.17 (25.22)	12.48 (20.68)	22.27 (28.13)	17.38 (24.62)	35.13	42.82	38.98
T2: BS 144 (AZ 6453ST)	9.43 (17.88)	13.28 (21.36)	11.35 (19.68)	6.45 (14.71)	11.62 (19.89)	9.04 (17.49)	49.67	55.8	52.74
T3: BS-133 (AZ-8433 DT)	7.29 (15.66)	11.45 (19.77)	9.37 (17.82)	6.94 (15.22)	13.49 (21.52)	10.2 (18.61)	46.26	51.13	48.7
T4: Ajaya	14.66 (22.5)	18.86 (25.73)	16.76 (24.16)	12.13 (20.35)	20.71 (27.01)	16.41 (23.88)	38.93	43.85	41.39
T5: KJ RTH-2 (Sahadri)	15.69 (23.33)	21.87 (27.87)	18.78 (25.67)	13.07 (21.19)	23.4 (28.91)	18.24 (25.27)	33.17	41.28	37.23
T6: Lalat	6.28 (14.51)	10.3 (18.71)	8.29 (16.73)	8.76 (17.21)	15.87 (23.46)	12.32 (20.54)	42.84	48.83	45.84
T7: MTU-1001	7.86 (16.27)	10.84 (19.22)	9.35 (17.8)	8.04 (16.57)	15.06 (22.81)	11.55 (19.9)	42.07	47.23	44.65
T8: MTU-1010	4.74 (12.57)	7.34 (15.71)	6.04 (14.22)	5.32 (13.3)	8.16 (16.55)	6.73 (15.03)	47.74	54.73	51.24
T9: Gobind	11.08 (19.44)	15.42 (23.11)	13.25 (21.34)	10.63 (19.02)	18.08 (25.15)	14.36 (22.26)	39.73	41.03	40.38
SEm (±)	0.923	1.046	0.785	1.022	0.868	0.754	1.246	1.687	1.035
CD (0.05)	2.77	3.14	2.35	3.1	2.6	2.26	3.74	5.06	3.1

*Values in parentheses are Arc Sine transformed values

Reaction of the test hybrids and HYVs to diseases

All the hybrids and high yielding varieties exhibited a significant variation among themselves with respect to their reaction to sheath blight and bacterial leaf blight disease. The minimum sheath blight incidence in the variety MTU-1010 with only 4.74 and 7.34 PDI during 2018 and 2019, respectively (mean PDI of 6.04) indicated its high level of resistance to the disease. The varieties Lalat (6.28 and 10.30 PDI, respectively during 2018 and 2019 with a mean PDI of 8.29) and MTU-1001 (7.86 and 10.84 PDI, respectively during 2018 and 2019 with a mean PDI of 9.35) and the hybrid BS 133 (7.29 and 11.45 PDI, respectively during 2018 and 2019 with a mean PDI of 9.37) also offered a good level of resistance to sheath blight. The hybrid BS 144 and the HYV Gobind with a mean PDI of 11.35 and 13.25 respectively witnessed a moderate incidence of sheath blight. However, the hybrids Ajaya (mean PDI of 16.76), Arize Bold (mean PDI of 18.17) and KJ RTH-2 (mean PDI of 18.78) were found to be susceptible to sheath blight with comparatively a higher disease incidence.

Among the test hybrids and HYVs the lowest BLB incidence was observed in MTU 1010 (5.32 and 8.16 PDI during 2018 and 2019, respectively with lowest mean PDI of 6.73), which was statistically superior to rest of the treatments. A comparatively lower BLB incidence was also recorded in hybrid BS 144 (6.45 and 11.62 PDI during 2018 and 2019, respectively with mean PDI of 9.04), BS 133 (6.94 and 13.49 PDI during 2018 and 2019, respectively with mean PDI of 10.20) and the variety MTU-1001 (8.04 and 13.49 PDI during 2018 and 2019, respectively with mean PDI of 11.55) and all the treatments had statistically similar reaction to BLB. A moderate level of BLB incidence was observed in the variety Lalat (mean I of 12.32). However, the higher BLB incidence was recorded in Gobinda (14.36 mean PDI), Ajaya (16.41 mean PDI), Arize Bold (17.38 mean PDI) and KJ RTH-2 (18.24 mean PDI).

Yield performance of the hybrids and HYVs

Among the hybrids and HYVs evaluated fort their yield performance under the study, the maximum mean grain yield was recorded in the hybrid BS 144 (52.74 q ha^{-1}) closely followed by the variety MTU 1010 (51.24 q ha^{-1}) and both were found to be statistically comparable with respect to their yield performance. The hybrid BS 133 also had a comparatively good yield performance with a mean grain yield of 48.70 q ha^{-1} which was found to be statistically at par with the variety Lalat (mean yield of 45.84 q ha^{-1}). The high yielding variety MTU 1001 registered a moderate level of yield potential with a mean yield of 44.65 q ha^{-1}. However, Ajaya (mean yield of 41.39 q ha^{-1}), Gobind (mean yield of 40.38 q ha^{-1}), Arize Bold (mean yield of 38.98 q ha^{-1}) and KJRTH-2 (mean yield of 37.23 q ha^{-1}) were found to have comparatively lower yield potential. The varied yield performance of different hybrids and high yielding varieties may be due to their different level of resistance to biotic stresses and inherent yield potential. The results of the experiment derived ample support from the findings of Bhogadhi (2015) who reported that MTU1010 and MTU1001 showed moderate level of resistance to BPH. Further, Udayasree et al. (2018) also observed the moderately resistance reaction of MTU1010 and MTU1001 to rice BPH.

CONCLUSION

The rice hybrids BS 144 and BS 133 and the high yielding varieties MTU 1010 were found to be suitable for the coastal agro-climatic zone of the state of Odisha owing to their higher resistance and tolerance to the major insect pests and diseases of rice and better yield potential. A comparatively lower pest load in these hybrids and variety may substantially reduce the pesticide application level in rice which can further contribute to higher farm profitability and environment sustainability. Though the results of this investigation provided a preliminary indication about the reaction of some selected HYVs and hybrids of rice to the plant and leaf hoppers, sheath blight and BLB, further experimentation in different agro-climatic conditions is essential to validate the findings.

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Variability and correlation studies of yield and yield attributing characters in finger millet [*Eleusine coracana* (L.) Gaertn.]

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ABSTRACT

A field experiment was carried out to estimate the correlation coefficient for eight quantitative characters *viz.*, days to heading, days to maturity, plant height, number of effective tillers per plant, number of fingers per earhead, weight of earhead per plant, 1000 grain weight and grain yield per plant in 18 genotypes of finger millet which were sown in a randomized block design with three replications under six environments. The six environments under which the genotypes were tested appear to be quite diverse. The environmental effects were highly significant for all the eight quantitative characters and constituted major part of the total variation. The genotypes showed low coefficient of variation for days to heading, days to maturity, fingers per earhead and 1000 grain weight, moderate coefficient of variation for plant height and effective tillers per plant where as high coefficient of variation found for earhead weight per plant and grain yield per plant. The study showed that grain yield per plant had positive and significantly correlated with earhead weight per plant followed by effective tillers per plant and 1000 grain weight which revealed that these characters were the major contributors to grain yield per plant. These characters can be considered as criteria for selection to improve the grain yield per plant in finger millet.

Key words: Coefficient of variation, correlation, environment, finger millet, grain yield

INTRODUCTION

Finger millet [*Eleusine coracana* (L.) Gaertn. 2n=4x=36] belongs to the family Poaceae and is an important staple food in parts of eastern and Central Africa and India. It is also known as African millet, ragi, mandia, nachani, nagali, kelvaragu, and koovasagu. Finger millet is very adaptable to a wide range of environmental and climatic conditions, thrives at higher elevations compared to other tropical cereals, significantly tolerates salinity, and is relatively resistant to waterlogging (Dida et al., 2008). It is intensively grown in Karnataka, Tamil Nadu, Maharashtra, Andhra Pradesh, Odisha, Bihar, Gujarat, Uttarakhand, and Himachal Pradesh with a total production of 2.2 million tonnes from an area of 2.5 million hectares (Sapkal et al. 2019).

Grain yield is a polygenic controlled complex character with low to moderate heritability owing to environmental effects and also greatly influenced by many interrelated component traits, which are also mostly polygenic and the direct selection for yield is often not much effective (Das and Baisakh, 2019). Thus the correlation between yield and other component traits would be of key consideration for all crop breeders. Sardar and Behera (2017) emphasized the importance of indirect selection for yield through component traits governed by genes with additive effect and strong correlation with yield. This necessitates a thorough knowledge of the nature of the relationship prevalent between contributory characters and grain yield and the extent of genetic variability (Mahanthesha et al., 2017). Therefore, identifying the characters which are closely related and have contributed to yield becomes highly essential. Correlation would give a better insight into the cause and effect relationship between different pairs of characters by Venkatesan et al. (2004). Correlations between yield and other characters are useful in selecting the desired plant type in designing an effective breeding program for improvement of grain yield. The estimates of correlation coefficients mostly indicate the inter-relationships of the characters and useful for breeders in selecting genotypes possessing groups of desired traits. Therefore, the present investigation was undertaken to study the performance of different genotypes and correlation of the yield attributing characters with the grain yield in six different environments.

MATERIALS AND METHODS

The experimental materials consisting of 18 genetically diverse genotypes of finger millet were evaluated at six environments and in a randomized complete block design in three replications with a spacing of 25 cm between rows and 10 cm between plants respectively, at each environment (Research farm, Orissa University of Agriculture and Technology, Bhubaneswar). The recommended package of practices was followed to raise a healthy crop. Ten competitive plants were selected at random from each replication and observations were recorded on eight quantitative traits *viz.*, days to heading and days to maturity, plant height, effective tillers per plant, number of fingers per head, earhead weight per plant, 1000 grain weight and grain yield per plant.

During cropping season, various meteorological observations i.e. rainfall, minimum and maximum temperature, relative humidity during morning and afternoon, and duration of sunshine hour of each environment were daily recorded for undertaking a comparative study between its effect on grain yield and other yield attributing characters.

The data for different characters were statistically analyzed by using analysis of variance technique described by Panse and Sukhatme (1985). The significance of the mean sum of the square for each character was tested against the corresponding error degrees of freedom. Correlation coefficients between grain yield and other yield attributing characters in different environments were worked out as per Snedecor and Cochran (1967), Singh and Chaudhary (1977) and Nadarajan and Gunasekaran (2014).

RESULTS AND DISCUSSION

Perusal of the data presented in Table 1. revealed that analysis of variance for eight characters indicated that the genotypes used in the present studies were significantly different. The effects due to the environment were highly significant for all the eight characters. In respect to G×E interaction, the effects were highly significant for days to heading, days to maturity, plant height, earhead weight per plant, 1000 grain weight, and grain yield per plant. The observed meteorological data of different environments are presented in Table 2.

The mean observations varies from 72.3-82.3 for days to heading, 91.1-119.6 for days to maturity, 61.7-98.7 cm for plant height, 2.44-3.40 for effective tillers per plant, 6.32-6.79 for fingers per earhead, 6.79-15.42 g earhead weight per plant, 2.23-2.71 g for 1000 grain weight and 4.03-11.48 g for grain yield per plant across the environments (Table 3). A high coefficient of variation (CV) was observed for grain yield per plant followed by earhead weight per plant. Moderate value of CV observed in plant height and effective tillers per plants. In the remaining traits the coefficient of variability was relatively small (< 10.0). The result indicated that there is a significant role of environmental factors and among all quantitative characters, the grain yield per plant and earhead weight per plant are highly influenced by climate. Among different environmental conditions the environment-3 condition i.e. on an average 31.5/ 19.70ºC temperature (max. and min.) with a longer sunshine period i.e. 9.2 hours having the relative humidity of about 88 % in the morning and 35 % in the afternoon found to be optimum for higher grain yield among the six diverse environments. It was observed that the temperature above 32ºC is adversely affecting the grain yield.

Table 1. Analysis of variance for different characters in finger millet

Sl.No.	Characters	Environments	Genotypes	G×E	Error
1	Days to heading	766.075**	55.191**	7.568**	2.407
2	Days to maturity	5552.500**	24.838**	5.609**	2.530
3	Plant height	7527.450**	252.544**	53.776**	8.823
4	Effective tiller per plant	7.964**	0.453**	0.184	0.139
5	Fingers per earhead	1.920**	0.398**	0.165	0.132
6	Earhead weight per plant	532.733**	3.516**	4.678**	1.596
7	1000 grain weight	2.153**	0.037**	0.018**	0.003
8	Grain yield per plant	383.143**	2.358*	3.277**	1.213

* , ** Significance at 5% and 1% level, respectively

Table 2. Meteorological observations of different environment during the cropping season

Environments	Rainfall (mm)	Temperature (ºC)		Relative humidity (%)		Sunshine (Hour)
		min	max	Morning	Afternoon	
E1	1173.0	24.94	32.86	89.20	71.60	6.44
E2	541.5	21.48	31.52	87.38	58.58	7.74
E3	89.0	19.75	31.55	88.00	35.00	9.20
E4	165.5	22.65	35.80	87.80	39.30	8.95
E5	833.2	25.00	32.74	91.80	71.40	5.80
E6	634.1	22.83	32.43	92.80	63.30	6.98

Table 3. Mean and coefficient of variation for yield and yield attributing characters under six environment

Sl. No.	Environments→	E1	E2	E3	E4	E5	E6	Over all mean	SE	CV
	Characters ↓	Mean	Mean	Mean	Mean	Mean	Mean			
1	Days to heading (days)	82.3	79.8	81.1	81.8	77.4	72.3	79.1	1.5	4.8
2	Days to maturity (days)	119.6	117.6	109.5	111.2	91.1	108.1	109.5	4.1	9.3
3	Plant height (cm)	83.0	61.7	82.3	84.5	98.7	82.0	82.0	4.8	14.4
4	Effective tiller per plant	2.73	3.18	3.40	2.44	2.54	2.62	2.82	0.16	13.63
5	Fingers per earhead	6.32	6.45	6.49	6.67	6.32	6.79	6.50	0.98	2.90
6	Earhead weight per plant	8.23	13.02	15.43	6.79	11.40	11.27	11.03	1.28	28.49
7	1000 grain weight (g)	2.36	2.33	2.71	2.23	2.60	2.48	2.66	0.08	8.05
8	Grain yield per plant (g)	6.31	10.05	11.48	4.03	8.50	8.18	8.71	1.09	32.57

Table 4. Correlation coefficient of yield attributing characters with yield under different environments

Sl. No.	Characters	Environments					
		E1	E2	E3	E4	E5	E6
1	Days to heading	-0.299	-0.093	0.149	-0.776**	-0.097	0.532*
2	Days to maturity	-0.184	-0.044	0.148	-0.617**	-0.262	-0.131
3	Plant height	-0.187	0.580*	0.125	-0.572**	0.206	0.152
4	Effective tiller per plant	0.249	0.714**	0.229	0.601**	0.401	0.580*
5	Fingers per earhead	0.045	0.416	0.197	0.085	0.198	-0.192
6	Earhead weight per plant	0.909**	0.875**	0.826**	0.953**	0.955**	0.948**
7	1000 grain weight	0.275	0.394	0.698**	0.064	0.271	0.201

Correlated characters are of interest for three chief reasons, firstly in connection with the genetic cause of correlation through the linkage and pleiotropic action of genes, secondly in connection with the change brought about by selections. It is important to know, how the improvement of one character will cause simultaneous changes in other characters and thirdly in connection with natural selection. In the present study, the correlation coefficients estimated between grain yields per plant with all other characters are presented in Table 4. The pattern of association varied greatly in different environments. The correlation coefficient of grain yield varies from -0.776 to 0.532 with days to heading, -0.617 to 0.148 with days to maturity, -0.572 to 0.580 with plant height, 0.229 to 0.714 with effective tillers per plant, -0.192 to 0.416 with number of fingers per head, 0.826 to 0.955 with earhead weight per plant and 0.064 to 0.698 with 1000 grain weight under different environment. It exhibited a highly significant positive correlation in all the environments condition with earhead weight per plant ranging from 0.826 to 0.955. All characters except the number of fingers per head and 1000 grain weight were shown a significant correlation in the 4th environment having maximum temperature and lower rainfall of which days to heading, days to maturity, and plant height exhibited a negative significant correlation with the grain yield. In many environment, days to heading and days to maturity found a negative correlation with yield. All other characters i.e. plant height, effective tillers per plant, number of fingers per head, earhead weight per plant, 1000 grain weight were found a positive correlation with the grain yield per plant.

The study showed grain yield per plant had a negative correlation with days to heading and days to maturity. Similarly, Bezaweletaw et al. (2006) found finger millet grain yield per plant to be significantly negative correlation to days to heading and days to maturity. The grain yield per plant had a positive and significant correlation with earhead weight per plant in all environments. Similar results were reported by Ganapathy et al.(2011) and Haradari et al. (2012). In all six environments, the number of effective tillers per plant recorded a positive correlation with grain yield per plant effective tillers per plant and in three environments, the value is significantly positive. This is in accordance with the findings of Anantharaju and Meenakshiganesan (2005), Anuradha et al. (2013) and Jyothsna et al. (2016). Grain yield per plant had positively correlated with the 1000- seed weight in all environments. Similar results were reported by John (2006). Therefore, any improvement of these characters would result in a substantial increment in grain yield of finger millet.

In the present investigation, the earhead weight per plant, effective tillers per plant, and 1000-grain weight shown a positive direct effect on grain yield per plant of which only the earhead weight per plant found significantly positive associated with grain yield per plant in all environment whereas effective tillers per plant and 1000 grain weight shown a significantly positive association with grain yield per plant in few environments. This revealed that although these characters were the major contributors to grain yield per plant but earhead weight per plant influenced the grain yield more than any of the other characters. Hence, it would be worth to lay more emphasis on this character in the selection and hybridization program to improve the productivity in finger millet.

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Influence of foliar application of micronutrients on growth, yield and quality of tomato (*Solanum lycopersicum* L.) cv. Bargad

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ABSTRACT

An investigation was undertaken to study the influence of foliar application of micronutrients on growth, yield and quality of tomato (*Solanum lycopersicum* L.) cv. *Bargad* during *kharif* 2016 at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India. It indicated that the maximum plant height plant girth (3.20) and minimum days to first flowering (24.29), first fruiting (35.33) and days to maturity (63.33) was recorded in T_5. Equally maximum numbers of fruits per plant (72.07), fruit length (5.66 cm), fruit diameter (4.77 cm), fruit weight (80.06 g), yield per plant (4.77 kg) and fruit yield per ha (562.57 q) was recorded in T5. In quality traits also this treatment (T_5) exhibited more shelf life (16.63 days), the maximum T.S.S (5.25 %), acidity (0.42 %), reducing (1.68 %), non-reducing (2.00 %), total sugar (3.63 %) and ascorbic acid content (19.94 mg). This treatment had the maximum net return (₹ 138528 ha^{-1}) and B:C Ratio 3.08 : 1 out all other treatments than over control.

Key words: Growth, micronutrients, quality, tomato, yield

INTRODUCTION

Vegetables are considering potential crops for improving nutrition, food security and also to generate employment in the country. Globally, vegetables are recognized as "protective foods" since they supply adequate quantities of vitamins, minerals, organic acids, folic acids, essential amino acids, dietary fibers, carbohydrates, have anti-carcinogenic and antioxidant properties. India is bestowed with varied favorable agro climatic zones and soils, makes it feasible to grow the largest number of vegetable crops in the world, all the year round and is regarded as a "Horticulture Paradise" (Saravaiya and Patel, 2005). As many as 61 annual and 4 perennial vegetable crops belonging to different groups are commercially cultivated in India. In India vegetables occupy an area of 9.40 million hectare (ha) with a production of 162.90 million tonne (t) and stands at second position in the world next only to China (Anonymous, 2015). However, the major concerns are low productivity, diminishing return from farming as a whole and lack of awareness among the vegetable growers regarding scientific crop management and quality product (Chattopadhyay et al., 2007).

Tomato (*Solanum lycopersicum* L.) is one of the most palatable vegetables which usually occupies the maximum number of our daily dishes and also takes its possession in market. Besides as rich source of vitamins and minerals Tomato contains lycopene pigment which is a vital anti-oxidant that helps to fight against cancerous cell formation as well as other kind of health complications and diseases (Kumavat and Chaudhari, 2013). A single tomato can provide 40 % of the daily requirement of Vitamin C and is a rich source of Vitamin K which plays a major role in blood clotting.

The productivity of tomato in India is quite low (18.7 t ha^{-1}) mostly due to the deficiencies of soil micronutrients that occurs because of intensive cropping, decreased availability and use of organic matter and imbalanced fertilization. Tomato being a heavy feeder and exhaustive crop removes substantial amounts of micronutrients from soil. To maintain sustainability in its production and nutritive value, it is becoming essential to apply micronutrients through foliar spray to meet the immediate need of the crop (Agarwal and Rao, 2000). The micronutrients like boron, zinc, copper and iron, if applied through foliar can also improve the vegetative growth and yield of tomato (Arora et al.,1982).

Micronutrients like Zinc, Iron, Manganese, Copper, Boron and Magnesium have an important role in the physiology of tomato crop and are required for physiological activities. (Azeem and Ahmed, 2011). Considerable research work has been done on the aspect of foliar application of micronutrient in different crops and the experimental results indicated not only increase in yield up to 20 per cent but also helpful to sustain crop production. Arora et al. (1979) reported that micronutrients like boron, copper, molybdenum and zinc through foliage can also improve the vegetative growth, fruit set and yield of tomato. Working with tomato, Mallick and Muthukrishnan (1980) reported that the role of micronutrients in the “nutrient element balance” of the plant is of considerable interest.

Looking at the importance of the crop, future scope and heavy demand of tomato fruits for the domestic as well as export business and for processing industry, a field trial of ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India during the kharif 2016 to assess the influence of foliar application of micronutrients on growth, yield and quality parameters related traits.

MATERIALS AND METHODS

A field experiment was conducted at the Regional Horticultural Research Station (RHRS) of Navsari Agricultural University (NAU), Navsari, Gujarat, India (20° 57' North latitude and 72° 54' East longitude) to study the effect of foliar application of micronutrients on the growth parameters, yield and quality of tomato (*Solanum lycopersicum* L.). The experimental site comes under the South Gujarat Heavy Rainfall Agro-climatic Zone, which has tropical climate with average annual rainfall of 1500 millimeters (mm). The field trial was conducted during *kharif* 2016 in the protected condition under natural ventilated polyhouse (NVPH), whereas, the laboratory work was undertaken in the Department of Post-harvest Technology, ASPEE College of Horticulture and Forestry, NAU, Navsari.

Tomato variety was transplanted during *kharif* and the crop was grown with the standard agronomic package of practices. The experiment was laid out in randomized block design with seven treatments (Table 1) and three replications. The source of micronutrients *viz.*, B, Zn, Cu, Fe and Mn were boric acid (0.1 %), zinc sulphate (0.25 %), copper sulphate (0.25 %), ferrous sulphate (0.25 %) and manganese sulphate (0.25 %), respectively. However, for the treatment T_7, general grade 1 % (Fe 5 %, Mn 2.5 %, Zn 3.5 %, Cu 1 %, B 0.65 %, and Mo 0.30 %) was used. Total three sprays of micronutrients were given at an interval of 20 days, starting from 40 days after transplanting.

Observations on different traits were recorded at different period of crop growth by using different methodologies. Plant height (m) was measured from ground level to tip of the main shoot at last picking with the help of meter tape, whereas, the leaf area was measured by leaf area meter (image analyzer). The number of days taken from the date of sowing to date on which first flower appeared in each plot were recorded as days to first flowering. The number of days from the date of transplanting to date on which 50 per cent of the plants flowered was recorded as days to 50 per cent flowering. The number of clusters bearing fruits was counted from the tagged plants and the average number of fruits per cluster was recorded and calculated at the final harvest. The first picking of fruit was started at breaker stage of maturity. The days to first picking were counted from the date of transplanting to date of first harvest of fruit. Total number of fruits of all the randomly selected and tagged five plants and the average per plant was worked out. The days to last picking were counted from date of transplanting to date of last picking and the randomly selected five fruits were cut horizontally and number of locules were counted and recorded. The total number of fruits from five randomly selected plant were weighed and the average fruit weight was worked out and expressed in grams. Total weight of fruits of the five randomly selected plants was recorded and the average yield of fruits per plant was worked out in kilogram (kg) by summing up of all the pickings. The fruits harvested from each net plot were weighed separately and recorded in kilogram (kg) at each picking. The final fruit yield was obtained by summing up the yield of all the picking and convert into meter square basis.

RESULTS AND DISCUSSION

Influence on vegetative parameters

The results obtained under the vegetative parameters like plant height and leaf area (Table 1) were accentuated and significantly prejudiced by different foliar application of micronutrient under protected culture in the present study. The robust vegetative growth is an essential prerequisite for better yield. The higher plant height (3.61 m) was recorded in the treatment T_7 consisting of combination of RDF + general grade (1%) which was statistically at par with treatments of T_3, T_2 and T_5, T_6 and T_4. Whereas, the lowest plant height (2.85 m) was recorded in the treatment T_1 that did not receive any micronutrient application. The leaf area (cm^2) obtained under different treatments was varied from 730.84 to 761 cm^2 with the higher leaf area (761 cm^2 in the treatment T_7 involving the combinations of RDF and general grade 1 % closely followed by T_6 (754 cm^2) and both were statistically at par with other. Research results pertaining to about vegetative characters as a consequence of foliar application of micronutrients might be due to the improvement in photosynthesis and other metabolic activity which leads to an increase in several plant metabolites responsible for cell division and elongation (Hatwar et al., 2003). The synergetic influence of Zn with P which may serve as a source of energy for the synthesis of auxin in the presence of Zn. Enhanced photosynthetic reaction in the presence of zinc and boron was also reported by Mallick and Muthukrishnan (1979) and explained that presence of zinc activates the synthesis of tryptophan, which is precursor of IAA and it is responsible to stimulate plant growth. Iron plays an important role in promoting growth characters, being a component of ferredoxin, an electron transport protein and is associated with chloroplast. It helps in photosynthesis might have helped in better vegetative growth (Hazra et al., 1987).

The positive Influence of micronutrients on vegetative characters have also been reported by Bose and Tripathi (1996) and Hooda et al. (1984) in tomato. Similarly, other scientists also reported that micronutrients had positive role in improving vegetative growth

Influence on reproductive parameters

Results on different reproductive parameters *viz.*, days to first flowering, days to fifty percent flowering, number of fruits per cluster and no. of locules per fruits (Table 1) and were significantly influenced by different foliar application of micronutrient under the present study.

The minimum days to first flowering (27.33 days) was noticed from the treatment T_7 involving the combinations of RDF + general grade 1 % which was statistically at par with the treatment T_5. In contrast the maximum days to first flowering (38.67 days) was observed under the treatment T_1 (only RDF), the lowest days to 50 % flowering (30.67 days) was achieved from the treatment T_7 which was statistically similar with the treatments T_5 and T_6. However, the maximum days to 50 % flowering (41 days) was observed under the treatment T_1 which indicated the effect of micronutrients in inducing early flowering.

Table 1. Influence of foliar application of micronutrients on growth parameters and yield of tomato

Treatments	Treatments Details	Plant height (m)	Leaf area (cm^2)	Days to first flowering	Days to 50% flowering	No. of fruits per cluster	No. of locules per fruit
T_1	RDF [N:P: K 250:125:125 kg ha^{-1}]	2.85	730.84	38.67	41.00	3.80	2.07
T_2	T_1+ Boric acid (0.1%)	3.22	736.84	36.33	38.67	3.50	2.77
T_3	T_1+ Zinc sulphate (0.25%)	3.35	741.00	35.00	37.67	3.70	2.13
T_4	T_1 + Copper sulphate (0.25%)	3.10	742.00	34.67	37.67	3.67	2.47
T_5	T_1+ Ferrous sulphate (0.25%)	3.21	744.17	31.00	34.67	3.87	2.50
T_6	T_1+ Manganese sulphate (0.25%)	3.15	754.00	33.33	36.00	3.47	2.33
T_7	T_1+ General grade 1% (Fe 5 %, Mn 2.5%, Zn 3.5%, Cu 1%, B 0.65%, Mo 0.30%)	3.61	761.00	27.33	30.67	4.67	3.07
	S.Em. ±	0.13	5.34	1.80	1.86	0.21	0.19
	C.D. at 5%	0.41	16.45	5.55	5.73	0.66	0.58
	C.V. %	7.26	6.24	9.24	8.80	9.76	13.26

Table 2. Influence of foliar application of micronutrients on fruit quality of tomato

Treatments	Treatments Details	Pericarp thickness (mm)	Equatorial diameter (cm)	Polar diameter (cm)	Fruit texture kg cm^{-2}	Shelf life (days)	Total soluble solids (^{0}Brix)	Ascorbic acid (mg 100 g^{-1})	Lycopene content (mg 100 g^{-1})	No. of fruits per plant	Fruit yield per plant kg m^{-2} (kg)	Marketable fruit yield
T_1	RDF [N:P: K 250:125:125 kg ha^{-1}]	5.33	4.67	5.47	2.67	13.00	3.00	11.83	4.12	34.67	3.10	8.85
T_2	T_1+ Boric acid (0.1%)	6.17	6.33	6.67	3.67	16.33	4.00	12.83	4.32	45.00	4.37	12.26
T_3	T_1+ Zinc sulphate (0.25%)	6.07	6.50	6.83	3.67	16.00	4.33	12.10	4.20	39.00	3.80	10.63
T_4	T_1 + Copper sulphate (0.25%)	5.74	6.23	6.17	3.67	16.00	4.00	12.50	4.14	35.00	3.35	9.41
T_5	T_1+ Ferrous sulphate (0.25%)	5.67	6.30	6.37	2.33	15.67	3.67	13.00	4.20	36.33	3.61	10.10
T_6	T_1+ Manganese sulphate (0.25%)	6.23	6.20	6.50	3.33	15.67	3.67	13.50	4.14	36.67	3.57	10.00
T_7	T_1+ General grade 1% (Fe 5 %, Mn 2.5%, Zn 3.5%, Cu 1%, B 0.65%, Mo 0.30%)	8.00	6.83	7.63	4.00	16.67	4.33	14.17	5.01	53.67	5.48	14.56
	S.Em. ±	0.50	0.39	0.29	0.30	0.67	0.26	0.87	0.18	1.72	0.27	0.78
	C.D. at 5%	1.54	1.19	0.89	0.94	2.05	0.79	2.68	0.55	5.29	0.83	2.42
	C.V. %	14.02	10.86	7.71	15.81	7.39	11.55	11.73	7.12	7.42	11.99	12.55

The higher number of fruits per cluster (4.67) was recorded in treatment T_7 which was found to be statistically at par with T_5, whereas, the minimum numbers of fruits per cluster (3.47) was observed under the treatment T_6 (T_1+ Manganese sulphate (0.25%).

The lower days to first picking (60 days) was realized from the treatment T_7 containing the combinations of RDF + General grade 1 % which was statistically at par with T_5. The maximum days to first picking (76) was observed under the treatment T_1 (RDF N: P: K 250:125:125 kg ha^{-1}).

The maximum number of fruits per plant (53.67) was achieved in the treatment of T_7 which were statistically at par with the treatment T_2. The minimum number of fruits per plant (34.67) was observed under the treatment T_1.

The results shown in the Table 8 indicated that the Influence of foliar application of micronutrient was found to be non-significant for days to last picking.

The higher number of locules per fruit (3.07) was achieved from the treatment T_7 consisting the combinations of RDF + General grade 1 % which was statistically at par with the treatments T_2, T_4 and T_5. The minimum no. of locules per fruit (2.07) was observed under the treatment T_1.

Improvement in reproductive characters as a result of foliar application of micronutrients might be due to the enhancement in photosynthesis and other metabolic activity which led to an increase in various plant metabolites responsible for cell division and elongation (Hatwar et al., 2003). The synergetic Influence of Zn with P which may serve as a source of energy for the synthesis of auxin in the presence of Zn. Enhanced photosynthetic reaction in the presence of zinc and boron was also reported by Mallick and Muthukrishnan (1979) explained that presence of zinc activates the synthesis of tryptophan, which is precursor of IAA and it is responsible to stimulate plant growth. Iron plays an important role in promoting growth characters, being a component of ferredoxin, an electron transport protein and is associated with chloroplast. It helps in photosynthesis might have helped in better reproductive characters (Hazra et al., 1987). According to Grewal and Trehan (1979) manganese increases the chlorophyll content and the photosynthetic efficiency and helps translocation of food. Dry matter accumulation in plant is a function of photosynthates produced, which mainly depends on photosynthesis. Thus, application of micronutrients might have resulted in more production of photosynthates and their translocation for dry matter accumulation. The positive Influence of micronutrients on reproductive parameters have also been reported by Bose and Tripathi (1996) and Hooda et al. (1984) in tomato. Similarly, other scientists also reported that micronutrients had positive role in improving reproductive traits.

Influence on yield parameters

Both the yield attributes *viz.*, fruit yield per plant (Table 2) total fruit yield per m^2 (Table 23) and marketable fruit yield per m^2 (Table 2) were significantly influenced by the application of different treatments of foliar application treatments of micronutrient. Average fruit weight was found non-significant. Results clearly emphasized the impact of foliar application of micronutrients for production of higher yield. Tomato plants fertilized with application of RDF with mixture of all micronutrients (T_7) favorably influenced the growth, reproductive, quality and yield parameters registering the higher values for all the above mentioned yield attributes *viz.*, fruit yield per plant kg (5.48 kg), total fruit yield per m^2 (14.60 kg) and marketable fruit yield per m^2 (14.56 kg) and proved superior to other treatments. However, it was followed with the other treatments (i.e. other combinations of RDF+ micronutrients). Treatment T_1 registered lower fruit yield per plant kg (3.10 kg) and marketable fruit yield per m^2 (8.85 kg) of tomato indicating that the use RDF alone for fulfilling the requirement of total nutrition was inadequate. The consequences shown in the (Table 2) indicated that the influence of foliar application treatments of micronutrient on average fruit weight was found to be non-significant.

Increased yield due to micronutrients application may be qualified to improve photosynthetic activity, resulting into the increased production and accumulation of carbohydrate and advantageous. Influence on vegetative growth and retention of flower and fruits which might have increased number of fruits per plant besides improvement in the fruit size. The increase in dry matter production of fruits may be attributed to greater accumulation of photosynthates by vegetative parts and its subsequent translocation to the sink. Also, role of boron which enhance the movement of sugar borate complex from the leaves to the fruit and ultimately increased the fruit yield according to result given by Singh et al. (2003). Increased yield in response to micronutrients had also been reported by Hazra et al. (1987), Husain et al. (1989), Yadav et al. (1999) as well as Bose and Tripathi (1996) and Azeem and Ahmed (2011).

Influence on quality parameters

The important aspects related to quality *viz.*, pericarp thickness, equatorial diameter, polar diameter, fruit texture kg cm^{-2}, shelf life day, total soluble solids (^{0}Brix), ascorbic acid mg per 100 g and lycopene content mg per 100 g of edible portion differed significantly among the treatments (Table 2).

It is noteworthy that the tomato crop responded well to combine application of foliar application of micronutrients. Interestingly the treatment T_7 consisting of the combination of RDF + General grade 1% mixture of all micronutrients produced the maximum value for the characters *viz.*,pericarp thickness (8 mm), equatorial diameter (6.83 cm), polar diameter (7.63 cm), fruit texture (4 kg cm^{-2}), shelf life (16.67 days), total soluble solids (4.33 ^{0}Brix), ascorbic acid (14.17 mg), lycopene content (5.01 mg) and physiological loss in weight (12.96 %). The lowest values for all these quality fruit characters were recorded in T_1 (RDF [N: P: K 250:125:125 kg ha^{-1}], where only RDF alone was applied. The study clearly indicated that the efficacy of the RDF fertilizers was pronounced when they were combined with foliar application of micronutrients.

Increase in average diameter and polar length due to foliar spray of micronutrients in tomato has been reported by Hazra et al. (1987). The variation in number of flowers per inflorescence, i.e. number of fruits per plant might be due to improvement in translocation of carbohydrate from the site of synthesis to the storage tissue in plant is due to borax in results of Singh et al. (2003). The findings of Brown and Hu (1998) reported that micronutrient namely boron increased the level of sugar on stigma of flower which helps in fruit set due to better pollen germination and pollen tube growth. Substantial increase in the number of bigger size fruits due to application of micronutrients in tomato was also reported by Mallick and Mathukrishnan (1979).

Increase in TSS might be due to increased carbohydrate production during photosynthesis. The findings of the present study are in conformity with that of Mallick and Muthukrishnan (1980) and Hooda et al. (1984).

An increase in ascorbic acid content of tomato fruit by application of zinc and boron salts had earlier been reported by Kumar et al. (2011). The increase in ascorbic acid content might be due to synthesis of some metabolic intermediate materials that promoted greater synthesis of the precursor of ascorbic acid after the spray of micronutrients. The copper is reported to increase the activity of ascorbic acid oxidase enzyme producing marked improvement in ascorbic acid content. Mallick and Muthukrishnan (1980) and Arora et al. (1982), also reported efficacy of micronutrients in increasing the ascorbic acid content of tomato fruits.

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Storage performance of horticultural crops in zero energy cool chamber: A case study in Mizoram, India

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ABSTRACT

Post-harvest loss is one of the major problems faced by the farmers which are further amplified in the hilly region owing to the lack of suitable on-farm storage facilities and remote locations. Zero energy cool chamber (ZECC) is one such technique which increases the shelf life of crops by lowering the temperature and increasing the relative humidity (RH). A comparative study was conducted for the storage of broccoli, tomato, passion fruit and banana inside the ZECC and under ambient condition during different harvesting months *viz.* January, March, April and August to evaluate their shelf life under the influence of changes in temperature, RH and physiological loss in weight (PLW) over the storage period. The shelf life of these crops was increased from nearly 7 days to 12, 11, 12 and 20 days respectively. An average reduction in temperature (°C) from 16.85-11.98, 16.47-12.05, 20.94 -16.49 and 25.67-20.67, respectively with increase in RH (%) from 81.92-94.17, 63.36-77.27, 53.75-67.67 and 80.67-93.67 was recorded inside the ZECC and ambient condition respectively. The highest PLW inside ZECC was observed in passion fruit (5.15 %) and lowest in banana while broccoli recorded highest PLW (16.19 %) under ambient condition which is lowered to only 4.51 per cent inside ZECC.

Key words: Fruit crops, physiological loss, relative humidity, shelf-life, temperature

INTRODUCTION

Post harvest loss in horticultural crops is one of the potent constraints that the tribal farmers of Aizawl District of Mizoram in India is facing during this inopportune COVID 19 pandemics. Agricultural lands are located at undulated tough hilly terrain having steep slopes composing of highly porous soil which are prone to soil erosion and frequent landslides. The problem is further amplified by poor road connectivity in the region particularly the steep hill slopes where majority of the farmlands are found. The farmers practice is the traditional methods of *jhum* or shifting cultivation with least improved scientific and technological interventions (Singh et al., 2013). Harvesting of horticultural crops is done on weekends involving transportation to a nearby road or a spot from where they can convey it to the mandis by means of vehicle which is still a great challenge to the farmers, meanwhile adding to their cost of production. There is a huge amount of loss of fruits and vegetables on the way from farm to fork owing to their highly perishable nature at different steps along the post harvest chain. The loss is further enhanced by the lack of proper cool storage and refrigerated storage facilities at the farm level and market respectively (Rosa, 2006). In cases when there is glut in the market, the farmers face difficulties in selling their produce which then are prone to spoilage resulting in considerable loss for the farmers. During the hardship of COVID 19 pandemic, the frequent imposition of lockdown in the region have impounded detrimental effect on the farmers' harvest to the existing post harvest loss. It has become very imperative for the tribal farmers' preparedness for such natural disaster and be equipped with suitable storage techniques for properly storing their hard-earned agricultural produces.

In a report published by the ICAR, the Indian post harvest losses in fruits and vegetable ranged 5.77 to 18.05 per cent (Narayana, 2014). The quality of vegetable crops deteriorates immediately after its harvest due to the high moisture content (Sundaram, 2013). Fruits and vegetables spoilage can greatly be controlled bydecreasing the storage temperature and increasing its relative humidity (RH) which restricts its biochemical and physiological changes to a minimum standard level (Devi and Singh, 2018 a,b; Kadar, 1992). Generally, storage conditions can be controlled by using various mechanical processes like air cooling, hydro-cooling, vacuum cooling, chilling devices and freezing (Kumar et al., 2018). Storage via refrigeration is one of the established techniques used widely for horticultural and fruit crops around the globe (Devi and Singh, 2018 a,b; Sunmonu et al., 2014). Refrigeration mechanical devices are mostly energy intensive involving huge capital investment and uninterrupted supply of electricity for operation. Moreover, its construction at remote areas or on-farm agricultural fields in rural areas is a meticulous task (Kumar et al., 2018; Basediya et al., 2013). Hence, such expensive mechanism is not render suitable for small and marginal farmers of rural areas (Kumar et al., 2018). Refrigeration storage is also reported to cause chilling injuries and damage of colour pigments in several tropical fruits and vegetables (Olosunde et al., 2009 ; Liberty et al., 2013).

A trending trace on the scope and applicability of evaporative cooling storage structure, Zero Energy Cool Chamber (ZECC) can be seen abundantly around the globe. Evaporative cooling is a well-known mechanism, the principle of which is based on cooling of a substance due to the conversion of sensible heat to latent heat when water evaporates and hence the rate of cooling is directly proportional to the rate of evaporation. The basic design of a ZECC consists of a doubled brick walled structure with sand-filled cavity. It is a great alternative to refrigeration cooling by providing many advantages like low cost, ease of construction and maintenance using locally available materials, environmental and user friendly, economical making it suitable for rural and remotely located farm areas. The cooling effect inside the chamber of a ZECC occurs as a result of evaporation of water from the brick walls and sand due to the transfer of heat from the air and brick having relatively higher temperature to the moistened sand via the process of conduction and convection, respectively (Roy and Khurdiya, 1986; Roy and Pal, 1989).Since the development of the ZECC based on the principle of passive evaporative cooling by Indian Agricultural Research Institute (IARI), New Delhi (Roy and Khurdiya, 1986), there has been numerous works conducted on the efficiency and effectiveness of the ZECC on various fruit and vegetable crops under different agro climatic conditions. Cool chambers are reported to be effective in maintaining the freshness of fruits and vegetables and minimizing the weight loss (Bhatnagar et al., 1990). Sarkar et al. (2014) evaluated the performance of ZECC in terms of inside and outside temperature and relative humidity at ICAR Research complex for Eastern Region, Patna, Bihar in India. Adopting ZECC designed by IARI Pusa, New Delhi, Devi and Singh (2018) conducted trials in Manipur, North Eastern hilly (NEH) Region in India for storing vegetable and fruit crops and found to be a very simple yet effective and farmers' friendly technology that can be adapted by the farmers. Khatun et al. (2018) used ZECC to increase the marketability of cauliflower and found that ZECC can reduce the temperature from 8^{o}C to 6^{o}C and increases relative humidity from 30% to 33% further the physiological loss in weight (PLW) was reduced by 10.94%. In a study conducted by Singh and Satapathy (2006) on different fruits and vegetables, the mean maximum temperature inside the ZECC was reported to be 5°C to 6°C lower than the ambient temperature and the relative humidity (RH) was in the range of 80 to 94 % round the whole year. Similarly, different researchers and extension expert have tested and redesigned ZECC as in an attempt to optimize the storage conditions for vegetables and fruit crops (Sundaram, 2013; Lata and Singh, 2013; Kumar et al., 2014; Mishra et al., 2020). In the present study, viewing to the trending effective storage quality of ZECC, an attempt has been made to assess the keeping quality of the ZECC at farmer's farm located in the mid hill altitude offour important horticultural fruit crops of the region.

MATERIALS AND METHODS

Study was conducted at on-farm in Sihphir Veng lun Village, Aizawl District of Mizoram in India by Krishi Vigyan Kendra Aizawl, Selesih, Mizoram during the year 2019-20. The state capital, Aizawl District altitudes to 1231 m gauged at Chatlang and receives 2492 mm of rainfall during the year 2019-20 and the maximum and minimum temperature was recorded to be 33.53°C and 7.28°C respectively with minimum and maximum relative humidity (RH) of 49.32% and 88.23%, respectively (Directorate of Agriculture, 2017). Its agro-climatic zone comes under humid temperate sub alpine, humid sub-tropical hill and humid mild-tropical zones (Directorate of Agriculture, 2017; MISTIC, 2017). In an attempt to propagate and assess the performance of storage quality for different vegetable and fruit crops, ZECC has been implemented at on farm level at Sihphir village of Aizawl District at Mizoram, NEH Region in India.

Fig. 1. On-field construction of ZECC

ZECC construction

ZECC construction was accomplished with materials that are easily available within the local market *viz.* bricks, sand, cement, galvanized tin sheet, wood, lock, plastic coated GI wire net, plastic crates, etc. The construction methodology involves the following steps:

i. Selection of site for ZECC construction.
ii. Site demarcation, leveling and preparation of layout of dimension 165 × 115 cm^2.

iii. Erection of double brick wall to a height of 67.5 cm, leaving a gap of 7.5 cm between the two erected brick walls.
iv. Installation of protective frame made of wood and plastic-coated GI wire net with proper locking system.
v. Preparation of proper shed with help of wood frame and galvanized tin sheet of dimension 200 × 160 cm^2 for protection from direct sunlight and rain.
vi. Filling up of the gap between the double walls with sand and subsequently soaking it with water during storage.

Fig. 1 shows on-field construction of ZECC for the present study. Constructed ZECC structure was then used for storing the harvested vegetable and fruit crops *viz.* Broccoli (var. CLX 3512) during the month of January and February 2020, Tomato (var. Arka Rakshak) during February and March 2020, Passion fruit (var. Local: Sapthei) during March and April 2020 and Banana (var. Giant Cavendish) during August and September 2020. As to assess the performance of ZECC, parameters such as physiological loss in weight (per cent), Temperature (°C) and relative humidity (per cent), daily data required were recorded during the storage period.

Physiological loss in weight (PLW)

In determining the quality of stored vegetables and fruits crops, physiological loss in weight stands as one of the important parameters (Sarkar et al., 2014). It's per cent decline affects the storage quality of the vegetables and fruit. Loss of freshness and withed appearances in stored vegetables and fruit crop can be a resultant of a 5 per cent drop in PLW (Ben-Yehoshua, 1987; Sondi and Sondi, 2004). With recorded initial weight before storage (w_1) and final weight after storage (w_2), PLW in per cent can be estimated using the following equation (1).

$$PLW = \frac{(w_1 - w_2)}{w_1} \times 100$$

PLW = Physiological loss in weight (per cent).
w_1 = Initial weight before storage (kg).
w_2 = Final weight after storage (kg).

Temperature and relative humidity

Temperature and relative humidity are two very important parameters that affect the storage keeping quality of vegetables and fruit crops. Storage temperature governs the viability and growth probability of microorganisms that affects the conditions of product storage life. Further, vegetables and fruit crops when stored under higher relative humidity improves the shelf life but promotes growth of fungus and molds, therefore it is essential to relatively maintain a lower temperature. The required temperature and relative humidity for the present study was recorded using Metravi HT-305 Digital Meter.

RESULTS AND DISCUSSION

ZECC constructed were successfully used for storing harvested vegetable and fruit crops *viz.* Broccoli, Tomato, Passion fruit and Banana during the month of January, March, April and August 2020, respectively in order to restrict post harvest losses. In the process, performance evaluation of the storage keeping quality of ZECC was compared with that of the ambient condition assessing the parameters namely shelf-life (days), Temperature (°C), Relative Humidity (%) and PLW (%). The marketability of broccoli, tomato, passion fruit and banana were enhanced from 7, 6, 7 and 7 days under ambient condition to 12, 11, 12 and 20 days respectively when stored under ZECC (Fig. 2).

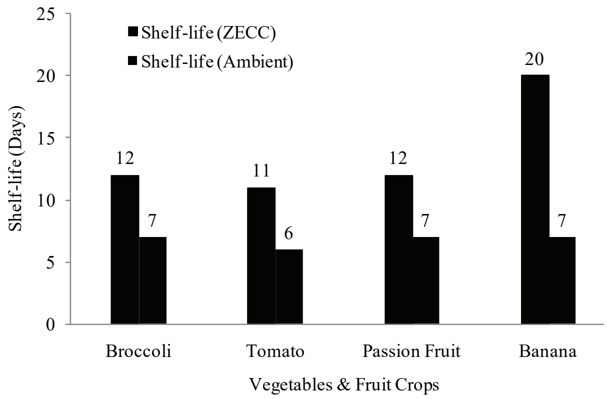

Fig. 2. Marketability of vegetable and fruit crops under ZECC and ambient condition

Temperature and relative humidity

In the present study the respective temperature and RH were recorded daily during early morning, noon and evening using Metravi HT-305 Digital Meter. The recorded trends of the temperature and RH inside ZECC and under ambient conditions during the months January, March, April and August 2020 are shown in Fig. 3 to 10. An average reduction in temperature from 16.85 to 11.98°C, 16.47 to 12.05°C, 20.94 to 16.49°C and 25.67 to 20.67°C for the month January, March, April and August respectively was observed. Highest and lowest daily reduction in temperature of 7.25 and 3.1°C were recorded in the month of April and March respectively. Recorded average increase in relative humidity in adoption of ZECC was found to be 81.92 to 94.17, 63.36 to 77.27, 53.75 to 67.67 and 80.67 to 93.67 per cent for the similar respective months. The highest and the lowest daily increases in RH were recorded in the month of January reading 25 and 8 per cent. Such decrease in temperature and increase in relative humidity inside the ZECC accords laws of thermodynamics where evaporation process causes a drop in several degrees of temperature and relatively increases the RH (Sundaram, 2013). As briefly stated by Sarkar et al. (2014) higher temperature with available moisture increases the rate of evaporation from the wetted sand and brick walls of ZECC. In such state, the surrounding atmospheric conditions around the ZECC attempts to maintaining equilibrium with ZECC causing the water from the wetted sand and walls to evaporate. During this process, the ZECC temperature lowers down due to the energy losses in evaporative cooling.

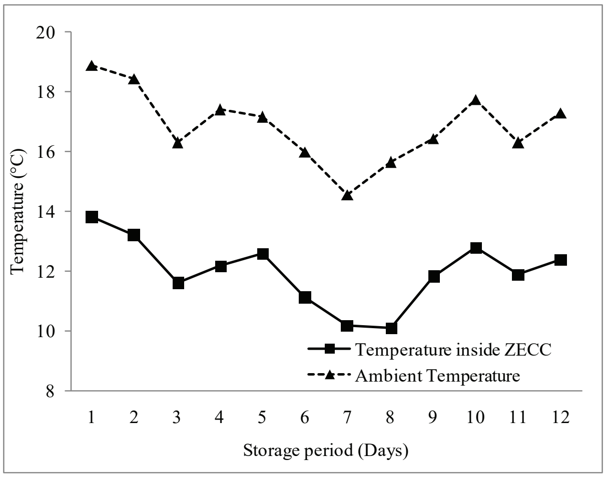

Fig. 3. Temperature variation in ZECC and ambient condition during January 2020

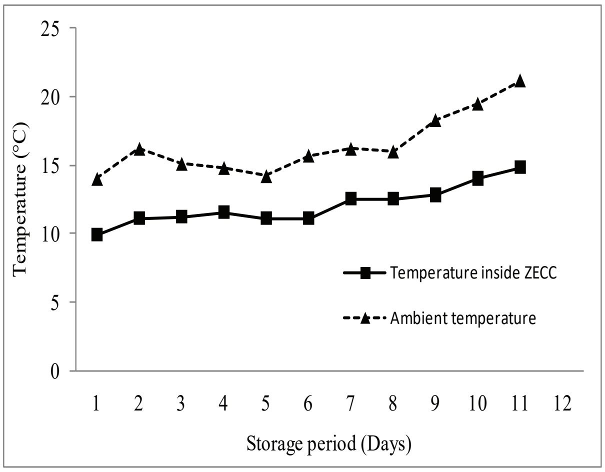

Fig. 4. Temperature variation in ZECC and ambient condition during March 2020

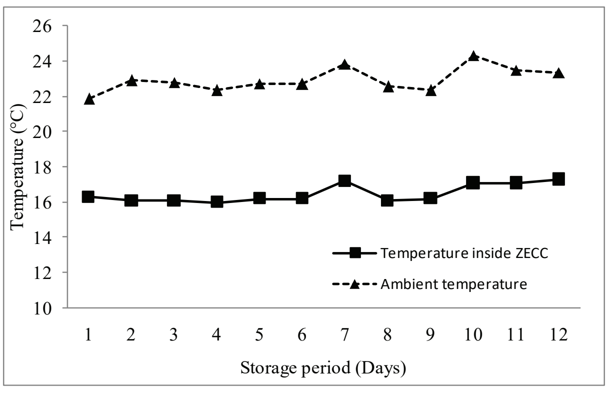

Fig. 5. Temperature variation in ZECC and ambient condition during April 2020

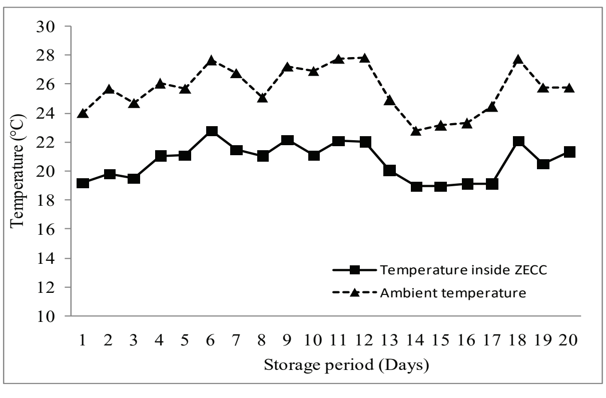

Fig. 6. Temperature variation in ZECC and ambient condition during August 2020

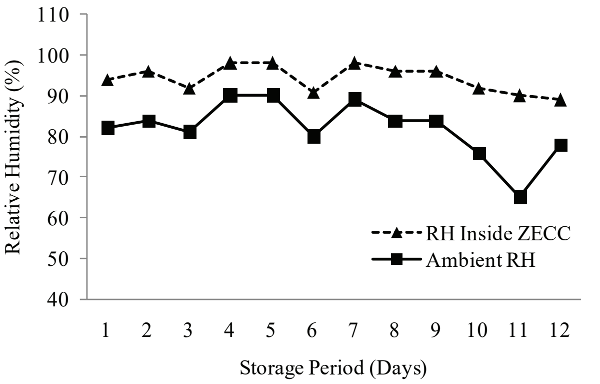

Fig. 7. Relative humidity variation in ZECC and ambient condition during January 2020

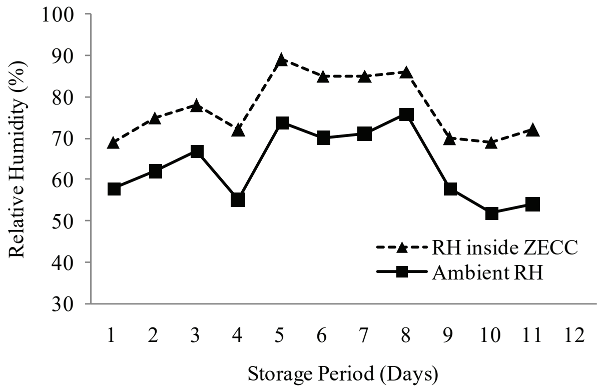

Fig. 8. Relative humidity variation in ZECC and ambient condition during March 2020

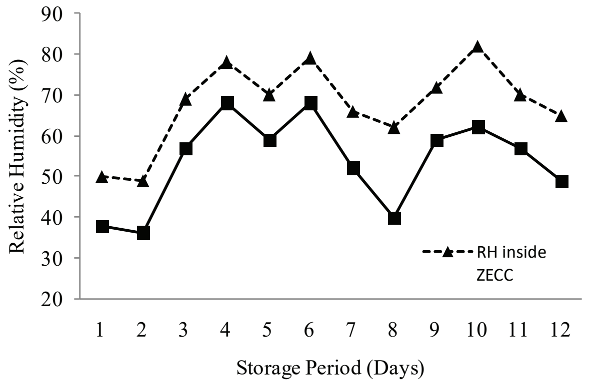

Fig. 9. Relative humidity variation in ZECC and ambient condition during April 2020

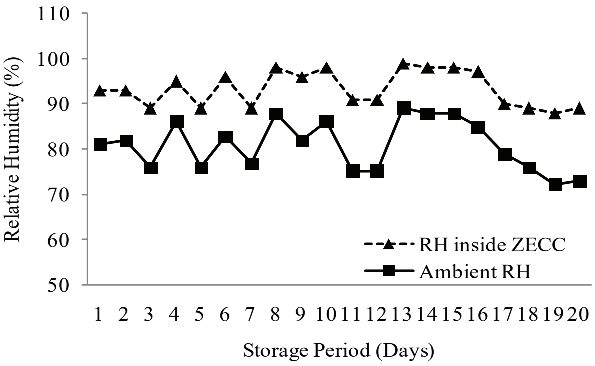

Fig. 10. Relative humidity variation in ZECC and ambient condition during August 2020

Physiological loss in weight (PLW)

Harvested crops are properly weighted and stored in plastic crates, a total of six numbers as shown in Fig. 1, when storing inside the ZECC. Estimated PLW in broccoli when stored for 12 days in ZECC was found to be 4.51 per cent only as compared to that of ambient condition that could only be stored for 7 days with 16.19 per cent of PLW. Stored tomato in ZECC for 11 days registered 3.9 per cent of PLW compared to a 5.54 per cent PLW under ambient condition for a mere of only 6 days. Stored banana for 20 days at ZECC registered a PLW of 2.5 per cent whereas under ambient condition it registered a PLW of 3.65 per cent after 7 days. Lastly, stored passion fruit at ZECC after 12 days, the PLW was found to be 5.15 per cent, where under ambient condition, the PLW was found to be 6.7 per cent after 7 days of storage. Fig. 11 show a comparative bar chart of physiological loss in weight (per cent) for different crops stored under ZECC and ambient condition, respectively.

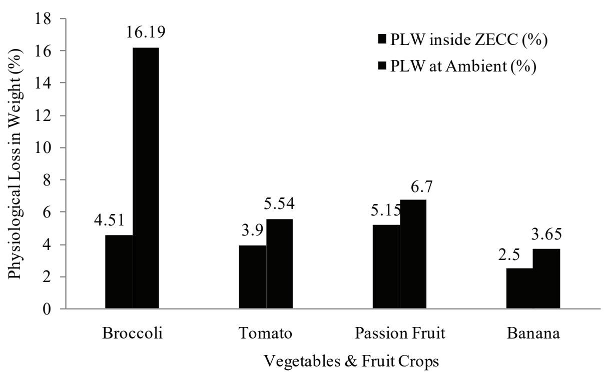

Fig. 11. Physiological loss in weight of vegetable and fruit crops under ZECC and ambient condition

CONCLUSION

In the search of a suitable storage technique, that is economical and simple yet effective in restricting the post harvest losses in horticultural crops, the Zero Energy Cool Chamber (ZECC) can be of great feasibility and adaptable. In the present study, constructed at on-field it was found that the ZECC can enhance the keeping quality from at least an average of 6-14 days as compared to that stored under ambient condition. An average reduction in temperature and relative humidity of 5.19°C and 13.14 per cent was observed respectively. Highest and lowest daily reduction in temperature of 7.25 and 3.1°C were recorded in the month of April and March respectively whereas, highest and lowest daily increase in RH were recorded in the month of January, reading 25 and 8 per cent. Further, highest reduction in the PLW was observed in stored broccoli at ZECC during the month of January 2020, an 11.68 per cent reduction. Adopted at farmers' farm, parts of harvested crops were successfully stored at ZECC and these stored crops were easily sold in other weekends. These have given the farmers an ample opportunity to avoid losses of harvested crops that are left off unsold in sale weekends. Being effective, the ZECC have gain popularity among the farming community in the region and more farmers have turn up willing to adopt it. Exhibited performance of the ZECC, its constructional and operational ease have shown that, its application in the region can be of great beneficial for the needy tribal farmers in restricting and mitigating the post harvest losses.

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Cabbage production in East Khasi Hills district of Meghalaya: A feasibility analysis

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ABSTRACT

The present study was designed to assess the economies of cabbage production in East Khasi Hills district of Meghalaya. As the cabbage crop is grown in two seasons namely *zaid* and winter, therefore primary data were collected for both the seasons. A sample of 80 cabbage growers was selected by multi-stage random sampling technique. The study revealed that the production of cabbage in both *zaid* and winter season were found to be profitable but the profit margin of winter season was higher to that of *zaid* season. The estimates of Cobb-Douglas production function indicated that per hectare gross returns were significantly influenced by cost of seeds, fertilizers and insecticides. Therefore, significant variable inputs must be taken care by the cabbage growers as well as researcher for enhancing the productivity of cabbage. Intervention of small machinery must be tapped to reduce the cost of production of cabbage in the study area.

Key words : Cabbage, Cobb-Douglas, feasibility analysis, winter, *zaid*

INTRODUCTION

India's Agriculture and horticultural sectors has registered an impressive growth during the past few decades. Horticulture sector has established its credibility in improving the income of the farmer by generating employment and increasing foreign exchange through the increased productivity. The present scenario of horticultural crops becomes very encouraging as it moves from the traditional approach and to the commercial scale. India has witnessed a shift in the area from agriculture to horticulture in recent years. It has boosted the socio-economic conditions of many farmers. India is the second leading producer of the vegetables and fruits. Presently, horticultural crops occupies about 13.6 million hectares of the gross cropped area. This sector contributes 18.20 per cent of gross value added product of India's agricultural output (Gupta et al., 2017). India ranks second position in both creage and production of Cabbage in the world. The area shows positive trend from 5593 thousand hectares with the production of 58532 thousand metric ton (MT) in the year 1991-1992 to 10259 thousand ha with the production of 184394 thousand MT in the year 2017-18. The productivity of vegetable has been increased from 101.2 million MT in the year 1991-92 to 184.40 million MT in the year 2017-18. Percentage share of vegetables in total horticultural crops is increased from 58.7 per cent in 2013-14 to 59.2 per cent in 2017-18. Uttar Pradesh has the highest production of horticultural crops in India contributing 392.48 lakh MT followed by West Bengal with 324.20 lakh MT (GoI, 2018).

In North Eastern India the area under the cabbage is 5649 thousand ha with the production of 1,027.42 MT. The average productivity of vegetables in North Eastern Hill region is far below the national average productivity and contributes 8.15 per cent to production from 9.05 per cent

(GoI, 2018). Amongst the North Eastern states in India, Meghalaya has favourable agro climatic conditions for growing vegetables throughout the year which helps the farmers to get premium price during off-seasons from neighbouring states. The returns and the revenue from the vegetables are higher than the cereals and pulses. More ever these vegetables can be grown in gentle slopes or homesteads GoM (2018). Recently the government of Meghalaya has introduced vegetable development scheme led by the Directorate of Horticulture with the association of Agriculture and Farmers Welfare Department which aims to promote vegetable production in Meghalaya. Amongst the vegetable crops, cabbage is contributing highest area and production after potato in Meghalaya. Consumption of cabbage keep the bones healthy it reduces the risk of cancer and aids in reducing the blood pressure (Ware, 2017). The area under cabbage in Meghalaya is 1943 ha; the production is 42.67 thousand MT with a yield of 21964 kg ha^{-1}. Among the different district of Meghalaya East Khasi Hills district is the major producer occupying 54.70% area and 68.70% production. Since, scanty research information is available on cabbage in Meghalaya, there is a need to study the economies of cabbage production in the state for constructive policy decision. The present paper is an overview of its economic feasibility in the state of Meghalaya.

MATERIALS AND METHODS

The study was conducted in two blocks *viz.*, Mawrykneng and Mawkynrew of East Khasi Hills district of Meghalaya due to their higher area and production. Two villages namely; Umphyrnoi and Sohryngkhemg from Mawrykneng block and three villages namely; Thangsning, Tynroit and Rapleng were selected from Mawkynrew block. A sample of 80 cabbage growers (Fig. 1) adopting proportionate random sampling in each selected village were selected. Primary data of two seasons *viz.*, *zaid* and winter were collected on seeds, fertilizers, organic manures, insecticides, pesticides including clod crushing, nursery bed and main field preparation, intercultural operations, harvesting and labour used in cabbage cultivation.

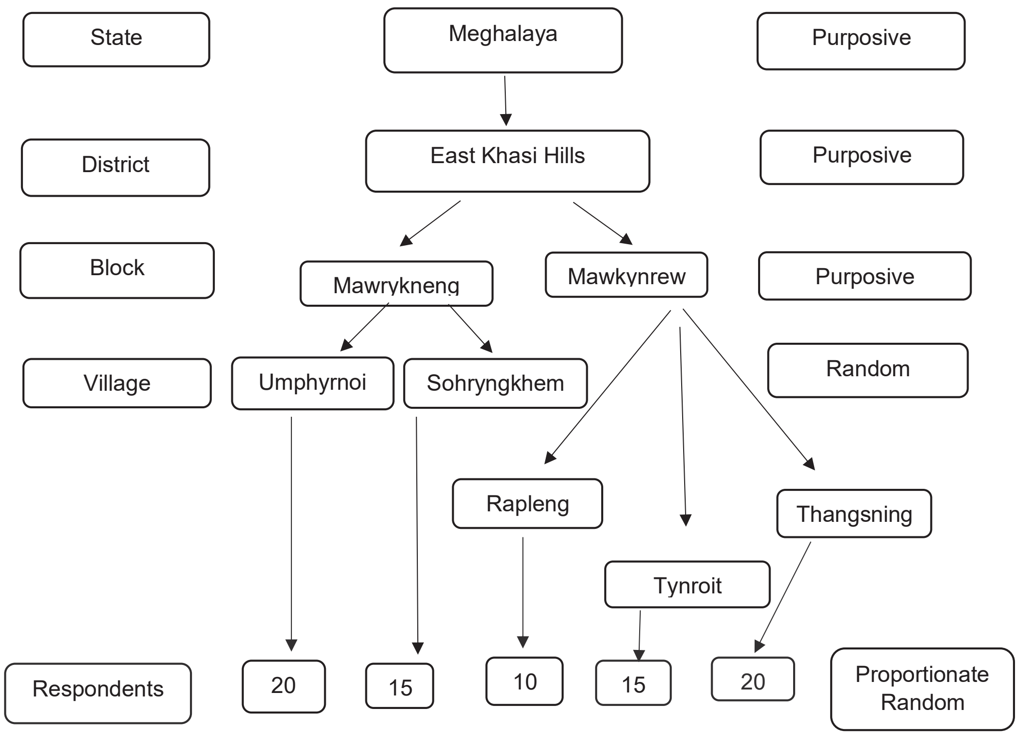

Fig. 1. Schematic representation of sampling plan

Analytical tools

Costs analysis

Cost concepts proposed by Special Expert Committee on (GoI, 1979) was used to calculate Cost A_1, Cost A_2, Cost B_1, Cost B_2, Cost C_1 and Cost C_2.

Cost A_1 includes

i) Value of hired human labor, animal labor (owned),

ii) Charges on hired farm machinery,

iii) Value of seed owned and purchased,

iv) Value of manures, value of fertilizers,

v) Value on plant protection chemicals,

vi) Depreciation on implements and farm buildingscesses and other taxes

vii) Repair and maintenance of farm machinery and farm implements and farm buildings,

viii) Irrigation charges,

ix) Land revenue,

x) Interest on working capital and miscellaneous expenses.

Cost A_2: Cost A_1 + rent paid for leased in land

Cost B_1: Cost A_1 + interest on value of owned fixed capital assets (excluding land)

Cost B_2: Cost B_1 + rental value of owned land (minus land revenue)

Cost C_1: Cost B_1 + imputed value of family labour

Cost C_2: Cost B_2 + imputed value of family labour

B. Return analysis

Gross farm income (GFI) = Value of main product (quantity × Price)

Net return including family labor = GFI − Total cost including family labor

Net return excluding family labor = GFI − Total cost excluding family labor

Farm business income = GFI – Cost A_2

Family level income = GFI − Cost B_2

Net farm income = GFI – Cost C_2

Farm investment income = Farm business income - imputed value of family labour

Cobb-Douglas production function

Cobb-Douglas production function model was chosen to estimate the effect of key variables on gross returns of cabbage production. The double log form of production proved to be superior alternative on theoretical and econometric grounds as given under.

$$Yi= \alpha X_1^{\beta 1} X_2^{\beta 2} X_3{}^{\beta}{}_3 X_4{}^{\beta}{}_4 X_5{}^{\beta}{}_5$$

By taking log in both sides, the Cobb-Douglas production function was transformed into the following logarithmic form because it could be solved by ordinary least square method.

$$\text{Ln } Yi= \text{In } \alpha+\beta_1 \text{In } X_1+\beta_2 \text{ In } X_2+ \beta_3 \text{ In } X_3+ \beta_4 \text{ In } X_4+ \beta_5 \text{ In } X_5$$

Where;

Y= Gross returns (₹ ha^{-1});

In α= Constant or a intercept of the function;

X_1= Seed cost per ha;

X_2= Organic fertilizers Cost per ha;

X_3 = Cost of fertilizers;

X_4= Insecticides cost per ha;

X_5= Labour cost per ha; B_1, β_2, β_3 *etc* are Co-efficient of respective variables;

In= Natural logarithm; e= Base of the natural logarithm;

Ui= Error term and i= 1,2,3…..n.

Economic viability

Benefit cost ratio (B-C Ratio)

This ratio indicates the rate of return per rupee invested in cabbage enterprises. It is worked out by dividing the discounted net cash flow by cost of cultivation.

BCR= {Gross present value of income ÷ Gross present value of cost}

Operating ratio

The operating ratio is firms operating expenses as a percentage of revenue. The smaller the ratio, the greater the firm's ability to generate profits.

RESULTS AND DISCUSSION

Cost of cabbage cultivation in *Zaid* season

The total cost A_1 was estimated to be of ₹27821.52 per ha. Cost A_2 was depicted as same as cost A_1 since no respondents found to have lease in land. Similarly, the cost B_1 was estimated to be of ₹28153.93 per ha. The respondents under research were giving their land for rent which costs ₹4500 and consequently the cost B_2 was estimated of ₹32653.93 per ha. The imputed value of family labour has been estimated of ₹19475.07. The cost C_1 was worked out to be of ₹47629 and cost C_2 to be of ₹52129. Per hectare Cost A_1 of cabbage cultivation in winter season was found to be of ₹26274.95. The Cost B_1 was worked out to be of ₹26607.37 per hectare. The cost B_2 was found to be of ₹31107.37. Cost C_1 was worked out to be of ₹43334.42 and cost C_2 was found to be ₹47834.42 per hectare. The cost A_1 was found to be more in *Zaid* season (₹27821.52 ha^{-1}) than winter season (₹26274.95 ha^{-1}). The reason might be the labour has charged more in *zaid* season than in winter season. Consequently, the Cost C_1 and C_2 were higher in *zaid* than the winter season. Hence, the comparative cost analysis for cultivation of cabbage in *zaid* and winter season provided an overview from which researcher can think of for intervene as per season (Table 1).

Table 1. Comparative cost of cabbage cultivation in *zaid* and winter season

Sl. no.	Particulars	Season (₹ ha^{-1})	
		Zaid (₹ ha^{-1})	Winter (₹ ha^{-1})
i	Hired labour	21792.84 (41.80)	18723.42 (39.14)
ii	Cost of the seeds	1166.66 (2.23)	2070.82 (4.32)
iii	Cost of Fertilizers	905.60 (1.73)	901.21 (1.88)
iv	Organic fertilizers	609.20 (1.16)	1188.55 (2.48)
v	Plant protection	1255.50 (2.40)	1365.8 (2.86)
vi	Interest of working capital @ 4.50	1157.80 (2.22)	1091.24 (2.28)
vii	Depreciation	933.91 (1.79)	933.912 (1.95)
viii	Cost A_1 (i to vii)	27821.52 (53.37)	26274.95 (54.93)
ix	Rent payed for the leased in land	-	-
x	Cost A_2 (viii+ix)	27821.52 (53.37)	26274.95 (54.93)
xi	Interest on the owned fixed capital assets excluding land @ 8.45%	332.41 (0.63)	332.4156 (0.69)
xii	Cost B_1 (x+xi)	28153.93 (54.00)	26607.37 (55.62)

xiii	Rental value of owned land	4500.00 (8.63)	4500 (9.41)
xiv	Cost B_2 (xii+xiii)	32653.93 (62.64)	31107.37 (65.03)
xv	Imputed value of family labour	19475.07 (37.35)	16727.05 (34.97)
xvi	Cost C_1 (xii+ xv)	47629.00 (99.99)	43334.42 (90.59)
xvii	Cost C_2 (xiv+xv)	52129.00 (100)	47834.42 (100)

Note: Figures in Parentheses are percentages in total to Cost C_2.

Returns from cabbage cultivation

Yield, total gross farm income, farm business income and family labour income of cabbage during winter has been observed to be higher than *zaid* crop. The net return including family labour was also found to be higher in winter compared to *zaid* season. If we see the net return excluding family labour it was higher in winter season than *zaid*. Hence, it is apparent from the analysis that there was huge investment on labour for cultivation of cabbage. Therefore, intervention of mechanization was a need of hour on the basis of season (Table 2).

Table 2. Comparative returns from cabbage cultivation in *zaid* and winter season

Particulars	Season	
	Zaid (₹ ha^{-1})	Winter (₹ ha^{-1})
Productivity (q ha^{-1})	58.33	68.00
Gross returns	84578.50	88400.00
Net return including family labour	51924.57	57292.63
Net return excluding family labour	32449.50	40565.58
FBI	56756.98	62125.05
Family labour income	51928.57	51928.57
Net farm income	32449.50	40565.68
Farm investment Income	37281.92	45398.00

Benefit cost and business operating ratio

The B:C ratio of cabbage cultivation during *zaid* and winter found to be of 1.60 and 1.84, respectively. It indicated that cabbage cultivation in winter is more profitable compared to *zaid*. The operating ratio of cabbage production in *zaid* and winter found to be of 54 per cent and 47 per cent, respectively indicating; the cultivation of cabbage economically profitable during both the seasons.

Factors ascertaining cabbage production

The magnitude of co-efficient of regression for seed cost was found to be of 0.01 with the positive sign and it was significant at 5 per cent of level of significance. It indicates that 1 per cent increase in the seed cost lead to increase in gross returns by 0.01 per cent. In the concerned research area most of the respondents were using the seeds less than the optimum usage recommended by government so in this case if respondents can purchase more quantity of seeds, more will be the production which will lead to higher gross return. Co-efficient of regression for fertilizer has shown a positive sign with 0.25 which was contributing significantly at 1 per cent. It indicates that 1 per cent increase in fertilizer cost will lead to 0.25 per cent increase in gross returns. Majority of the respondents in the study area were using less than the required level of fertilizers. Since cabbage is a heavy fertilizer consuming crop, if the respondent will apply more fertilizer to cabbage then both the production and gross returns will increase (Table 3). The co-efficient of regression was found to be 0.02 which was statically significant at 1 per cent level. It indicates that 1 per cent increase in insecticides costs leads to increase in gross returns by 0.02 per cent. Similar findings were given by Somajpoti et al. (2016). The crop was prone to attack of insects and sucking pests which resulted in crop damage and gross returns. The value of co-efficient of multiple determinations (R^2) was 0.60; which indicates that 60 per cent of variation in gross returns of cabbage was due to explanatory variables included in the model and remaining of other factors which were not taken into model.

Table 3. Estimated Cobb-Douglas production function of cabbage production

Explanatory variables	Co-efficient	Standard error	P-value
Intercept	6.89	2.52	0.00
Seed costs	0.01**	0.11	0.03
Organic fertilizers	0.79	1.36	0.24
Fertilizer costs	0.25***	0.141	0.00
Insecticides	0.02**	0.1	0.04
Labour	-0.03	0.09	0.69

**Indicates $p<0.05$ and ***indicated $p<0.01$ respectively.

CONCLUSION

Cabbage crop has been observed to be highly beneficial in the state of Meghalaya. The significant input variables need to take care by the farmers which are playing vital role in enhancing the yield of cabbage. The season wise analysis has given clear way forward in which the winter season must be popularized to produce cabbage. The agricultural engineering department of the state must come forward to develop small size of machinery to reduce human labour use which will reduce in cost of cabbage production.

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Hibiscus panduriformis Burm. f. (Malvaceae): A new distributional record from Odisha

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ABSTRACT

Hibiscus Linn., a quite large genus of family Malvaceae, is mainly distributed in the warm temperate, tropical and sub-tropical regions of the world. The members of the genus are popular not only as ornamental, medicinal, fibre and culinary purposes, but also for religious traditions. During the exploration mission and germplasm collection in parts of Odisha, the occurrence of *Hibiscus panduriformis* Burm.f., a wild crop relative, used as coarse fibre, was reported from Ganjam and Kalahandi districts of Odisha. After critical review on its distribution, its natural occurrence was found to be a new distributional record to the flora of the state. A detailed diagnostic description, ecology, germplasm collected and conserved and the photographs of the species were provided for easy identification and further utilization.

Key words: Fibre crop, *Hibiscus panduriformis*, new plant record, Odisha, seed germplasm

INTRODUCTION

Genus *Hibiscus* Linn. of family Malvaceae, subfamily Malvoideae is quite large and represented by about 200 species in the world of which 28 species are found in India (Sivarajan and Pradeep, 1996). The members are native to warm, temperate, tropical and subtropical regions throughout the world. The genus includes both annual and perennial herbs, woody shrubs and small trees. Various species of *Hibiscus* are popular for ornamental, fibre, medicinal, culinary purposes as well as spiritual traditions. Some of them are renowned for large and showy flowers and widely cultivated as ornamental plants. In India, most of the species are distributed in the warmer regions with a moderate to heavy annual rainfall.

Hibiscus panduriformis Burm.f., popularly called as '*Yellow Hibiscus*", is widely distributed in tropical Africa, Madagascar and tropical Asia. It occurs from sea level up to 2000 m altitude in the woodland and grassland, alluvial clay flats, riverbanks, roadsides, cultivated land and fallows. It also grows as a weed on black soil, in dry sandy places, often in places of old cultivation and disturbed areas. The plant is mainly utilised by local people as a source of fibre and as ornamental plant.

During the course of plant exploration and germplasm collection of allied fibre crops and wild okra in parts of Odisha during December 2014 and 2017 respectively, an interesting wild relative of *Hibiscus* was collected from natural habitat of two phyto-geographical zones of the state. On critical examination and reference of relevant literature (Master, 1874; Cooke, 1901; Gamble, 1915; Paul and Nayar, 1988; Sivarajan and Pradeep, 1996), the specimen was identified as *Hibiscus panduriformis* Burm.f., a plant species which has not been reported till date from the state. The present collection counts an addition of species and forms a new record for the flora of Odisha (Saxena and Brahmam, 1994).

The seed germplasm after collection was multiplied and the live plants were maintained in the field gene bank of the ICAR-National Bureau of Plant Genetic Resources (NBPGR) Base Centre, Cuttack. The morphological features on vegetative and floral parts were examined and the taxonomic characters were described. The seed germplasms bearing accession number IC-614085 (collection number RCM/MR/14) and IC-627240 (collection number RCM/PK/10) were conserved in the National Gene Bank, ICAR-NBPGR, New Delhi for long term storage. The plant specimens having vegetative and flowering parts were deposited to the herbarium of ICAR-NBPGR Base Centre, Cuttack and National Herbarium of Cultivated Plants, ICAR-NBPGR, New Delhi. The photographs of plants in the natural habitat along with flowering and fruiting stages, and seeds were presented for reference of easy identification (Fig. 1).

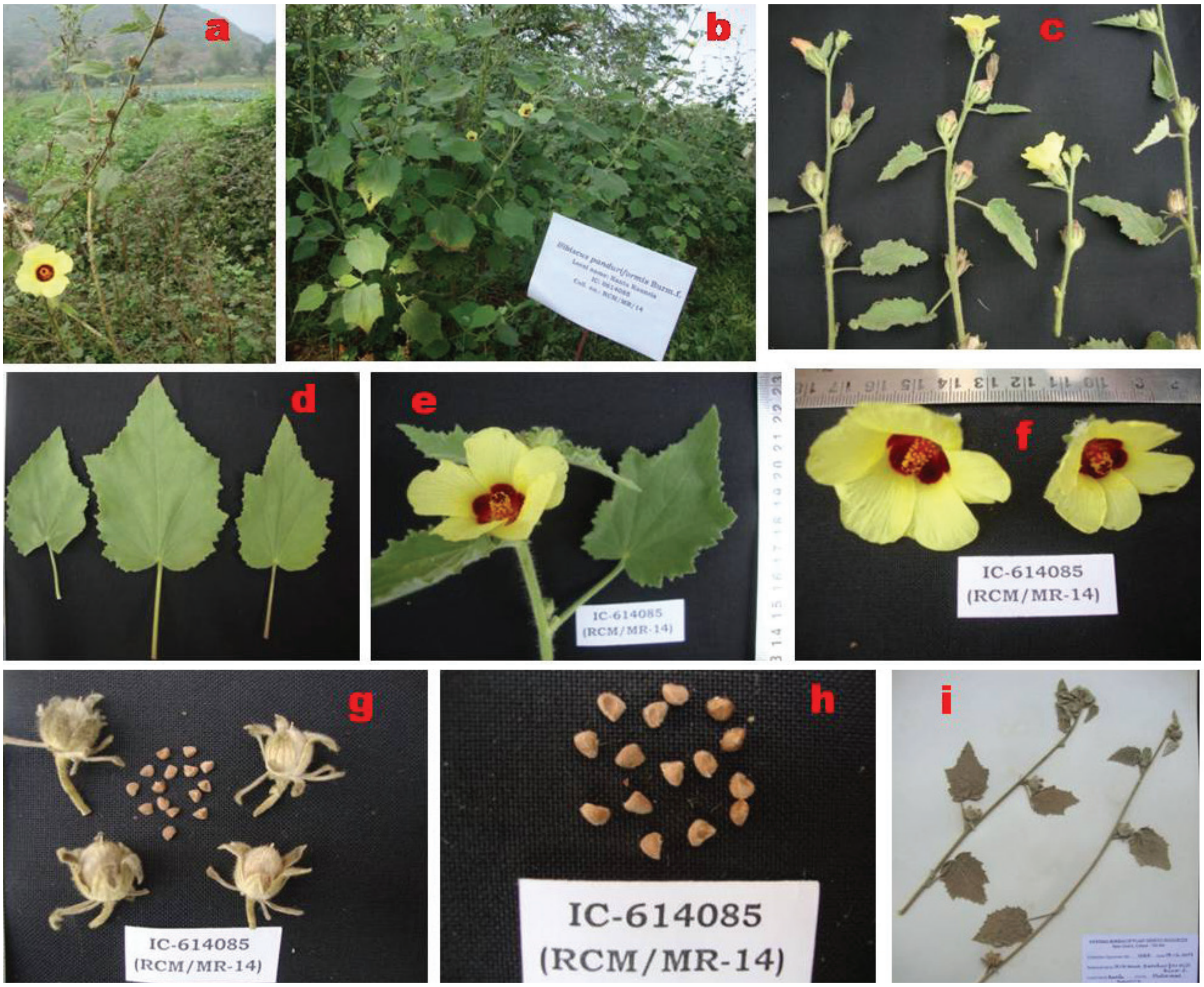

Fig. 1. *Hibiscus panduriformis*: a. Occurrence in natural habitat, b. Maintained in field gene bank, NBPGR regional station, Cuttack, c. Branch morphology, d. Structure of leaves, e. Apical twig, f. Flowers, g. Capsules, h. Seeds, i. Herbarium preserved at regional station, Cuttack

Habitat/ Ecology

The plant specimens were growing naturally in two different landforms in the disturbed habitats among the weeds on roadside wastelands and along the field bunds interspersed with herbs and grasses. The live specimens were recorded on the roadside near cultivated crop lands in Ganjam district in East coastal zone and the other was collected from a field bund in Kalahandi district in the Eastern Ghat zone of Odisha. The plant prefers tropical climate with open sunny areas and well-drained soils. The plants are readily propagated from seeds and sufficient seedlings were raised and further transplanted in the field gene bank of the centre for morphological observation and record.

Taxonomic description

Hibiscus panduriformis Burm.f. Fl.Ind.151.t.47.fig.2.1768; Master in Hook. f. Fl. Brit. Ind. 1:338.1874; Dunn in Gamble Fl. Presid. Madras 1:98.1915; Borss.Blumea 14:79.1966; Saldanha and Ramesh in Sald. Fl.Karnataka 1:251.1984; Paul and Nayar in Nayar et al. (eds.) Fasc. Fl.India 19:142.1988; Paul in Sharma and Sanjappa (eds.) Fl.India 3:339.1993 ('*panduraeformis*').

A tall erect undershrub up to 3 m height. Stem and branches pubescent with pungent rigid hairs, often with bristles. Leaves cordate-ovate, obscurely five-angled or five-lobed, 5-12 × 3-8 cm, 7-nerved at base, coarsely irregularly toothed, hoary-tomentose both sides, apexacute; petioles 3-8 cm, hairy; stipules and bracts filiform, hairy, caducous. Flowers are solitary, axillary and sub-terminal, 4-5 cm diameter; pedicel short, stout, axillary, solitary or in pairs, articulated near the middle. Involucellar bracts 8, free, linear-spathulate, densely ciliate, united into a cup at base, more than half as long as calyx. Sepals 5, lobes lanceolate, 3-angled, acute, prominently 3-nerved, hairy, 1.0-1.5 cm long. Petals 5, yellow with deep purple centre, hairy outside, ca 3.0 cm length and 2.5 cm width, adnate to staminal tube at the base. Staminal tube truncate, yellow, 10-15 mm long, filaments few. Ovary 5-celled, styles 5-fid above, stigma capitate or spathulate. Capsules ovoid, 1.5 × 1.0 cm included the calyx, densely hairy. Seeds angular, wedge shaped, 3 × 2 mm, densely velvety, brown. Flowering and fruiting: November to January.

Specimens examined and germplasms collected and conserved

i) Site 1: Odisha state, Ganjam district, Hinjilikatu block, nearby village: Burupada; 19° 29' 57.1 N latitude and 84° 41' 30.3''E longitude; R.C. Misra, HS number 1085 and 1086 (Herbarium of ICAR-NBPGR Base Centre, Cuttack), dated 13.12.2014; seed germplasm accession no. IC-614085 (collection no. RCM/MR/14); source: natural wild, disturbed, roadside wasteland; frequency: rare; Local name: *Kantakaunria*.

ii) Site 2: Odisha state, Kalahandi district, Bhawanipatana block, nearby village: Udayapur; 19° 57' 41.3" N latitude and 83° 14' 30.0" E longitude; R.C. Misra, HS number 1087 and 1088 (Herbarium of ICAR-NBPGR Base Centre, Cuttack), dated 20.12.2017; seed germplasm accession no. IC-627240 (collection no. RCM/PK/10); source: natural wild, disturbed, field bunds; frequency; rare; Local name: *Jangli nalita*.

Etymology

The genus name *Hibiscus* is an old Greek name for mallow and the species '*panduriformis*' is derived from fiddle-shaped or pandurate form of leaves.

Economic uses

The local people of Kalahandi district use the stem bark as coarse fibre after drying and dipping in water for making twines and ropes for thatching of huts and for fishing-lines. The flowers are consumed and the bastfibre is used for cordage in DR Congo and Tanzania. In Kenya, the stem bark is used for weaving bags.

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Mammalian diversity of Sunabeda Wildlife Sanctuary, Odisha, India

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ABSTRACT

A camera trap survey was conducted for terrestrial mammals in Sunabeda Wildlife Sanctuary from November to December 2018. Camera traps were deployed at 35 locations comprising of one pair camera trap which accumulated data over 875 camera trap-days. A total of 2650 photographs were captured out of which 632 photographs of mammals belonging to 12 families and 22 species were recorded. The leopard *Panthera pardus* was the most frequently captured species and had high relative abundance (RAI =7.31) among the other carnivore species and the Ruddy mongoose, *Herpestes smithii* (RAI =0.69) were represented by a relatively low abundance. Frequency of various anthropogenic activities related to movement of livestock, feral dogs and human traffic accounted for maximum photo capture and found to be negatively correlated with mammalian species. This result highlighted the fact that all mammalian species presence occurred in the sanctuary and were confirmed by the photographs captured, which resulted in knowing the distribution pattern of the species. In the study, assessing mammalian prey relative abundance and distribution are required to further manage the threatened and endangered species of the sanctuary.

Key words : Camera trap, livestock pressure, mammalian diversity, relative abundance index, Sunabeda

INTRODUCTION

Camera trap, which have been used widely in wildlife studies (Wemmer et al., 1996), are ideal for identifying the species in habiting a particular area, monitoring relative and absolute abundance of species and studying activity pattern (Karanth, 1995; Das et al., 2016). Camera traps have become an important tool for inventorying and estimating species diversity at a site (Cutler and Swann, 1999; Silveira et al., 2003; O'Connell et al., 2011). Camera trapping is a widely popular technique to study the presence and distribution of wildlife. While there are several types of camera traps, all models have the same basic principle: a photo (and / or video) camera protected by some sort of weather proof housing, coupled to a mechanism that allows the camera to be triggered automatically when an animal moves in front of it. Since camera traps were first used to estimate the density of tiger *Panthera tigris* populations in India (Karanth, 1995). This methodology has been widely used to study a variety of species: leopards *Panthera pardus* (Henschel and Ray, 2003; Kostyria et al., 2003). Due to increasing anthropogenic pressure, half the world's known mammalian species have declined and almost one among five are clearly at the verge of extinction (Anon, 2016). Although the use of Relative Abundance Index (RAI) generated from camera trap encounter rates is controversial as it gets biased with animal body mass and study design (Sollmann et al., 2013), there are examples of a linear relationship between RAI with abundance, estimation, especially of cryptic species (Karantha and Nichols, 1998; Datta et al., 2008; Rovero and Marshall, 2008; Jenks et al., 2011; Gonthier and

Castañeda, 2013; Lahker, et al., 2018). In recent years, camera trapping is increasingly used for species inventories and population abundance and has been widely used in the state of Odisha as well (Debata et al., 2015; Palei et al., 2015; Kar et al., 2018; Debata and Swain, 2018; Mishra et al., 2018; Palei et al., 2018 a,b; Palei et al., 2019 a,b; Debata and Swain, 2020).

In the western part of Odisha state, large stretch of dry deciduous natural shrubs are contiguous with Chhattisgarh forest and it has been degraded due to open coal mining. Sunabeda used to have good numbers of endangered wild buffalo (*Bubalus arnee*) till 1960s. At present, they are found in Udanti Wildlife Sanctuary in Chhattisgarh, about 20 km away, but there is a Patdhara Reserve Forest of Sunabeda Wildlife Sanctuary (Kotwal, 1997). Hunting, cattle borne disease and habitat destruction led to extinction of Wild Buffalo in the region. Efforts should be made to improve the habitat so that the wild buffalo can come back to Sunabeda using this corridor.

In the present study, the camera trap survey was carried out in the tropical dry deciduous forest of Sunabeda Wildlife Sanctuary in the western parts of Odisha to estimate mammalian species and their relative abundance and occurrence of anthropogenic disturbance.

MATERIALS AND METHODS

The sanctuary is located in the Western Odisha adjacent to the interstate border of Odisha and Chhattisgarh and situated between Latitude 20° 24' N to 20° 44' N and Longitude 82° 20' E to 82° 34' E located in the Nuapada District of Odisha (Fig. 1). The entire sanctuary area comes under the administrative control of Sunabeda Wildlife Division with headquarters at Nuapada in Nuapada district. This Wildlife Division has three ranges, i.e. Nuapada, Komna, and Sunabeda having headquarters at Nuapada, Komna, and Sunabeda, respectively. It was declared as a Wildlife Sanctuary in 1983 with total geographical area of 600 sq. km. This sanctuary comes under the Deccan Peninsular Zone of the Indian Bio-geographical Zone and Eastern Plateau Province and Chhattisgarh -Dandakaranya Sub-Division. The mean daily temperatures of winter range from 6°C to 20°C and that of summers range from 28°C to 47°C. The average annual rainfall varies from 600 to 1400 mm. Most of the villages are outside the sanctuary and most of the people belong to tribal community. Their activities inside forest are grazing livestock and collection of forest products (e.g. fodder for livestock, non-timber). The forest division is dominated by northern dry mixed deciduous forest, dry peninsular Sal forest and dry Teak forest (Champion and Seth, 1968).

These types of forests are seen in all the forest blocks and constitute about 75% of the crop found over all types of geological formations. The top canopy is open and irregular frequented with numerous large gaps. Trees in this type of forests have relatively shorter boles and poor form. The trees under this type remain completely leafless for a period of about four months beginning from the month February to the middle of June. With the onset of monsoon, the forests change their appearance with green foliage with their crowns and moderately dense undergrowth. In these forests the top level consists of mainly the following species. Asan (*Terminalia tomentosa*), dhaura (*Anogeissus latifolia*), bija (*Pterocarpus marsupium*), haldu (*Adina cordifolia*), mundi (*Mitragyna parviflora*), kusum (*Schleichera oleosa*), pahadi sissoo (*Dalbergia latifolia*), harida (*Terminalia chebula*), bahada (*Terminalia bellirica*), moi (*Garuga pinnata*), teak (*Tectona grandis*), kendu (*Diospyros melanoxylon*), sidha (*Lagerstroemia parviflora*), simul (*Bombax ceiba*) and jamun (*Syzygium cumini*). The tree species in the middle canopy are *D. latifolia, Morinda tinctoria, Buchanania lanzan, Cleistanthus collinus, Bridelia retusa, Acacia arabica*. The ground flora contains *Indigofera pulchella, Phoenix acaulis, Woodfordia fruticosa,* and *Holorrhena antidysentrica. Butea superba, Ventilago calyculata, Smilax macrophylla, Millettia auriculata* and *Bauhinia vahlii* etc. are the dominant climbers found in this type of forest.

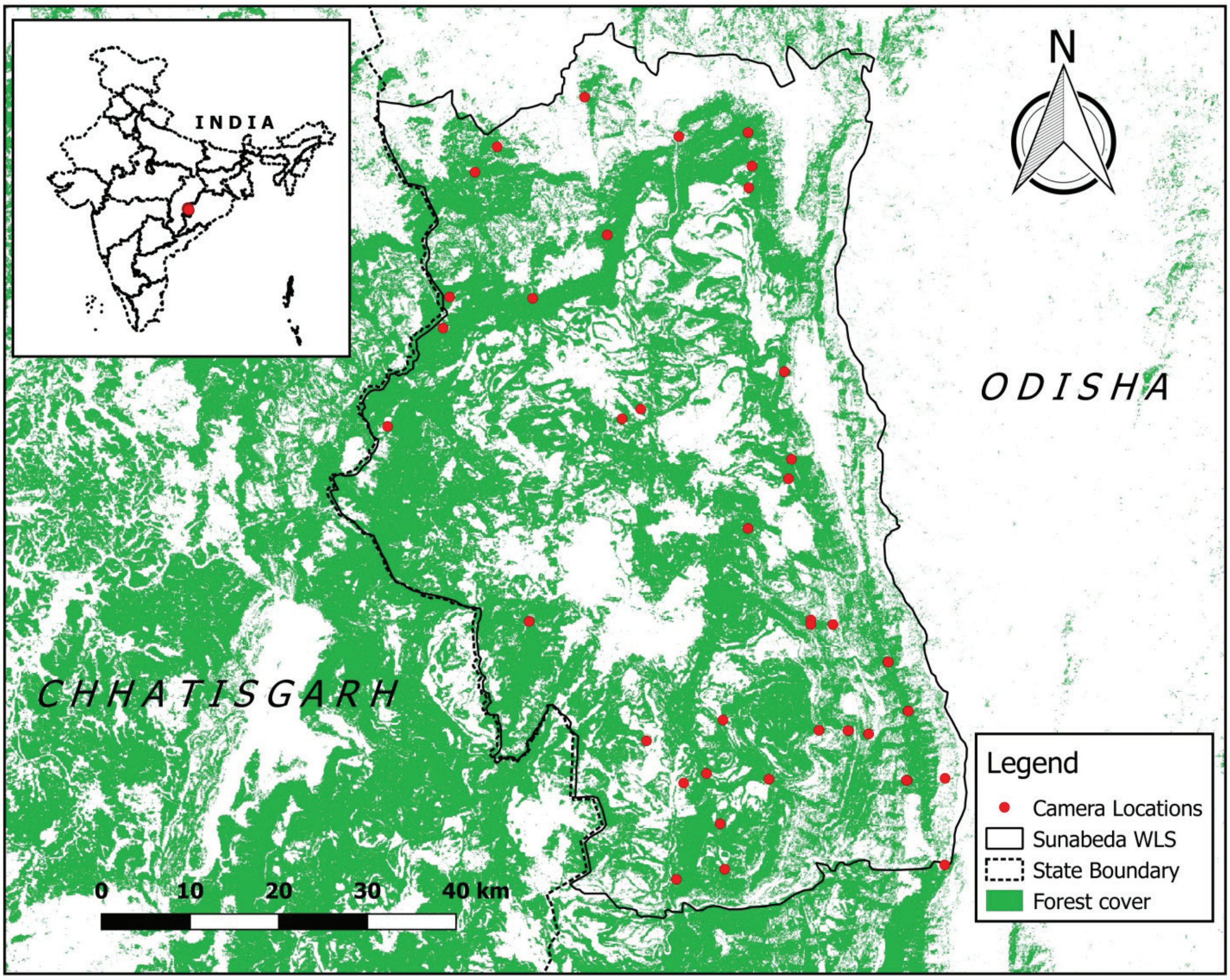

Fig. 1. Study area showing locations of camera traps in the Sunabeda Wildlife Sanctuary, Western Odisha.

An extensive reconnaissance survey was carried out in three wildlife forest ranges within Nuapada, Komna, and Sunabeda Range of Sunabeda Wildlife Sanctuary. During the survey, signs of carnivores, *viz.* scats, pug-marks, claw marks, scraps and scent marks, were recorded and geo-referenced using a geographical positioning system (GPS). To assess the status of carnivores and herbivores and their prey species in the study area, 70 numbers of motion sensor camera traps (Cuddeback Model C1) were used to carry out a mammal survey from 13th November 2018 to 7th December 2018 covering all the three ranges Sunabeda Wildlife Sanctuary. Camera traps were predominantly set along forest roads, game trails and footpaths. All camera traps were strapped to trees approximately 45 cm above ground. At each location, a pair of traps on either side of the path facing each other was set up to photograph simultaneously both flanks of the animal passing between the cameras. Each location consists one pair camera trap and set to operate 24 hours with programmed to delay sequential photographs by 30 second delay time for capturing for 25 days, yielding a total of 875 trap nights. Each camera traps were checked at least once a week for battery level, positioning and to replace memory (SD) cards. Each and every photograph was manually checked to identify the species. Total sampling effort was calculated as the sum of the effective days across all stations that each camera was functioning (Boitani and Powell, 2012). Photos separated by at least 30 minutes were considered as independent events (Ohashi et al., 2013; Guo et al., 2017). Data on large and medium sized mammals, bird, reptiles, birds, human traffic and livestock including date time, year and behavior were collated from camera trap photographs. Relative abundance was calculated as RAI = A/N × 100

Where A is the total number of detections of a species by all cameras and N is the total number of camera trap days by all the cameras throughout the study area following Jenks et al. (2011). All photographs of animals captured in the camera traps were identified to the species level and the time and date of the capture (inbuilt in the camera) were noted. Consequently, each photo was rated as a dependent or independent event. All camera trap pictures were screened for the presence of animals and all data was entered in an Office Access 2010 database. Identification of the animals was done using the field guide (Menonn, 2016).

RESULTS AND DISCUSSION

A total of 35 camera trap locations with an effort of 875 trap nights with 2650 photographs were captured. Out of which 632 photographs were of mammals belonging to 22 mammalian species from 12 families. The mammals reported were from six carnivore species, nine herbivore species, three omnivore species, two primate species, two rodent species and four bird species. Table 2 shows all identified species (common and scientific names), the total number of pictures obtained, the RAI for each species as well as the total number of locations where each species was photographed. Out of the twenty two species of mammals, two species have been categorized as Endangered, two species as Vulnerable, and one species as Near Threatened sixteen species as Least Concern and 1 species as Lower risk as per the IUCN Read list of Threatened species (IUCN, 2017; Table 1). Out of all the photographs, majority of them were anthropogenic i.e. movement of livestock, feral dog and human traffic (72%; n=1917), whereas the rest (24%; n=632) were wildlife, mostly herbivore mammals (13%; n=344) followed by carnivore mammals (7%; n=191), omnivore mammals (4%; n=97), birds (4%; n=101) (Fig. 3).

In Sunabeda Wildlife Sanctuary, during the camera trap survey we recorded the large and medium-sized mammalian species. The large carnivores, *Panthera pardus,* were detected in all locations in contiguous forest and represented high relative abundance (RAI =7.31) among the carnivore while the Indian grey wolf (*Canis lupus)* was among the omnivores (RAI = 6.40) and the Hanuman Langur *(Presbytis entellus)* (RAI =6.17). Besides that, camera traps also captured four bird species including the Jungle fowl *(Gallus gallus)* (RAI=5.37) followed by Indian peafowl (*Pavo cristatus)* (RAI=4.34) and Grey francolin (*Francolinus pondicerianus*) (RAI=1.37) and Painted spurfowl *(Galloperdix lunulate)* was the minimum photographed species (RAI=0.46) (Fig. 2). Ruddy mongoose *(Herpestes smithii)* (RAI=0.69) was the rarest species photo-captured followed by Nilgai *(Boselaphus tragocamelus)* (RAI=0.91) and striped hyaena *(Hyaena hyaena)* (RAI=0.91). Leopard, *Panthera pardus,* was distributed throughout the sanctuary with relatively higher concentration in the periphery of the core zone in moderately dense forests. However, few captures were also obtained towards the eastern side of the sanctuary in the buffer zone. Grey wolf *(Canis lupus)* showed patchy distribution within the sanctuary with higher concentration of photo-captures within the moderately dense forest and open forest within the buffer area. Jungle cat (*Felis chaus*) was photo captured at ten locations, mostly on the buffer area of the sanctuary. Sambar *(Rusa unicolor)* and cheetal *(Axis axis)* photo-captures was recorded within moderately dense forests and the open forests of the core zone. Apart from this, few captures were also found in the very dense forests. Sloth bear *(Melursus ursinus)* was distributed throughout the sanctuary with higher concentration of photo-captured in the central and eastern side of the sanctuary. Four-horned antelope *(Tetracerous quadricornis)* was distributed throughout the sanctuary with higher concentration of photo-captures in the core zone of Sunabeda plateau. Golden jackal *(Canis aureus)* was distributed throughout the western part of the buffer zone in the sanctuary with relatively higher concentration of photo-captures on the Patadhara, Gatibeda and Manikagarh and the adjoining of Sunabeda plateau. Hanuman langur (*Presbytis entellus)* and rhesus macaque *(Macaca mulatta)* were distributed throughout the sanctuary with higher concentration of photo-captures towards the north and north-western boundary of the core and in moderately dense forests of the buffer zone. Grey mongoose *(Herpestes edwardsii)*, ruddy mongoose *(Herpestes smithii)* common palm civet *(Paradoxurus hemaphroditus)*, small Indian cvet *(Viverricula indica)*, honey badger *(Mellivora capensis)* and Indian hare *(Lepus nigricollis)*, was photo captured at very few locations, mostly on the inside of the sanctuary.

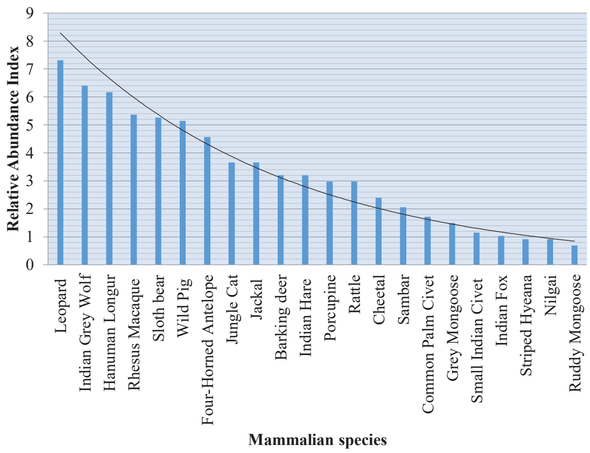

Fig. 2. Relative abundance index of different mammals in Sunabeda Wildlife Sanctuary from November to December 2018.

During the camera traps period various anthropogenic activity including human traffic and livestock photographs captured. As per activity cattle, goat, buffalo, camels, horses, sheep and donkeys was the maximum photograph activity (RAI=85.94) followed by private vehicle (RAI=40.69), villagers (RAI=37.14), department vehicle (RAI=20.80), forest department staff (RAI=16.00), feral dog (RAI=14.40) and poachers (RAI=4.11). It is observed that detection rate and relative abundance index of livestock was higher than any other species photo-captured in Sunabeda Wildlife Sanctuary and is indicative of a high level of anthropogenic disturbances of the sanctuary. As per report of the Wildlife Management Plan of the sanctuary (Banchhur, 2007), wild buffalo (*Bubalus arnee)*, Indian gaur *(Bos gaurus)*, wild dog *(Cuon alpinus)*, leopard cat (*Prionailurus bengalensis)*, fishing cat *(Prionailurus rubiginosus)*, pangolin *(Manis crassicaudata)* and mouse deer (*Moschiola indica)* are distributed all over the sanctuary, but there is no photo captured during the camera trap period and also there is no photographs captured of tiger *(Panthera tigris)*. Since it is adjacent to Udanti-Sitanadi Tiger Reserve of Chhattisgarh State, it can be a potential site for tigers to breed in the wild. Steps to expedite the process of declaration of Sunabeda Wildlife Sanctuary to Sunabeda Tiger Reserve shall change the scenario in terms of management which will emerge the area as a potential tiger reserve. The sanctuary requires intensive management input in terms of habitat management and law enforcement for increasing the prey base. It is well connected to Udanti-Sitanadi Tiger Reserve in the west and has remote connectivity with the Indravati Tiger Reserve of Chhattisgarh. Better management interventions such as minimizing human disturbance and prey augmentation would be required for improving the wildlife conservation status for this area (Jhala et al., 2020). Hence, this landscape has been identified as a potential tiger meta-population landscape and requires intensive conservation efforts for better gene pool exchange. Connectivity between these sites should be protected for the future tiger and wildlife conservation. About 52 villages, with 11572 human population and 8303 cattle population fragment this sanctuary. The villagers subsist on forest products to a great extent, as they have land holdings with poor yield.

Since Sunabeda Wildlife Sanctuary is connected with Chhattisgarh state in the western side, the nomads from other adjacent states bring their livestock in form of camels, horses, goats sheep, donkeys, cows and buffaloes to graze in the sanctuary causing a severe biotic pressure (Fig. 26). Also, the villagers in the plateau use the sanctuary as their grazing ground. This was clearly proved during the camera trap survey. Grazing has affected the regeneration of forest in the sanctuary which may lead to human-animal interface. In the current case the staff should be vigilant along the border to prevent any intrusion of livestock. This may lead to better connectivity with Udanti-Sitanadi Tiger Reserve and further to Indravati Tiger Reserve. Long term management and conservation efforts should be taken to overcome this issue. Livestock movement in the sanctuary may spread diseases from domestic to wild animals. Due to grazing in the sanctuary there may be shortage of food for herbivores which may directly affect the population of large cats. During grazing cattle lifting by large cats cannot be ruled out along with human causality.

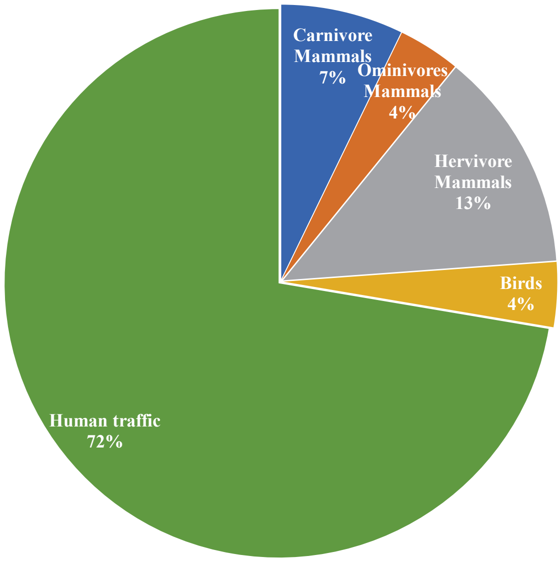

Fig. 3. Different wildlife species and others activities based on camera trap photographs captured in Sunabeda Wildlife Sanctuary

Fig. 4. Leopard, *Panthera pardus*

Fig. 5. Jungle cat, *Felis chaus*

Fig. 6. Indian grey wolf, *Canis lupus*

Fig. 7. Jackal, *Canis aureus*

Fig. 8. Hyeana, *Hyaena hyaena*

Fig. 9. Indian fox, *Vulpes bengalensis*

Fig. 10. Sloth bear, *Melursus ursinus*

Fig. 11. Wild pig, *Sus scrofa*

Fig. 12. Porcupine, *Hystrix indica*

Fig. 13. Nilgai, *Boselaphus tragocamelus*

Fig. 14. Sambar, *Rusa unicolor*

Fig. 15. Cheetal, *Axis axis*

Fig. 16. Four horned antelope, *Tetracerus quadricornis*

Fig. 17. Barking deer, *Muntiacus muntjak*

Fig. 18. Honey badger, *Mellivora capensis*

Fig. 19. Indian hare, *Lepus nigricollis*

Fig. 20. Rhesus macaque, *Macaca mulatta*

Fig. 21. Hanuman langur, *Presbytis entellus*

Fig. 22. Small Indian civet, *Viverricula indica*

Fig. 23. Common palm civet, *Paradoxurus hermaphroditus*

Fig. 24. Grey mongoose, *Herpestes edwardsi*

Fig. 25. Ruddy mongoose, *Herpestes smithii*

Fig. 26. Activities of livestock in Sunabeda Wildlife Sanctuary, Nuapada

Table 1. Comparative Relative Abundance Index (RAI) of different wildlife species and others based on camera trap photographs in Sunabeda Wildlife Sanctuary during the field-work with their current IUCN status and type of encounter

Sl.	Common Name	Families	Scientific Names	WPA Status	IUCN Status	N Camera trap stations with occurrence	%	Total Photo Captured	RAI
1	Leopard	Felidae	*Panthera pardus*	Schedule-I	VU	15	42.86	64	7.31
2	Jungle cat	Felidae	*Felis chaus*	Schedule-II	LR	10	28.57	32	3.66
3	Indian grey wolf	Canidae	*Canis lupus*	Schedule-I	LC	8	22.86	56	6.40
4	Jackal	Canidae	*Canis aureus*	Schedule-II	LC	5	14.29	32	3.66
5	Striped hyeana	Canidae	*Hyaena*	Schedule-III	NT	8	22.86	8	0.91
6	Indian fox	Canidae	*Vulpes bengalensis*	Schedule-II	LC	5	14.29	9	1.03
7	Sloth bear	Ursidae	*Melursus ursinus*	Schedule-I	EN	17	48.57	46	5.26
8	Wild pig	Suidae	*Sus scrofa*	Schedule-III	LC	20	57.14	45	5.14
9	Porcupine	Hystricidae	*Hystrix indica*	Schedule-IV	LC	7	20.00	26	2.97
10	Nilgai	Bovidae	*Boselaphus tragocamelus*	Schedule-III	LC	3	8.57	8	0.91
11	Four-horned antelope	Bovidae	*Tetracerus quadricornis*	Schedule-I	EN	30	85.71	40	4.57
12	Sambar	Cervidae	*Rusa unicolor*	Schedule-III	VU	7	20.00	18	2.06
13	Cheetal	Cervidae	*Axis axis*	Schedule-III	LC	2	5.71	21	2.40
14	Barking deer	Cervidae	*Muntiacus muntjak*	Schedule-III	LC	5	14.29	28	3.20
15	Honey badger	Mustelidae	*Mellivora capensis*	Schedule-I	LC	18	51.43	26	2.97
16	Rhesus macaque	Cercopithecidae	*Macaca mulatta*	Schedule-II	LC	12	34.29	47	5.37

17	Hanuman langur	Cercopithecidae	*Presbytis entellus*	Schedule-II	LC	9	25.71	54	6.17
18	Small indian civet	Viverridae	*Viverricula indica*	Schedule-II	LC	3	8.57	10	1.14
19	Common palm civet	Viverridae	*Paradoxurus hermaphroditus*	Schedule-II	LC	5	14.29	15	1.71
20	Grey mongoose	Herpestidae	*Herpestes edwardsii*	Schedule-II	LC	2	5.71	13	1.49
21	Ruddy mongoose	Herpestidae	*Herpestes smithii*	Schedule-II	LC	3	8.57	6	0.69
22	Indian hare	Leporidae	*Lepus nigricollis*	Schedule-IV	LC	5	14.29	28	3.20
	Birds								
23	Indian pea fowl	Phasianidae	*Pavo cristatus*	Schedule-I	LC	15	42.86	38	4.34
24	Red jungle fowl	Phasianidae	*Gallus gallus*	Schedule-IV	LC	18	51.43	47	5.37
25	Painted spurfowl	Phasianidae	*Galloperdix lunulata*	Schedule-IV	LC	2	5.71	4	0.46
26	Grey francolin	Phasianidae	*Francolinus pondicerianus*	Schedule-IV	LC	5	14.29	12	1.37
	Human traffic and livestock								
27	Forest department staff					25	33.78	140	16.00
28	Department vehicle					15	20.27	182	20.80
29	Private vehicle for villagers					26	35.14	356	40.69
30	Villagers					28	37.84	325	37.14
31	Poachers					12	16.22	36	4.11
32	Cattle, goat and buffalo					35	47.30	752	85.94
33	Feral dog					21	28.38	126	14.40

(EN-Endangered, NT-Near Threatened, VU- Vulnerable , LC- Least Concern, LR-Lower Risk, RAI- Relative Abundance Index, IUCN-International Union for Conservation of Nature, WPA-Wildlife Protection Acts)

In the present context for management of habitat and livestock, there is immediate need to strengthen the protection activities to control on livestock grazing by deployment of staff at the entry point in form of random patrolling. Awareness campaign along the forest fringe villages can be the way forward to the issue.

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Successful rescue and rehabilitation of an injured wild sloth bear trapped in a poacher's snare

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ABSTRACT

An adult male sloth bear of ten years of age was rescued by Karnataka Forests Department, Bellary division was shifted to Wildlife SOS, Bear Rehabilitation Centre with a severely injured left hind limb severed at the level of metatarsals. The paw was putrefied with purulent exudation and loosely hanging broken metatarsals. After immobilizing the bear with medetomidine-ketamine at 0.05 mg kg^{-1} and 3 mg kg^{-1} body weight, respectively the wound edges were debrided for apposition. Necrotic tissues and three remaining metatarsals were removed and four stay sutures were placed. Suturing was accomplished with 2-0 absorbable sutures and the wound was dressed with 5 % povidone iodine and vet wrap. The wound was secured with a fluid bottle, tied to the paw of the sloth bear to prevent the soiling of the wound. Therapeutic management was done using long acting antibiotics like Benzathine penicillin @ 40,000 IU kg^{-1} q 7 days and Enrofloxacin @ 5 mg kg^{-1} q 72 hour for 20 days. Administration of fluids at the rate of 50 ml kg^{1} and opioid analgesics (Tramadol @ 5 mg kg^{-1}) was done at the time of surgery. Thereafter, regular dressing was done with collagen silver sulphadiazine cream and antiseptic powder. Analgesia was achieved by oral supplementation with gabapentin @ 2 g for 10 days. Also, for the prevention of decubitus ulcers, a wooden plank was placed in the bear enclosure. After continuous dressing for 60 days the wound showed remarkable healing. Partial amputations and post-operative management are often lifesaving human interventions that become necessary in human-animal conflict zones.

Key words: Amputation, gabapentin, sloth bear, snare trap

INTRODUCTION

Melursus ursinus, commonly known as the Indian Sloth bear, is an endemic inhabitant of the Indian subcontinent with population scattered across several Indian states, but primarily concentrated in Central India and southernmost forest ranges of the Western Ghats (Yoganand et al., 2006). They are primarily confined to moist and dry deciduous forests but can also be found in moist evergreen forests, rocky outcrops, and caves (Kumar et al., 2014; Abdul and Hosseti, 2016). The Indian sloth bear has been considered as a "Vulnerable" species by the International Union for Conservation of Nature and Natural Resources (IUCN) Red List and remains protected under Schedule 1 of the Indian Wildlife (Protection) Act, 1972 (Shanmugam et al., 2008; Singh et al., 2018).

Ecological studies of sloth bear have speculated that the lower metabolic rates and high thermal conductance in them have been associated with their dense fur and myrmecophagic and frugivorous feeding habits (McNab, 1992). This adaptation has also enabled them to survive in sweltering hot climatic conditions by restricting themselves to nocturnal activities. Anatomical features such as a missing pair of upper incisors and protruding loose lips have led to them extensively feeding on termites, ants, and fruits (Shanmugam et al., 2008). Despite these evolutionary adaptations, the sloth bear population is threatened.

Since historical times, illegal sloth bear poaching has been rampant for live animal trade, bear meat, and traditional Chinese medicine. The barbaric practice of "dancing sloth bears" was a significant reason for poaching of bear cubs by the Kalandar community for exhibition and entertainment purposes. (Shanmugam et al., 2008; Palita et al., 2014; Crudge et al., 2020). Traditional Chinese medicines used bear gallbladder and bile for treatment of cardiac problems, eye puffiness, asthma, cancer, burns, liver problems, and impotence (Feng et al., 2009). Reproductive organs of the male sloth bears were considered as aphrodisiacs and used as sex stimulants by the Pardhi-Behelia tribe.

Reports of accidental deaths of Schedule I animals from wildlife corridors and surrounding human settlements have shown a steady rise over the years, owing to the illegal installations of snare traps to protect farmlands from the nuisance caused by wild boars (Gupta, 2017). The Karnataka Forest Department has adopted several conservation efforts in collaboration with the Bannerghatta Biological Park and Wildlife SOS in rehabilitating sloth bears that fall prey to this snare culture. The current case report describes the rescue and rehabilitation of one such sloth bear that was found to be trapped in a deadly snare trap in the Bellary district of Karnataka.

CASE REPORT

Rescue operation

The present paper describes the rescue and rehabilitation of a male wild sloth bear trapped in a poacher's snare in the Bellary district of Karnataka. Wildlife SOS, in collaboration with Karnataka Forest Department, received a call from the Bellary forest range regarding a distressed sloth bear with a snare wrapped around his foot. Upon reaching the site, the rescue team observed that the snare was tightly fastened around the left foot of the sloth bear, at the level of the metatarsals with severed toes and multiple wounds on the body. After retracting the snare from the bear's ankle, the sloth bear was brought to the Bannerghatta Bear Rescue Centre (BBRC), Bannerghatta Biological Park, for further treatment and therapy.

Emergency veterinary care

Upon arrival at BBRC, the sloth bear was sedated using Medetomidine-Ketamine combination @ 0.05 mg kg^{-1} and 3 mg kg^{-1} body weight, respectively, and was subjected to complete health examination. Blood samples were collected, and radiographs of the injured left foot were taken.

Fig. 1. Sedation of the injured wild sloth bear for blood collection and radiography

Fig. 2. Injured left hind foot with severed toes and broken metatarsals

The injured leg was flushed with the hydrogen peroxide solution and dressed with collagen-based ointment and antiseptic powders, followed by bandaging to prevent contamination of the wound. In an attempt to stabilise the severely dehydrated bear, immediate treatment with fluids and supplements was initiated. Long-acting Benzathine penicillin @ 40,000 IU kg^{-1} administered for antibiotic cover. Supportive therapy with anti-inflammatory drug (Meloxicam @ 0.2 mg kg^{-1}) and analgesic (Tramadol @ 5 mg kg^{-1}) was undertaken for pain management.

Fig. 3. Cleaning and dressing of the injured foot with hydrogen peroxide followed by sterile bandaging

Stabilization of the patient

The sloth bear was kept under observation for ten days during which the injured leg was regularly cleaned and dressed inside the squeeze cage. Analgesia was achieved by providing Gabapentin @ 5 mg kg^{-1}, and infection was kept under control by long-acting Enrofloxacin @ 5 mg kg^{-1}. The bear was given fruits and honey and was slowly introduced to the cereal-based porridge mixed with milk.

Surgical intervention

Surgical correction of the injured foot was necessary to remove the loosely hanging metatarsals and the surrounding necrotic tissue. The sloth bear was fasted for 12 hours before sedating with Xylazine-Ketamine combination @ 2 mg kg^{-1} and 5 mg kg^{-1}, respectively. A series of radiographs were taken to assess the damage to the injured foot.

Fig. 4. Surgical debridement of the wound to remove surrounding necrotic tissue, and broken metatarsals

The leg was thoroughly cleaned with ciprofloxacin solution, and the remaining three loosely hanging broken metatarsal bones were retracted. Debridement of the necrotic tissues was done to facilitate apposition of the wound edges, which were sutured using absorbable 2-0 polyglycolic acid (PGA) suture material.

A total of four loop sutures were placed at the level of the ankle for securing the bandage. The sutured tissue was flushed and dressed with povidone iodine solution and antibiotic powder. Bandaging was done with sterile gauze after placement of cotton padding and covered with vet wrap. The bandaged limb was secured with a fluid bottle to prevent contamination of the wound.

Fig. 5. A three-layer compression bandage was applied over the wound after surgical procedure. Couple of stay sutures were applied to hold the bandage in position

Post-operative management

The sloth bear was housed at the sick animal room for observation post the surgical procedure. Combination course of Enrofloxacin @ 5 mg kg^{-1} q3 days and Benzathine penicillin @ 40,000 IU kg^{-1} q10 days was given along with antacid (Rantac 0.5 mg kg^{-1}). Analgesia was achieved with gabapentin @ 5 mg kg^{-1} orally. Regular cleaning of the wound and dressing with silver sulphadiazine collagen-based cream and cipladine antiseptic powder was done through the squeeze cage. The sloth bear was provided with a nutritious cereal based porridge along with milk and honey and fresh fruits as enrichment. Development of decubitus ulcers was controlled by placement of a wooden plank in the enclosure with soft bedding for comfort.

RESULTS AND DISCUSSION

An injured wild sloth bear trapped in a poacher's snare was rescued from Bellary district of Karnataka and rehabilitated at the Bannerghatta Bear Rescue Centre, under the Bannerghatta National Park. Preliminary blood testing revealed that the sloth bear was severely dehydrated and anaemic with slightly elevated white blood cells. Serum biochemistry showed hypoproteinemia, elevated liver enzymes, and lactate dehydrogenase levels indicative of tissue damage along with electrolyte imbalances. Radiographic evaluation of the injured leg revealed completely severed metatarsal bones due to the poacher's snare.

Surgical correction of the left foot resulted in gradual healing of the wound after 90 days during which the leg was regularly cleaned and dressed through the squeeze cage.

The sloth bear was provided the required nourishment with a balanced cereal-based porridge diet along with honey and seasonal fruits, which resulted in weight gain and hastened the recovery of the bear. Supplementation of the sloth bear with oral haematinics and liver tonics resulted in the improvement of the anaemia and body condition.

Fig. 6. Radiographic image of both normal and damaged digits of hind limb of the injured wild sloth bear

Fig. 7. The injured foot 10 days after the procedure with intact sutures and no exudation

Fig. 8. The gradual formation of granulation tissue and complete closure of the wound after 90 days of dressing

Fig. 9 (a and b). Complete healing of the wound and proper weight bearing was observed by the end of six months

The sloth bear had shown remarkable improvement after three months of therapy. Before re-introducing the sloth bear to the socialisation area along with other bears, he was trained to follow simple commands like "hands out" and "open mouth", using dates and honey. This practice also termed as "positive conditioning" that helps not only in strengthening of the bond between the keeper and the animal, but also enables the veterinary team to perform simple procedures like blood collection, nail trimming and wound dressing, efficiently. Within a couple of months after complete healing of the wound and stable health, the sloth bear was released into the socialisation area with other bears.

The barbaric practice of using snare traps for poaching of wild animals by poachers has been practiced, for decades, favouring the illegal trade and marketing of animal organs (Lee, 1995; Shepherd and Shepherd, 2010). Several modes of poaching, including firearms, the country-made explosives and muzzle-operated guns, have been widely used by poachers in spite of which wire snares are preferred among poachers due to their easy installation with very meagre investment. Besides this, snare traps are not easily visible in forest patches unless they are being searched for meticulously. These snare traps either kill or amputate the animal, leading to lifelong casualties and the inability for them to be released into the wild again (Hermon, 2017; Balseiro et al., 2020).

Snare trap injuries are very complicated and require prompt veterinary intervention to save the life of the distressed animal. Animals trapped in snares often struggle very hard to free themselves by pulling or biting the wires leading to additional trauma and dental injuries. They suffer from starvation, thirst, strangulation, self-mutilation wounds, excruciating pain, and discomfort, and sometimes, even predation from carnivores (Rochlitz et al., 2010). On several occasions, even before the arrival of the rescue team, local people would end up cutting one end of the snare attached to a tree branch, setting the bear free. Such human interventions cause more harm as the bear still entangled within the trap starts running frantically, aggravating the injuries. Severely injured sloth bears unable to move into deeper areas of forests stay near the forest fringes surrounding human settlements leading to more conflict zones. Rescued animals fight a long battle against physical injuries as well as mental trauma, and have to undergo several correction surgeries, which is why most of the time, they end up losing the functionality of the affected body part.

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Vegetative propagation of Guggul [*Commiphora wightii* (Arn.) Bhan.]: A commercially important and threatened medicinal plant species

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ABSTRACT

Vegetative propagation of *Commiphora wightii* through semi-hardwood branch cuttings was undertaken in the experimental nursery of College of Forestry, Navsari Agricultural University, Navsari. Total five treatments of different concentration of IBA (control, 500, 1000, 1500, 2000 ppm) in three repetitions were undertaken with completely randomised design. Maximum establishment of 90 per cent with significantly superior number of leaves (7.2) and branches (3.64) along with the maximum length of shoot, length of root and number of roots (91.26 cm, 21.93 cm and 8.16, respectively) were recorded in semi-hardwood branch cuttings of *C. wightii* treated with IBA@1000 ppm as compared to other treatments. Moreover, cuttings treated with 1000 ppm IBA exhibited increase in length of shoot, number of leaves per plant, number of branches, length of root and number of roots per plant of 86.97%, 188%, 30.94%, 74.32% and 226.4%, respectively as compared to the control. Thus, *C. wightii* can be propagated by using its semi-hardwood cuttings treated with 1000 ppm IBA for production of quality planting materials.

Key words: Branch cuttings, *Commiphora wightii*, guggul, IBA, vegetative propagation

INTRODUCTION

Commiphora wightii belongs to family Burseraceae is one of the slow growing medicinal plant species. It is commonly known as Guggul in Hindi and Indian myrrh or Indian bdellium in English. Four species of the genus *Commiphora viz. C. wightii*, *C. agallocha*, *C. caudata and C. stocksiana* were reported from India (Patel et al., 2013 and Bishoyi et al., 2018). Out of these four species, *Commiphora wightii* is highly valued for its medicinally important guggul gum resin. It is a perennial, highly branched, thorny and woody shrub. It thrives well in arid, semiarid and rocky regions with scanty rainfall. The plant is normally with a long dormant phase having deciduous with dimorphic in nature (Dalal and Patel, 1995). *C. wightii* is distributed naturally in pockets of Rajasthan, Gujarat, Maharashtra and Karnataka, Madhya Pradesh in India and adjoining countries of Sind, Baluchistan and Afghanistan (Atal et al., 1975; Lal and Kasera, 2010). In India, Rajasthan and Gujarat have been identified as the main commercial centres (Mertia et al., 2010).

The plant has enormous economic value and a broad range of medicinal uses in both ancient and modern therapeutics. The plant yields medicinally important natural gum resin and has wide ethnobotanical usage (Singh and Pandey, 2006). Further, guggul gum is known to be hypolipidemic, hypocholestrolemic and antiobesity, astringent and antiseptic, antiarthritic, antimicrobial, antiinflammatory and anticancerous (Tripathi et al., 1968; Kasera et al. 2002; Urizar and Moore, 2003; Ishnava et al., 2010). The gum is also used in perfumery, calico- printing, fumigation, dyeing silk and cotton and as incense (Reddy et al., 2012).

Moreover, over a hundred metabolites of various chemical compositions were reported from the leaves, stem, latex, root and fruit samples. High concentrations of quinic acid and myo-inositol were found in fruits and leaves. *C. wightii* has been a key component in ancient Indian Ayurvedic system of medicine. The extract of gum guggul, called gugulipid, guggulipid, or guglipid, has been used in Unani and Ayurvedic medicine, for nearly 3,000 years in India (Mohan et al., 2019).

C. wightii has been included in IUCN Red data list whereas UNDP has listed this species as "Critically Endangered" (UNDP, 2008). The Govt. of India has banned the export of this species. Presently this species is under threat in its entire range of distribution in Rajasthan and Gujarat (Reddy et al., 2012). Several reasons such as low global and regional distribution, decline in population, narrow extent of occurrence, poor seed setting with meagre seed germination rate, over exploitation, are responsible for the plant being listed as endangered species (Mertia et al., 2010; Reddy et al., 2012). As there is inadequate replenish in their natural habitat, for the in situ as well as ex situ conservation of highly medicinally important plant, there is an immense need for multiplication and large scale commercial plantation (Diwakar et al., 2011).

The major constraint in cultivation and domestication of *C. wightii* is lack of availability of quality planting material due to delayed germination. In scientific observations, it was noticed that propagation of *C. wightii* through seeds is a not viable method due to its slow and erratic germination. Hence, there is need for alternative method to generate quality planting materials. Vegetative propagation through stem cutting is most common and successful method (Kumar et al., 2006; Thosar and Yande 2009; Hamayoun and Zahiryan, 2019). For the successful of propagation through stem cuttings, auxins play a vital role in coordination of plant growth and behavioural processes in the life cycle. While treatment of auxins given to the cuttings, mostly enter through the cut surface. Role of some auxins like IAA, IBA and NAA has been examined for their stimulatory effects on adventitious root formation in stem cuttings as well as on subsequent growth and survival of cuttings. It induces shoot apical dominance as the axillary buds are inhibited by auxin. When the apex of the plant is removed, the inhibitory effect is eliminated and the growth of lateral buds is enhanced (Kenney et al., 1969; Pop and Pamfil, 2011; Gehlot et al., 2014; Sure et al., 2018).

Since Guggul is placed in endangered category with immense medicinal values and, the recent trial was carried out with the objective to develop a suitable propagation technique for large scale production of quality planting material of *C. wightii* under South Gujarat conditions.

MATERIALS AND METHODS

The experiment was conducted at nursery of College of Forestry, Navsari Agricultural University, Navsari (Gujarat) during the year 2020. The healthy propagation material of semi hardwood branch cuttings for the experiment was collected from the Centre for Agroforestry, Forage crops and Greenbelt, Sardarkrushinagar Dantiwada Agricultural University Sardarkrushinagar, Dantiwada. Semi-hardwood portion of the branches of vigorously growing and disease pest free plant were selected for collection of propagation material. The stem cutting size of 8-10 mm diameter and 15 cm length were prepared by giving a slant cut at the base. The basal portion of the cuttings was dipped for 10 minutes in freshly prepared different concentrations of IBA solution as rooting hormone. Immediately after treatment with growth hormone IBA, cuttings were planted in the poly bags of size 6×8 inch which were properly filled with potting media comprising of soil+sand+FYM in the ratio of 2:1:1.

The cuttings were placed in open nursery and watered regularly. The experiment was laid out in completely randomized design with three repetitions having 20 cuttings in each repetition. Data were recorded daily for sprouting up to 30 days after planting and plants shoot developed from these sprouting containing branches and leaves were considered as establishment which were further considered for growth parameters observation. The shoot parameters like shoot length (cm), number of branches per plant, number of leaves per plant and root parameters of root length (cm) and number of roots were recorded at 180 days after planting. The experimental data recorded on various parameters were statistically analysed as per the method suggested by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Influence of different concentrations of IBA on growth parameters of guggul branch cuttings are presented in (Table 1). From the perusal of data, it was observed that, different concentrations of IBA had a significant effect on growth parameters of guggul. Data indicated that branch cutting treated with 1000 ppm of IBA observed higher percentage of establishment (90.00%) and was at par with IBA 1500 ppm (83.33 %), whereas the minimum establishment percentage (56.66%) was recorded in cuttings treated with 500 ppm. Further, early sprouting initiation was observed in IBA @ 1500 ppm at 18 days which was at par with 2000 ppm and 1000 ppm at 18.33 and 21 days, respectively. Other parameters such as length of shoot, number of leaves per plant and number of branches per plant were recorded the highest in IBA @1000 ppm. The maximum length of shoot (91.26 cm), the highest number of leaves (7.20) and branches (3.64) were observed in cuttings treated with IBA @1000 ppm, whereas the minimum length of shoot (48.81 cm) and the minimum number of leaves (2.50) were recorded in control. The minimum number of branches (2.33) was recorded in cuttings treated with IBA @ 2000 ppm. These findings may be due to effect of growth hormone auxins, which would have triggered the activity of specific enzymes that promoted early sprouting. Early sprouting of cuttings will make the cuttings less dependent on stored food (Sen and Bose, 1967; Sure et al., 2018). Similar inference was made by Mishra and Kumar (2014) in guggul *Commiphora wightii* and Shwetha (2005) in *Bursera* spp.. Tripathi et al. (2014) reported length of root was higher and increased in IBA treatment, compared to similar concentration of IAA in C. *wightii*.

Table 1. Impact of different concentrations of IBA on survival and growth parameters of *Commiphora wightii* stem cuttings

Treatments		Establishment percentage (%)	Sprouting initiation (days)	Length of shoot (cm)	Number of leaves per plant	Number of branches per plant
T_1	Control	73.33	24.00	48.81	2.50	2.78
T_2	500 ppm	56.67	22.66	53.02	2.83	3.16
T_3	1000 ppm	90.00	21.00	91.26	7.20	3.64
T_4	1500 ppm	83.33	18.00	85.23	6.44	2.93
T_5	2000 ppm	73.33	18.33	78.93	4.67	2.33
	Mean	75.33	20.80	72.07	4.66	2.93
	SEm (±)	2.98	1.22	1.49	0.18	0.14
	C D at 5%	9.51	3.92	4.75	0.59	0.46
	C V %	6.85	10.23	3.61	6.77	8.40

Significant differences were noted in length of root and number of roots (Table 2). The highest length of root was recorded in 1000 ppm of IBA (21.93 cm) and found at par with 1500 ppm of IBA (19.91 cm) whereas the shortest length of root was recorded in control (12.58 cm). Further, the maximum number of roots (8.16) was recorded in IBA 1000 ppm and minimum was in control (2.50). The formation of adventitious roots is a high energy requiring process, which involves cell division, in which predetermined cells switch from their morphogenetic path to act as mother cells for the root primordial, hence need more reserve food material for root initiation (Aeschabacher et al., 1994; Sure et al., 2018).

Table 2. Impact of different concentrations of IBA on root parameters of stem cuttings of *Commiphora wightii*

Treatments		Length of root (cm)	Number of roots per plant
T_1	Control	12.58	2.50
T_2	500 ppm	16.35	4.16
T_3	1000 ppm	21.93	8.16
T_4	1500 ppm	19.91	6.00
T_5	2000 ppm	18.78	4.50
	Mean	17.84	5.06
	SEm (±)	0.65	0.20
	C D at 5%	2.09	0.65
	C V %	6.33	7.04

Fig. 1. Mother plants of Guggul

Fig. 2. Collection of branch cuttings

Fig. 3. Semi hardwood branch cuttings of Guggul

Fig. 4. Treated semi hardwood cuttings of Guggul

Fig. 5. Established plants from cuttings of Guggul

Fig. 6. Seedling of 1000 ppm IBA

Fig. 7. Uprooted seedling of Guggul

Fig. 8. View of seedlings developed from cuttings treated with different concentration of IBA

Further, different portion of a single branch vary in their rooting and sprouting response depending on the seasonal, physiological conditions and age factor, thus their response will differ under same environmental conditions. The increase in number of roots in the cuttings treated with IBA @ 1000 ppm can be attributed to the action of auxin activity which might have caused hydrolysis and translocation of carbohydrate and nitrogenous substances at the base of cuttings and resulted in accelerated cell elongation and cell division in suitable environment (Singh et al., 2003; Sure et al., 2018). Similar inference was made by Mishra and Kumar (2014) in Guggul and Shwetha (2005) in Bursera. Tripathi et al. (2014) reported length of root was higher and increased in IBA treatment as compared to similar concentration of IAA in *C. wightii*.

CONCLUSION

The experiment revealed that semi-hardwood branch cuttings of *Commiphora wightii* could be rooted at 500 to 2000 ppm concentration of IBA and had a significant effect on the growth and development parameters. IBA at 1000 ppm had strong beneficial effect than other different concentrations of IBA under open condition which influenced on growth and survival of cuttings of guggul. Therefore, *C. wightii* can be propagated by semi-hardwood branch cuttings at 1000 ppm IBA for production of planting materials. In fact, this technique is highly useful for multiplication of clones of this species.

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Performance evaluation of Vietnam koi (*Anabas cobojius*) in biofloc culture system: A case study

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ABSTRACT

The study investigated the growth and economic performance of Vietnam koi (*Anabas cobojius*) using biofloc culture technique in farmers' field. The experiment was carried out in two number of tarpaulin (650 GSM) biofloc tanks of with 4 meter diameter, 1.3 meter height. The stocking density of each tank was @5000 numbers per 8000 liters with initial average weight of each as 5.1 g with the depth of water between 90-100 cm. For better growth performance and to avoid the growth disparity the fishes were separated based on size and kept in separate tanks as bigger and smaller between the tanks every month. The feeding rate was gradually reduced from 2% to 0.05% of body weight from June 2019 to November 2019 and the feed conversion ratio (FCR) was found to be 0.59. The specific growth rate (SGR;%) was achieved the highest in the month June (3.27) and the lowest in the month of November (0.44). Based on the performance evaluation a total yield of 872 kg (Tank-1@460 kg per 8000 liter and Tank-2 @412 kg per 8000 liter) of Vietnam Koi (*A. cobojius*) was harvested from both the cultured biofloc tanks within a period of six months. The net profit was of Rs. 21,020.00 (including infrastructure cost and of Rs. 63,020.00 (excluding infrastructure cost) with B:C ratio of 1.16 and 1.70 respectively.

Key words: *Anabas cobojius*, biofloc technology, performance, SWOT

INTRODUCTION

Vietnam koi (*Anabas cobojius*), a variety of exotic koi, native to Vietnam is getting tremendous popularity in different parts of India which is generally called as Gangetic koi. Now it is found in lakes, ponds, ditches or paddy fields and able to live out of water for protracted period. Its external physical appearance is similar to native climbing perch as of India, but two black spots found, one in operculum and another is in caudal peduncle which is not found in native climbing perch *Anabas testudineus* (Hasan et al., 2010; Datta and Ghosh, 2015; Kohinoor et al., 2016). Biofloc fish farming has become very popular all around as an alternative to open pond fish farming. In aquaculture, the major prominent factors are the feed cost (accounting to 60-70% of the total production cost) and the most limiting factor in the water and or land availability. The main principle of this technique is the in situ production of large range of microorganisms and accelerating the nitrogen cycle by maintaining higher C: N ratio through stimulating heterotrophic microbial growth, which assimilates the nitrogenous waste that can be exploited by the cultured species as a feed (Daniel and Nageswari, 2017). By addition of carbohydrates the desired C: N is generally maintained through the source (molasses) and the water quality is improved through the production of high quality single cell microbial protein (De Schryver et al., 2008). This technology is based also on the principle of flocculation within the system. With this condition, dense microorganisms develop and mainly function both as bioreactor controlling water quality and protein food source. In biofloc environment the control of toxic nitrogen species occurs more quickly because of the growth rate and microbial production per unit substrate of heterotrophs are ten-times greater than that of the autotrophic nitrifying bacteria (Ray, 2012; Avnimelech, 2015). In this study, the performance and economic viability of Vietnam koi using biofloc technology was evaluated in the farmer's field.

MATERIALS AND METHODS

Study site

The map of the study site (with latitude 21.72° N and longitude 86.86° E) is presented below (Fig.1).

Fig. 1. The study site of Village Nadpur, Block Betonati, Dist Mayurbhanj, Odisha.

Experimental design

The total land area for fish farming was about 400 m^2 (20 m × 20 m) including tank area, solar panel and go down area. Two circle tanks made up of tarpaulin (650 GSM) used for the grow-out of Vietnam koi with the diameter of 4 m, 1.3 m height and 0.9-1.0 m water depth. The slope maintained for the drainage pipe sloping around 1.5 ft from the center for better outlet of water. A protective sheet outside of the tank was used to protect the tarpaulin from external damages. The experiment was carried out for six months, i.e. from June 2019 to November 2019. The Vietnam koi fishes were stocked in the two biofloc tanks (BFT) @5000 numbers per 8000 liters having capacity of each tank 10000 liters with initial average weight of each as 5.1±0.13 g. The fishes were treated in the hospital tank with potassium permanganate ($KMnO_4$) @ 2 mg l-1 as disinfectant before stocking in the biofloc tank. The fishes were fed with the floating feed three times per day with respect to the percentage (%) of body weight of the fishes. First two months (June and July) the fishes were fed with 2% of body weight followed by 1% in the month of August and September and 0.5% in the month of October and November. The heterotrophic organisms by using the organic matter and the available ammonia in the biofloc tank accelerated in the decomposition of the organic matter to generate large amounts of bacterial biomass to accelerate the nitrogen cycle. The C: N ratio was maintained as 15: 1 throughout the culture period.

RESULTS AND DISCUSSION

Water quality parameters

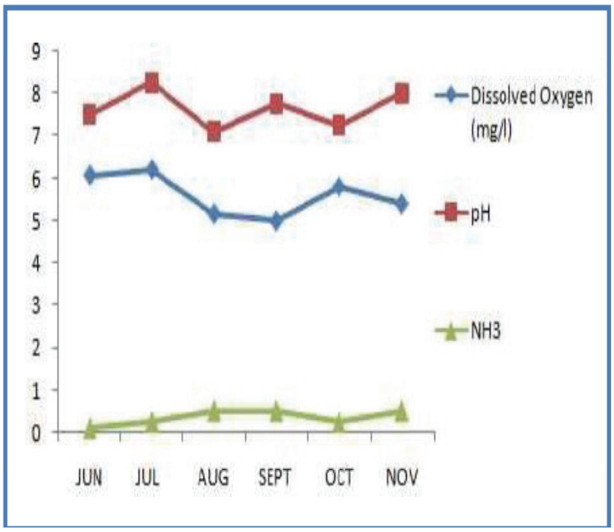
The water parameters were analyzed by kit method Dissolved oxygen (CIFEDO, ICAR, CIFE), pH (CIFE pH test Kit, ICAR, CIFE), Ammonia (Ammonia test kit, API), but the TDS and Temp (TDS-3) with digital meter. The water analysis of both the tanks was done on weekly basis and the average of different parameters calculated. The average values of the water quality parameters of the biofloc tanks are shown in Table 1 and Fig. 2. Sarma et al. (2010) observed role of water quality parameters on dissolved oxygen concentration in water, temperature and oxygen consumption by fishes. Emerenciano et al. (2017) stated that biofloc technology helps to maintain water quality parameters at the optimal level for fish cultivation.

Growth parameters

The growth parameters like average body weight, average daily weight gain, specific growth rate (SGR; %), mortality in numbers and survival rate (%) of both the tanks were calculated month wise shown in Table 2. The maximum mortality was found in the month June (230 nos) and there were nil mortality from the month of September. SGR was the highest in June (3.27) and the lowest in the month of November (0.44). The feed conversion ratio (FCR) and the total fish production were 0.59 and 872 kg, respectively. The detail results of the growth parameter were shown in Table 3 and Fig. 3.

Table 1. Average values of the observed water parameters during culture period (June to November 2019)

Sl. No	Parameter	June	July	August	September	October	November
1	Temperature (°C)	28	26.5	25.57	22.29	21	20
2	Dissolved oxygen (mg L^{-1})	6	5	6	5	5	5
3	pH	7.5	8.25	7.1	7.75	7.25	8
4	Total dissolved solids	88.5	128.1	220.6	260.5	318.4	350.5
5	NH_3	0.1	0.25	0.5	0.5	0.25	0.5



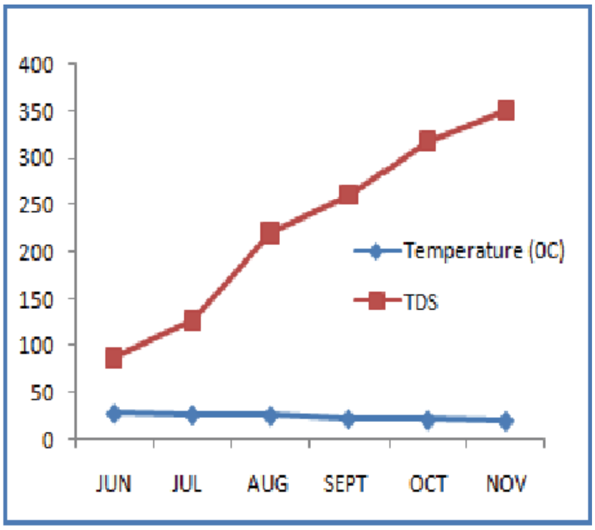


Fig. 2. Average values of the observed water parameters during culture period (June to November 2019)

Economic performance

The economic performance Vietnam Koi (*Anabas cobojius*) in biofloc farming system of both the two biofloc tanks during culture period (June-19 to Nov-19) was calculated and found that a net profit of ₹ 21,020.00 (including infrastructure cost) and profit of ₹ 63,020.00 (excluding infrastructure cost) with B:C ratio of 1.16 and 1.70 respectively (Table 5). The details of the economic performance was mentioned in Table 4 and Table 5.

Table 2. Observed average weight (g m^{-1}), mortality and feeding schedule during culture period (June to November 2019)

Month	Stock status (Nos)	Month wise Morality (Nos)	Average weight (g)	Type and size of feed in millimeters	Feeding rate (% of body weight)	Month wise feed used (kg)
June	9770	230	5.1	Floating feed (1 mm)	2	29.90
July	9630	140	13.6	Floating feed (1 mm)	2	81.20
August	9530	100	24.4	Floating feed (1 mm)	1	72.08
September	9530	0	45.7	Floating feed (2 mm)	1	130.66
October	9530	0	64.8	Floating feed (2 mm)	0.05	95.72
November	9530	0	79.2	Floating feed (2 mm)	0.05	113.22

Table 3. Growth parameters of Vietnam koi during culture period (June to November 2019)

Parameters	Months					
	June	July	August	September	October	November
Average weight (g)	5.1	13.6	24.4	45.7	64.8	79.2
Weight gain	8.5	10.8	21.3	19.1	14.4	11.1
Average daily weight gain (g) per day	0.28	0.35	0.69	0.64	0.46	0.28
Specific growth rate (%)	3.27	1.89	2.02	1.16	0.67	0.44
Mortality (pieces)	230	140	100	0	0	0
Survival rate (%)	97.7	98.56	98.96	100	100	100
Feed Conversion Ratio	0.59					
Total production in both the tanks (BFT-1+BFT-2)= 872 kg within six months (June to November 2019)						

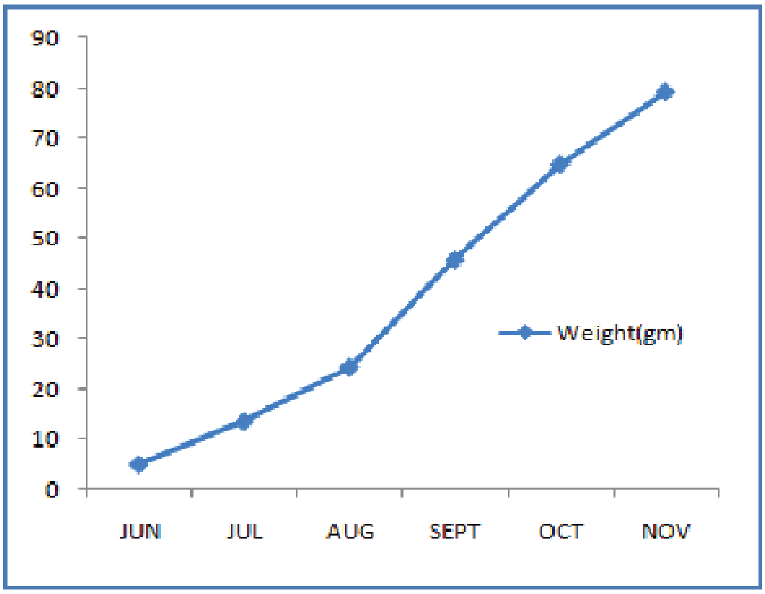


Fig. 3. Observed average weight (g per month) during culture period (June to November 2019)

Table 4. Cost involvement during the study

Components	Amount (₹)
Construction of biofloc tank (2 nos) (4 m diameter × 1.5 m height, Water holding capacity 10000 L) with accessories	42,000.00
Labor cost (provides protection, feed supply)	30,000.00
Seed 10000 nos @ ₹ 2 per piece	20,000.00
Feed (Floating feed , 522 kg)	24,300.00
Probiotics, medicine and test kit	10,800.00
Electricity	4,000.00
Total expenses	1,31,100.00

Table 5. Revenue generation after completion of the culture period

Type	Production	Unit price (₹ per kg)	Revenue (₹)	Total income (₹)	Total expendi-ture (₹)	Net profit (₹)	B:C	
							II	EI
Revenue from the fish cultured from six months	Local sell: 252 kg	210	52920	1,52120	1,31,100	Profit including infrastructure (II) as 21,020.00 and excluding infrastructure (EI) 63,020.00	1.16	1.70
	Mass sell: 620 kg	160	99200					

CONCLUSION

Biofloc is an alternative technology to open pond fish farming. It provides a boost to doubling fish production and encourages small landholders and entrepreneurs to take up fish farming. In the present study the biofloc technique was used for Vietnam Koi (*A. cobojius*) fish production in a small scale. The growth and benefit cost ratio was encouraging. Their consumer demand is very high due to the high nutritional and medicinal value. and farmers can get good price by selling the fishes in live conditions. This technique is also best suitable for the areas where the land and water availability is the major constrain. There is a need of more research on water quality, microorganism profile and growth related parameters due to consumption of floc and conversion of ammonia to protein with reference to Vietnam Koi culture with higher stocking density .

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Mini-sprinkler irrigation uniformity and crop water productivity of summer clusterbean in Indian arid zone

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ABSTRACT

Judicious use of water resources has always been a focal point in agriculture sector and it has gained further importance under the changing climatic scenario. So, the use of pressurized irrigation systems has become an inevitable option for enhancing the water use efficiency. The field study was conducted for determination of actual water balance components for summer clusterbean in the Research Farm of ICAR-Central Arid Zone Research Institute, Jodhpur during the summer of 2015-17 through mini-lysimetric approach, where irrigation water was delivered through mini-sprinklers. Under this study, the coefficient of uniformity (C_u) and distribution uniformity (D_u) of the mini-sprinkler system were evaluated. Water was applied to the crop through mini-sprinklers at four irrigation levels of I_{1oo}, I_{80}, I_{60} and I_{40}%, when the cumulative pan evaporation (CPE) attained a value of 50 ± 5 mm. Twin nozzle mini-sprinklers of Model Monsoon S-10 with nozzle size 2.5 × 1.5 mm were used in the field to irrigate the area. For each irrigation level, six sprinklers were used, out of those, 2 sprinklers were fixed at 180° (middle of the plot) and four at 90° (corner of the plot) and the experiment was conducted at operating pressure of 2.0 kg cm^{-2}. Christiansen equation was used for determining the coefficient of uniformity for different irrigation levels and it was found to be 84.22, 84.30, 84.27 and 83.99%, while distribution uniformity was calculated to be 74.12, 74.70, 72.90 and 72.39% at I_{1oo}, I_{80}, I_{60} and I_{40}% irrigation levels. Both C_u and D_u coefficients give complementary information. C_u was consistently found higher than D_u. Water productivity was found the highest (0.35 kg m^{-3}) at the irrigation level of 80% CPE.

Key words: Coefficient of uniformity, irrigation uniformity, mini-sprinkler, water productivity

INTRODUCTION

Improving the productivity of existing irrigation schemes, especially with the limited water and land resources availability has got an increasing attention for global increase in food security (Ahaneku, 2010). This improvement becomes an all-important issue because of the serious constraint faced by irrigators due to water scarcity and the ensuing competition for water by other sectors e.g., industries and urban uses. This becomes much more pertinent for arid condition due to availability of lesser water quantity and erratic nature of rainfall. It is obvious that many irrigation systems are performing below their capacities. This situation may lead to non-uniform and unreliable water distribution. An ideal irrigation system should apply the correct amount of water, minimize the losses, and apply the water uniformly. It necessitates assessing the performance of available irrigation systems in order to identify areas of lapses in the system design and make corrections. Evaluation is an indispensable tool in irrigation project management since it enables irrigation managers to measure and determine actual performance, and the factors that are responsible for low or less performance. The uniformity of water application in a sprinkler irrigation system is an important aspect of the system performance (Solomon, 1979). The two most common methods of expressing uniformity are the coefficient of uniformity (C_u) and distribution uniformity (D_u).

Several researchers have reported on the evaluation of sprinkler systems with emphasis on irrigation uniformity **(**Dukes et al., 2006; Nasab et al., 2007). Ahaneku (2010) evaluated the performance of sprinkler system by catch can tests and results indicated the average Christiansen's uniformity (C_u) and delivery performance ratio were 86 and 87% by using American Society of Agricultural and Biological Engineers (ASABE) standard procedures. Siosmarde and Byzedi (2012) found the mean values of Christiansen's uniformity (C_u) and distribution uniformity (D_u) to be 62 and 49.4% for five solid set randomly selected sprinkler irrigation systems. The performance evaluation of sprinkler system performed by Frank (2009) yielded the Christiansen's uniformity (C_u) to be 91 and 87% and mean application rates (MAR) to be 10.4 and 4.7 mm h^{-1} at 12 m × 12 m and 18 m × 18 m spacing, respectively.

MATERIALS AND METHODS

The present study was conducted at the Research Farm of ICAR-Central Arid Zone Research Institute, Jodhpur (26.3°N and 73.02°E; 224 m amsl) during the summer season of 2015 to 2017. The climate of the region is arid characterized by high diurnal and seasonal temperature variations and annual and inter-annual irregular rainfall with long dry seasons associated with strong winds.

Clusterbean cv. RGC 936 was sown after pre-sowing irrigation of 60 mm on 11th March in 2015, 2nd March in 2016 and 4th March in 2017 using seed rate of 10-12 kg ha^{-1}. Distance between two rows was 50 cm, whereas spacing between plants in a row was 10 cm. All agronomic and cultural practices followed were kept uniform for all the treatments. The crop was harvested on 1st June, 25th May and 25th May in 2015, 2016 and 2017, respectively. Treatments consisted of four irrigation levels, *viz.* irrigation at 100% ($I_{100\%}$), 80% ($I_{80\%}$), 60% ($I_{60\%}$) and 40% ($I_{40\%}$) of cumulative pan evaporation. The irrigation was applied, when cumulative potential evaporation value reached to 50 ± 5 mm.

The performance evaluation of a sprinkler system in the present study was evaluated by obtaining nozzle discharge (q), Christiansen's uniformity coefficient (Cu), distribution uniformity (Du), and application rate (MAR). Christiansen's coefficient (C_u) of uniformity (Christiansen, 1942) was first used to introduce a uniformity coefficient to the sprinkler system. C_u calculates the average deviation of the catch compared to the depth of the catch, while D_u compares the driest quarter of the field to the rest. The mini-sprinkler system was setup with the following components.

Pump

The existing tube well of 200 mm diameter and submersible pump of 15 HP was used to lift the water from submersible pump to the ground surface with 61 m static head (suction head + discharge head), where it was stored in a tank of 1000 L capacity, from where water was supplied to mini sprinklers by one HP pump. The water was diverted from the existing delivery line of 63 mm diameter to the experimental setup field. There was an existing submersible pump used for miscellaneous purposes for farm and other operations. The irrigation water for this research study was provided by the farm section by this pump only. Although the mini-sprinkler does not require such a heavy pump for its operation, it is has been used only as a water source.

Filter

A screen filter of 25 m^3 h^{-1} capacity was provided to filter out the soil particles and impurities from the water.

Pressure measuring device

A dial pressure gauge of range 0 to 7 kg cm^{-2} was used to measure the pressure over mini sprinkler. The dial pressure gauge was installed on the main pipe to monitor the pressure in the main line in the unit of psi and kg cm^{-2}. Sprinklers were operated at the operating pressure of 2 kg cm^{-2} and a by-pass valve was used to regulate the pressure. Pitot pressure gauges of the rage 0 to 7 kg cm^{-2}

were also used to measure the pressure near the sprinklers.

Main line and lateral line

Main line: 63 mm ϕ (diameter) High-density polyethylene (HDPE) × pressure 2.5 kg cm^{-2}; Laterals line: 32 mm ϕ (diameter) Linear Low-Density Polyethylene (LLDPE) × pressure 2.5 kg cm^{-2}.

Mini sprinkler assembly

In the present study, twin nozzle mini-sprinklers of Model Monsoon S-10 with nozzle size 2.5 × 1.5 mm were used in the field to irrigate the area. It was mounted on an installation stake 1.2 m long, 8 mm ϕ (diameter). The mini sprinkler was connected to the lateral using a vinyl tube of 1.2 m and 12 mm ϕ (diameter).

Hydraulic evaluation of mini sprinkler system

For the determination of sprinkler discharge (q), Christiansen's uniformity coefficient (CU), distribution uniformity (DU), and precipitation rate (MAR), the mini sprinklers were evaluated at the pressure of 2 kg cm^{-2} at the spacing arrangement of 10 m (along the main line) × 10.5 m (along the lateral). The net area under one irrigation level was kept as 21 m × 11 m. One meter gap was left between the rows of two irrigation levels plots. The mini-sprinklers were used in a part circle. The sprinkler fixed at the middle of the individual plot was fixed at 180° (half circle), while sprinklers at the corner of the plot were fixed at 90° angle (quarter circle). For each irrigation level six sprinklers were used, out of that, 2 sprinklers were fixed at 180° and four at 90°. Discharge of a single nozzle was found to be 480 L per hour. Precipitation rate of the sprinkler system was calculated to be 4.6 mm h^{-1} with the use of following equation.

$$\text{Precipitation rate (MAR)} = \text{Discharge of the sprinkler nozzle x } \frac{1000}{\text{Wetted area}}$$

Determination of sprinkler discharge (q)

Sprinkler discharge was assessed by collecting the water emitted by the sprinkler into a bucket in a time interval of 2 minute. The discharge was calculated by dividing the collected volume by the time of filling. The observations of discharge were recorded thrice for operating pressure.

Uniformity evaluation for sprinkler system

Uniformity evaluation tests are of fixed duration (generally half an hour to one hour duration) for each treatment. Once the test is over, the water collected in each catch-can is measured volumetrically with a calibrated test tube. For each treatment, coefficient of uniformity (CU), distribution uniformity (DU) and coefficient of variation (CV) are determined as the follows:

Determination of Christiansen's uniformity coefficient (C_U)

Christiansen's uniformity coefficient (C_u) is the most commonly used statistical method for evaluating sprinkler system uniformity (Warrick, 1983). Christiansen's uniformity is defined as

$$Cu = [1 - \frac{\Sigma(X-\bar{X})}{n \times \bar{X}}] \times 100$$

Where, C_u = Christiansen's uniformity coefficient (%)

$\bar{X}$ = mean water depth collected in the catch can.

$\Sigma X - \bar{X}$= cumulative of numerical deviation of individual observation from the mean water depth. n = total no. of catch cans (observation points)

20 catch-cans for each irrigation level were placed at a grid of 2 m × 2m for one hour. It was repeated four times and then the average was taken for each irrigation level.

Distribution uniformity

The distribution uniformity (DU) was calculated using the eq. (2) (Merriam and Keller, 1978):

$$DU = \frac{ADC_{25}}{\bar{X}} \times 100$$

Where,

ADC_{25} = the lowest quarter of the average water depth of catch cans

$\bar{X}$ = mean water depth collected in all catch cans (mm)

Coefficient of variation

The coefficient of variation (CV) is the quotient between the standard deviation of the applied water depths (σ) and the average of water depth collected according to ASAE (1991):

$$CV = \frac{\sigma}{\bar{X}}$$

Where,

σ = Standard deviation of the water depth of catch cans.

RESULTS AND DISCUSSION

Christiansen's uniformity coefficient (C_u)

The results obtained are presented in Fig. 1, showing uniformity coefficient at operating pressure at 2 kg cm^{-2} for different irrigation levels. For all the irrigation levels, C_u was recorded ≥84%, which is satisfactory. According to Keller and Bliesner (1990), the coefficient of uniformity of irrigation below the specified value 84%, following Christiansen, represents a low work quality of irrigators. Absolute uniformity is not required because it is almost impossible to achieve it with spray irrigation technology due to the effect of wind.

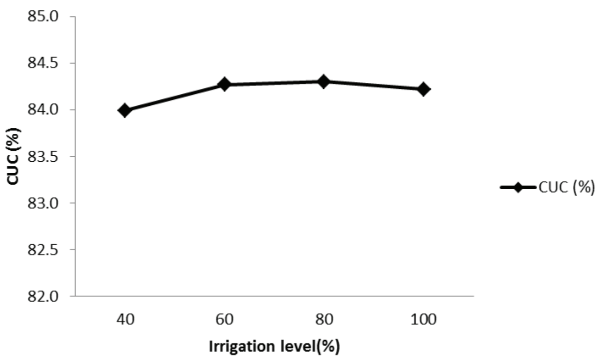

Fig. 1. Uniformity coefficient (C_u) in different irrigation levels

Distribution uniformity (D_u)

As shown in Fig. 2, the value of distribution uniformity ranged between 72.39 and 74.12%. The lowest value of distribution uniformity coefficient was obtained at irrigation level I_{40}%. All these values were greater than the minimum acceptable D_u of 60% specified by Keller and Bliesner (1990). As reported by (Keller and Bliesner, 2000), the distribution uniformity and application efficiency of sprinkler irrigation systems are potentially high, but these parameters are highly dependent on the weather conditions, especially on wind. Further, Al-ghobary and Al-rajihy (2001) reported that single nozzle sprinklers gave better C_u and D_u values than twin nozzle sprinklers at moderate wind speed.

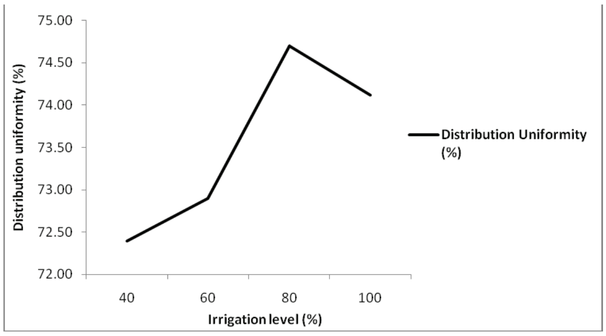

Fig. 2. Distribution uniformity (%) at different irrigation levels

Coefficient of variation (Cv)

The coefficient of variation varied from 19.25% at 40% irrigation level to 21.08 at 60% irrigation level. It was 20.42 and 19.73 for irrigation levels at 100 and 80%. It can be seen from the graph that Cu was consistently higher than Du. This result is found to be on line with the finding obtained by Keller and Bliesner (2000). They reported that, according to the mathematical relationship between Cu and Du, Cu will always be larger since positive and negative deviations from the mean application volume are used in calculating Cu. But, only negative deviations are used in the calculation of D_u. Similar results were reported by Tarjuelo et al. (1999).

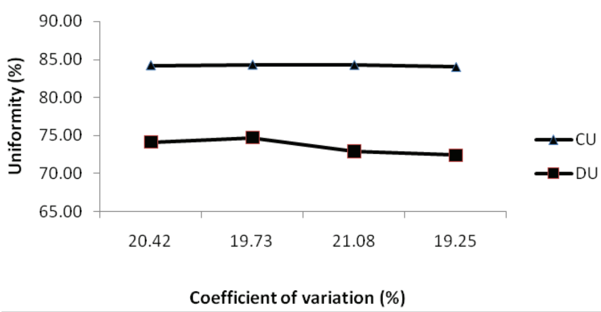

Fig. 3. Relationship of C_u and D_u with respect to C_v

Crop water productivity of summer clusterbean

Crop water productivity of clusterbean is presented in Table 1. Average value of water productivity for three seasons of 2015, 2016 and 2017 are presented in the table. Crop yield was recorded as 2149, 1924, 1119 and 708 kg ha^{-1} under 100, 80, 60 and 40% irrigation levels, respectively. During the growing seasons, average crop water productivity observed from 0.21 ($I_{40\%}$) to 0.35 kg m^{-3} ($I_{80\%}$). Water productivity was found maximum, 0.35 kg m^{-3}, at irrigation level equivalent to 80% CPE compared to control (100% of CPE) for which the water productivity was 0.30 kg m^{-3}. Applied water consumed by crop as crop evapotranspiration was maximum (686 mm) for 100 % irrigation level while lowest (340 mm) for 40% irrigation level (Table 1). In a study done by Kumar et al. (2016) water productivity of *kharif* clusterbean in hot arid region was found to be 0.38 kg m^{-3}, which has been found similar to our results. It can also be seen from Table 1 that uniformity coefficient and distribution uniformity are on higher side for irrigation level at 100 and 80% which might have resulted in more uniform application and distribution of water under these two treatments for better crop water productivity.

Table 1. Water productivity of summer clusterbean

*Treatment	Actual crop ET (mm) (mean of three seasons)	Yield (kg ha^{-1})	Water productivity (kg m^{-3})	Uniformity coefficient (%)	Distribution uniformity (%)
T_1 (I_{100}%)	686	2149	0.31	84.22	74.12
T_2 (I_{80}%)	554	1924	0.35	84.30	74.70
T_3 (I_{60}%)	454	1119	0.25	84.27	72.90
T_4 (I_{40}%)	340	708	0.21	83.99	72.39

CONCLUSION

Based on the results obtained under this study, Christiansen's uniformity coefficient (C_u) for all the irrigation levels was found in the range of 84-85%. Distribution uniformity (D_u) was found in the range of 72.39 and 74.12%, which can be put under satisfactory category. Under a mini-lysimetric approach for direct measurement of crop water use or actual evapotranspiration, a water application depth of 40 mm ($I_{80\%}$) showed highest water productivity, while 30 mm ($I_{60\%}$) and 20 mm ($I_{40\%}$) water application depth was insufficient to maintain a wet soil profile, resulting in lower crop water productivity value with 0.25 and 0.21 kg m^{-3}. Better uniformity coefficient and distribution uniformity at 100 and 80% of irrigation level resulted in more uniform application and distribution of water for better crop water productivity. As was indicated in previous studies researchers use various methods to evaluate work quality of irrigation machinery, e.g. coefficient of uniformity, coefficient of non-uniformity, degree of uniformity and coefficient of variation. It means that the expressed individual equations may achieve different results in irrigation water distribution uniformity on the same elementary areas.

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Estimation of cost of pumping from a shallow tubewell for agricultural usage

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ABSTRACT

The cost of pumping takes a major share under an irrigated agriculture condition, similarly for perennial aquacultural practices the importance of assured water cannot be ruled out. The procedure for determination of the cost of pumping is a cumbersome job. In this paper, the various steps involving the development of a shallow or deep tubewell and determination of unit cost of pumping under a sub-humid and sub-temporal condition of eastern India are discussed. Considering the electricity charge same as that of agricultural use, cost of pumping one cubic meter of tubewell water was estimated to be ₹ 1.93 or say ₹ 2.00.

Key words: Aquacultural practices, irrigated agriculture, sub-humid condition, tubewell water, unit cost

INTRODUCTION

The importance of water is realized in agriculture and allied activities. Due to shortage of surface water resources, pressure is now to exploit ground water for fruitful usage. Due to shortcomings of rainfed agriculture where sustainable grain production may not be assured, importance is given on irrigation. Irrigated agriculture provides around 40% of global food production and covers about 20% of the cultivated land (Ray et al., 2018). It was estimated that irrigated agriculture is twice more productive and allow intensification and crop diversification in long run. Under global climate change scenario, it is estimated that we need to produce around 70% of more food grain globally by 2050 to maintain the basic minimum requirement (Lorenzo et al., 2018). Pumping huge amount of water either by adjacent river lift or from ground water involves a good amount of monetary outlay. Apart from direct agricultural water usage and domestic water demands, water demands from various sectors like livestock sector, poultry etc. too depend on a constant and perennial water supply (McDougall, 2015). Though aquaculture is not a consumer of water, still for its sustenance an assured water supply is also mandatory (Ray et al., 2006, 2008).

Electricity and diesel energy in one hand and solar and other forms of renewable energies on the other hand have put the end users at a cross juncture to take some critical decision. The importance of renewable forms of energy is advocated by various agencies; however, its huge initial infrastructure cost and limitation of technical knowhow could not bring this technology under farmers` friendly umbrella. The importance of electric and diesel operated pumps has been realized for agricultural and allied sectors and their number is also increasing steadily in the 21st century. About 18.5 million electric operated pump sets are available in India (GoI, 2012) and this number is gradually increasing.

In this paper an attempt has been made to discuss the various aspect of development of a deep tubewell and the procedure for evaluation of unit cost of pumping water from an aquifer using the tubewell.

MATERIALS AND METHODS

Field experiments were conducted at the aquacultural experimental farm, Agricultural and

Food Engineering Dept., IIT, Kharagpur, West Bengal to assess the unit cost of pumping ground water for agricultural usage. The site selected for the field experiments represents a typical upland condition seen in eastern India. It is located at a latitude of 22° 19' N and longitude of 87° 19' E with an altitude of 48 m above the mean sea level. The site falls under sub-humid, sub-tropical region with an annual rainfall of 1400 mm, 80% of which is received during the rainy season that spreads over June to September. The rainfall pattern of this region is quite erratic.

Development of a deep tubewell

Resistivity survey

Before drilling a deep tubewell scientific resistivity survey was conducted at the experimental site to assess the potential aquifer at a particular depth. Resistivity survey was carried out with the Wenner`s Array arrangement up to 120 m depth to assure the availability of the potential aquifer. The variation of apparent resistivity measured at various depths was noted and plotted in a graph (Fig. 1).

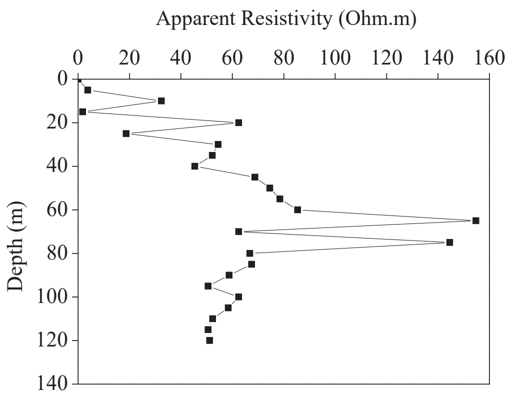

Fig. 1. Variation of apparent resistivity with depth

It may be noted from Fig. 1 that, with the increase in depth, the apparent resistivity value goes on increasing steadily upto 60 m depth. However, after 60 m depth there is a sharp decline in the resistance value showing the potential occurrence of groundwater but this depth did not last long predicting a less width band of aquifer. After 100-110 m there is a gradual decrease in resistance. Hence, the potential aquifer thickness is likely to be large.

Drilling activities

A schematic diagram of the mini deep tubewell is shown in Fig. 2.

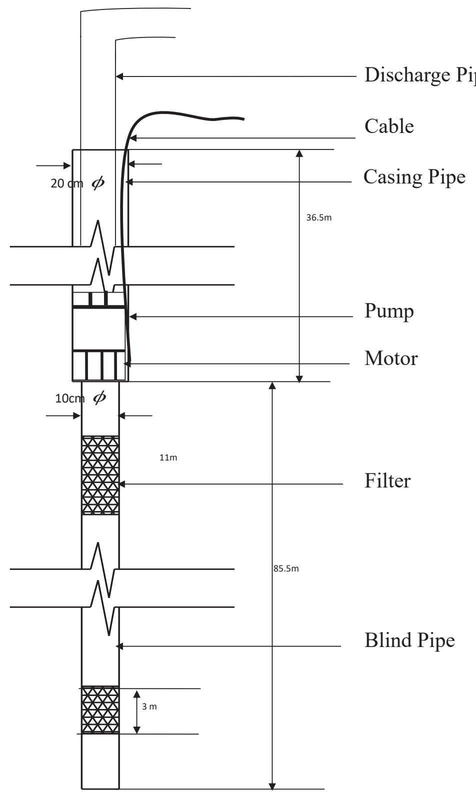

Fig. 2. Schematic diagram of the mini deep tubewell fitted with pump assembly

Direct rotary drilling was done with the help of a 10 hp modified engine setup. Two potential aquifers were located at 40 m and 110 m below the soil surface. Tubewell screens were provided at these depths to harness the maximum possible groundwater. Blank pipes of 100 mm diameter were lowered in the lower aquiclude portion to act as the tubewell pipe. Above this, casing pipes of 200 mm diameter were lowered. Suitable pea size gravel packing was done around the well pipe up to the top screen. The well was developed by using a high pressure compressor. After the well development, a 5 hp submersible pump was lowered to pump the ground water. The deep tubewell yields an average discharge of about 4 litres per second. While selecting a particular size or specification of a submersible pump, the aquifer discharge curve and delivery head of water to be pumped are mostly matched and based on the intersection of these two curves the pump capacity is decided (Machiwal et al., 2011). Under the present study, the intersection point was 4.73 hp, hence the next higher capacity pump, *i.e.*, 5 hp was taken.

Initial investment

The initial investment includes the cost of the following components, *viz.*, drilling pipe cost, cost of labour work per unit depth based on the depth of drilling, costs of pump along with motor, casing, filter, necessary fittings and accessories. The cost of development of the tubewell using a compressor is also included in the initial investment.

RESULTS AND DISCUSSION

The details cost of development of a deep tubewell is presented in Table 1. The various cost components, *viz.*, resistivity survey, cost per unit depth of drilling, cost per unit length of pipe, cost of filter, cost of pea gravel, cost of pump assembly, cost of well development and other miscellaneous cost also included. The various items cost was taken from the West Bengal Public Works Department, 2006 (GoWB, 2006).

Table 1. Cost of development of a deep tubewell

Sl.	Particulars/ items	Unit	Construction/ development made	Rate per unit (₹ per unit)	Cost (₹)
1.	Resistivity survey	Lumpsum	One unit	6,000	6,000
2.	Labour cost for tubewell drilling	Per meter	150	120	18,000
3.	Pipe	-do-	130	120	15,600
4.	Filter	-do-	120	15	1,800
5.	Pump assembly	Lumpsum	1	7,500	7,500
6.	Cable and electrical units	-do-	50	15	750
7.	Pea gravel	-do-	1,000	-	1,000
8.	Development of tubewell	-do-	One unit	8,000	8,000
9.	Miscellaneous work	Lumpsum	2,000	-	2,000
	Total				60,650

The cost of development installation of a deep tubewell along with accessories amounts to ₹ 60,650/-. Considering 10 years of working life of the system, 10% annual interest on the investment and 1,000 hours of yearly operation, the hourly fixed cost comes to ₹12.13 ≈ ₹ 12.00 (say). The electricity cost for agriculture is subsidized and in it was ₹ 2.25 only per unit. The pump is of 5 kW capacity and therefore, consumes 5 units of electricity per hour for which the charge is ₹11.25. Annual maintenance cost was taken as 7.5% of the initial investment. Therefore, annual maintenance cost comes to ₹ 4,548. For 1,000 hours of annual operation, hourly maintenance cost is ₹ 4.55. Adding all these costs, hourly cost comes to ₹ 27.80. For a discharge of 14.4 m^3 (4.0 liter per second), cost of production of unit volume (one m^3) of water is obtained as ₹ 1.93 ≈ ₹ 2.00 (say). The unit cost of tubewell water was calculated and is presented in Table 2.

However, for pumping from river or other open water sources, the cost of development of tubewell need not be considered. The costs of pump and engine or motor along with necessary pipelines need to be included in the fixed cost. Remaining calculation procedure will be same as mentioned in Table 2.

Table 2. Unit cost of tubewell water

Item	Interest (10%)	Amount (₹)
Fixed cost		
i. Cost of tubewell and other accessories app expected life (10 year)	6,065	Fixed cost 60,650 Lumpsum
		Depreciation (10%) 6,065
ii. Hourly fixed cost per 1000 hour of yearly operation		12.13
Running/ Operational cost		
i. Electricity cost 5 KW h ₹ 2.25 per unit (agricultural usage)		11.25
ii. (a) Maintenance cost	7.50%	4549
(b) Hourly maintenance cost		4.55
iii. Hourly fixed cost		
(a) Tubewell + other accessories		12.00
(b) Electric cost		11.25
(c) Maintenance cost		4.55
(d) Total hourly cost		27.80
Average discharge from deep tubewell (4 Lps) ≅ 14.4 $m^3 h^{-1}$		
Cost of production of one cubic meter of tubewell water		₹ ≅ 1.93

CONCLUSION

Considering the various fixed and variable cost components for installation of a tubewell in an aquifer and pumping water from the same, it was estimated that for pumping 1,000 liter of water from a deep tubewell installed in a typical aquifer prevailing under Kharagpur situation, West Bengal, India using a submersible pump of 5 hp capacity the unit cost of pumping was ₹ 1.93 or say ₹ 2.00. The cost of electricity varies from state to state; however, government provides subsidized electricity for agricultural and allied sector usage in all states.

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Application of aerator in aquaculture: A review

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ABSTRACT

Dissolved oxygen (DO) is one of the most important water quality parameters and its control is also vital in aquaculture water treatment practices. Dropdown of DO creates several problems for the aquatic life, like respiration, growth etc. even leading to deaths. Therefore, artificial aeration is necessary to maintain adequate DO level in the water bodies under culture practice. Artificial aeration system is presently the most common and effective way of increasing DO concentrations in aquaculture or general water treatment process. Artificial aerator has also added advantage of better mixing, breaking of stratifications of water quality parameters (DO, temperature, salinity, nutrient, etc.) and removal of various harmful gases. A comparative performance and features of various aerators used in aquaculture or general water treatment have been reviewed in this paper. This study demonstrates the requirements, several types and effective use of aeration practices for the betterment of aquaculture water treatment practices.

Keywords: Aerator, dissolved oxygen, water quality

INTRODUCTION

Water is essential for existence of human or animal life. The growth of human population has led to industrial development to produce necessary commodities and utilization of natural resources, including water. The presence of biodegradable organic compounds reduces oxygen levels in natural water bodies like lakes and rivers, resulting in bad odours and death of aquatic animals. Other organic materials *viz.* pesticides, detergents, fat, oil, grease, and solvents create toxic effects, aesthetical inconvenience and bioaccumulation in the food chain. Due to the problems mentioned above, the treatment of water becomes necessary (Nadayil et al., 2015). However, water quality is totally dependent on physical, biological and chemical parameters that affect the growth of aquatic flora and fauna. It also affects the general conditions required to maintain health and growth of culture organism. Dissolved Oxygen (DO) is the amount of gaseous oxygen (O_2) dissolved in water. Any method for adding oxygen into water can be considered a type of aeration (Ahmad and Boyd, 1988). Oxygen enters into the water body by absorption from the atmosphere or by plant photosynthesis. It is removed by respiration of organisms and decomposition of organic matter.

General wastewater can be defined as liquid waste, and includes domestic or municipal wastewater, and industrial wastewater (McGhee and Steel, 1991). It can be classified into strong, medium or weak depending on the concentration of different contaminants (McGhee and Steel, 1991). Industrial wastewater is the liquid discharged from industrial applications, such as manufacturing, dairy, food processing, textile (McGhee and Steel, 1991).

Nowadays aerators are widely used in large-scale aquaculture operations and in general water treatment plant. Purpose of artificial aeration is to increase the contact area between air-water interfaces, so that more amount of oxygen from the air can mix in water by agitating water. In the absence of mechanical or artificial aeration facility and at the time when premature harvesting is not possible the splashing of water with the help of bamboo sticks will also help improve the dissolved oxygen level up to a certain level. The aerators work on two basic principles: (1) aeration by splashing water into the air i.e. paddle wheel aerator, spiral aerator, vertical pump, pump sprayer, gravity aerators, etc. or (2) aeration by bubbling/ diffusors air into water i.e. propeller aspirator, diffused aeration system etc. In aquaculture, paddle wheel aeration system, diffused-air aeration system, propeller-aspirator-pump aeration system and vertical-pump aeration system are generally used. A type of gravity aeration system, cascade aeration system is commonly used as pre or post-aeration system in general wastewater treatment. Keeping in view the above points the current review was carried out to focus on the need and importance of aeration and the different types of aeration practices for aquaculture and general water treatment.

APPLICATION OF AERATOR FOR WASTE WATER TREATMENT

One of the most common methods for water treatment is the activated sludge process. The activated sludge process is a suspended - culture system that has living, or active been in use since the early 1900s. The process derives its name from the fact that settled sludge containing, microorganisms is returned to the reactor to increase the available biomass and speed up the reactions. It may be either a completely mixed or plug flow process. The process is aerobic, with oxygen being supplied by dissolution from entrained air. Activated sludge processes consist of a tank within which the biological reaction occurs, a settling tank, a recycle pumping system, and an aeration system. An activated sludge plant is characterized by four elements (Fig. 1):

- An aeration tank equipped with appropriate aeration equipment, in which the biomass is mixed with wastewater and supplied with oxygen.
- A final clarifier, in which the biomass is removed from the treated wastewater by settling or other means.
- Continuous collection of return sludge and pumping it back into the aeration tank.
- Withdrawal of excess sludge to maintain the appropriate concentration of mixed liquor.

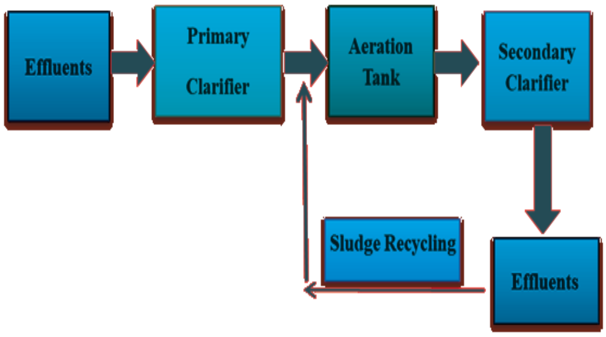

Fig. 1. Schematic diagram of activated sludge process

Water treatment of surface aerator

Paddle wheel and spiral aerator

Paddle wheel aerator is the most widely used surface aerator in the world (Boyd, 1998). It mainly consists of a number of paddle blades rotated in a vertical plane to spray large volumes of water into the atmosphere for oxygen transfer. The high velocity spray induces a turbulent flow on the surface creating a white water effect due to the large volume of entrapped air bubbles. This flow is also the driving force for convective mixing in the wastewater, which leads to uniform mixing of DO throughout the water (Moulick et al. 2005, 2009).

A new modified design of the paddle wheel aerator is the spiral aerator (Roy et al., 2015, 2017). In this aerator, a number of handles fitted with cups at their two ends rotate inside the water surface in a vertical plane to effect aeration. These handles are attached to a shaft in a spiral pattern which is connected to a motor. As this spiral aerator works similar to that of a paddle wheel aerator, it appears that this aerator may also be useful in general water treatment and aquaculture water treatment.

Propeller aspirator pump and submersible aerator

The propeller-aspirator-pump aerator consists of a rotating, hollow shaft attached to a motor shaft. The submerged end of the rotating hollow shaft is fitted with an impeller which accelerates the water to a velocity high enough to cause a drop in pressure over the diffusing surface. Hence, atmospheric air is drawn into the hollow shaft. This air passes through a diffuser and enters the water as fine bubbles which are thoroughly mixed into the pond water by the turbulence created by the propeller and aeration takes place.

A modified design of propeller-aspirator-pump aerator is the submersible aerator (2 horse power, 3 phase, Make; Sagar Aqua Pvt. Ltd., Rajkot, India), The propeller-aspirator-pump aerator introduces atmospheric air through a rotating shaft, connected to an electric motor outside the water body and a propeller at the other end which is submerged under water. Basically the propeller rotates at a very high speed inside the water. This causes a drop in pressure inside the water. This pressure difference forces air to pass through a diffuser in the hollow shaft and enter into the water as fine bubbles. In case of submersible aerator, a submersible pump fitted with a propeller and also connected with a hollow pipe (mouth is above water), draws air from atmosphere and mixes air with water. It is presumed that this new aerator may also be useful in aquacultural ponds and general water treatment.

Cascade aerator

Cascade aerators, a type of gravity aerators, are generally used as pre- or post-aeration system. They consist of a number of steps over which water flows. The turbulence created on the water surface due to its fall over the steps, breaks the air-water interface and helps in oxygen transfer as well as removal of volatile organic contents such as methane and chlorine, dissolved iron and manganese, carbon dioxide, hydrogen sulphide, as well as the colour and tastes caused by volatile oils (Toombes and Chanson, 2005). A circular stepped cascade (CSC) aerator was developed by Singh (2010) at IIT Kharagpur. Performance evaluation of prototype CSC aerators was evaluated at optimum geometric condition.

Perforated tray aerator

The perforated tray aerator is also being used in aquaculture water treatment. It is like a column in which water is supplied through a riser pipe to the top of the column and water flows down under gravitational force over a series of trays located one below the other. This arrangement allows the water to fall from one tray to the next one in the form of water droplets. During the fall of water, air bubbles rise up. As air gets dragged in, gas exchange occurs between the air in the bubbles and the water. Oxygen diffuses from the air into the water and thus increases dissolved oxygen content of the water. Vertical distances between the trays are typically 10–25 cm, and the number of trays varies between 4, 5 and to 6. The effectiveness of the aerator increases with number of trays and distance between them. The water is distributed throughout the perforated tray and drops down from tray to tray until it reaches the level basin located under below the last one. When the water flows down through the holes in the perforated trays, drops are formed and this ensures a large contact area between the air and the water.

Comparative performance of aerators

Boyd and Ahmad (1987) tested a large number of electric aerators for oxygen-transfer efficiency. Propeller-aspirator-pump aerators, vertical pump aerators and diffused-air aeration systems also are widely used in aquaculture for aeration of small ponds (≤ 1 ha). Values of SOTR (kg O_2 h^{-1}) and SAE (kg O_2 kWh^{-1}) for different electric aerators have already been used in aquaculture (Boyd and Ahmad, 1987). Propeller-aspirator-pump-aerators are more suitable than the other aerators in case of small pond (Engle, 1989) described in Table 1.

Table 1. Summarized values of SOTR and SAE

Type of aerator	Number of aerators	Range of SOTR	SAE*	
			Average	Range
Paddle wheel	24	2.5 - 23.2	2.2	1.1 - 3.0
Propeller-aspirator-pump	11	0.1 – 24.4	1.6	1.3 – 1.8
Vertical pump	15	0.3 – 10.9	1.4	0.7 - 1.8
Pump sprayer	3	11.9 – 14.5	1.3	0.9 – 1.9
Diffused-air	5	0.6 – 3.9	0.9	0.7 – 1.2
Circular cascade	4	0.11 – 0.135	2.57	2.2 – 2.7

Note: * SAE is based on estimated brake power.

CONCLUSION

Aerators nowadays represent a commonly used device for the intensification of oxygen input into biological wastewater treatment plants. Dissolved oxygen is the most important factor in an aerobic biological process and aquaculture system due to the vital need of all organisms living and having an aerobic respiration in water. Currently, the mechanical aerators are widely used all over the world due to their advantage of increasing dissolved oxygen concentration. Main advantage of these types of aerators is to remove volatile organic matters, gases like sulphide, carbon dioxide etc. which are toxic to the aquaculture pond and thereby maintain the water quality.

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    - 2.7. **Results and Discussion.** In this section, only significant results of the experiment(s) should be reported. Along with the tables and figures, the discussion should deal with interpretation of results and relate the author's findings with the past work on the same subject. The conclusions drawn should be explicitly listed at the end of this section.
3. **References.** Please refer "Misra, R.C., Pani, D.R., Kumar, P. and Das, P. 2018. Vegetation mapping and management strategy of mangroves of Bhitarkanika wildlife sanctuary, Odisha: A remote sensing approach. *e-planet* **16**(2): 89-101. Distinction for the same author and same year be done as 2017a, 2017b etc. Unpublished data, thesis and personal communication are not acceptable as references.
4. **Table.** Number the tables consecutively in Arabic numerals. Tables should have comprehensible legends. Conditions specific to a particular experiment should be stated. Zero results must be represented by 0 and not determined by n.d. The dash sign is ambiguous. For values <1, insert a zero before the decimal point.
5. **Illustrations.** All graphs, diagrams and half-tones should be referred to as Figure and should be numbered consecutively in Arabic numerals. The figures should either match with the column width (8.5 cm) or the printing area (17.8 x 22 cm). The legends should be brief and self-explanatory. All graphs, figures should be drawn by EXCEL and submitted in editable format. Define in the footnote or legend any non-standard abbreviations or symbols used in a table or figure.
6. **Reviews.** Full length review articles are also invited.

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