RNI No. ORI ENG / 2003 / 15643 / 22.11.2005

ISSN No. 0974 - 4398 / 2008

ORGANISATION FOR PROTECTION OF ECOSYSTEM ENVIRONMENT AND ENDANGERED SPECIES

e-planet

Volume - 14 June - 2016 Issue No. - 1

A Multi-disciplinary International Journal of Ecology, Environment, Agriculture and Allied Sciences

Printed, publised & edited by Dr. R.K. Samantaray, 1(A), Nandankanan Zoo, P.O. Barang, Dist- Khurda, Odisha, India, Pin - 754005. Owned by the Organisation for Protection of Ecosystem, Environment and Endangered Species (OPES), Plot No. - A-47, Rameswarpatna, Maushima Square, Old Town, Bhubaneswar-751002, Odisha, India. Published and printed at Print-Tech Offset Pvt. Ltd., Bhubaneswar - 751024

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e-planet

Volume - 14 **June - 2016** **Issue No. - 1**

A Multi-disciplinary International Journal

of

Ecology, Environment, Agriculture and Allied Sciences

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e-planet **14** (1): 1-10 (June 2016)

Consequences of metabolic scaling and log-scale allometry on means, variances and parameters from type I and type II linear regression models

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Date of receipt: 29. 01. 2016 Date of acceptance: 10. 06. 2016

ABSTRACT

The slope bias when the predictor variable suffers from measurement errors is investigated. The presence of measurement errors can undermine the least squares linear regression parameter estimates, which in turn will have consequences if slope-based meaningful functions are calculated and used. Methods to determine suitable regression model choice are outlined. Also, the consequences of data size shrinkage due to scaling by metabolic weight in energy balance studies are illustrated. A problem arises when the assumed value of the metabolic index (b) changes. In the literature, this index varies from 0.62 to 0.75 for calculation of metabolic weight (MW) from live weight (LW) *i.e.* $MW=LW^b$. The estimates of regression parameters vary according to the assumed value of the metabolic index b and that will impact further on intercept and slope based calculations. Similar problems occur when allometry functions are linearized using logarithmic transformation. Disproportional shrinkage of data size introduces scale bias which can introduce inaccuracies in further use of the regression parameters. Both of these issues have potential difficulties when using databases where data size is unevenly distributed.

Key words: Allometry, energy balance, measurement errors, metabolic scaling, scaling index, type I model, type II model

INTRODUCTION

Measurement errors in the predictor variable lead to slope ($\hat{\beta}$) attenuation or negative slope bias when using linear type I or ordinary least squares regression (OLS). This bias is proportional to simple correlation ($1/r_{xy}$). Mitigation of this problem is achieved by using a type II regression instead, which accounts for these errors in the x-variable.With assumptions about the measurement error variances, two options of type II model are relevant: (1) major axis regression (MA) when error variances of the y- and x-variables are deemed to be equal; and (2) reduced major axis regression (RMA) when the

error variances of the y- and x-variables are proportional to their underlying true variances. RMA is related to the usual "y-on-x and x-on-y" regression lines. Application of type II regression models is demonstrated for metabolic scaling of data and estimation of allometric relationships.

The power model, $y = ax^b$, is the most commonly used and debated model in allometry studies. Historically, the allometry function is linearized using logarithmic transformation. Justification for this transformation tends to be the equalisation of variance and also allometry index estimation is much simpler on the log-scale using linear regression. However, parameter estimation of allometric functions on the log-scale has the additional problem of unequal shrinkage of data size, which in turn introduces bias in relation to the original scale. To alleviate this problem, Guest (1961) recommended use of weighted linear regression as mentioned below. To accommodate changes in the variance of the predictor variable, type II regression methods are needed. The objectives of this study were to analyse changes in the variables when scaling factors or logarithmic transformations are introduced and the influence of the type of regression used on the estimation of biologically meaningful parameters from scaled or log-transformed variables. The analysis is based on two case studies (energy balance and allometry) with fundamental relevance in the field of animal nutrition and metabolism.

MATERIALS AND METHODS

Type II regression models

The type II model is also known as Deming regression (Deming, 1943) with the measurement error variance ratio $\lambda_{\text{Deming}} = 1/\lambda_{\text{ML}}$ (see below). This model is necessary in cases where meaningful interpretation of regression coefficients and their functions is required. Type II regression allows incorporation of predictor measurement errors to estimate the maximum likelihood (ML) slope (β_{ML}) with the model defined (Deming, 1943; Kendal and Stuart, 1966; Madansky, 1959; Dhanoa, *et al.*, 2010a) as:

$$\hat{\beta}_{\text{ML}} = \frac{\hat{\sigma}_y^2 - \lambda_{\text{ML}}\hat{\sigma}_x^2 + \sqrt{(\hat{\sigma}_y^2 - \lambda_{\text{ML}}\hat{\sigma}_x^2)^2 + 4\lambda_{\text{ML}}\hat{\sigma}_{xy}^2}}{2\hat{\sigma}_{xy}}$$

where $\lambda_{\text{ML}} = \hat{\sigma}_\varepsilon^2 / \hat{\sigma}_\delta^2$ *i.e.* the ratio of the measurement error variances of the y- and x-variables, $\hat{\sigma}_x^2$ and $\hat{\sigma}_y^2$ are the sample variances of the x- and y-variables, respectively, and $\hat{\sigma}_{xy}^2$ is the sample covariance between the x- and y-variables. Mandel (1964) showed that the above slope estimate is related to the ordinary least squares (OLS) slope estimate as:

$$\hat{\beta}_{\text{ML}} = \frac{\hat{\beta}_{\text{OLS}:y,x}}{1 - (\hat{\sigma}_\delta^2 / s_x^2)}$$

Snedecor and Cochran (1980) give this formula in the alternative form:

$$\hat{\beta}_{\text{ML}} = \hat{\beta}_{\text{OLS}:y,x} \frac{\hat{s}_x^2}{\hat{s}_x^2 - \hat{\sigma}_\delta^2}$$

For the special case MA, set $\lambda_{\text{ML}}=1$ in the above maximum likelihood (ML) equation. For alternative forms of the major axis slope, β_{MA}, see Dhanoa *et al.* (2010a).

In the ML equation it is assumed that the variance of the data values is contstant. In cases where this assumption is not tenable, Ripley and Thompson (1987) proposed a reiterated weighted procedure referred to as functional relationship estimation by maximum likelihood (FREML; Royal Society of Chemistry, 2002).

Metabolic scaling of data

In animal energy balance studies, it is customary to scale data with metabolic weight (MW) where MW = LW^b (LW denotes live weight and b metabolic index). Unfortunately such scaling results in nonlinear effects on data value size and variance (Dhanoa *et al.*, 2015) and has consequences for regression parameter estimates. OLS regression may no longer be appropriate.

Allometry on the log-scale

The general allometry function $y = ax^b$ (Huxley, 1924), where a is the scaling constant and b the metabolic index, is usually expressed as a linear function on the log-scale:

$$\log(y_i) = \log(a) + b\log(x_i) + \varepsilon_i$$

Here, subscript i denotes the ith item of samples x and y, and ε_i are assumed to be normally distributed additive errors. This equation holds for any base of logarithm but in this paper $\log_e$ is assumed. In the absence of measurement error estimates OLS, MA or RMA regression models are used to derive estimates of the metabolic index b. In the case of OLS regression, slope (and hence the intercept) are biased estimates which may be corrected as explained above. Also in the case of OLS regression, unequal shrinkage of small to large values causes scale mismatch which requires that weights are necessary to approximate nonlinear estimates. These weights (w'_i) were proposed by Guest (1961) and were shown to be $w'_i = w_i y_i^2$ where w_i= 1/var (y_i). On the importance of weights, Guest (1961) stated 'even if the original observations were all of equal weight, the transformed observations must be weighted, for otherwise the estimates will be inefficient and the standard deviation calculations completely incorrect'.

RESULTS

Metabolic scaling effects on energy balance analysis

In the particular case of energy balance studies, a further complication arises from scaling the energy components (*i.e.* energy retention (ER) and metabolisable energy intake (MEI)) by the metabolic weight (LW^b) of the animals. Due to lack of consensus, various values for the metabolic index (b), ranging from 0.62 to 0.75 have been used. These values result in respective metabolic weights that follow a nonlinear trend over the range of b for both the mean and variance (Fig.1). Rate of metabolic-weight-value shrinkage from b = 0.75 down to b = 0.62 is faster for variance than for the mean.

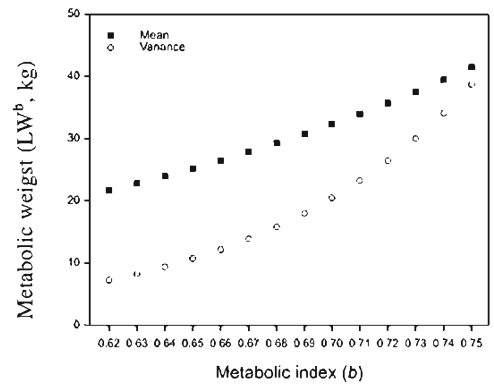

Fig. 1. Data from a calorimeter study using thirty-one growing steers with mean live weight of 142.4 kg (Sanderson *et al.*, 1995)

One of the main purposes of energy balance studies is to derive estimates of efficiency of energy utilisation for growth (k_g or k_f) and metabolisable energy requirement for maintenance (M_m). Mostly, the type I model or OLS regression is used to fit a linear model to relate ER and MEI:

$$ER = (MEI - M_m) \times k_g = k_g \times MEI - k_g \times M_m$$

so that k_g and $k_g \times M_m$ are the slope and the intercept, respectively, of the model. In OLS, metabolic scaling effects on MEI variance will not be accounted for as predictor variables are assumed error free which results in attenuation of the least-squares slope estimate (Dhanoa *et al.*, 2000; 2007; 2010b). However, with the type II regression model, predictor measurement errors are modelled and slope attenuation is avoided (McArdle, 1988; Dhanoa and Sanderson, 2010).

Uncertainty from both ER or MEI and LW^b gets propagated into the ratios ER/LW^b and MEI/LW^b according to the formula (Ku, 1966; Wikipedia, 2016):

$$\sigma^2_{P/Q} \approx (P/Q)^2 \left[(\sigma_P / P)^2 + (\sigma_Q / Q)^2 - 2\frac{\sigma_{PQ}}{PQ} \right]$$

where P = ER (or MEI) and $Q = LW^b$ and $\sigma^2_Q = (LW^b)^2 b \left(\frac{\sigma_{LW}}{LW}\right)^2$

Decreasing values of b cause shrinkage of the LW^b scale which in turn causes reverse shrinkage of ER and MEI data scaled by LW^b (Table 1).

Table 1. Influence of metabolic scaling index (b) on mean scaled daily ER and MEI (Sanderson *et al.*, 1995) and their correlation (r)

b	ER (MJ/kg LW^b)		MEI (MJ/kg LW^b)		$r_{ER,MEI}$
	Mean	SD	Mean	SD	
0.62	0.1463	0.12553	1.2937	0.20631	0.6970
0.63	0.1392	0.11949	1.2310	0.19501	0.7016
0.64	0.1325	0.11375	1.1714	0.18434	0.7063
0.65	0.1261	0.10828	1.1146	0.17428	0.7109
0.66	0.1200	0.10308	1.0606	0.16478	0.7156
0.67	0.1142	0.09813	1.0092	0.15582	0.7203
0.68	0.1087	0.09341	0.9603	0.14736	0.7250
0.69	0.1035	0.08893	0.9138	0.13937	0.7298
0.70	0.0985	0.08466	0.8695	0.13183	0.7345
0.71	0.0938	0.08059	0.8274	0.12471	0.7392
0.72	0.0892	0.07673	0.7873	0.11800	0.7440
0.73	0.0849	0.07304	0.7492	0.11166	0.7487
0.74	0.0808	0.06954	0.7129	0.10567	0.7535
0.75	0.0769	0.06621	0.6784	0.10002	0.7582
1.00	0.0224	0.01945	0.1964	0.02684	0.8577

Table 2. Influence of metabolic scaling index (b) on k_g and M_m (MJ/kg LW^b)

b	Type I		Type II					
	OLS		FREML		MA		RMA	
	k_g	M_m	k_g	M_m	k_g	M_m	k_g	M_m
0.62	0.4241	0.9489	0.5268	0.9884	0.5030	1.0030	0.6085	1.0534
0.63	0.4299	0.9073	0.5329	0.9439	0.5096	0.9579	0.6128	1.0039
0.64	0.4358	0.8674	0.5391	0.9015	0.5162	0.9147	0.6170	0.9567
0.65	0.4417	0.8291	0.5453	0.8608	0.5228	0.8734	0.6213	0.9116
0.66	0.4476	0.7925	0.5516	0.8220	0.5293	0.8338	0.6255	0.8687
0.67	0.4536	0.7574	0.5580	0.7849	0.5359	0.7960	0.6298	0.8278
0.68	0.4596	0.7237	0.5644	0.7494	0.5424	0.7598	0.6339	0.7888
0.69	0.4656	0.6915	0.5708	0.7155	0.5488	0.7252	0.6381	0.7516
0.70	0.4717	0.6607	0.5773	0.6831	0.5552	0.6921	0.6422	0.7161
0.71	0.4777	0.6311	0.5838	0.6522	0.5616	0.6604	0.6462	0.6823
0.72	0.4838	0.6028	0.5904	0.6226	0.5679	0.6302	0.6502	0.6501
0.73	0.4898	0.5758	0.5970	0.5943	0.5741	0.6012	0.6542	0.6193
0.74	0.4958	0.5498	0.6036	0.5673	0.5802	0.5735	0.6581	0.5900
0.75	0.5019	0.5250	0.6103	0.5415	0.5862	0.5471	0.6619	0.5621
1.00	0.6215	0.1603	0.7656	0.1667	0.6884	0.1638	0.7246	0.1654

Any impact of the b scaling on regression parameters and their functions such as k_g and M_m are illustrated with energy balance data recorded in respiration chambers over two days (Sanderson *et al.*, 1995). Four linear regression models are relevant to energy balance data analysis, *viz.*

i. Ordinary least squares (type I model; OLS)

ii. FREML (type II model)

iii. Major axis (type II model; MA)

iv. Reduced major axis (type II model; RMA)

M_m (the MEI required for maintenance) was calculated for each model as {–intercept/slope}. Each of the b index values gives different scale to the resulting MW and also leads to different scaled ER and MEI values. To get comparable data we calculated daily metabolisable energy required for maintenance of an animal with the mean LW for each b index value using M_m from the above four regression models. These models give different estimates depending on how they deal with changes of scale and variances (Table 2).

The allometry power function on the log-scale

Empirical evidence for log-transformation: the Horvitz rule

When variance of the response variable y increases as its mean or expected value E(y) increases, *i.e.*

$$\text{var } y_i \propto \{E(y_i)\}^{2(1-\lambda_{BC})}$$

then Taylor series analysis shows that variance is approximately stabilised (Atkinson, 2003) by using response as:

$$y_i^{\lambda_{BC}} \qquad \lambda_{BC} \neq 0$$
$$\log(y_i) \qquad \lambda_{BC} = 0$$

For a Box-Cox lambda (λ_{BC})=1 no transformation is needed, λ_{BC}=0 indicates log-transformation, λ_{BC}=0.5 will be square root transformation whilst other non-zero λ_{BC} values may point to Box-Cox system of transformations (Box and Cox, 1964).

The above expression can be written as:

$$\log(s_y) = \gamma_0 + (1-\lambda_{BC})[E(y_i)]$$

where s_y is the standard deviation of y_i if replicate values of y are available and γ_0 is the intercept. Throughout this paper $\log_e$ is adopted but the equations can be used with any log-base using the relationship $\log_e X / \log_e NN = \log_{NN} X$, where NN is any logarithmic base *e.g.* 10, 2 etc. and X is any data. In the absence of replicates, data may be compressed into smaller size by clustering into groups of increasing mean values.

Data size shrinkage when transforming to the log-scale

To demonstrate log-transformation shrinkage effects, we have taken unadjusted mammal species metabolic rate (MR; ml O_2 h^{-1}) and mass (g) data (N = 469) from the electronic appendix to the article by White *et al.* (2006) on the scaling and temperature dependence of vertebrate metabolism. Many of these data are from relatively smaller size species and that makes it unsuitable for nonlinear fitting of the allometry power function.

Skew data distribution does not always imply a log normal distribution. An overlapping mixture of normal distributions can cause skewness and multimodality. For example, Box-Cox transformation of the mammal species data (both MR and mass) gave λ_{BC} = –0.2 instead of 0 which would indicate a log normal distribution (only amphibians gave λ_{BC}= 0). Therefore, a multimodal distribution is indicated. Given no species misclassification, the distribution mixture is most likely due to lack of data over the range where these two components overlap. Further analysis of these data on a log-scale showed a double-normal model fitted well with either common variance or separate variance (Table 3). These results may be used to partition data into two component distributions before analysis. However, for a single species one expects a common allometric index. More data are required to correct distribution fragmentation in the White *et al.* (2006) databases.

Table 3. Parameters of the fitted double normal distribution with component means (Mean 1; Mean 2) with standard deviations (SD 1; SD 2) respectively and the proportion of the larger mean component (p)

		λ_{BC}	Mean 1	Mean 2	SD 1	SD 2	p
Mammals	MR	−0.2	6.793	4.213	0.9583	0.9583	0.2468
	Mass	−0.2	6.644	3.584	1.8112	0.8906	0.4908
Birds	MR	−0.5	5.630	3.820	0.8045	0.4235	0.3254
	Mass	−0.3	6.038	3.066	0.8453	0.8453	0.2635
Reptiles	MR	−0.1	3.481	0.290	1.3378	1.3378	0.4019
	Mass	−0.1	5.090	2.335	1.2145	1.2145	0.4399
Fish	MR	0.1	1.894	−2.058	1.4050	1.4050	0.8292
	Mass	0.1	5.186	1.093	1.4777	1.4777	0.7444
Amphibians	MR	0.0	0.422	−1.586	1.1540	0.2818	0.7043
	Mass	0.0	2.660	0.048	1.6440	0.2625	0.8694

Here, we will concentrate on the problem of data size shrinkage and its consequences when analysis is performed on the log-scale. Using mammal mass data on the log-scale as percentage of the original mass observations, the differential size reduction can be seen in Fig. 2. It is evident that larger size observations are shrunk to a greater extent relative to the smaller size observations, leading to changes in the variance. The effect on log-scale variance change is accommodated by type II regression models, *e.g.* RMA, but not by OLS.

Further, we use quantile regression (Koenker, 2005) of $\log_e$(MR) on $\log_e$(Mass) for mammals to see if data distribution on the log-scale is free from unexpected serious stratification. For this purpose 10th, 25th, 50th, 75th and 90th percentile regression lines are selected as shown in Fig. 3. Despite observation crowding at the lower end (original scale), slopes are generally parallel from the 10th (lower line) to the 90th (upper line) percentiles. A normal distribution with mean 4.850 (±0.0678) and standard deviation 1.468 (±0.0480)was fitted to the log-scale data for MR. However, lack of fit as measured by deviance (distributed as χ^2) was 69.86 on 19 degrees of freedom, which was significant ($P < 0.05$). When examined further using a probability plot, some observations did not fall within the 95% confidence interval. Also, the Box-Cox λ was slightly less than zero. As shown above (Table 3), the best fit model was an overlapping double-normal with unequal variances for the two components. Such features can cause variation or bias in the slope estimates if sub-samples of these data are used for regression analysis. Quantile regression also shows how the slope estimate (allometric index) varies across the entire range of the percentiles as shown in Fig. 4. These changes in the slope estimate will cause variation in the estimates of the y-axis intercepts. If one is using regression parameter estimates for further calculations, these variations are worth considering.

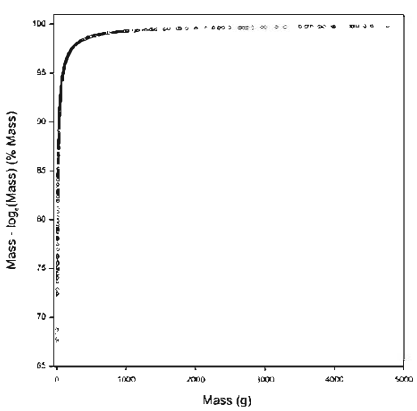

Fig. 2. Shrinkage of White *et al.* (2006) mammal mass data (≤ 5000 g) on transformation to the $\log_e$-scale

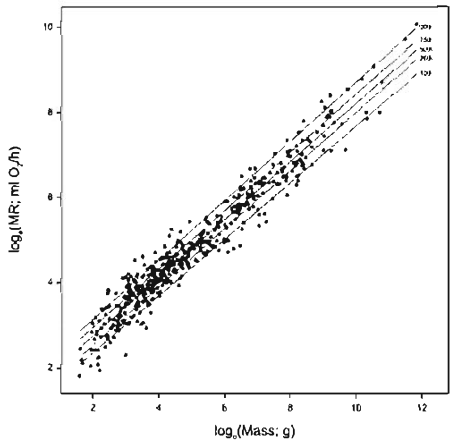

Fig. 3. Fitted linear quantile regression lines for White *et al.* (2006) mammal data at 10th, 25th, 50th, 75th and 90th percentiles

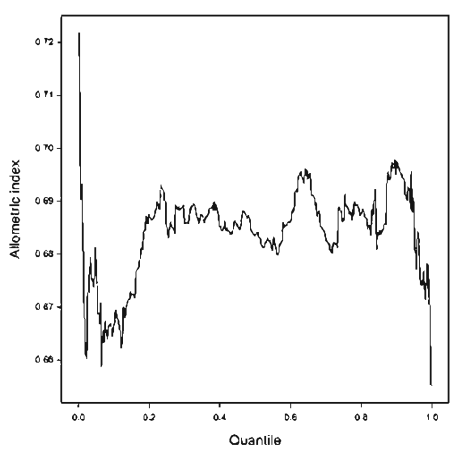

Fig. 4. Variability of the linear quantile slopes, *i.e.* allometric index, from log$_e$(MR) versus log$_e$(Mass) over the entire quantile range

Table 4 shows allometry index estimates using nonlinear, type I, type II and quantile regression models for each of the five classes of animals in the White *et al.* (2006) data set. In these data, there are some outliers which will undermine the weighted regression model (possibly an indirect way to detect outlier problems).

Bias correction in the log-scale allometric equation

The logarithm of the linear scale mean is not equal to the mean of logged values. This difference is equal to the gap between the geometric mean (GM) and arithmetic mean (AM) in the original observations. Anti-log of log-scale mean equals GM, whilst for AM a correction derived by Finney (1941) and illustrated by Sprugel (1983) needs to be applied. Finney (1941) showed that:

$$\mathrm{AM} = e^{\hat{\mu}+\hat{\sigma}^2/2} = e^{\hat{\mu}} e^{\hat{\sigma}^2/2}$$

where $\hat{\mu}$ and $\hat{\sigma}^2$ are estimates of mean and variance on the log-scale respectively. Sprugel (1983) called this variance estimate SEE which is also known as mean square prediction error (MSPE), *i.e.*

$$\mathrm{SEE} = \sqrt{\sum \left\{ \log(y_i) - \log(y_i)_{\text{fitted}} \right\}^2 \Big/ (N-2)}$$

where $\log(y_i)_{\text{fitted}}$ are the log-scale fitted values (we use log$_e$ here but this can be converted to any other base) and N is the sample size. The correction factor $e^{\hat{\sigma}^2/2}$ must be applied if log-scale quantities are to be transformed back to the original scale.

Allometry data compression

In the Deming, MA and RMA models, it is implicitly assumed that measurement errors are equal across the whole data range. In order to illustrate the relevant methodology for handling individual observation variances, we arbitrarily compress the example data into 40 groups on the basis of MR, temperature and mass data size using non-hierarchical cluster analysis. The mean and variance of these groups were used to calculate linear functional relationship estimates using the FREML software of Ripley and Thompson (1987) as implemented in an Excel Add-In (Royal Society of Chemistry, 2002). Thus, using means and variances of these 40 groups the fitted linear equation was:

$$\log_e(\mathrm{MR}) = 1.4716\ (\pm 0.10175) + 0.6788\ (\pm 0.01828) \log_e(\mathrm{Mass})$$

The fitted line with both y-axis and x-axis error bars is shown in Fig. 5.

Table 4. Allometry index estimates using nonlinear, type I, type II and quantile regression models from unadjusted White *et al.* (2006) data set.

Method	Mammals	Birds	Reptiles[@1]	Fish	Amphibians[@2]
Nonlinear ($y = \omega x^b$)	0.879 (±0.0136)	0.724 (±0.0248)	0.416 (±0.1170)	0.786 (±0.0156)	0.529 (±0.0447)[@2]
Nonlinear bootstrap	0.843 (±0.0833)	0.721 (±0.0358)	0.518 (±0.0525)	0.784 (±0.0303)	0.598 (±0.0477)[@2]
With data transformed to natural log-scale					
OLS	0.684 (±0.0076)	0.645 (±0.0181)	0.752 (±0.0189)	0.826 (±0.0094)	0.666 (±0.0139)
OLS bootstrap	0.684 (±0.0090)	0.644 (±0.0159)	0.751 (±0.0978)	0.826 (±0.0110)	0.667 (±0.0155)
OLS weighted	0.786 (±0.0085)	0.658 (±0.0163)	0.760 (±0.0259)	0.931 (±0.0778)	0.780 (±0.0114)[@2]
RMA	0.703 (±0.0084)	0.665 (±0.0149)	0.858 (±0.0191)	0.883 (±0.0114)	0.758 (±0.0153)[@2]
RMA bootstrap	0.703 (±0.0080)	0.666 (±0.0132)	0.857 (±0.0173)	0.883 (±0.0109)	0.758 (±0.0153)[@2]
MA	0.697 (±0.0088)	0.657 (±0.0155)	0.840 (±0.0211)	0.875 (±0.0120)	0.730 (±0.0170)[@2]
MA bootstrap	0.696 (±0.0093)	0.654 (±0.0169)	0.840 (±0.0218)	0.876 (±0.0113)	0.733 (±0.0180)[@2]
Quantile linear at median	0.684 (±0.0112)	0.641 (±0.0211)	0.750 (±0.0157)	0.788 (±0.0149)	0.688 (±0.0170)[@2]
Quantile linear at median weighted	0.781 (±0.0355)	0.649 (±0.0724)	No fit due to outliers	0.687 (±0.0420)	No fit due to outliers
Dataset size	469	82	483	1107	681

[@1]Some very large size outliers cause fitting problems.

[@2]Unreliable estimates (dataset dominated by majority of small amphibians).

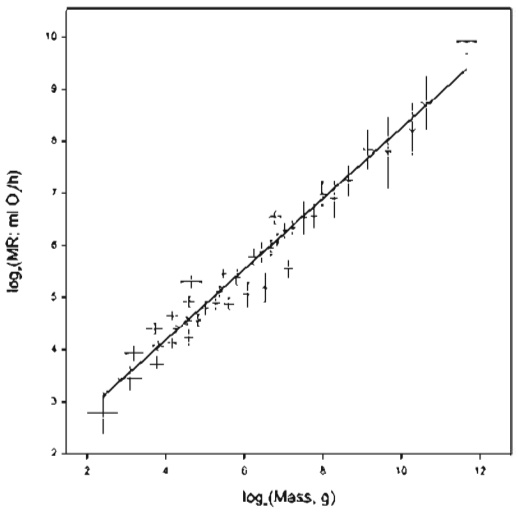

Fig. 5. Allometric relationship (solid line) between $\log_e$(MR) and $\log_e$(Mass) for White *et al.* (2006) mammal data as a ML regression with variable λ estimated using the FREML software of Ripley and Thompson (1987). Error bars represent ±1 SD about the means of each of the 40 groups.

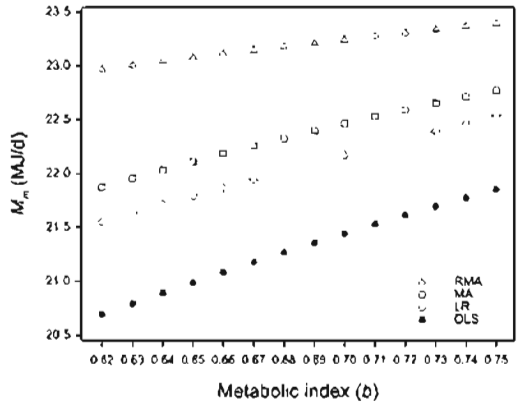

Fig. 6. Influence of metabolic scaling index (b) and regression model on estimates of metabolisable energy for maintenance of a steer with live weight of 142.4 kg.

DISCUSSION

Energy balance analysis

Because of measurement errors, slope attenuation is largest for OLS and mitigated to different degrees by the three type II models discussed here. Scale and variance shrinkage of LW^b and energy balance components have consequences when different values of the metabolic scaling index are used. Estimates of linear regression parameters and their meaningful functions are also affected both by LW scaling and type I and type II regression models (Fig. 6). It is therefore necessary to account for these effects with an appropriate regression model when conducting literature reviews and further data analyses such as modelling and meta-analysis. Smaller differences on the analysis scale may translate to larger differences on the original scale.

Allometry analysis on the log-scale

In order to cover the whole domain of a species, a large data set is needed which can have implicit shortcomings due to data coming from different sources and also not covering the whole range adequately. That results in distribution fragmentation as illustrated above for our example data. We have used bootstrap (Efron and Tibshirani, 1993) to verify regression parameter estimates and their standard errors. Allometry analysis procedure is quite well established but one needs to be aware of some of the log-transformation effects such as unequal data size shrinkage and need for an appropriate regression model to deal with changing variances. Inevitably, a type II regression model will be needed to deal with consequences of log-transformation in relation to scale and variances.

CONCLUSION

In this paper we have explained and illustrated problems due to the metabolic scaling index used to calculate MW from an animal's LW which is needed to scale energy balance components, *e.g.* ER and MEI. Regression slope of ER versus MEI is used as an estimate of efficiency of energy retention for growth k_g, and the x-axis intercept as an estimate of maintenance energy M_m. A suitable regression model is needed to cope with changes in variances caused by scaling with metabolic weight at a chosen value of the metabolic index b. Similarly log-transformation to linearize the allometry equation for estimation of the metabolic index has associated problems. As illustrated above, this transformation has a disproportional effect on both data scale and variances. As in the case of energy balance data

analysis, an appropriate regression model is necessary. Furthermore, in taking regression quantities back to the original scale, bias corrections need to be carried out.

ACKNOWLEDGEMENT

Rothamsted Research is sponsored by the Biotechnology and Biological Sciences Research Council, UK. The Canada Research Chairs Program (National Science and Engineering Council, Ottawa) is thanked for part funding.

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e-planet **14** (1): 11-21 (June 2016)

Carbon stock estimation in different forest lands: A review

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Date of receipt: 04. 04. 2016 Date of acceptance: 05.06.2016

ABSTRACT

Terrestrial biosphere comprising of mainly forests, the major source of carbon absorption and the stock estimation methods are initiating to mitigate the threats concerned with climate change. In order to increase the global carbon stock United Nations Framework Convention on Climate Change (UNFCCC) has introduced Reducing Emission from Deforestation and Forest Degradation (REDD+) programme. Thus, several standard procedures applicable to the forestry and agroforestry land use systems have been developed. They introduced the set of methodologies for measuring, monitoring and estimating carbon stock in several forests of the world. Forest Survey of India (FSI) is the foremost contributor to measure forest biomass and carbon stock in India with the joint association of UNFCCC since 2004. This review cited the process of total carbon stock in different forests including organic carbon estimation in above ground biomass, below ground biomass, soil as well as litter biomass through remote sensing method, destructive method, non-destructive methods, ground based inventory data for consistent, precise, pertinent estimation of carbon stock. This review covers various scientific approaches for estimating carbon stock in forests.

Key words: Biomass, carbon estimation, forest lands, IPCC, soil organic carbon

INTRODUCTION

The global carbon cycle has drawn increased (microorganisms) of forest land. Overall, forests concern to address issues associated with are the repository of natural source of atmospheric environmental pollution focusing on the derelict carbon stock. The biological carbon cycle is mostly ecosystem, forest degradation and global climate regulated by four reservoirs including fossil carbon, change. The estimation of carbon stock is taken oceans, atmosphere and terrestrial ecosystems, primarily by indirect methods and is concerned about forest soil and biomass. Potentially soil organic the control of terrestrial carbon exchange factors, carbon is more reliable in the short term storage of its magnitude and primary location. The reduction organic carbon rather than oceans. The amounts of fossil fuel, sovereignty and methods to measure and dynamics of carbon in the world's soils are still emission reduction and new initiatives led by forest relatively poorly known as the carbon stock changes rich developing countries has drawn global attention. dynamically over time and space. The carbon Need of the era is to control high emission and balance of terrestrial ecosystems deteriorate by storage of carbon compounds (e.g. CO, CO etc.) the impact of human activities, deforestation,

in the biosphere. The natural processes of trading biomass burning, land use changes, conversion and carbon are done through autotrophs and heterotrophs environmental pollution. Soil carbon pools have

decreased by 40 Pg. C from the original 1471 Pg. C during 1850-1980 and carbon held in vegetation by 80 Pg C down from 672 Pg C in 1850. Global release of carbon from land use change in 1990 was between 1.1 and 3.6 Pg C yr^{-1}, as compared to 5.5-6.5 Pg C yr^{-1} from fossil fuel combustion. The annually displaced soil due to global soil erosion is about 5.7 Pg C from the total estimated carbon i.e. approximately 1500Pg C.

Forests occupy nearly 4 billion hectares (about 30 per cent) of the earth's land area and evenly divided between tropical , subtropical, temperate and boreal forests. Two third of world's forests are found in Australia, Brazil, Canada, China, Democratic Republic of Congo, India, Indonesia, Peru, Russia, USA etc. The present review discussed several methodologies for estimating the carbon stock in forests. The forest inventory and analysis (FIA) program (2012) estimates that 14.1% of CO_2 emission sequestration occur in US forests and associated wood products.

MAJOR FOREST TYPES OF WORLD

World Wide Fund for Nature (WWF) has categorised the type of forests, mainly based on location (distance from equator and altitude) and climate, as tropical forest, sub-tropical forest, mediterranean forest, temperate forest, montane forest, coniferous forest etc. which acts as carbon pool as well as carbon storage for a long period. United Nations Environment Programme- World Conservation Monitoring Centre (UNEP-WCMC) classification divides the world's forest into 26 major types, redirecting climatic zones as well as the principal types of trees. These 26 major types can be reclassified into 6 broader categories occupying about 250 Gt carbon in above and below ground biomass of forest vegetation (Global forest resources assessment, 2015). Several forest lands of world like low land evergreen broadleaf rain forest, montane forest, freshwater swamp forest, semi-evergreen moist broadleaf forest, mixed broadleaf/ needle leaf forest, mangroves, disturbed natural and deciduous/semi-deciduous broadleaf forest, sparse trees and parkland refer natural forests (10-30% canopy cover) e.g. savannah regions of world stores maximum organic carbon.

Table 1. Carbon pools indicating essential of forest lands

Living biomass	Above ground biomass	All living vegetation above the soil including stem, stumps, branches, bark, seed and foliage.
	Below ground biomass	All biomass of live roots, excluding fine roots of less than 2mm diameter as these often cannot be distinguished empirically from soil organic matter or litter.
Non-living biomass	Dead wood	Dead wood includes wood lying on the surface, dead roots and stumps, lager than or equal to 10cm in diameter.
	Litter	Include all non-living biomass with a size greater than 2mm and less than 10cm, lying dead, in various states of decomposition above or within the mineral or organic soil. This include the litter layer as usually defined in soil typologies .Live fine roots above the mineral or organic soil are included in litter where they cannot be distinguished from it empirically.
Soils	Soil organic matter	organic carbon in mineral soils up to a depth of 1m and applied consistently through the time series. Live and dead fine roots and DOM within the soil are included in soil organic matter

CARBON POOLS OF FORESTS

Measuring carbon stock can be quite challenging, but a few basic assumptions can make estimating it much easier. IPCC (2003, 2006) has defined five carbon pools indicating the essential of forestlands which have been discussed in Table 1.

Table 2. Global carbon stock in different ecosystems

Biome	Area (million Km ^{2})	Global carbon stock (GtC)
Tropical forests	1.76	428
Temperate forest	1.04	159
Boreal forest	1.37	559
Tropical savannas	2.25	330
Temperate grasslands	1.25	304
Deserts and semi-desert	4.55	199
Tundra	0.95	127
Wetlands	0.35	240
Croplands	1.60	131

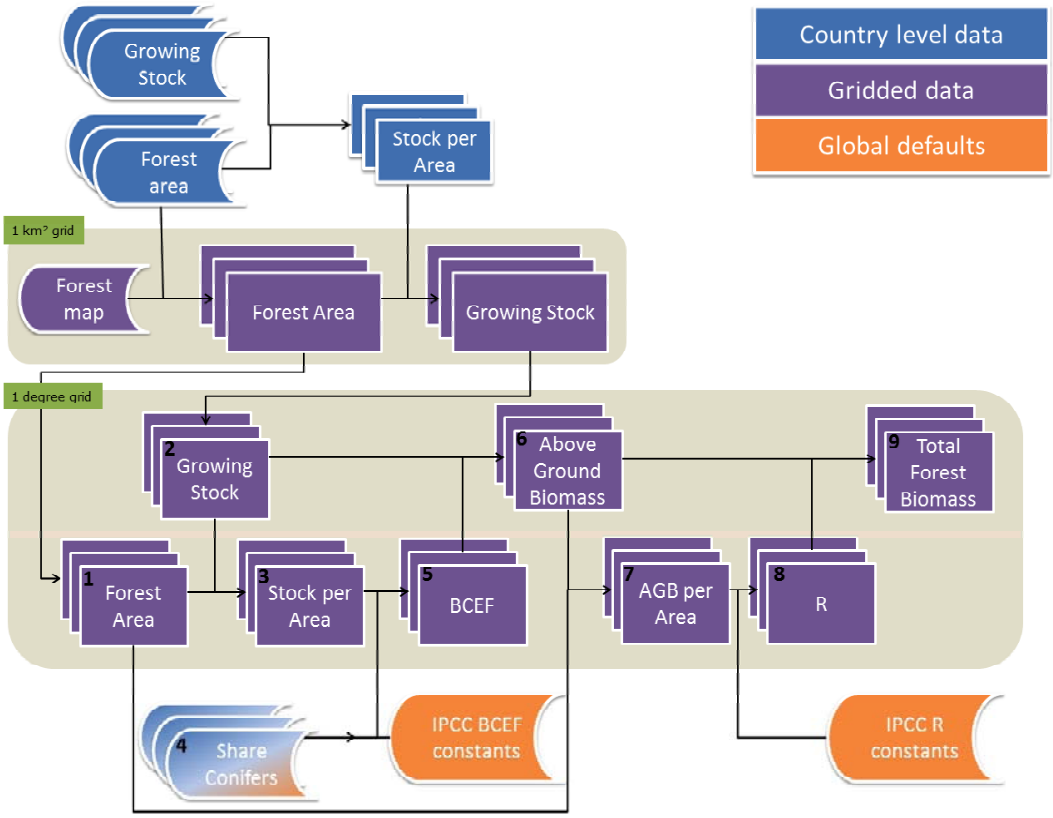

Fig. 1. Depiction of the data flow towards forest biomass maps, showing dependencies (Global 1-degree maps of forest area, carbon stock and biomass, 1950-2010, 2015)

Carbon stock in Indian forests

The forest carbon stocks of different regions of India including the biomass and soil carbon are collected from several literatures. In the year of 1986 Indian forest carbon stock ranged from 8.5 to 9.5 Gt C. FAO study reported the same as 10 GtC for the year 2005. The carbon stock in biomass as well as soil has increased by 377 MtC between 1995 to 2005 (Kishwan *et al.*, 2009). Out of the total forest carbon 50 per cent accounts only the forest soil carbon. FSI reported different forest type stratification regarding carbon stock estimation in several forest lands of India. IPCC, 2014 has reported about 56% of carbon stock as soil organic carbon and 32% as above ground biomass due to the forest cover.

Approaches of carbon stock estimation

Direct measurement approach (destructive method)

Vashum and Jayakumar (2012) had suggested method for field measurement and carbon stock estimation. They followed initially the harvested method for estimation of carbon stock by harvesting all the trees and measuring their biomass as well as carbon stock deposited in that forest ecosystem.

Forest area approach

Nasi *et al.* (2008) had focused on the carbon stock in Congo basin in accordance of Kyoto protocol. Carbon stock was accounted based on 27 sites and 2410 trees of this regional tropical forest using diameter and specific wood density. Generally, trees above 10 cm diameter were considered for biomass estimation. Both plot based and destructive data was summarised and total carbon stock of humid forests, Congo Basin was estimated.

Monte *et al.* (2000) had a survey on juniper woodland of Azzaden valley, Morocco. They collected different parts of plants and their dendrometric measurements, calculated bulk density of different plant parts and finally estimated the biomass showing the total carbon, then validation.

Indirect approach (non-destructive method)

Gao *et al.* (2015) developed a comparative estimation of carbon stock of tree components and the total by different methods like (1) Additive systems of carbon models can be directly used to compute the carbon stocks of tree components and total, given tree diameter and height (2) Additive systems of biomass models were first used to estimate the biomass of tree components and total, and then the predicted biomass was multiplied by the carbon conversion factor 0.5 (3). The biomass models can be used to estimate the biomass of tree components and total, and the predicted biomass was multiplied by the average carbon concentration of total tree.

Mathematical modelling

Bird *et al.* (2015) had followed generic framework. IPCC methodology includes carbon stock changes in different carbon pools on annual basis by applying several formulas. The survey also estimates the carbon stock changes following accounting method (loss-gain method and stock difference method) etc.

Total carbon stock present in biomass and soil could be estimated through IPCC guidelines or through the use of actual conversion and expansion factors which can be represented as:

C carbon = C biomass + C soil

Where,

C carbon = Total available carbon in the forest type, i.e., in the vegetation and in soil

C biomass = Total available carbon in the above and below ground biomass of all vegetation in the forest type

C soil = Total available soil organic carbon (SOC) up to 30cm depth in the forest type

Under REDD measurement guidelines for carbon stock leaf litter, herbs and grass of $1m^2$ plot is considered and weighted; above ground sapling biomass and regeneration of species is noted for sustainable growth and future forest enhancement; DBH of standing dead trees, logged trees and fallen branches are measured; soil collected from default depth prescribed by IPCC (2006) and organic

carbon can be calculated through oxidation method. Biomass of above ground and below ground parts of trees can be estimated through regression equations referring the total biomass as well as the total carbon.

Sahu *et al.* (2015) estimated carbon stock and carbon fluxes in forests of Odisha, India using recent IPCC guidelines. They included several parametric information for carbon stock estimation like Above Ground Biomass (AGB), Below Ground Biomass (BGB), Dead Wood Biomass (DWB), Litter biomass and Soil organic carbon etc. They also calculated the annual carbon flux through rate of gain and loss of carbon from the pools following the steps likewise.

Ground-based forest inventory data from sample sites

Sampling data for developing allometric relationships can originate from sample sites or forest inventories (Gibbs *et al.,* 2007): Sampling approaches typically consist of country or region-specific sampling designed for broad forest categories (sampling strata). Gibbs *et al.* (2007) recommend the development of a 'stratification matrix' for each country or region using broad forest types and forest conditions (e.g., drainage slope, age, and level of degradation). Such stratification can increase accuracy and precision and reduce costs (Pearson *et al.,* 2008). Focusing first on using stratification to estimate carbon stocks for forests most likely to be deforested or degraded can further reduce uncertainty and cost (Brown 2008).

Suryawanshi *et al.* (2014) elaborated another method for carbon stock estimation. Generally, for any plant species, 50 per cent of its biomass is considered as carbon (Pearson *et al.,* 2005) i.e. Carbon Storage = Biomass/2

The above ground biomass (AGB) of tree species has been calculated by multiplying volume of biomass and wood density (Pandya *et al*., 2013).

AGB (g) = volume of biomass (cm^3) wood density (g cm^{-3})

The below ground biomass (BGB) has been calculated by multiplying above ground biomass taking 0.26 as the root shoot ratio (Chavan and Rasal, 2011; Hangarge *et al.,* 2012).

BGB (g) = 0.26 X above ground biomass (ton).

Total Biomass (TB) = Above Ground Biomass + Below Ground Biomass

Sharma and Phuong (2013) estimated a method for the mapping potential of carbon stock density in Vietnam forests. Biomass carbon stock density in both AGB and BGB pools was estimated for each forest stratum. AGB is estimated from the volume and density relationship of forest types using Eq. 1

$$AGB = VOB \times WD \times BEF$$

Where,

AGB = above-ground biomass (tdm. ha) (tdm is tonnes of dry matter),

VOB = inventoried stem volume over bark (m3 /ha),

BEF = biomass expansion factor (to convert over bark volume to total volume) and

WD = basic wood density (kg/ m¾).

A study on tropical forest shows quantitative contribution regarding global carbon stocks. Here the study was restricted in tropical growing forest climates that regenerated naturally. Further the old, and young or successional forest were taken into account. This survey appraised the biometric variables (i.e. GBH, total tree height) and wood specific gravity for each collected tree. A compared number of statistical models used to estimate the total carbon stock of tropical forest zone of earth.

Another method to estimate forest biomass carbon shows spatial area of interest. This method involved assessing of data on biomass carbon stock density, forest area, forest types, root to shoot ratio, wood density and carbon fraction etc.

Mushtaq and Malik (2014) reported on estimation of biomass from growing stock and forest biomass change regarding total carbon and carbon dioxide emission from forest zones of Western Ghats. Using the conversion factors they estimated the biomass from forest cover. Frontier forest cover change data was obtained from temporal satellite,

then converted into forest biomass. They took several steps for accounting carbon stock involved in the study:

i. Estimation of growing stock from vegetation cover:-

Growing stock = vegetation cover × growing stock conversion factor × root to shoot ratio.

Growing stock = forest cover × 1.314 × 0.28

ii. Estimation of dry matter biomass from growing stock:-

Biomass = Growing stock × mean density (biomass conversion factor)

Biomass = Growing stock × 0.41

iii. Estimation of carbon from biomass:

Total carbon = Dry matter biomass × carbon fraction

Total carbon = Dry matter biomass × 0.47

Domke *et al.* (2012) developed Component ratio method (CRM) for live tree biomass estimation from the central stem volume in standing live and dead trees. The CRM value is determined through regional volume models and specific gravity information to estimate tree biomass (Heath *et al.*, 2009 and Woodall *et al.*, 2011).

During 1998, German Advisory Council on Global Change, assessed areas and carbon storage capacity of various zones. Tropical forest occupies second highest amount of carbon (212 Gt.), where as boreal forests store the highest (559 Gt.). With largest area desert or semi desert zones store relatively small amount of carbon whereas wetlands cover a small area but store relatively high carbon in it (240 Gt.). Rather grass lands also signify an increased amount of carbon density growing on alluvial clay soils.

Carbon stock in mangroves

Kauffman and Donato (2014) have experimented on the ecosystem components of mangroves for the quantification of forest biomass and ecosystem carbon stock as mangroves possess specific physical, climatic, hydrologic features of the environment and can fix much carbon in comparison to tropical forests. The main diversity centre of mangroves is found in indo-pacific regions. They developed a measurement plan following project boundaries, stratify project area, measurement of carbon pools, determine measurement frequency and finally estimate the total carbon stock in the area of Sundarbans of Bangladesh, Kalimantan, Indonesia Riverine. They considered parameters like diameter at breast height for species-specific equations and for general equation wood density.

GIS and remote sensing methods

The indicative estimation of carbon stock in Victoria's publicly managed land used data was developed via a database, into full CAM (i.e. Plot files, Carbon models). The biophysical data like GIS (Tree cover, harvesting etc.) described the features influencing carbon stock on site and included harvesting extent, fire history, vegetation type and geographic region.

SOIL ORGANIC CARBON

Reporting rates for soil carbon were the lowest of all carbon pools, perhaps indicating scarcity of country data or problems in applying the IPCC (2003) default values. The IPCC 2006 Guidelines provides a range from 20 to 300 t C per hectare. The global average soil carbon content to a depth of 30 cm estimated from the FRA 2005 data set was 73 t C per ha^{-1}. The carbon balance of terrestrial ecosystems deteriorates by the impact of human activities, deforestation, biomass burning, land use changes, conversion and environmental pollution. Again the soil carbon pools have decreased by 40 Pg. C from the original 1471 Pg. C during 1850-1980 and carbon held in vegetation by 80 Pg C down from 672 Pg C in 1850. Global release of carbon from land use change in 1990 was between 1.1 and 3.6 Pg C yr^{-1}, as compared to 5.5-6.5 Pg C yr^{-1} from fossil fuel combustion. The annually displaced soil due to global soil erosion is about 5.7 Pg C from the total estimated carbon i.e. approximately 1500Pg C. Estimation of SOC stock generally refer to given depth of soil (i.e. 0 - 15 cm, 15 - 30 cm, 30 - 50 cm, 50 - 100 cm, > 100 cm). The compactness of soil is measured

through the calculation of bulk density (BD) of soil.

Soil with high clay content therefore tends to have higher SOC than soil with low clay content (under similar land use and climate conditions.) which offers a range of 20 to 300t C. per hectare. The FRA, 2005 data set had estimated the organic carbon content was 73 t C per hectare and the range varies from 20 to 300 t C per hectare (IPCC, 2006). In most soil types the majority of C is held as soil organic carbon (SOC) were be determined by a partial oxidation method (Walkley and Black 1934).

The estimates presented by IPCC guidelines designate the global forest vegetation stores 283 Gt C in its biomass, and an additional 39 Gt C as deadwood, for a total of 359 Gt C. Soils to a depth of 30 cm and litter contain 312 Gt C. Thus, even to a depth of only 30 cm, they store about the same amount of carbon as the forest vegetation. Expanding carbon content in soils to a depth of 1m by applying the correction factor, litter and soil together contain 448 Gt C.

The SOC stock of a given area of soil with the same soil type can then be expressed as below-SOC stock = (SOC content of the soil × BD × area × depth)/10,where SOC stock is given in Pg. (1015g), SOC content is in g C g-1, BD is in Mg m-3, area is in Mha and depth is in m.

A study report by Ajonina *et. al* (2014) provided a method for soil measurement of carbon in mangrove ecosystem for carbon content of soil. Dried soil sample of 5-10 gm were weighed through the process of Loss- On- Ignition, the sample set in a muffle furnace for combustion at 550° C for 8 hours. The prepared set of sample cooled in a decicator and reweighed. Then the SOC can be calculated as :

SOC (t ha^{-1}) = Bulk density x g cm^{-3} x organic carbon %

A forest inventory study by FSI (2002-2008) established a comparative measures of 15 forest type cover in India. Carbon stock was estimated following the various result of carbon pools listed in Table 3.

The total scenario of carbon stock in several regions of India explicitly indicate the states rich in forestlands like Andaman and Nicobar, Puducherry, Chandigarh, Sikkim etc. contributed more organic carbon stock.

Ramachandran *et al.* (2007) extrapolated different methods for carbon content of soil i.e. the data were statistically analysed for the computation of standard deviation, frequency distribution and analysis of variance (ANOVA) for each forest type using Microsoft® Excel® worksheet. The total SOC estimated as follow

SOC density (mg ha^{-1}) = SOC (%)/100 × corrected BD (mg m^{-1}) × Soil layer depth (m) × 10^{-4} (m^2 ha^{-1}),

Where BD = bulk density.

Corrected bulk density (mg m^{-3}) = BD (Mg m^{-3}) × (100- per cent coarse fraction)/100,

Data on SOC content (%) and SOC density (mg ha^{-1}) of surface, middle and bottom were mapped using the ArcGIS software.

Total SOC storage = SOC density (mg ha^{-1}) × forest area (ha)

The least significant difference (LSD) was worked out using MstatC software (a one-way analysis of variance (Russel *et al.,* 1991), to compare the SOC mean values of different forest types at different depths (0-30,30-60 and 60-90).

The forest inventory and analysis (FIA) program initiates a new approach towards carbon stock accounting and estimation in 2016. They are developing a framework for quick addressing of new questions that enables carbon analytics by using all the inventory information like disturbances and land use changes. The annual inventory system and total carbon stocks on all forests will serve as the foundation of this type of accounting system.

Table 3. State/UT wise per hectare carbon stock of India in different carbon pools (Fifth Assessment Report of the IPCC 2014)

Sl. No.	State	Area Km²	AGB	BGB	Dead wood	Litter	SOM (t ha^{-1})	Total
1	Andhra Pradesh	44372.00	35.42	13.74	0.16	1.09	39.28	89.69
2	Arunachal Pradesh	67777.00	34.54	7.74	0.55	2.37	96.85	142.05
3	Assam	27645.00	16.11	3.70	0.38	1.96	38.95	61.10
4	Bihar	5579.00	29.45	11.06	0.19	0.75	42.77	84.22
5	Chhatisgarh	55863.00	36.46	12.11	0.43	1.15	48.70	98.85
6	Delhi	176.00	11.29	2.54	0.10	0.53	32.03	46.49
7	Goa	2164.00	19.03	5.07	0.42	1.44	51.57	77.53
8	Gujarat	14715.00	23.68	8.56	0.21	0.67	44.02	77.14
9	Haryana	1587.00	24.86	8.54	0.13	0.46	45.91	79.90
10	Himachal Pradesh	14369.00	44.15	11.63	0.37	1.65	54.41	112.21
11	Jammu & Kashmir	21273.00	45.17	12.34	0.35	1.46	54.30	113.62
12	Jharkhand	22591.00	36.48	14.11	0.19	0.54	43.37	94.69
13	Karnataka	35251.00	33.07	9.58	0.40	4.84	76.77	124.66
14	Kerala	15595.00	38.25	9.75	0.55	3.86	75.53	127.94
15	Madhya Pradesh	76013.00	34.25	13.08	0.20	0.92	41.34	89.79
16	Maharashtra	47476.00	29.73	10.28	0.40	1.83	58.56	100.80
17	Manipur	17086.00	15.29	5.00	0.29	2.24	58.03	80.85
18	Meghalaya	16988.00	13.65	3.73	0.46	2.90	67.02	87.76
19	Mizoram	18684.00	8.48	1.75	0.35	1.47	40.36	52.41
20	Nagaland	13719.00	12.08	3.11	0.43	1.86	77.19	94.67
21	Orissa	48374.00	30.41	10.08	0.38	1.56	45.04	87.47
22	Punjab	1558.00	28.02	10.35	0.16	0.37	49.95	88.85
23	Rajasthan	15850.00	20.64	8.08	0.13	0.40	26.97	56.22
24	Sikkim	3262.00	32.22	9.24	0.48	1.40	78.46	121.80
25	Tamilnadu	23044.00	31.72	10.63	0.34	2.04	47.04	91.77
26	Tripura	8155.00	17.34	3.57	0.63	1.96	48.75	72.25
27	Uttar Pradesh	14127.00	29.50	8.93	0.27	1.11	40.60	80.41
28	Uttarakhand	24442.00	43.51	11.25	0.51	2.31	59.29	116.87
29	West Bengal	12413.00	29.45	9.33	0.23	1.42	56.04	96.47
30	Andman & Nicobar	6629.00	49.83	15.12	1.99	4.59	79.72	151.25
31	Chandigarh	15.00	29.50	10.13	0.18	0.69	52.20	92.70
32	Dadra & Nagar Haveli	221.00	23.67	5.63	0.59	1.99	41.54	73.42
33	Daman & Diu	9.00	3.96	0.97	0.09	0.79	32.72	38.53
35	Puducherry	41.00	21.57	4.61	0.14	1.66	58.64	86.62
Total		677088.00	31.03	9.79	0.37	1.79	55.43	98.41

CONCLUSION

The amount of forest biomass is very crucial for monitoring the carbon stocks as well as carbon loss due to deforestation. This review correlates the several carbon measurement methods to mitigate global climate change. Although direct approach method provides accurate measures, it is time and resource consuming and destructive as well as expensive. However comparative estimation of carbon stock through non-destructive method or indirect approaches are more reliable and saving of the degraded forest vegetation. The soil organic carbon rather measured through estimation of bulk density. Soil depth up to 0-30 cm is suitable by means of deposition of fresh carbon due to active participation soil microbes. Rather a new approaching method by FIA programs establishes a knowledge of carbon estimation through annual inventory system of past decades upto 1990 as well as a decade forward. This study also comprehends forest types of world and their vegetation pattern which acts like a major carbon pool of terrestrial ecosystem. The growing or regenerated forest lands store and sequester more carbon through rapid growth of canopy cover and above ground biomasses.

Thus it is necessary to conserve forest through mass plantation and creating a grading status for public awareness. Thus constant efforts should be taken to conserve natural forest ecosystem and for implementation of reducing emissions from deforestation and forest degradation (REDD) programmes. Implication in sustaining soil productivity, several biological activities and complimentary effect of organic carbon in soil and their storage enhance total carbon stock.

ACKNOWLEDGEMENT

The authors are grateful to Prof. B.K. Mishra, Director, CSIR-IMMT, Bhubaneswar for laboratory facilities and DFO, Chandaka Wildlife Sanctuary, as well as forest department Govt. of Odisha for financial support.

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e-planet **14** (1): 22-27 (June 2016)

Nanocomposites for dental application - A review

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Date of receipt: 30. 03. 2016 Date of acceptance: 10. 06. 2016

ABSTRACT

Nanotechnology was first described by physicist Richard P Feynman, who viewed it as an unavoidable development in the progress of science, and has since been part of mainstream scientific theory with potential medical and dental applications since the early 1990s. Nanoparticles, nanospheres, nanorods, nanotubes, nanofibers, dendrimers and other nanostructures have been studied for various applications in different biological spheres. Nanotechnology's most tangible contribution to dentistry to date has been the restoration of tooth structure with nano composites. Nanocomposites are characterized by filler-particle sizes of < 100 nm, which offer these materials' aesthetic and strength advantages over conventional micro filled and hybrid resin-based composite (RBC) systems. They offer advantages primarily in terms of the smoothness, polishability and precision of shade characterization, not withstanding the flexural strength and micro hardness they offer similar to those of the better-performing posterior RBCs. The strength and aesthetic properties of the resin based nanocomposite make it possible for it to be used for both anterior and posterior restorations. This article aims at to address the current major uses of practical nanotechnology in dentistry, mainly the restoration of tooth structure with RBCs that make use of nanoparticles.

Key Words : Dentistry, nanocomposite**,** nanoparticles**,** tooth structure

INTRODUCTION

Nanotechnology in medicine has been recently reviewed from various perspectives relative to the human molecule-tissue interface (Borlongan *et al*. 2007; Catledge and Vohra, 2002; Dalby, 2007; Dalby and Gadegaard, 2007). A common trend in this ongoing discussion is the capability to operate on a scale small enough to interact with intracellular components including DNA (Abeil and Leinfelder, 1983; Abu-Bakr, 2001 and Adabo, 2001). Over the last 40 years, the routine use of dental amalgam is gradually decreasing due to poor aesthetics of amalgam especially for anterior restoration, mercury toxicity, and environmental consideration arising from mercury disposal, potential dental fracture, secondary carries, and marginal leakage. Dental composites are among the synthetic resins used as adhesives or restorative material in dentistry and now represent general alternation to dental amalgam. However, composites have limited uses because of low durability and strength (Antonson *et al.*, 2001; Anusavice, 2003; Asmussen and Peutzfeldt, 1998). Nanocomposites are the premises of new materials that can be applied in many fields due to their improved mechanical properties (determined by the

reinforcement of nanoparticles in the organic part), to their light weight, and to their light conducting properties.

TYPES OF NANOCOMPOSITES

When inorganic phases in an organic/ inorganic composite become nano-sized, they are called nanocomposites. Nanocomposites may be metal, ceramic and polymer depending on the type of matrix where dispersed phase is nano size. Nanocomposites are available as nanohybrid types containing milled glass fillers and discrete nanoparticles (40 – 50 nm) and as nanofill types, containing nano-sized filler particles, called nanomers and agglomerations of these particles described as nanoclusters (Abeil and Leinfelder,1983). Increasing the filler fraction in a nanocomposite is a good strategy for manufacturers in aiming for improved mechanical performance. A higher filler fraction helps in increasing the fracture toughness because fillers decrease the volume of the weak polymer matrix and act as toughening sources, besides increasing the elastic modulus. Filler packing is also influenced by the size, arrangement, distribution and shape of the particles. Another commercially available nanocomposite is an ormocer-based, nano-ceramic composite. It contains glass fillers (1.1 - 1.5 μm), but differs from the conventional hybrid composites in two main features. Inorganic-organic composites are used as dental cements, implant super structures and fillings. The long term prognosis of dental implants and fillings shall be improved by optimizing the degradation stability and the mechanical properties of the composites by the development of innovative nanoscale fillers and tailored polymeric binders.

NECESSITY OF NANO MATERIALS FOR DENTAL APPLICATION

Due to the improvement in physical properties of nano composite material, no such material has been found to be ideal for any dental application (Mitra and Wu, 2003). For example, silver amalgam has been used for dental restoration for more than a century; however, there has been a major concern about mercury toxicity from the amalgam restorations for many years (Eley, 1997 and Jones, 1998). Another major issue is the color of amalgam for aesthetic considerations and alternative materials are being sought to replace (Eley, 1997, Mclean, 1984 and Yardley, 1984).The composite restorative materials have promising aesthetics; however these materials are very technique sensitive and mechanical properties are not as good as of amalgams (Saunders, 2009). Nature has arranged complex biominerals in the best way from the micro to the nano-scale and no one can yet combine biological and physical properties to get ideal structures. In addition, no synthetic material can be intelligent enough to respond to external stimuli and react like nature made tissues (Kanaparthy 2011 and Kanaparthy, 2011). There are number of possible options to make smart materials for the construction and mimicking of nature (Table 1).

Table 1. Options for the production of smart materials for dental applications

Option	Description
Material synthesis	Producing synthetic materials matching morphology and properties similar to natural dental tissues.
Biomimetic approaches	To replace lost dental tissues follow the nature's principles producing biomaterials resembling their properties very closely to the replacing tissues.
Tissue engineering	Use of regenerative medicine and tissue engineering approaches for replacing the lost dental tissues by regenerations.

PROPERTIES OF NANO COMPOSITES FOR DENTAL APPLICATIONS

The most unique nature of the filler particles of nanocomposites provides it with the mechanical strength and wear resistance similar to hybrid composites, and superior polish and gloss retention similar to microfill composites. The following are the properties of nano composites described here.

Polymerization shrinkage

The polymerization shrinkage especially in composite resin is reported to be 1.4% to 1.6%. The low shrinkage value of nanocomposites is due to the low shrinkage epoxy resin and strong interfacial interactions between resin and nanoparticles (Fortin and vargas, 2000; Chen *et al.*, 2006; Boaro and Goncalves, 2010).The volumetric shrinkage also depend on the total content of organic matrix of composites. Nanohybrid composites (Grandio) showed least amount of organic matrix (13.0 wt-%) and least shrinkage when compared to nanofill composites (Filtek Supreme Translucent), which had 30.0 wt % organic matrix. Polymerization shrinkage depends on the chemistry of the organic matrix (Moszner and Klapdohr, 2004; Mitra, 2003; Dresch, 2006 and Goncalves, 2009)

Water Sorption

Polymeric phase of composites in water causes generally two opposing processes. The solvent will extract unreacted components, mainly monomer, resulting in shrinkage, reduction in mechanical properties and loss of weight. Conversely, solvent uptake leads to swelling of the composite and increase in weight. This solvent diffuses into the polymer network and separates the chains creating expansion (Asmussen, 1998). However, since the polymer network contains micro voids created during the period of polymerization and free volume between chains, a part of the solvent is accommodated without creating a change in volume. Thus, the dimensional change of a polymer composite in a solvent is complex and difficult to predict that depends on the chemical structure of the polymer matrix. In general, nanohybrid composites show less water sorption than nanofill composite.

Wear and gloss retention

The primary particles having nano-sized in the nanoclusters wear by breaking off individual primary particles rather than plucking out the larger secondary particles from the resin which may result wear surfaces having smaller defects.

Flexural strength

The flexural strength depends on both filler content and filler chemistry. The flexural strength of nanocomposites was found to be statistically equivalent or higher than that of the hybrid or micro hybrid composites. It is significantly higher than those of the micro fill composites.

Nano fill composites have higher filler loading, also show greater flexural strength than nanohybrid composites and also have lesser filler loading (Fortin, 2000).

APPLICATION OF NANOTECHNOLOGY IN DENTISTRY WITH AVAILABLE PRODUCTS

In recent years, remarkable research has been obtained on nanocomposite materials which have transformed it from theoretical foundation to clinical practice. Currently, there is a wide range of nanomaterial's applications (Table 2) in different subspecialties of dentistry (Mitra, 2003; Kanaparthy, 2011; Chandki, 2012; Gaiser, 2012 and Mikkilineni, 2013). As a result of active and continued research to develop new nano-products, the variety of available products for various dental applications are expected to increase remarkably in the near future.

The properties of nanocomposites (good translucency, contouring and surface finish) are excellent and can restore lost or damaged dental tissues (Fig. 1). Current research is focused on reducing the polymerization shrinking. The addition of using monovinyl methacrylate monomers into dental resin was introduced by Decker, and reported enhanced polymerization kinetics and improved mechanical properties. They were made of secondary and tertiary functionalities including urethanes, carbonates or cyclic carbonates. They were also referred as ultra-rapid monomethacrylates. Recently researchers are investigating options of adding acidic functional groups in monomers (Cramer, 2011).

Table 2. Application of nanotechnology in dentistry with available products

Discipline	Available Materials
Restorative dentistry	Ketac™ (3M ESPE, St. Paul, MN, USA), Ketac N100; Nano-ionomers (3M ESPE), Filtek Supreme XT (3M ESPE), Fuji IX GP (GC, Leuven, Belgium), Nano-primer, Premise™ (Kerr/Sybron, Orange, CA, USA), Adper™ Single bond plus Adhesive (3M ESPE), Ceram X™ (DENTSPLY International, Milford, CT, USA).
Regenerative dentistry and tissue engineering	Ostim® (Osartis GmbH, Elsenfeld, Germany), VITOSSO™ (Orthovita-Inc, Malvern, PA, USA), Nano-Bone® (ARTOSS, Rostock, Germany).
Periodontics	Arestin® (Valeant, Bridgewater, MA, USA), Nanogen® (Orthogen, Springfield, IL, USA).
Preventive dentistry	NanoCare® Gold (Nano-Care, Saarwellingen, Germany).
Orthodontics	Ketac™ N100 Light Curing Nano-Ionomers (3M ESPE), Filtek Supreme Plus Universal (3M ESPE).
Prosthodontics	Nanotech elite H-D plus (Zhermack, Badia Polesine, Italy), GC OPTIGLAZE color® (GC).
Oral implantology	Nanotite™ Nano-coated implant (BIOMET 3i, Palm Beach Gardens, FL, USA).

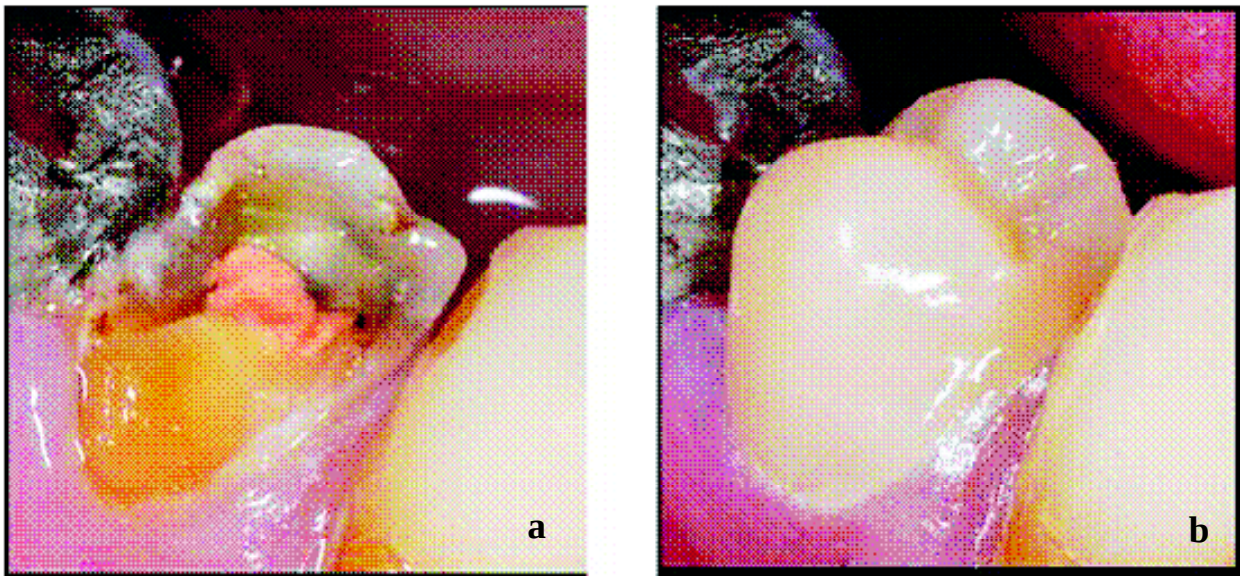

Fig. 1. Clinical applications of tooth colored nanocomposite restorative materials (**a**) Root treated and unrestored premolar tooth; (**b**) Crown build up with a post and core using a modern nanocomposite restorative material

In the process of evolution of dental composites, the alteration of filler size, shape, morphology and loading efficiency still remains a landmark. Various methods adapted to synthesize nanofillers are, flame pyrolysis, flame spray pyrolysis or sol-gel processes. Since the dimensions of these filler particles are below that of visible light, it is impossible for them to either scatter or absorb visible light. This phenomenon plays a key role in getting excellent aesthetic properties and can be used for anterior teeth restorations (Fig. 2 a,b,c).

Fig. 2. Aesthetic applications of resin nanocomposite restorative materials (**a**) Preoperative labial aspect of defective maxillary anterior segment with recurrent decay and discoloration; (**b**) Composite layering technique adapted to restore decayed tooth structure and midline; (**c**) Postoperative appearance of midline correction using a nanocomposite dental restorative material

CONCLUSION

Nanocomposite materials maintain its physical properties as well as wear resistance equivalent to different types of hybrid composites. It is used for dental restorative composites and it offers high translucency, polish retention and high polish. It is very much useful for on posterior andanterior restorative applications. The nanocomposite material for dental application has been performing a remarkable job for the past four decades. In recent times, a tremendous progress has been made in terms of mechanical performance with increase in flexural strength and fracture toughness for dental applications.

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e-planet **14** (1): 28-32 (June 2016)

Coastal dune flora and fauna of Arribada beach, Rushikulya in Ganjam district, Odisha, India

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Date of receipt: 27. 03. 2016 Date of acceptance: 24. 06. 2016

ABSTRACT

Coastal sand dunes are susceptible and fragile ecosystems with an array of floral and faunal species composition. Studies on coastal sand dunes especially those of eco-sensitive coastal and marine ecosystem of Indian coast are scanty. Hence, a detailed survey along the coast of Rushikulya sea turtle Arribada beach in Ganjam district, Odisha was carried out. A total of 37 species belonging to 32 genera and 17 families of plants and 15 species belonging to 11 genera and 09 families of faunaal elements were encountered on the beach and identified at different locations from the shoreline towards inland of the coastline. The flora and fauna composition of Rushikulya coast was found to be rich, indicates to constitute a variety of habitats and gather vital ecological and economic importance. Such sensitive eco-systems have to be protected from habitat degradation in order to protect their diversity and ecological functioning and to supporter the associated floral and faunal assemblages in the area.

Key words: Conservation, fauna, flora, Rushikulya, sand dune

INTRODUCTION

Dunes occur throughout the world, from coastal and lakeshore plains to arid desert regions. In addition to the remarkable structure and patterns of sand dunes, they also provide habitats for a diversity of life which is a remarkable in terms of adaptation also. Coastal sand dunes are natural abotic component which protect the coastal environment by absorbing energy from wind, tide and wave action. Sand dunes due to their dynamic but fragile buffer zones of sand and vegetation resulted in large quantities of sand, persistent wind capable of moving the sand and suitable locations for sand to accumulate. Coastal sand dune formations ultimately depend on embayment size and prevailing wind energy (Kumar *et al.*, 1993). Their heights differ in response to adequate sand supply, climate and local topographic features (Barbour *et al.*, 1985). Despite geographical differences, coastal sand dunes have been considered as a specific ecosystem due to numerous general environmental features. Coastal sand dunes constitute a diversity of microenvironments due to substrate dynamism and physical processes. Vegetations and faunal communities establishing on

coastal sand dunes are subjected to environmental variation which affect their growth, survival and community structure and composition. Plants on coastal dunes are specially adapted to withstand various environmental stresses which allow them to grow, establish and to trap sand in such harsh conditions of coastal zones, so they are mostly represented by herbs, shrubs, creepers or runners. Similarly, animals on the coastal dunes are adapted primarily to burrowing habitat to withstand environmental stress *viz.* heating of the sand and escape from predators.

Pioneer zone, intermediate zone and back zone / forest zone were recognized earlier in coastal dunes and later several workers found shore, fore dune, main dune with wind ward and lee ward slopes, wet dune slacks and back dunes with plateaus, holes complex ecosystem diversity (Wood house 1978; Hesp 2004). Temperate coastal dunes are well studied and documented (Koske and Gemma 1997; Sridhar and Bhagya, 2007) as compared to studies on tropical coastal dunes (Kulkarni *et al.,* 1997; Sridhar and Bhagya, 2007).

Coastal sand dunes provide ecological services in more than one ways *viz.* storing of essential sediments, act as a barrier against storm erosion and by curbing potential sea level rise; rainwater and ground water filtration, act as niche for shore birds, and animals, act as nesting habitat and incubator for egg laying animals on the shore *viz.* shore birds, sea turtles, horseshoe crabs, sea snake (*Laticauda* sp.) etc. This paper aims to provide some baseline biodiversity information on the coastal sand dune of Rushikulya sea turtle rookery at Ganjam along Odisha coast.

MATERIALS AND METHODS

Study site

The study was carried at Rushikulya rookery which is the mass nesting beach for Olive Ridley sea turtles. The Rushikulya river estuary is a shallow tidal estuary, which opens into the Bay of Bengal near Ganjam town. The estuary mouth is connected with the southern sector of the Chilka lagoon through a man-made channel known as Palur channel. The Palur channel runs parallel to the nesting beach for 8 km. The physiographic features of the estuarine environment have undergone many recognizable changes since the last two-decade (Gouda and Panigrahy, 1992). The irregular floods in river Rushikulya leading to formation of new mouths on several occasions.

The mass nesting beach is located on the sand spit along the northern side of Rushikulya River mouth (19º 22’ N and 85º 02’E; Fig. 1). Turtle nesting at this rookery takes place along a stretch of 5 km immediately north of Rushikulya River mouth from the village Purunabandha (1 km north of the Rushikulya River mouth) to Kantiagada village. The beach is more or less flat with scattered sand dunes of 1-2 m high. The average beach width is 80 m above the high tide line, though at some places, the extent of beach is more than 150 m. The extended sandy beach adjacent to north of Rushikulya river mouth has been proved as a favorable site for mass nesting of Olive Ridley turtles since its discovery. However, with the change of the beach topography, the mass nesting has shifted towards further north up to four kilometer from the earlier nesting area. Remarkable changes such as development of a typical lagoon like structure comparably lowering of wave action and beach gradients and enormous growth of vegetations on the beach taken place in the old nesting beach. The new nesting beach located between the Gokhurkuda and Kantiagarha village, two kilometers north of

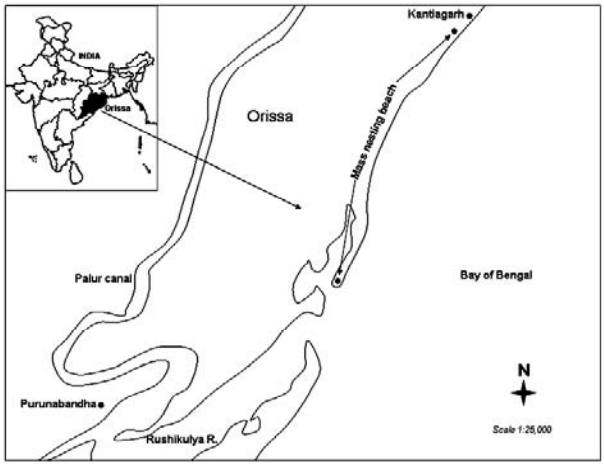

Fig.1. Map of Rushikulya beach at Ganjam in Odisha

Rushikulya river mouth. The new nesting site which is relatively flat and subjected to minimum human interference and away from the fish-landing centres.

At present, this rookery and its near shore coastal waters does not come under any Protected Area management. Gopalpur (20 km north of Rushikulya) is being developed as a sea port. Recently the Reliance Petroleum and the Indian Oil have identified the offshore waters (~ 75 km from the seashore and inside the sea) of the rookery for major oil exploration. Near Arjipalli, the Indian Rare Earths Limited mines the beach for sand. There are abandoned prawn farms that are immediately behind the nesting beach. A chloro-alkali plant situated on the right bank of the Rushikulya River, which discharges effluents directly into the estuary. The Ganjam Township as well as the NH-5 is just a kilometer away from the mass-nesting beach. During night high illumination on the beach occurs due to these establishments.

Table 1. List of coastal dune plants recorded from Rushikulya beach, Ganjam district Odisha

Sl.No.	Family	Scientific Name	English Name
1	Convolvulaceae	*Ipomoea pes-caprae*	Sea morning glory
2	Cyperaceae	*Cyperus alternifolias*	Dwarf beach grass
3	Cyperaceae	*Cyperus arenarius*	Dwarf beach grass
4	Cyperaceae	*Cyperus compressus*	Nut grass
5	Cyperaceae	*Cyperus rotundus*	Nut grass
6	Cyperaceae	*Bulbostylis barbata*	Water grass
7	Cyperaceae	*Fimbristylis cymosa*	Hurricane grass
8	Cyperaceae	*Fuirena ciliaris*	Umbrella grass
9	Cyperaceae	*Kyllinga triceps*	White water sedge
10	Cyperaceae	*Pycreus polystachyos*	Bunchy flat sedge
11	Poaceae	*Spinifex littoreus*	Feathertop
12	Poaceae	*Spinifex squarrosus*	Feathertop
13	Poaceae	*Cynodon dactylon*	Bermuda grass
14	Poaceae	*Cynodon sp.*	Bermuda grass
15	Poaceae	*Dactyloctenium aegyptium*	Egyptian grass
16	Poaceae	*Eragrostis viscosa*	pond lovegrass
17	Poaceae	*Panicum repens*	Torpedo grass
18	Poaceae	*Zoysia matrella*	Siglap grass
19	Asteraceae	*Launaea sarmentosa*	Beach launea
20	Fabaceae	*Indigofera enneaphylla*	Birdsville indigo
21	Fabaceae	*Mimosa pudica*	Sleeping grass
22	Fabaceae	*Canavalia virosa*	Maunaba
25	Fabaceae	*Canavalia maritima*	Bay bean
26	Fabaceae	*Desmodium triflorum*	Black clover
27	Asclepiadaceae	*Calotropis gigantea*	Milkweed or swallow-wort
28	Casuarinaceae	*Casuarina equesitifolia*	Beach sheoak
29	Pandanaceae	*Pandanus fascicularis*	Screw pine
30	Arecaceae	*Cocos nucifera*	Coconut
31	Rubiaceae	*Hydrophylax maritima*	East Indian water bluet
32	Cactaceae	*Opuntia dillenii*	Chenille prickly pear
33	Anacardiaceae	*Anacardium occidentale*	Cashew nut
34	Euphorbiaceae	*Acalypha indica*	Indian nettle
35	Euphorbiaceae	*Croton bonplandianus*	Ban tulsi
36	Euphorbiaceae	*Euphorbia rosea*	Rosy spurge
37	Nyctaginaceae	*Boerhavia diffusa*	hogweed
38	Apocynaceae	*Catharanthus roseus*	Rosy periwinkle
39	Molluginaceae	*Glinus oppositifolius*	Indian tree pix

Data Collection

A total of 10 belt transects of about 5 × 100m were laid randomly (wherever the vegetation cover was predominantly found) in 10 different regions at different distance gradients from high tide line till the estuary/lagoon/*Casuarina* plantation boundary begins. Every plant and animal species found along the 10 transects were recorded by observation and photographed while walking. Species were identified then and there and doubtful specimen were brought to the field laboratory and identified with the help of keys. Species list of plants are given in Table 1 and animals in Table 2.

RESULTS AND DISCUSSION

In the present study, 37 species belonging to 32 genera and 17 families of plants were identified. Cyperaceae was the most common and dominant family followed by Poaceae, Fabaceae, Euphorbiaceae and Rubiaceae (Table 1). A conspicuous feature of the Rushikulya beach is the absence of *Casuarina* plantation in the old nesting area and dense *Casuarina* plantation in the new nesting stretch. The natural beach vegetation on the sand dunes also includes psammophytes such as sea morning glory (*Ipomea pescaprae*), feathertop (*Spinifex littoreus*), *Gisekia phranacoides* and Indian waterbluet (*Hydrophylax maritima*). On the beach, exotic and invasive species like prickly pear (*Opuntia* spp.), swallow-wort *(Calotropis gigantea),* sleeping grass (*Mimosa pudica*) can be seen. Besides, species such as Bermuda grass (*Cynodon dactylon),* screw pine (*Pandanus fascicularis)* and casuarina (*Casuarina equisetfolia*), which grows in patches in some parts. The backwater of the river Rushikulya fringed by cashew (*Anacardium occidentale*) and coconut (*Cocos nucifera*) which extended to 4 km northwards along the nesting beach.

Similarly, 15 species belonging to 11 genera and 09 families of animals were encountered on the sandy beach of Rushikulya estuary and were

Table 2. List of fauna encountered at the Rushikulya beach, Ganjam in Odisha, India

Sl. no.	Family	Scientific name	English name
Mammals			
1	Hyaenidae	*Hyaena hyaena*	Striped hyaena
2	Canidae	*Canis familiaris*	Domestic dog
3	Canidae	*Canis aureus*	Jackal
Birds			
4	Laridae	*Larus ichthyaetus*	Pallas's gull
5	Laridae	*Larus brunnicephalus*	Brown-headed gull
6	Laridae	*Larus hemprichii*	Sooty gull
7	Corvidae	*Corvus splendens*	House crow
8	Accipitridae	*Haliastus indus*	Brahminy kite
9	Accipitridae	*Haliastus leucogaster*	Sea eagle
Reptiles			
10	Agamidae	*Sitana ponticeriana*	Agamid lizard
11	Chelonidae	*Lepidochelys olivacea*	Olive ridley
Invertebrates			
12	Accipitridae	*Haliastus leucogaster*	Sea eagle
13	Ocypodidae	*Ocypode ceratophthalmus*	Ghost crab
14	Portunidae	*Ovalipes australiensis*	Sand crab
15	Paguridae	*Pagurus berhardus*	Hermit crab
16	Ocypodidae	*Ocypode ceratophthalma*	Red ghost crab
17	Ocypodidae	*Uca sp.*	Fiddler crab

identified either by direct sighting or through photographs (Table 2). During the sea turtle hatching period, hatchlings turtles on the beach were found predated by feral dogs (*Canis familiaris*), house crows (*Corvus splendens*), brahminy kites (*Haliastur indus*) and brown-headed gulls (*Larus ridibundus*) mostly during early morning hours. Besides ghost crab, large numbers of nests were found predated by various mammalian species *viz.* feral dog, hyenas and jackals immediately after nesting was over. Those sea turtle nests that were laid inside the *Casuarina* shrubs were found to be immediately predated upon by jackals and dogs at Rushikulya beach.

As evident from literature that sand dune ecosystems support high species richness and diversity values (Grootjans *et al.*, 2004; Fontana 2005; Celsi and Monserrat 2008). The present study corroborates the observation made elsewhere and also indicates that the study area preserves a rich flora and fauna with high number of native dune biodiversity. Moreover, the different vegetation formations together with the dune field geomorphologic heterogeneity of the beach provide a wide range of environmental conditions and habitat types that support a diverse native fauna like crabs, dune lizards etc. More importantly, the sand dune binders viz. *Ipomea*, *Spinifex* etc. makes the sand conducive for sea turtle nesting. Therefore, the conservation of the native vegetation of the Rushikulya sea turtle beach is a priority to conserve the integrity of the natural communities in coastal regions as well as making the beach suitable for sea turtle egg laying.

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e-planet **14** (1): 33-39 (June 2016)

Study of ecology of leopard (*Panthera pardus*) in Lakhari valley wildlife sanctuary, Gajapati district, Odisha, India

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Date of receipt: 28. 03. 2016 Date of acceptance: 10. 06. 2016

ABSTRACT

Monitoring tiger, co-predator and their habitat in tiger reserves and sanctuaries is not only a protocol but also an intensive survey methodologies to analyze the wildlife status; mostly predator animals with relation to the prey base of the forested landscape. The tigers and leopards are wide ranging large carnivores covering a large landscape which may include forests of different administrative boundaries within or outside the state of Odisha. A survey was undertaken from November 2015 to February 2016 in Lakhari valley wildlife sanctuary through camera trap and rigorous field surveys on foot inside the sanctuary and also the periphery forest area to track the movement and study the ecology of leopards. From camera trap study, 2 numbers of leopards were captured which confirmed the presence of leopards, but no traps of Royal Bengal Tigers noticed. The result through camera trap and field surveys through pug marks, scat etc. showed that the population density D was 6 ± 2 leopards in 300 square km area. The individual leopards were differentiated according to the size of the pugmark. In a sampling area of 30 sq km under camera trap surveillance for other prey species have also been recorded.

Key words: Camera trap surveillance, Lakhari valley wildlife sancturary, leopard, prey base

INTRODUCTION

There is a habitat linkage for leopards along the Ramagiri range forests of Lakhari sanctuary and Tumba beat area of Samantiapalli range of Berhampur forest division. During the last tiger census of 2014, sign of three individual leopards were recorded from Samantiapalli and Digapahandi ranges. These are the migratory large carnivores from Lakhari forests and occupied the peripheral forest area of other division. No other specific studies have been undertaken for monitoring large carnivores and their prey base except the all India tiger monitoring work 2005, 2010, 2014 and state level tiger monitoring survey works. Because of varied causes, it has been extremely difficult to carry out research on leopards and its genetic makeup in different races in India. The body size and colouration also vary from region to region throughout India (Prater, 1971). Hence, the conservation of the leopards is more difficult in forest fringes bordering human dominated landscapes other than the protected areas, sanctuaries and national parks.

MATERIALS AND METHODS

Lakhari wildlife sanctuary is situated in the north eastern part of the Gajapati district of Odisha.

The geographical co-ordinates within which Lakhari Valley Sanctuary is located are 19^0 15′ to 19^0 25′ N latitude and 84^0 15′ to 84^0 25′ E longitude . The sanctuary is constituted of mostly the hilly tracts ranging from 8m to 700m of elevation endowed with flat valleys and sloppy drainages. It was declared as sanctuary vide Notification No. 8 (F) W-37/85-2333-FFAH dated 8.2.1985. The main objective of the declaration is to protect the flora, fauna, zoological, ecological and geo-morphological value of the valley.

At the time of declaration, the entire area of Chandragiri Reserve Forest (RF), Allarara-Ramaguda P.R.F. and Dhobadhoboni P.R.F. combine to cover a total area of 18586.72 ha. Later, the entire area of Dhobadhoboni P.R.F. was excluded and an extent of 373.15 ha. of revenue area was added to the sanctuary. Thus, the present sanctuary area covers 17495.80 ha. In the sanctuary area, there are three main revenue villages namely Balliganda, Kamarakhal and Manikapur (Fig. 1 to Fig. 4).

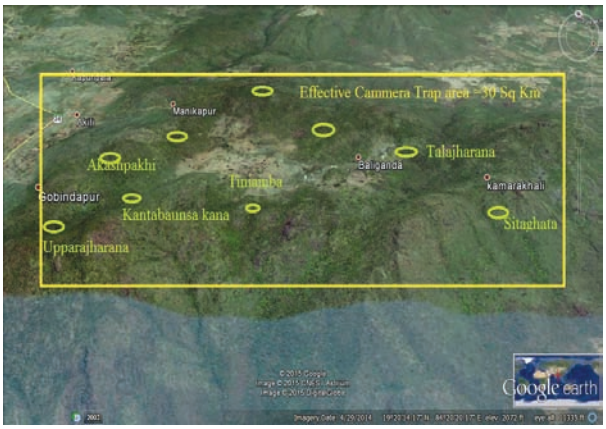

Fig. 1. The surveyed area of Lakhari valley sanctuary in satellite immegery

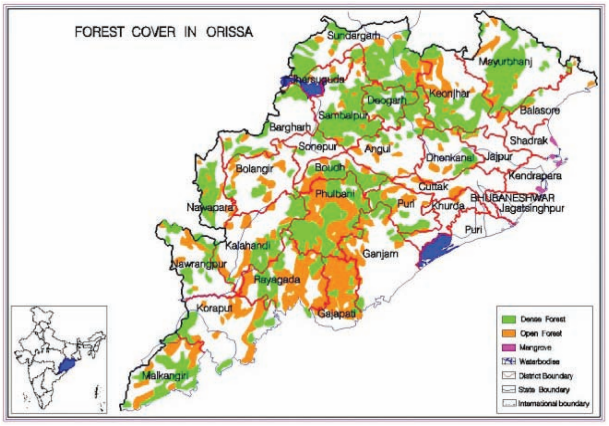

Fig. 2. Map of Odisha showing forest cover

Fig. 3. Forest cover map in India

Fig. 4. Yellow portion of the forest division map showing the Lahkari sanctuary area

To capture the movement of leopards, specialized cameras were installed at different selective pockets. Cudde Back Digital camera (Infra red, long range, 20 mega pixel, model no. 1248) was fixed in a special designed wooden sized pole and carved to fit within. The camera happens to be highly sensitive and it's range covers a distance of 10-12 m. For a clever and sensitive animal like leopard, the camera post was well camouflaged along the forest trail and fitted in pair by facing to each other. Both the two cameras were well alligned. Hence, there would be no miss in capture either by one of the camera instantly within fraction of 2-4 seconds. Here, the camera delay was kept minimum_5 seconds. The front opening of the camera box was covered with iron fabrication work. In other cases, the camera may be closed from the back side of the pole. And in both cases the camera traps were locked to avoid theft. It was decided to keep minimum of 2 kms distance from one working unit to the other and a range of 4 sq km to be covered by one unit of camera in the forest. In order to avoid trap shyness by animals, in a particlar location, the camera had to be shifted a little distance in the same trails or in the same water body or salt lick area. This, actually helped more captures of the same or new animals providing more results in the capture- recapture procedures.

RESULTS AND DISCUSSION

The animals were recorded either on camera trap or through vocalisation, spotting of fresh scat or pug marks by field surveys and informations collected from working staff. At some of the important spots in the core area of the Lakhari sanctuary such as Akashpaki, Bamboo coupe road, Tiniamba, Talajharan, Uperjharan, Kamarakhala, Kanta baunsa kana, Jhirijhira, the leopard signs were encountered more frequently. Table 1 shows the effect of the camera traps in trap nights wich overlap the lapse day periods before and after deployment of camera traps.

Three pairs of camera were under operation for 7 different places in 3 different phases, described in 3rd coloumn of Table 1. For 7 places, in total 20 days and nights were covered. In some day times, camera was taken off for recharge of batteries and cleaning of moisture and fungus. Hence, total camera traps for 7 different places from 3 pair of cameras in 3 different phases were recorded to be 108 traped days. But since, less failure in night traps, the total trap nights became 122. The animals captured and recaptured have been calculated from the above recordings Table 1.

The preybase for the leopard in LWS were found to be langur, rhesus monkey, wild pig, barking deer, giant squirrel, hare, peafowl, porcupine, jungle fowl etc (Fig. 6 to 10). Instead of such prey base in the forest, occasional small cattle kill and the predation of goats and sheep occurred in the sanctuary peripheral villages. In a particlar location, the camera had to be shifted little distance in advance or back in the same trails and some times it was to back in the line of same water body or salt lick area to avoid camera trap shyness. The movement of animals initially was affected by the flash light of the camera at night by exposures to cameras. After number of captures, they were accostomed to the flash lights. In few occasions, there were instances of avoidance to the camera post by the clever animals like leopards and tigers in the trap deployed place or path. In large cats, the studies were seriously affected due to trap shyness affecting the results (Wegge, 2004; Karanth and Nicols, 2002). Hence, practice of shifting of cameras helped more captures of the same or new animals (tiger or leopard) providing better results in the capture- recapture procedures. As noted in various studies the photographic recaptur method is most reliable for population estimation of creptic animals like leopard and tigers (Karanth and Nichols 1998, 2000, 2002)

To meet the assumptions of a closed population, the camera trap study period should be kept for 8-12 weeks (Karnth and Nichols 1998). Wild prey density always acts as indicator over the population of leopards, as leopard population is directly proportional to available prey base and cattle population. The above study shown that there were no Royal Bengal Tigers in the study area. Apart from leopards, the capture of other animals in the study area was presented in Table 2.

Fig. 5. Hanuman langur; prey base of leopard in LWS, Paralakhemundi division, Odisha

Fig. 6. Hare; prey base of leopard in LWS

Fig. 7. Group of young wild pigs in saltlick trail

Fig. 8. Barking deer; prey base of leopard in LWS, Paralakhemundi division , Odisha

Fig. 9. Rhesus macaque under camera trap

Fig. 10. Fresh leopard scat in survey route

Table1. Details of camera trap deployment period

Sl. No.	Study / trap sites	Days/ dates of operation(For 3 pair camera units)	Total Trap days	Trap nights per camera pair
1	Akashpaki,	6 Nov 2015 to 15Nov 2015	10	18Nights
2	Tiniamba	6 Nov 2015 to 15 Nov 2015 and 1 Feb 2016 to 7 Feb 2016	17	18Nights
3	Talajharana	6 Nov 2015 to 15Nov 2015 and 1Feb 2016 to 7 Feb 2016	17	18Nights
4	Kamarakhala	15Nov 2015 to 26 Nov 2015 and 1Feb 2016 to 7 Feb 2016	19	20 Nights
5	Uperjharana	15Nov 2015 to 26 Nov 2015 and 1Feb 2016 to 7 Feb 2016	19	20 Nights
6	Kantabaunsa kana	15Nov 2015 to 26 Nov 2015 and 1Feb 2016 to 7 Feb 2016	19	20 Nights
7	Bambo coupe road and other temporary sites	1Feb 2016 to 7 Feb 2016	7	8 Nights
Total		Camera trap deployment period 29 days	108 Trap days	122 Trap nights

Table 2. Details of animals captured in camera traps during survey period

Main Camera trap sites and survey routes	Total no. of animal species captured in cameras									
	Leopard	Barking deer	Wild pig	Hare	Percupine	Langur	R. monkey	Junglefowl	Peafowl	cattles
Akashpaki	1	2	4	2	1	0	0	1	2	1
Tiniamba	0	1	6	0	0	5	1	2	0	0
Talajharana	1	2	2	0	0	7	6	1	0	1
Kamarakhala	0	0	2	1	0	3	0	1	1	0
Uperjharana	0	2	5	0	0	2	4	2	0	1
Kantabaunsa kana	0	1	2	0	0	0	2	2	2	10
Total	2	8	21	3	1	17	13	9	5	13

Table 3. Details of animals encountered directly in field surveys in LWS

Forest roads and survey routes	Total no of animal species and enconteredd in forest routes.								
	Giant squirrel	Barking deer	Wildpig	Hare	Percupine	Langur	R. monkey	Red Junglefowl	Peafowl
Manikapur to Balliganda	0	3	4	2	1	19	0	2	3
Balliganda to Kamarakhal	0	2	4	0	0	5	1	2	0
Balliganda to Talajharana	1	1	1	0	0	7	6	0	0
Kamarakhala to Sitaghat gorge	0	1	2	1	1	3	0	0	0
Kantabaunsa kana to Uperjharana	0	2	5	0	0	5	4	0	1
Kantabaunsa kana to Bamboocoupe route.	2	1	2	0	2	2	2	1	2
Total animals encountered during survey	3	10	18	4		41	13	5	6

Under camera traps (Table 2 and Table 3), it was noticed that pigs, monkeys, jungle fowls and pea fowls were found in good numbers. From direct sighting method, deer, monkeys, pigs were encountered in large numbers (Table 3). The result indicated that there has been a standard prey base which has been regulating the sustenance of leopard population (Fig. 5 to 9).

Activity pattern

In two trap occasions, the first capture in camera was at 22. 47 hrs night on the same day of deployment of 6 Cudde back cameras on 6th Nov 2015 (Fig. 11). The second capture was at 17.45 hrs evening on dated 15 Nov 2015 (Fig. 12). Under R. Udayagiri forest range near Bursi, the leopard call was listened on 6th Feb 2016 at around 21.50 hrs. On the next day morning, the entire area was searched for any sign and a very fresh scat found in the compartment no. 1 indicating the presence of leopard (Fig. 10). One leopard was also sighted in the sanctuary on forest road through vehicle spot light during late evening. The leopards like other carnivores remain active during night as they hunt primarily after dark when their superior confers an advantage for such predators (Sunquist, 1981; Karanth and Sunquist, 2000). The leopards also frequented to the salt lick area and waterholes during night followed by preys like barking deer, wild pig, hare and pea fowls. These spots were intensively surveyed during every morning from 5th Feb to 11th Feb 2016. This large cat predator species can co-exist with tigers by hunting smaller prey and hiding by lifting the prey in trees. They prey upon cattle, dog and even children and notoriously known as man-eaters (Menon, 2003).

Fig. 11. The 1st Leopard that captured in the LWS, Paralakhemundi on 06-11-15 at 22 hrs 47 mts night , just after 4 hours of deployment of camera

Fig. 12. Capture of leopard in the LWS, Paralakhemundi on Dt. 15-11-15 at 17. 45 hrs evening, during 2nd week of deployment of camera trap

CONSERVATION STRATEGIES

Source population of tigers and leopards are of great importance for its survival and their conservation and it should be best practiced in the protected areas including tiger reserves, sanctuaries and national parks. The periodicity of four years for assessing the status of tigers and leopards is too long for monitoring source population. The wildlife institute of India recommended that these source population be monitored on a seasonal basis (Jhala, 2013). Presently, the state level tiger and co-predator monitoring work were done in every two years giving more emphasis to the sanctuaries in India. But, in Lakhari valley wildlife sanctuary, the wildlife monitoring work was done both seasonally and annually.

Leopards population can be well sustained if the key prey base in LWS be conserved. From the above survey, it was found that there were good numbers of barking deer in LWS and no spotted deer. In this forested landscape, the barking deer is the only surviving ungulate prey base for leopards as they can better escape from bush hunting than

other ungulates. It does have better hiding nature and less dependent of meadow grasses. It quickly revives from population depletion due to its shorter and prolific breeding capacity. Hence, if barking deer population will be survived in LWS, the leopard population will be stabilized.

The advantages over the previously tiger occupied area by the leopards in a sanctuary like LWS in Odisha is quite noticeable because of its survival status. The smaller prey base provides a good life support system for survival of leopards in Odisha. The prey base and large predators like leopard should be conserved at any cost specially in and around the sanctuary area to maintain a healthy ecosystem.

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e-planet **14** (1): 40-52 (June 2016)

Human-elephant conflict due to interstate movement of wild Asian elephants (*Elephas maximus*) from West Bengal to Odisha, India

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Date of receipt : 27. 02. 2016 Date of acceptance: 10. 06. 2016

ABSTRACT

Interstate movement of elephants from Odisha to neighboring states or vice versa was known earlier, but it was not a major concern at that time for the state as vast forest areas were available for their regular movement and bordering states i.e. Jharkhand and West Bengal. Fragmentation and degradation of elephant habitat along with developmental projects such as Subarnarekha canal project, electric power lines, road ways, railways, industries, expansion of agricultural fields, increase of anthropogenic pressure on habitat, etc. have posed wide spread and significant threat to elephants corridors and their habitats. A study was conducted during July 2010 to July 2014 in Baripada and Balasore Wildlife Division, Odisha, India. The present study took an effort to understand the migration pattern, herd behaviour, crop damage, house damage, human death, human injuries and present mitigation pattern for the period 1997-98 to 2013-14 and to formulate a comprehensive planning for conflict management and mitigation. Elephants killed or injured 31 people over the 17 years in villages of Baripada and Balasore Wildlife Division. During this period 1155 nos. house damaged, 757 nos. houses partly damaged, 398 nos. houses fully damaged, 3832.42 acres of crop damaged and 579 nos. of villages affected and 2539 nos. families affected. During 1997 to 2014 showed a higher frequency of human elephant interface in comparison to previous years. Some recommendations are put forth based on the present study to mitigate the human elephant conflict to certain extent.

Key words: Crop raiding, human elephant conflict, interstate elephant migration, Odisha, West Bengal

INTRODUCTION

India holds the largest population of Wild Asian elephants (*Elephas maximus*) with nearly 27,000–29,000 animals found in the country (Rangarajan *et al.*, 2010). During the 20th century the number of elephants surviving in the wild declined drastically all over Asia (Sukumar, 2006) including India. Elephant travel long distances as part of their migration activities and at the same time they stay within different forest habitats that are enriched with water and fodder (Graham *et al.*, 2010, Hedges *et al.*, 2009). Interstate movement of elephants from Odisha to neighboring states or vice versa was known earlier but it was not a major concern for the State as vast forest areas were available for their regular movement. Such interstate migration of elephants extends to four neighboring

states such as Andhra Pradesh, Chhatisgarh, Jharkhand and West Bengal. The present study emphasizes the migration and movement of elephant between West Bengal- Odisha.

Home range of elephants spreads over a length of 250 km from Lakhari in Odisha to Andhra Pradesh. Home ranges extends up to 600 km^2 – that have been recorded for females in Nilgiri in south India. In Rajaji National Park, home range of females extends 184-326 km^{-2} whereas male ranges over 188-407 km^2 (Ritesh *et al.,* 2009). Movement of elephants in Dudhwa National Park has been also seasonal and erratic. Animals of the western Nepal population range south along the Karnail river from the reserve to a patch of riverine forest across the border along India (Javed, 1996). The home range estimated to be 258.6 km^2, 3343.1 km^2 and 4348.9 km^2 for three different bulls in Dalma Wildlife Sanctuary and Chhotanagpur Plateau of Central India. Some studies also highlighted that home ranges expanded to be maximum in winter and shrunk to minimum in summer (Datye and Bhagwat, 1995). Movement of animals in general and elephants in particular has been studied and reported by author like Eisenberg and Haynes (1949), Buss (1961), McNab (1963), Buechner *et al*., (1963), Khan (1967), Lockhart (1972), Leuthoid (1977), Allaway (1979), Peters (1983), Sahi *et al.* (1985), Mckay (1990), Easa (1992), Johnsingh (1992), Hemanta *et al.* (1993), Joshua and Johnsingh (1995), Sunderraj *et al.* (1995), Tiwari (2005), Wesley *et al.* (1995), Wittemyer (2007), Ritesh and Rambir (2007), Santra (2007), Ritesh *et al.* (2009), Mishra *et al.* (2009), Ritesh and Rambir (2009) and Palei *et al.* (2013) and Mishra *et al.* (2014).

MATERIALS AND METHODS

Baripada Forest Division is situated towards northern most part of Odisha (Fig. 1) between N 22° 33' 45" to 21° 17' 0" latitude and 85° 45' 30" to 87° 13' 15" E longitude. The area is bounded by the Singhbhum, Medinapur district, Balasore and Keonjhar on the east. Interstate elephant movement and human-elephant conflict is a major issue at present in the study area. Balasore Division is located on the northern front of the state being bordered by Subarnarekha River.

Balasore district spreads over an area of 1968 km^2. where about 4.47 km^2 of sal bearing DPFs are located in a splayed way. Similarly, the elephant passage area in Mayurbhanj district spread over an area of 17489.82 km^2 out of which the forest area comes to the 52.64 km^2.

Information from 1997-98 to 2013-14 from the Forest Department records was used to quantify elephant depredations in the Baripada and Balasore Wildlife Division. Data on crop damage and house damage in incidents, human kill, human injury and elephant mortality was collected from office of the Divisional Forest Offices. To get a quantitative measure of economic losses due to the crop raiding and to evaluate people's attitudes, a survey of affected villages in the reserve was conducted. These data were verified through field visits to specific sites and by conducting informal interviews with government officials, local people or local community leaders. Rapidly assessments were carried out using the focus groups, field visit to area of elephant damage, and reconnaissance in to the forest with villagers to observe habitat types. To find out the nature of the conflict questions were asked about the land use pattern, details of human death and injury, ethnic composition of the villages and preventive measures.

RESULTS AND DISCUSSION

Human death and injury due to elephants

A total 16 cases human death and 15 cases human injury by elephants were reported during the period 1997 to 2014 (Fig. 2). Out of these 16 death, 9 (56%) death occurred in the winter, 4 (25%) in summer and 3(19%) in monsoon season (Fig. 3). The high deaths in winter may be correlated to the increase out door activities of men like in NTFP (Non-Timber Forest Product) collection in Forest and winter crop pattern during the season. Out of 16 death cases 12 deaths occurred in Baripada Forest Division under Deoli and Rasgovindapur Range and four death cases were in Nilgiri Range of Balasore Wildlife Division (WL).

The maximum number of human death and human injury in was reporting in the year 2011-12 in Baripada Forest Division. The majority of human death and human injury cases took places during the month October-December with the month of November (n=9cases). Out of 31 human death and human injury cases, the incidents happened more in the agriculture area 42% followed by Forest Area 35% and close to Village area 23% (Fig. 4).

Crop damage due to elephants

During the study from 1997-98 to 2013-14, migrating elephants herd damaged 2565.4 acres of paddy in these Forest divisions (Fig. 5). Major crop damage occurred in Baripada and Balasore WL division (62% of the total area) mostly in 76 villages. A total of 1145 persons received the compensation in these forest divisions. Other economically important field and garden crops were damaged including fruit tree (banana, jackfruit, pineapple, coconut, and sugarcane, vegetables (cauliflower, cabbage, etc.),. Whereas Baripada Forest and Balasore WL Division mostly affected due migration of elephant, the highest number of crop depredations occurred in the year 2010-11 in Balasore Division 721 cases 435.65 acre. A total of Rs. 14 lakhs was sanctioned as ex-gratia payment for the victim of Human Elephant Conflict (HEC) in Balasore (Wildlife) division.

During 2012-13 in Balasore (Wildlife) Division, 971 cases with 724.06 acres of land and total 70 lakhs was sanctioned as ex-gratia payment for the victim of human elephant conflict in Balasore (Wildlife) Division. There was a elephant movement and damage for the last 17 year 1997 to 2014 but the number of incident as well as magnitude of loss was highest in the month of September to December (Fig. 6). Elephant damage more than 7 different type of major cultivated fruit tree plants and cash crops where paddy (*Oryza sativa*), sugarcane (*Saccharum afficinarum*), maize (*Zea mays*),mango (*Mangifera indica*), jack fruits (*Artocarpus heterophyllus*), vegetable, coconut *(Cocos nucifera)* cabbage, cauliflower, and banana were the most common. The highest incidences of crop raiding was recorded in Balasore Wildlife Division during the period 2011-12 (Table-1).

House and property damage

During the study period, 1155 houses damaged comprising of partly damaged 757 and fully damaged 398; 579 villages and 2539 house holds were affected (Fig. 5). The maximum number of house were damaged during 2012 and the peak month was December that is just after harvesting when stored grain becomes the target. In 70% of cases house with stored paddy and brewed Rice were damaged. Maximum house hold and property damaged (60%) caused by the male Tusker, followed by herds (25%) and adult female (15%).

Some observations on elephants

A qualitative assessment was made of factors responsible for crop damage. This was carried out by discussion with local people and forest department field staff. These are briefly stated below:

i. Elephants used reserved forest patches for shelter during the day and as refused for raiding crops. Crops near forest or where agricultural fields are interspersed with forest are more prone to attack by elephants.

ii. Un-harvested crops, harvested crops left in the fields and harvested crops stacked outside the house are prone to raids by elephants.

iii. During the movement of elephants, they were not eating Swarna variety rice crop reason being due to spray of pesticides. Crop damage is mainly due to trampling. But elephant are used to eat local desi rice, Pratikhya, Mugei, Moti, Nagraj, Salphul, Sunapani, Gruhalaxmi, Puja and Malati etc.

iv. Elephant have favor love for paddy, rice beer (Handia), brewed rice (Pakhala), and Mahua flower and stored paddy. It has been observed that elephant raids tribal houses for rice beer, brewed rice and local country liquor made out of mahua flowers. After drinking the brew they run amok destroying field and breaking the house.

v. The crop damage due to elephant was increased because of unruly behavior of the public who were gathering in thousand numbers and preventing the movement of elephants and took photographs with flash light.

Migratory elephants from West Bengal to Odisha

Elephants are long ranging migratory animals especially in search of food and require substantial areas to support their ecological needs. Habitat loss and fragmentation of traditional elephant corridors due to expansion of human habitation and agriculture has forced the elephants to split into a number of meta populations or herds and move to new areas in search of food and shelter. As a result, the interface of elephant and human has increased manifold. This results in conflicts with humans due to elephants raiding or destroying their crops.

There is large scale sugarcane cultivation goes on in West Bengal on the other flank of Subarnrekha river which lures the wild elephants of Dalma during winter season when the crop matures. Deuli and Suliapada are part of Suliapada tahasil of Mayurbhanj district bordering South-West Bengal where there is good patch of Sal forest intercepted by low lying cultivated lands. The Elephants raid on these crop fields in West Bengal during November – December. To tackle these animals from damaging their crop, the local people in course of time have developed the art of driving them into Orissa, torturing them by several means in organized way. There is continuous migration of elephants from Jharkhand to Odisha via West Bengal. The interstate migration of elephants is recorded during 1997-98 to 2013-14 (Table 2 and Fig. 7). Deuli and Rasgovindpur Range under Baripada Forest Division is the most affected Range in respect of man elephant interface. Mainly migratory elephants from neighboring state West Bengal intrude Orissa through Suliapada Section of Suliapada Block and also through Moroda Block. Maximum number of elephant migrates from West bengal to Odisha during the winter season i.e. October to December (Fig. 8). The no. of elephants in herds ranging from 50 to 150 elephant intrude into Suliapada Block during the harvesting period i.e. from the month of November to February and cause damages to the paddy crops, mud and thatched houses of the villagers and also to the lives of the people. The migratory elephants of different age groups come from Dalma Sanctuary of Jharkhand and then to Tapoban sanctuary of West Bengal and then to Odisha (Table 2).

Raibania is a part of Jaleswar Tahasil of Balasore Civil District located on the northern front of the state being bordered by Subarnarekha River. On the other flank of Subarnarekha large scale Sugarcane cultivation goes on in West Bengal which lures the wild elephants of Dalma, Tholkabad to that area during winter season when the crop matures. Deuli and Suliapada are part of Suliapada Tahasil of Mayurbhanj district bordering South-West Bengal where there is good patch of Sal forest intercepted by low lying cultivated lands. The Elephants raid on these crop fields in West Bengal during September – December (Fig. 6). But it is seen that, the migratory elephants instead of using the forested areas intrude in to areas they feel safe being chased by the people in mob. Even if, they use the said forest in the day time, during the

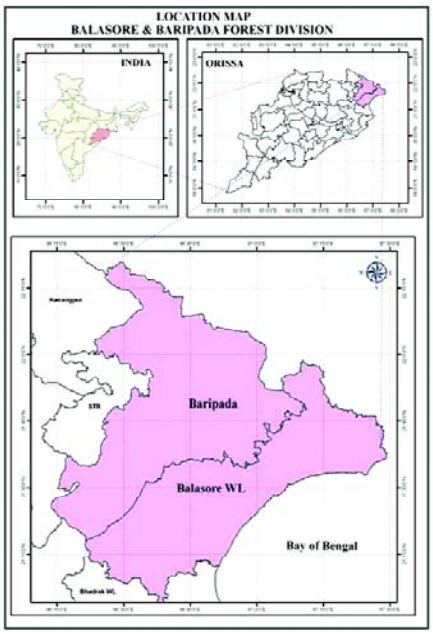

Fig. 1. Map showing Baripada and Balasore Wildlife Division

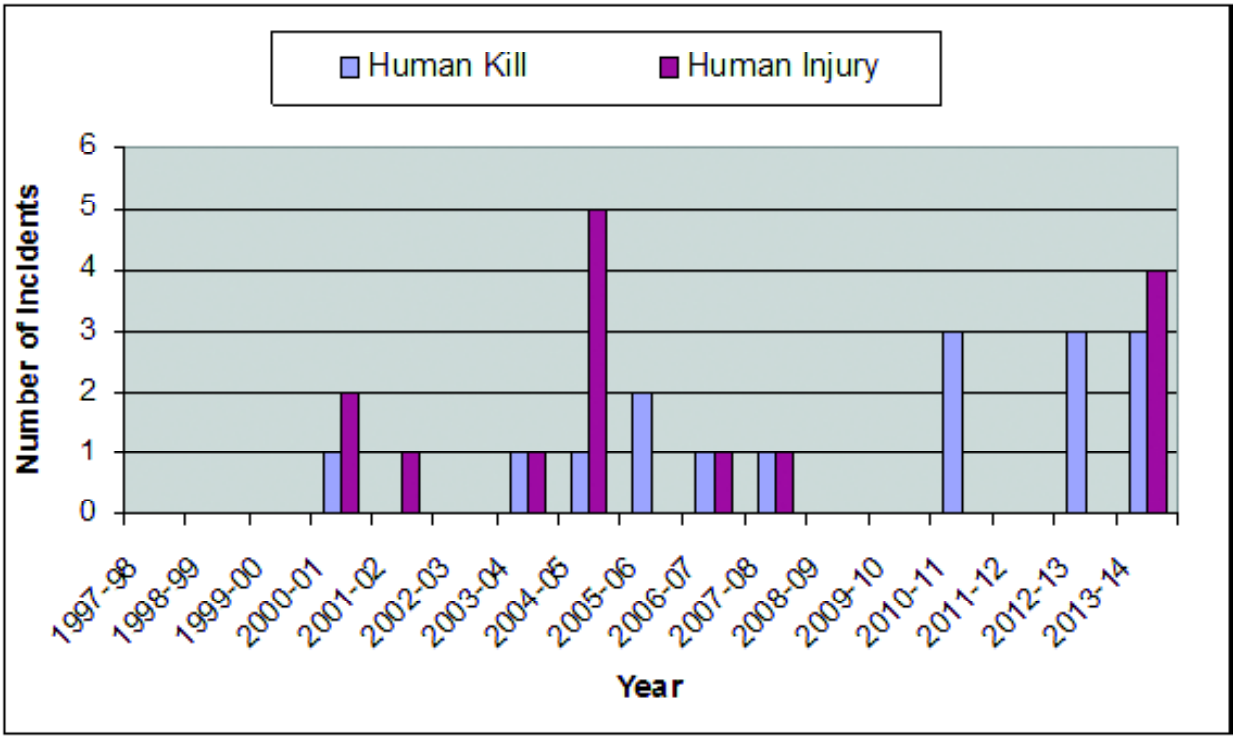

Fig. 2. Human death and human injury due to migration of elephants from West Bengal to Odisha during the period 1997-98 to 2013-14

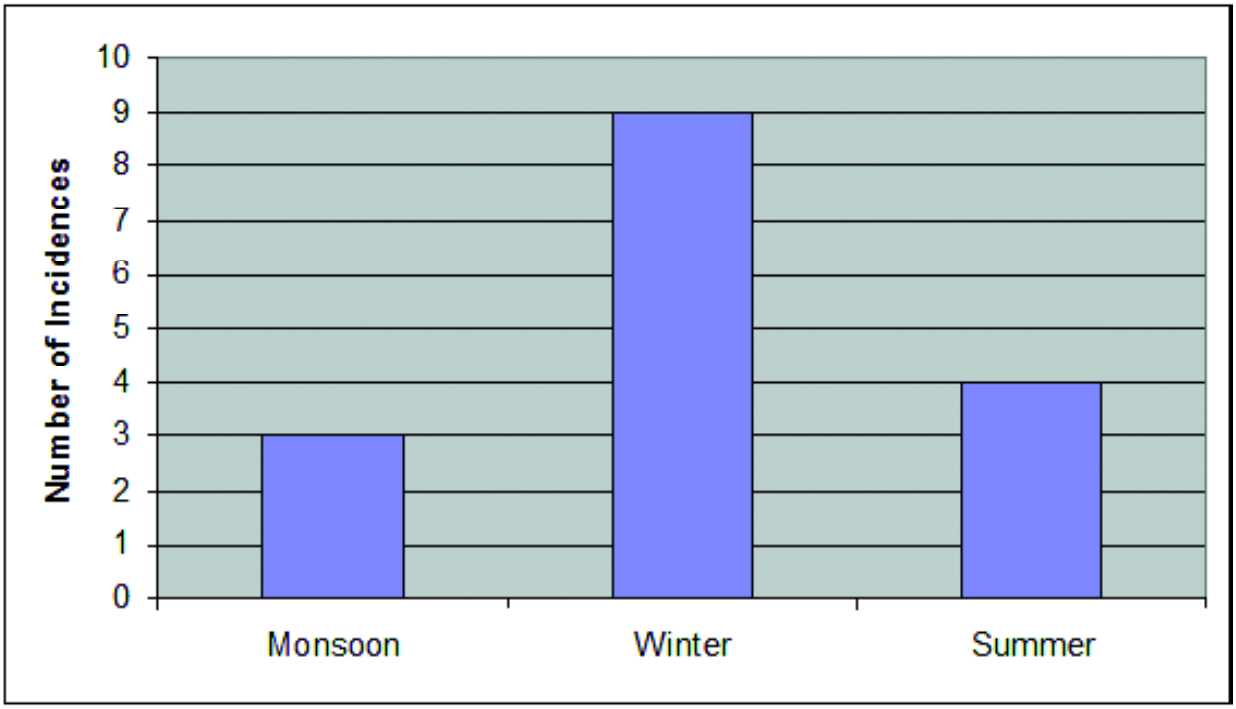

Fig. 3. Maximum attacks happened during the winter season followed by summer season

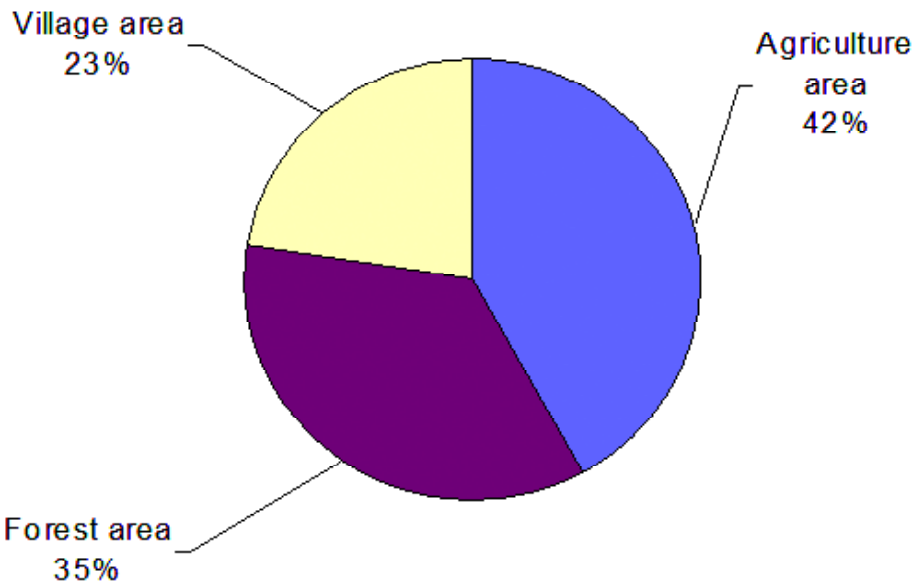

Fig. 4. Elephant attacks were highest in Agricultural area where activities of both elephants and human overlap

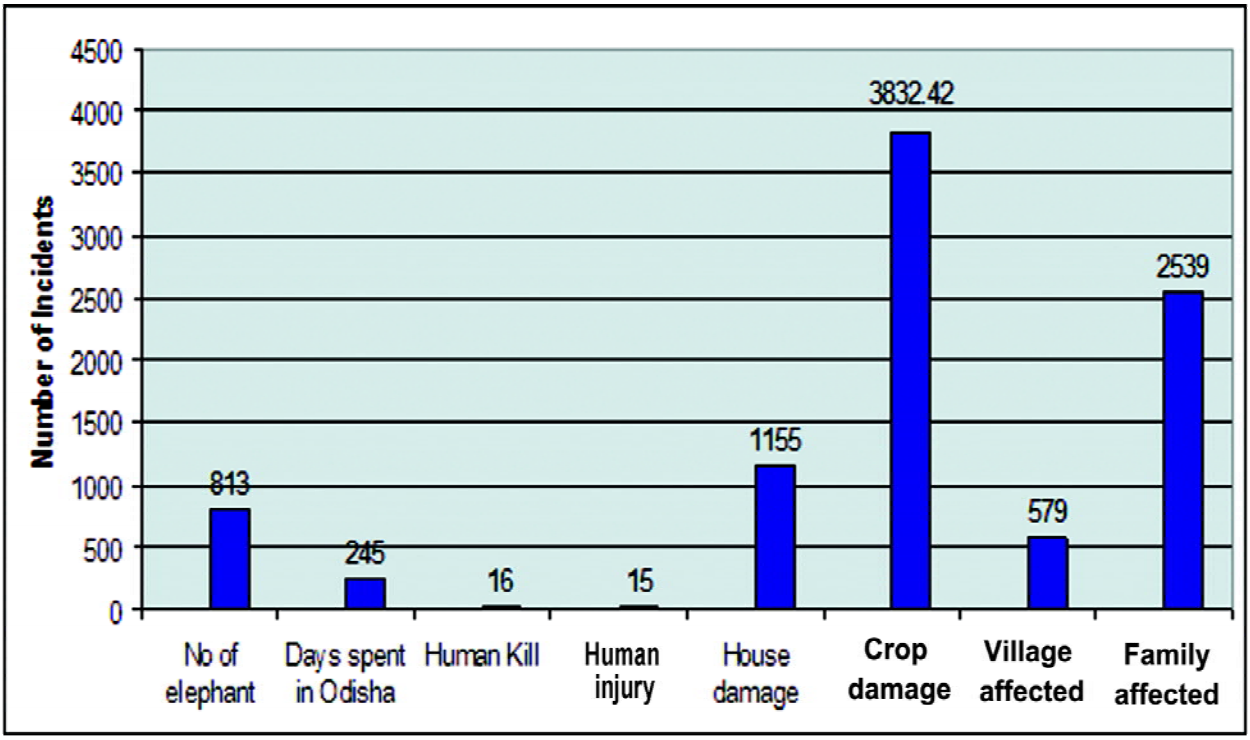

Fig. 5. Human death, injury, crop damage, house damage etc. by migrating wild elephants from West Bengal to Odisha during the period 1997-98 to 2013-14

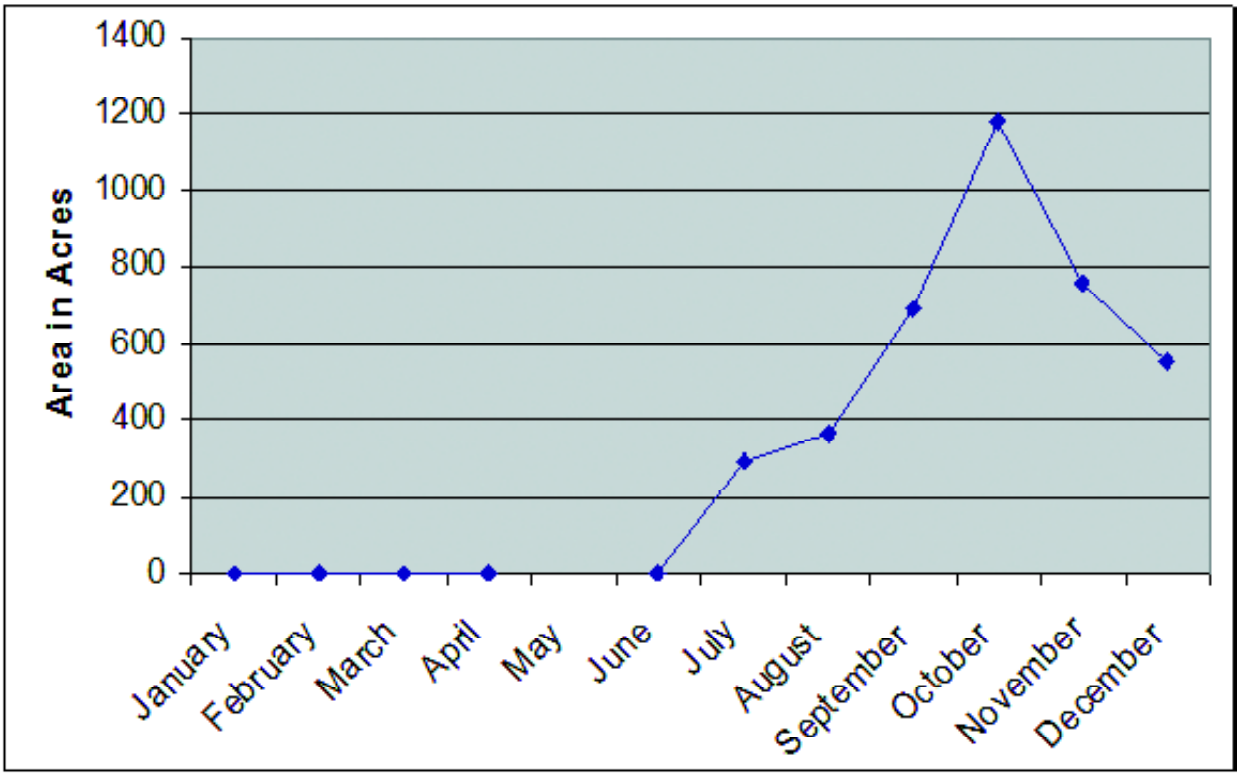

Fig. 6. Month-wise crop damage by migrating wild elephants from West Bengal to Odisha during the period 1997-98 to 2013-14

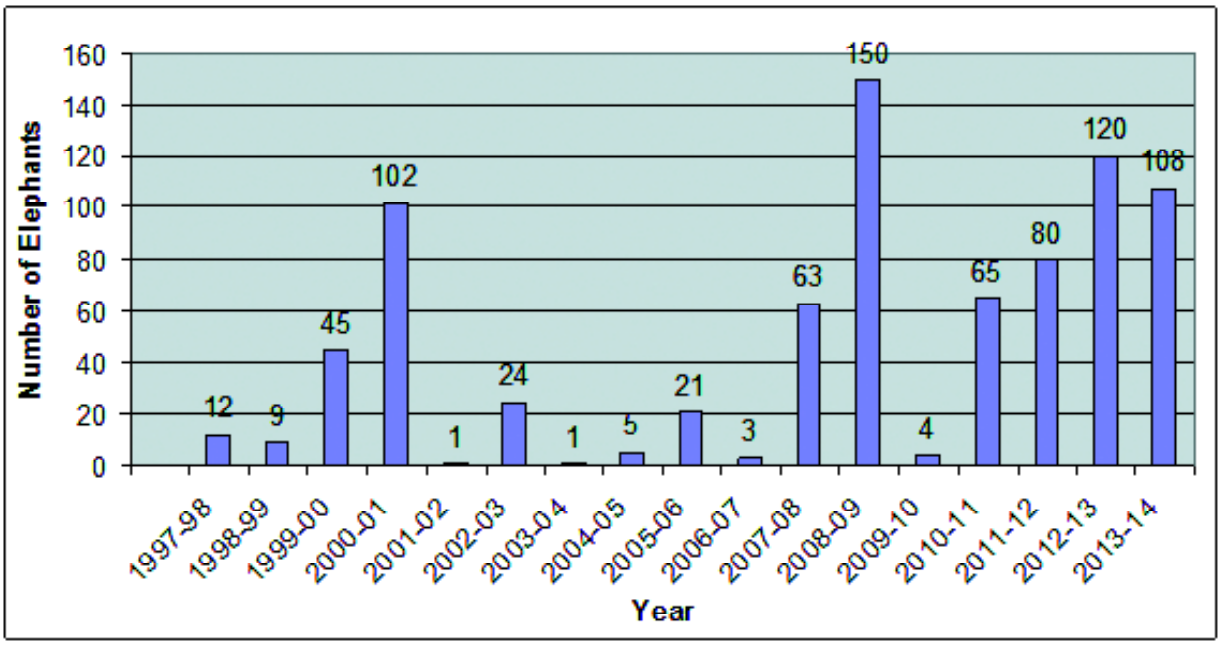

Fig. 7. Year-wise elephant migration from West Bengal to Odisha during the period 1997-98 to 2013-14

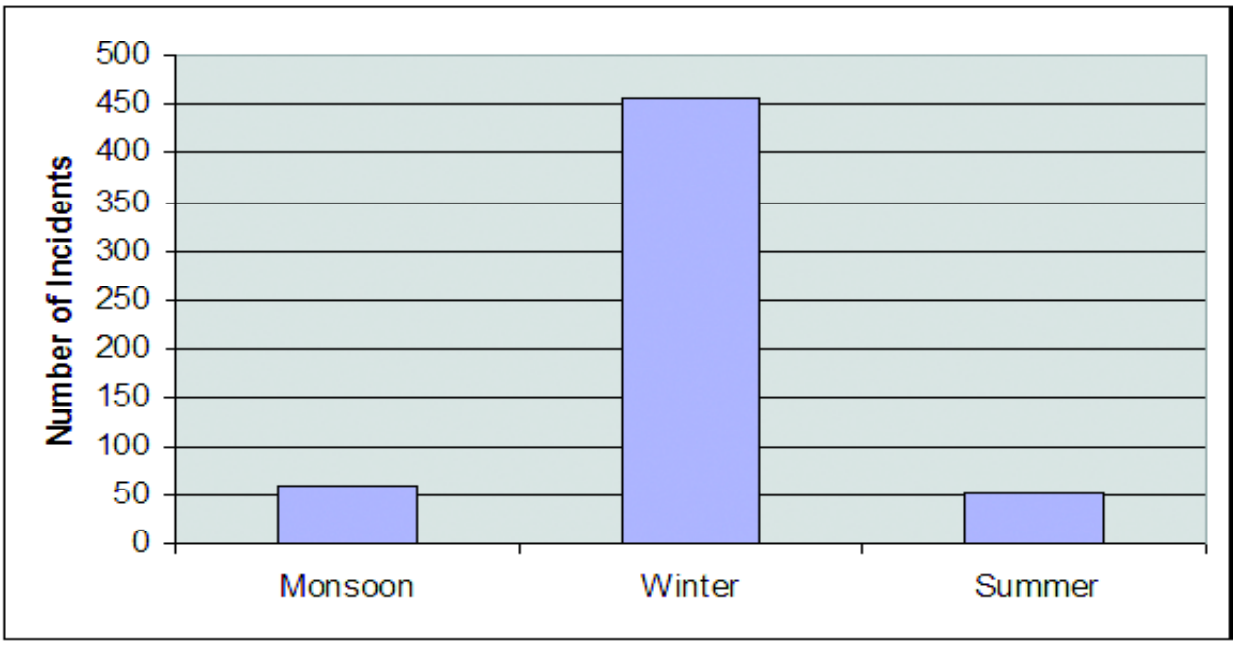

Fig. 8. Maximum movement of elephant migration from West Bengal to Odisha during winter season followed by monsoon season from 1997-98 to 2013-14

night again they move out of the area and tend to visit the sugar cane and other crop field. The people from both flanks obstruct the movement which agitates them to retaliate and cause damage. Usually the route followed by the animals is covered under paddy field on the side of the boundary with very closely located human habitations. In course of their movement they cause damage to house frequently if not guided properly. During last four years with the local people, attempt is being made to guide the intruding animals safely back to their original habitat minimizing disturbance enroute and making people alert in advance to minimize damage to life and property of people as well threat to the life of animal. For the sake two active Elephant drive squads, Hulla Parties are to be kept in readiness round the clock, with provision of their vehicular movement required at times. Provision for food for hulla parties, light, kerosin oil, crackers, mashal, shoes for hulla parties, megaphone, beat drum, etc. becomes necessary at the time of elephant depredation.

Throughout their range wherever they occur, elephants are known to explore newer areas and extend their range. Several explanations have been suggested. Local overa bundance of animals, habitat loss, shortage of food and water resources, or simply a natural instinct to explore newer areas are some of the possible causes for elephants to make forays in new areas (Sukumar, 2006). Fragmentation of forests in Baripada, or creation of a large Subarnarekha canal near the border of West Bengal may be responsible for elephant movement in Baripada. Sometimes such forays are attributed to elephants having memorized past migratory routes which they are trying to use again. Migration by elephants is a natural process that helps sharing of grazing pressure between foraging areas. Where home ranges are totally lost the herds end up Wandering. The herd that went into Jharkhand from Dalma Wildlife Sanctuary to West Bengal forest after considerable initial conflict. It is being seen that, the migratory elephants instead of using the forested areas intrude in to areas they feel safe being chased by the people in mob. Even if, they use the said forest in the day time, during the night again they move out of the area and tend to visit the sugar cane and other crop field. The people from both flanks obstruct the movements which agitate them to retaliate and cause damage. Usually the route followed by the animals is covered

under paddy field on the side of the boundary with very closely located human habitations. Apart from these factors, scientists have explained elephant's attraction to field crops as an optimal foraging strategy wherein elephants visit crop fields because here food is available in large quantity and variety which makes foraging easier without having to spend time and energy looking for the food in the forests (Datye, 1995). Therefore it appears that elephants occurrence in West Bengal could be a result of combination of the above factors and not due to one single factor.

Interstate migration of elephants from Dalma Wildlife Sanctuary of Jharkhand State to Nilgiri area of Balasore district in Odisha through Midnapore district (West Bengal) and Mayurbhanj district of Odisha is being observed for the last 5 years. Dalama Wildlife Sanctuary is situated at 10 km^2. south of Jamshedpur in Jharkhand State and is a small wildlife sanctuary over 193 km^2 area having 158 elephant population (Once their number was 300 as per 2007 census), which is beyond the carrying capacity of that sanctuary. Therefore, more than 100 elephants seasonally migrate to West Bengal and Odisha. These elephants from Dalma Wildlife sanctuary raid crop in Midnapore, Bankura and Bardhaman district of West Bengal. The people in these districts are forcibly driving the elephants from their traditional migratory routes using cruel means towards Odisha state. The increase of man animal conflict in South West Bengal *viz.*, Purulia, Bankura and Midnapore, has been a major administrative issue for the West Bengal Forest Department.

The problem started in 1987 when elephant herds from Dalma Wildlife Sanctuary, situated in the State of Jharkhand started migrating to Jhargram Division in the state of West Bengal. Initially this did not pose any significant problem for Odisha. Later, due to development in irrigation facilities the farmers in West Bengal started growing cash crops like sugarcane. Therefore to avoid damage to the cash crop, they are now indulging in unfair means to forcibly drive the elephant towards Odisha. The people of West Bengal have been trying to stop the elephant from migrating towards Bankura, Bardhaman by a method locally known "hulla parties". These hulla parties with crackers, red hot spears and search lights drive elephants into Odisha. Burn to injury of many elephants entering Odisha is a testimony to these practices.

Attitude of local villagers and their behavior towards elephants

Surveys suggest that the locals are emotionally attached to elephants because of their religious beliefs. Since most of the villagers do not have any previous experience of dealing with wild elephants, they live in great fear. Irresponsible news published in the local newspapers has also elephants in aggravated these fears. The masses are of the opinion that they will take suitable measures to protect their life and property if these elephants were to make the nearby forests their permanent home. A few of them preferred the stronger options of killing the elephants either by electrocution or by using fire arms, if elephants cause extensive damage. It is also noticed that elephants were disturbed by villagers during the day in the forests and therefore, retaliated by extensively damaging village property. Awareness programmes among villagers would help control this threat to elephants.

Mitigation measures

Mitigation measures presently adopted involve traditional drive-away techniques including making noise by shouting, drum beating, bursting fire crackers and firing gun shots into the air, and using torch light, pelting stones and throwing burning torches has been used in severe cases. Machans are used for guarding the crops. Combinations of methods are most effective. Family herds were easily deflected, while single bulls were difficult to ward off. Affected villagers have suggested methods like regular patrolling by the Forest Department officials along the village near the forest, installing electric fencing, construction of stone wall, culling and lighting the village during night hours. Attempts are made to reduce conflict by changing the traditional cropping pattern by introducing some elephant-repellent alternative cash crops.

Table 1. Year wise elephant migration and depredation from West Bengal to Odisha during the period 1997-98 to 2013-14

Year	Human Kill		Human Kill	Human Injury		Human Injury	House damage		House damage	Crop damage		Crop damage
	Baripada	Balasore		Baripada	Balasore		Baripada	Balasore		Baripada	Balasore	
1997-98	00	00	00	00	00	00	30	00	30	9.8	00	9.8
1998-99	00	00	00	00	00	00	14	00	14	25	00	25
1999-00	00	00	00	00	00	00	03	00	03	10	00	10
2000-01	01	00	01	02	00	02	125	00	125	52	00	52
2001-02	00	00	00	01	00	01	00	00	00	00	00	00
2002-03	00	00	00	00	00	00	01	00	01	00	00	00
2003-04	01	00	01	01	00	01	00	04	04	00	00	00
2004-05	01	00	01	05	00	05	05	05	10	00	00	00
2005-06	02	00	02	00	00	00	10	07	17	2.5	00	2.5
2006-07	01	00	01	01	00	01	07	08	15	00	00	00
2007-08	01	00	01	01	00	01	04	09	13	00	00	00
2008-09	00	00	00	00	00	00	157	13	170	295.95	00	295.95
2009-10	00	00	00	00	00	00	00	25	25	00	00	00
2010-11	03	00	03	00	00	00	124	80	204	374.54	485.46	860.00
2011-12	00	00	00	00	00	00	131	49	180	259.94	385.62	645.56
2012-13	00	03	03	00	00	00	100	116	216	570.37	690.58	1260.95
2013-14	02	01	03	02	02	04	97	31	128	334.09	336.57	670.66
Total	12	04	16	13	02	15	808	347	1155	1934.19	1898.23	3832.42

Table 2. Elephant migration from West Bengal to Odisha

Year	State from where entered	Entry point (Odisha)	No of elephants entered	Days spent in Odisha
1997-98	West Bengal	Deuli Range	12nos (M-2,F-6,C-4)	06
1998-99	West Bengal	Deuli Range	9nos (M-3,F-5,C-1)	01
1999-00	West Bengal	Deuli Range	45nos (M-4,F-35,C-6)	04
2000-01	West Bengal	Deuli and Rasgovindapur	102 nos (M-7,F-65,C-30)	01
2001-02	West Bengal	Bangriposi Range	01nos (M-1)	10
2002-03	West Bengal	Dukura and Deuli	24nos (M-2,F-18,C-4)	03
2003-04	West Bengal	Deoli and Rasgovindapur	07nos (M-3,F-2,C-2)	03
2004-05	West Bengal	Deuli,	05nos (M-1,F-2,C-2)	02
2005-06	West Bengal	Dukura Range	21nos (M-2,F-9,C-10)	35
2006-07	West Bengal	Deoli Range	24nos (M-4,F-8,C-12)	21
2007-08	West Bengal	Deuli range	63nos (M-19,F-13,C-31)	19
2008-09	West Bengal	Deuli Range	150nos (M-21,F-62,C-67)	25
2009-10	West Bengal	Deuli Range	04nos (M-1,F-2,C-1)	21
2010-11	West Bengal	Rasgovindapur	65nos (M-19,F-13,C-33)	19
2011-12	West Bengal	Rasgovindapur	80nos (M-17,F-34,C-29)	25
2012-13	West Bengal	Rasgovindapur	120nos (M-28,F-48,C-44)	23
2013-14	West Bengal	Rasgovindapur	108nos (M-26,F-52,C-30)	27

*M-Male , F-Female, C-Cub

Anti-depredation strategy

This would require a well organized set up in the Forest Divisions to continuously monitor elephant movement in all forest fringe areas, and to sound alert in the villages likely to be visited by elephants, in advance. The anti-depredation units are required to quickly take charge of the situation when the elephants enter into village area, and to organize a regulated drive operation of elephants to minimize damage to houses and crops. In selected locations, barriers would be constructed to secure the human habitations and paddy fields, and at the same time to allow safe passage to elephants. To check depredation elephant proof barriers like trenches, solar fencing, boulders packing etc, will be used to prevent exit of elephants from forest areas or to check entry in to the villages.

Recommendations

i. An interstate committee must be created comprising representatives from West Bengal, Chhattisgarh, Jharkhand and Orissa. This committee should decide on the collection of uniform information relevant for elephant management. The collected information should be shared directly between the concerned Divisional Forest Officers. This committee should involve individuals who have worked on elephant related issues in West Bengal and Odisha so that an effective management plan can be developed for elephant populations. During these meetings, emphasis should be given on quality improvement of elephant habitat in West Bengal and Odisha so that disoriented elephant migration can be stopped.

ii. All the interstate border forest divisions should create elephant squads so that they can keep proper records of elephant movements and other variables important for management of elephant populations the squad continuing the monitoring 24 hours the month September to December. All the team members of such a elephant squad should be properly trained and equipped, including siren, wireless sets, binoculars, digital still Camera, night vision binocular and other equipment.

iii. Development of interstate elephant corridor, West Bengal –Deuli- Suliapada corridor

iv. Regular monitoring of maintenance of existing trenches, solar fencing and stone wall of the border area of Odisha and West Bengal

v. Developing an action plan to mitigate human-elephant conflict and conservation of migrating elephant from Jharkhand via West Bengal to Odisha.

ACKNOWLEDGEMENT

We are thankful to Principal Chief Conservator of Forests (Wildlife) and Chief Wildlife Warden, Odisha Forest Department for facilitating this study. We extend our sincere thanks to Mr.Abhaya Acharya, Assistant Conservator of Forests (Wildlife) for his valuable support to carry out this research. We thank the Regional Chief Conservator of Forests, Baripada Circle and Divisional Forest Officers of Baripada and Balasore Wildlife Division and the front line field staffs for their co-operation.

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e-planet **14** (1): 53-57 (June 2016)

Effect of moisture conservation practices on productivity and economics of finger millet and pigeon pea intercropping system in the dry zone of Eastern Karnataka

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Date of receipt : 04. 04. 2016 Date of acceptance: 10. 06. 2016

ABSTRACT

A field experiment was conducted during *Kharif* season of 2013 to study the effect of moisture conservation practices on productivity and economics of finger millet + pigeon pea intercropping system under dry land situations at AICRP on Dryland Agriculture field unit, UAS, GKVK, Bangalore. The experiment consisted of multiple treatments such as mulching with maize residues, repeated inter-cultivation, green leaf manuring, tank silt application and their combination with a control replicated thrice in RCBD. Growth and yield attributes in both finger millet and pigeonpea was superior with green leaf manure + maize residue mulch as compared to control. Higher gross and net returns were observed in green leaf manure + maize residue mulch (Rs. 95026 ha^{-1} and Rs. 70118 ha^{-1}, respectively). Equivalent higher yield of finger millet yield was recorded in the same treatment compared to the control.

Key words: Economics, finger millet, moisture conservation, pigeon pea, productivity

INTRODUCTION

The main concept of intercropping is to get higher total productivity per unit area and time, besides equitable and judicious utilization of land resources and farming inputs including labour. One of the main reasons for higher yields in intercropping is that the component crops utilize the natural resources differently and efficiently than grown separately (Willey, 1979). The major constraint limiting crop production in finger millet + pigeon pea intercropping is the lack of assured supply of available soil moisture throughout the cropping season due to low and erratic distribution of rainfall. Lack of sufficient soil moisture hinders the crop growth affecting soil - plant water relations viz., reduced evapotranspiration, C fixation, uptake of water, nutrients *etc*. This complex situation brings the dryland production always unstable. Although, the finger millet and pigeon pea are reported to be tolerant to moisture stress, even short period of moisture stress during critical stages of growth, markedly reduces the yield. Soil and water conservation measures are aimed at management

of rain water, soil and vegetation in a manner that makes perceptible change with regard to water resources development for increasing land productivity on a sustainable basis (Arora *et al*., 2006). Field based soil and water conservation measures are essential for *in-situ* conservation of soil and water. *In-situ* moisture conservation practices are reported to provide an advantage in conserving the rainfall in soil profile and reducing the runoff, providing more opportunity time to infiltrate into soil, reducing evaporation losses and minimize the risk of uncertain rainfall. Measures to conserve soil moisture may therefore, help to improve the productivity of dryland crops.

MATERIALS AND METHODS

Experiment was conducted at AICRP on Dryland Agriculture field unit, UAS, GKVK, Bangalore. The centre is situated in the Eastern dry zone (zone-V) of Karnataka at 12°35' North latitude and 77°35' East longitude with an altitude of 930 m above the mean sea level. The experimental soil was red sandy clay loam, medium in organic carbon (0.55 %), slightly acidic in reaction (pH 5.7), normal EC (0.09 d Sm^{-1}), medium in available N (235 kg ha^{-1}), K (170 kg ha^{-1}), and high in available P (80 kg ha^{-1}). The field experiment carried in finger millet + pigeonpea (8:2) intercropping with moisture conservation furrow in between paired rows of pigeonpea laid out in randomized complete block design (RCBD) with 10 treatments (Mulching with maize residues, repeated inter-cultivation (3 times), green leaf manuring, tank silt application and their combination with a control) and 3 replications. The gross plot size was 6.6 m X 3.6 m and net plot size was 5.4 m X 3.0 m. Finger millet cv MR-1 and pigeon pea cv TTB-7 was sown during first week of July. Calculated quantity of *ex-situ* green manure (*Gliricidia sepium*) in T_4, T_6 and T_8 treatments, tank silt application in T5, T_7 and T_9 treatments were incorporated as per the treatment schedule. Fifteen days prior sowing and maize residue comprising rind and sheath of cob, straw was analysed for the nutrient status before mulching. Calculated quantity of sun dried maize residue was mulched in T_1, T_2, T_6 and T_7 as per the treatment detail on 20 DAS. In the treatment, T_3, T_8 and T_9 having repeated inter-cultivation, three inter-cultivations were adopted including the common inter-cultivation. Finger millet was harvested on 15th November 2013 and pigeon pea on 1st February, 2014.

Statistical analysis

The experimental data collected on various growth, yield and other aspects were subjected to Fisher's method of analysis of variance (ANOVA) as per methods outlined by Panse and Sukhatme (1967). Critical difference (CD) was calculated wherever the 'F' test was found significant. The data were analyzed and are presented with 5 per cent level of significance.

RESULTS AND DISCUSSION

Growth parameters

Different soil moisture conservation practices such as green leaf manuring, maize residue mulch, tank silt application, repeated inter-cultivation operation and combination of these significantly influenced the growth parameters of finger millet and pigeon pea. In finger millet, combination of green leaf manure with maize residue mulch treatment showed significantly taller plants, higher leaf area and total dry matter accumulation (T_6: 98.6 cm, 1600.00 cm^2 $hill^{-1}$ and 86.00 g $hill^{-1}$) as compared to control (86.0 cm,1100.00 cm^2 $hill^{-1}$ and 58.89 g $hill^{-1}$, respectively). The increase in the dry matter production and accumulation in both green leaf manure and tank silt with maize residue mulch treatment might be due to higher plant height and leaf area compared to control treatment. These results are in close conformity with the results of Singh and Rana (2006); Patil *et al*. (2011) in sorghum. In case of pigeonpea green leaf manure with maize residue mulch treatment recorded higher plant height (Table 1) and total dry matter

accumulation (132.0 cm and 195.1 g plant^{-1}) as compared to control (100.7 cm and 137.0 g plant^{-1}). Which is ascribed to the better nutrient availability in the early stage of crops, which might favoured initial establishment and rapid growth of photosynthetic area. Further, mulches helped in maintaining microclimate besides its decomposition add nutrients in soil.

Yield parameters

Higher finger millet ear weight (39.83 g hill^{-1}) and test weight (3.43 g) recorded in green leaf manuring with maize residue mulch (Table 2) and it was on par with tank silt with maize residue mulch treatment (38.60 g hill^{-1} and 3.43 g respectively). Significantly higher grain yield per hill was registered with tank silt along with maize residue mulch treatment (32.71 g hill^{-1}) and it was on par with green leaf manuring with maize residue mulch treatment (32.40 g hill^{-1}). Lower grain yield was recorded in control (25.93 g hill^{-1}). Seed yield of pigeon pea per plant differed significantly due to different moisture conservation practices. Green leaf manure with maize residue mulch treatment recorded higher seed weight (43.81 g plant^{-1}) and test weight (13.02 g). Lower seed weight (28.21 g plant^{-}1) and test weight (11.80 g) was noticed in control. The significant improvement in yield components in both green leaf manure and tank silt along with maize residue mulch treatment might be attributed to beneficial effect of green leaf manure, tank silt and maize residue mulch on physical and chemical properties of the soil, besides supplying essential nutrients to plant growth. This also could be attributed to ability of plants to absorb the required moisture and nutrient as per its requirement resulting in better yield component and grain yield of pigeon pea. Similar results were found by Anon. (2012) in moong bean ; Karunakaran and Behera (2013) in soybean.

Finger millet equivalent yield and economics

Higher gross and net returns were observed in green leaf manure with maize residue mulch with Rs. 95026 ha^{-1} and Rs. 70118 ha^{-1} respectively (Table 3). Green leaf manure with maize residue mulch treatment recorded higher finger millet equivalent yield (4460 kg ha^{-1}) followed by tank silt with maize residue mulch treatment (4244 kg ha^{-1}) and tank silt along with repeated inter-cultivation(4244 kg ha^{-1}). Lower finger millet equivalent yield was noticed in control (3503 kg ha^{-1}). Increased gross and net returns were due to the higher finger millet equivalent yield (4460 kg ha^{-1}) in green leaf manure treatment compared to control. Higher finger millet equivalent yield might be due to availability of sufficient moisture and nutrients to the crop compared to control. The higher B: C ratio of 3.32 was noticed in maize residue @ 5 MT ha^{-1} mulch treatment followed by maize residue mulch @ 2.5 MT ha^{-1} and green leaf maize residue @ 5 MT ha^{-1} mulch treatment (3.29 and 2.82, respectively). Lower B:C ratio in green leaf manure with repeated inter-cultivation and tank silt with repeated inter-cultivation were due to higher cost of cultivation (Rs.25608 ha^{-1} and Rs.25608 ha^{-1}) compared to the other treatments. Similar results were also obtained in sorghum crop (Sharma *et al.,* 2004 and Devaranavadagi *et al.,* 2004).

CONCLUSION

Green leaf manure along with maize residue mulch treatment improved the yield of finger millet and pigeon pea followed by tank silt along with maize residue mulch treatment. Combination of soil moisture conservation practices performed better followed by their effect on isolation for productivity of finger millet + pigeon pea intercropping and conservation of natural resources compared to control. Economic analysis shows superiority of maize residue @ 5 MT ha^{-1} followed by maize residue mulch 2.5 MT ha^{-1} and combination of green leaf manure + maize residue mulch @ 2.5 MT ha^{-1}. This practice also helps in improvement of soil physical, chemical and biological properties due to addition of organic matter into the soil. Therefore application of green leaf manure with maize residue mulch or tank silt with maize residue mulch is a recommendable option for improving the productivity of finger millet + pigeon pea intercropping system under deficit rainfall situation.

Table 1. Effect of moisture conservation practices on growth parameters of finger millet and pigeon pea

Treatment	Finger millet			Pigeonpea	
	Plant height (cm)	Leaf area (cm^2 $plant^{-1}$)	TDMP (g $hill^{-1}$)	Plant height (cm)	TDMP (g $hill^{-1}$)
T_1: Mulching with maize residue @ 2.5 MT ha^{-1}	90.8	1289.00	72.72	115.0	152.3
T_2: Mulching with maize residue @ 5 MT ha^{-1}	92.0	1216.67	76.33	115.7	162.4
T_3: Repeated inter-cultivation (3 times)	89.3	1181.00	65.90	112.5	141.9
T_4:Green leaf manuring @ 10 MT ha^{-1}	92.1	1277.33	74.90	127.7	170.8
T_5: Tank silt @ 10 MT ha^{-1}	91.3	1324.00	74.55	117.7	164.7
T_6: $T_4 + T_1$	98.6	1600.00	86.00	132.0	195.1
T_7: $T_5 + T_1$	97.0	1402.00	83.60	119.7	191.9
T_8: $T_4 + T_3$	93.9	1375.33	77.00	129.7	175.3
T_9: $T_5 + T_3$	92.0	1320.00	77.68	119.0	167.6
T_{10}: Control (Recommended practice)	86.0	1100.00	58.89	100.7	137.0
S.Em.±	1.48	39.74	0.83	3.9	1.3
CD (P=0.05)	4.44	118.08	2.60	11.7	4.0

TDMP- Total dry matter production

Table 2. Effect of moisture conservation practices on yield parameters of finger millet and pigeon pea

Treatment	Finger millet			Pigeonpea	
	Ear weight (g $hill^{-1}$)	Grain weight (g hil^{l-1})	1000 grain weight (g)	Seed weight (g $plant^{-1}$)	100 Seed weight (g)
T_1: Mulching with maize residue @ 2.5 MT ha^{-1}	37.72	27.60	3.20	30.00	12.10
T_2: Mulching with maize residue @ 5 MT ha^{-1}	38.00	27.83	3.25	32.21	12.61
T_3: Repeated inter-cultivation (3 times)	32.57	25.97	3.15	28.51	12.01
T_4:Green leaf manuring @ 10 MT ha^{-1}	35.73	28.23	3.23	36.20	12.62
T_5: Tank silt @ 10 MT ha^{-1}	38.05	28.77	3.37	35.22	12.4
T_6: $T_4 + T_1$	39.83	32.40	3.43	43.81	13.02
T_7: $T_5 + T_1$	38.60	32.71	3.43	43.20	12.50
T_8: $T_4 + T_3$	37.33	27.50	3.23	37.80	12.60
T_9: $T_5 + T_3$	38.35	28.33	3.33	36.01	12.62
T_{10}: Control (Recommended practice)	31.05	25.93	3.10	28.21	11.80
SEm±	0.62	0.86	0.05	0.60	0.30
CD (P=0.05)	1.83	2.54	0.15	1.80	0.90

Table 3. Economics of finger millet + pigeon pea intercropping system as influenced by different moisture conservation practices

Treatments	FM grain yield (kg ha^{-1})	PP seed yield (kg ha^{-1})	FMEY (kg ha^{-1})	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C
T_1: Mulching with maize residue @ 2.5 MT ha^{-1}	3621	223	4100	87199	20308	66891	3.29
T_2: Mulching with maize residue @ 5 MT ha^{-1}	3744	241	4223	89906	20808	69098	3.32
T_3: Repeated inter-cultivation (3 times)	3292	185	3771	79831	21008	58823	2.80
T_4:Green leaf manuring @ 10 MT ha^{-1}	3740	251	4219	89763	24258	65505	2.70
T_5: Tank silt @ 10 MT ha^{-1}	3734	244	4213	89064	24258	64806	2.67
T_6: $T_4 + T_1$	3981	273	4460	95026	24908	70118	2.82
T_7: $T_5 + T_1$	3765	264	4244	90242	24908	65334	2.62
T_8: $T_4 + T_3$	3760	260	4239	89901	25608	64293	2.51
T_9: $T_5 + T_3$	3765	252	4244	90375	25608	64767	2.53
T_{10}: Control (Recommended practice)	3024	146	3503	74340	19658	54682	2.78
S.Em.±	132.78	4.10					
CD (P=0.05)	394.51	12.30					

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e-planet **14** (1): 58-68 (June 2016)

Evaluation of performance of maize (*Zea mays* L.) varieties under varying planting geometry under Kandahar situations in Afghanistan

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Date of receipt : 15. 02. 2016 Date of acceptance: 10. 06. 2016

ABSTRACT

A field experiment was conducted during spring season, 2015 at Tarnak Research Farm of Afghanistan National Agricultural Sciences and Technology University (ANASTU), Kandahar, Afghanistan with semi-arid climate to evaluate the performance of maize varieties under varying planting geometry. The experiment was conducted in Randomize Complete Block Design and replicated thrice. The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction having pH of 8.30 and organic matter 0.18, with a cation-exchange capacity of 80.58 meq/100g and electrical conductivity of 0.210 dSm^{-1} .The initial N (0.06 %) content of soil was low having P content of 1.23 mg kg^{-1} and K content of 1,089 mg kg^{-1}. The treatment details include: two maize hybrids - CS-200 and AB-01 and four planting geometry [P1 (75 × 33.3cm) with plant population of 40,000 plants ha^{-1}, P2 (75 × 22.2cm) with plant population of 60,000 plants ha^{-1}, P3 (75 × 16.7cm) with plant population of 80,000 plants ha^{-1} and P4 (75 × 13.3cm) with plant population of 100,000 plants/ha]. Results revealed that maize hybrid AB-01 recorded significantly greater performance in terms of growth attributes, *viz*, leaf area index (LAI) and dry matter accumulation, compared to hybrid CS-200. While maize hybrid CS-200 performed significantly superior in terms of grain yield (6.41 t ha^{-1}) and harvest index (37.6%) compared to AB-01 (5.81 t ha^{-1} and 33.4%, respectively). Both of maize hybrids (CS-200 and AB-01) did not differ significantly with respect to gross return, net return. B: C ratio, energy output and energy use efficiency due to their significant variation in producing grain and stover yields. Among the varying planting geometry, the narrow planting geometry showed significantly greater LAI and dry matter accumulation, cost of production and input energy. While the wider planting geometry recorded significantly better performance for all yields attributes. Planting geometry P2 recorded significantly greater performance in terms of growth and yields attributes. Therefore, hybrid CS-200 and planting geometry P2 is recommended for obtaining higher yield of maize, which can assure a net income of 221,371Afn ha^{-1} to the farmers of Kandahar region.

Key words: Economics and energy relations, maize varieties, optimum planting geometry

INTRODUCTION

Maize (*Zea mays* L.) enjoys an important position in the existing cropping systems of Afghanistan; it ranks third after wheat and rice in the country for its grain production. Maize is grown in almost all the provinces of the country. It is not only consumed by human beings in the form of food grain but it is also used as feed for livestock and poultry besides being a good forage crop. In Afghanistan, it is grown on 0.142 million hectare in all of the provinces in irrigated and rain fed areas. The total production of maize in the country is 0.312 million tons with the average productivity of 2.2 tons ha^{-1}. The average grain yield of maize is not only substantially lower compared to other important maize growing countries but also less than the production potential of existing genotypes. Maize is grown twice a year in Afghanistan (spring, autumn). Although the soil and climatic conditions of Afghanistan are favorable for maize production but it's per hectare yield is very low as compared to other maize growing countries of the world. Maize crop bears high yield potential and responds to various agro-management practices. Low yield of maize is due to many constraints but among them, cultivation of local genotypes, imbalanced use of fertilizers, traditional sowing methods, lack of optimal crop stand and optimum planting geometry are the factors of prime importance. Successful maize production requires an understanding of various management practices as well as environmental conditions that affect crop performance (Ecker, 1995). Selection of appropriate genotypes, plant population and planting geometry are cultural practices that have been shown to affect maize yield potential and stability (Norwood, 2001). Moreover, there are number of biotic and a biotic factors that affect maize yield considerably, however, maize grain yield is more affected by variations in plant population density than other members of the grass family due to its low tillering ability, its monoecious floral organization and the presence of a brief flowering period (Vega *et al.*, 2001). In Afghanistan situation very less work has been done to evaluate the different maize varieties in order to find out the suitable varieties and optimum planting geometry of maize genotype to explore the yield potential at higher level under agro-climatic situations. Hence, the study was undertaken to evaluate the performance of maize varieties under varying planting geometry in Kandahar situations of Afghanistan.

MATERIALS AND METHODS

Experiment site

The experiment was conducted at Tarnak Research Farm of Afghanistan National Agricultural Sciences and Technology University (ANASTU). Kandahar, Afghanistan. The experiment was carried out under irrigation condition during the period from April to August 2015. The site of experiment was located in south region of country at a distance of 30 km from Kandahar city (31° 262' 57") N latitude and (65° 512' 59") E longitude, altitude of the location was 990 m from sea level.

Climate and soil

The minimum and maximum temperature, relative humidity and total rainfall during crop growth period were recorded that ranged between 14.4 to 42.8 ^{0}C, 10.8 to 24.6 % and 0 to 443mm respectively. The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction having pH of 8.30, with a cation-exchange capacity of 80.58 meq/100g and electrical conductivity of 0.210 dSm^{-1}. The initial N (0.06 %) content of soil was low having P content of 1.23 mg kg^{-1} and K content of 1089 mg kg^{-1}.

Experimental design and treatments

The experimental design was a factorial arranged in a Randomized Complete Block Design with three replications. The two factors included of two hybrid genotypes (CS-200 × AB-01) and four planting geometries for each genotype with four plant populations (40,000 plants ha^{-1} 60,000 plants ha^{-1}; 80,000 plants ha^{-1} and 100,000 plants ha^{-1}), each replication consisted with eight treatment and in all there were 24 treatment. Plant population was replicated three times for either genotype. Net plot size was 3 m × 4 m =12 m^2 included four rows of 75cm inter-row and with varying intra-row

spacing The experiment site was ploughed and harrowed to a good tilth with plain seed bed.

Data collection

Data of the field experiment were recorded on the basis of grain yields economics and energy relation as followed.

Grain yield

The dried cobs of each harvested row from each plot were threshed by hand then obtained grains were cleaned, dried and weighted separately by using sensitive electronic balance. Grain yield of each harvested row of each plot was recorded as kg per hectare individually and converted to tons per hectare basis**.**

Harvest index

The harvest index (HI) was computed by dividing grain yield with total biological yield.

HI (%) = Grain yield/Total biological yield ×100

Benefit cost ratio (BCR)

The benefit cost ratio for each treatment of interaction was calculated on the basis of the price of harvested crop, cost of each treatment and the cost of cultivation.

$$\text{BCR} = \frac{\text{Net return}}{\text{Total cost of production}}$$

Energy input and output

Energy input and output for the purpose of the analysis undertaken in this study, the energy values for inputs (e.g. machinery, seeds, fertilizer, water, and labour requirements) and outputs (e.g. grain and stover) were estimated using energy equivalents were entered into excel spreadsheets and automatically calculated as recommended by Behera *et al.* (2015) and Shahan *et al*. (2008) are given in the (Table 1).

Energy use efficiency

The energy use efficiency was calculated by equation following Shahan *et al.* (2008).

$$\text{Energy use efficiency} = \frac{\text{Energy Output (MJ ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})}$$

Table 1. Energy equivalents of inputs and outputs in agricultural production for the maize varieties under varying planting geometries during spring, 2105 under Kandahar situation

Particulars	Unit	Energy equivalent (MJ/unit)
A. Inputs		
1. Human labor (man)	hr	1.96
2. Machinery (tractor)	hr	62.7
3. Diesel fuel	liter	56.31
4. Chemical fertilizers		
(a) Nitrogen (N)	kg	66.1
(b) Phosphate (P_2O_5)	kg	12.4
(c) Potassium (K_2O)	kg	11.2
(d) Zinc (Zn)	kg	8.4
7. Water for irrigation	m^3	1.02
8. Seed (maize)	kg	14.7
B. Outputs		
1. Grain wheat	kg	14.7
2. Stover	kg	12.5

Statistical analysis of data

The data were analyzed using standard procedure of data analysis (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth parameters

Growth parameters of maize varieties under varying planting geometry are predicated (Table 2 and figs 1, 2, &3). Hybrid CS-200 was significantly taller (152.6, 174 and 182.1cm) than hybrid V2-AB-01(125.5, 162.1 and 173.1cm) at all the growth stages. But there was no significant difference at 30 days after sowing (DAS). This result is in line with report of Nanda, 2015. Hybrid AB-01 recorded significant greater LAI (0.27, 4.28 and 5.18) at all growth stages as compared to hybrid CS-200 (0.21. 3.07 and 3.92). This is similar to the findings of (Nanda, 2015) and (Alias *et al*., 2010). Hybrid AB-01 gave the significantly greater dry matter accumulation (44.9, 811.3, 1610.8 and 1798.6 g m^{-2}) than hybrid CS-200 (35.1, 635.4, 1512.6 and 1688.9 g m^{-2}) at all the growth stages. This might be due to the high leaf area index, number of leaves per plant and genetic potential of the concerned hybrid. The result was in agreement with Nanda (2015). Under varying planting geometry, plant height was not significantly different at 30 DAS. While there were significantly taller plants (157.1, 181.4 and 187.9cm) recorded under wider planting geometry P1 which was statistically at par with planting geometry P2 at 60 DAS, 90 DAS and maturity respectively. These findings are in line with the findings of Muniswamy *et al.* (2007) and Boomsma *et al.* (2009). Sachan and Gangawar (1996) reported that the plant height declined with increasing in plant density. The narrow planting geometry P4 exhibited significantly greater LAI at all the growth stages from each other. The LAI increased linearly as the density increased. These findings were supported by Suryavanshi *et al.* (2009); Abuzar *et al*. (2011) and Ashwani *et al.* (2015), who indicated that the highest value of LAI was recorded under high planting density. Dry matter accumulation also concomitantly linearly as the planting geometry declines. Dry matter accumulation was significantly higher in linear fashion along with increased plant population and decreased planting geometry. Narrow panting geometry (P4) also recorded significantly greater dry matter accumulation (48.6 and 877.7 g m^{-2}). While under P1, dry matter accumulation was lower (29.2 and 527.1 g m^{-2}) at 30 and 60 DAS. Similarly, planting geometry P4 showed significantly greater dry matter accumulation (1664 and 1858 g m^{-2}) that was statistically at par with planting geometry of P3 and P2. However, the planting geometry P1 showed significantly minimum dry matter accumulation (1317.5 and 1471.1g m^{-2}) at 90 DAS and maturity respectively. These experimental results are in agreement with the findings reported by Singh and Tajbaksh (1986) and Singh e*t al*. (1997).

The interaction effects among the varieties and planting geometry for the growth parameters indicated that hybrid AB-01 performed significantly higher in terms of leaf area index (0.43 and 6.05) at vegetative growth of 30 DAS and 60 DAS under planting geometry P4. Similarly, hybrid AB-01 showed significantly greater dry matter accumulation (1887.4 g m^{-2} and 2107.4 g m^{-2}) under planting geometry P4 but, it was statistically at par when hybrid AB-01 was placed under planting geometry P3 and hybrid CS-200 under planting geometry P2 at the growth stages of 90 DAS and maturity. These findings showed that planting geometry P4 was a suitable geometry for the hybrid AB-01 in terms of the concerned parameters of growth.

Yield and yield attributes

Yield and yield attributes of maize varieties under various planting geometry are presented in (Table 3). The number of cobs/plant, cob length, cob girth, number of grains/cob and 1,000-grain weight are the fundamental yield contributing parameters. The genetic potential of particular genotype can be judged by these attributes to determine yield of maize plant. Results revealed that, performance of both the hybrids was not significantly different in terms of evaluated parameters. These results are in agreement with the findings of Azam *et al.* (2007)**;** Saqib *et al.* (2012) and Karki *et al.* (2015) who stated that

maize hybrids were not differed for the mentioned attributes. Maize hybrid CS-200 gave higher grain yield (6.41 t ha^{-1}) than hybrid AB-01, (5.81 t ha^{-1}). It might be attributed to differences in genetic characteristics of the particular variety. These findings are in line with those reported by Alias *et al*. (2008); Azam *et al.* (2007), and Saqib *et al.* (2012). Maize hybrids AB-01 revealed significantly greater stover yield (12.2 t ha^{-1}), while hybrid CS-200 showed least stover yield (10.5 t ha^{-1}). These results indicated that hybrid AB-01 was not more efficient in transporting photosynthates from leaves, stem to grains (source to sink). Hybrid CS-200 showed high harvest index than as hybrid AB-01. These findings showed that hybrid CS-200 was more efficient to convert photosynthates into economical yield (Azam *et al.,* 2007 and Saqib *et al.,* 2012). Among the varying planting geometries, P1 recorded significantly greater number of cobs/ plant (1.65) than others while, the minimum number of cobs/plant was recorded under P4 (0.98). These results are in agreement with the report of Abuzar *et al*. (2011) who revealed that high stand establishment crop creates competition for light, aeration, nutrients and consequently compelling the plants to undergo less reproductive growth. Similarly, wider planting geometry P1 observed significantly longer cobs (20.2 cm) than others but, it was statistically at par with planting geometry P2. This could be due to the effect of interplant competition for light, soil water and nutrients. These results are validated by the conclusion of Sarjamei *et al*. (2014). Cob girth of the maize varieties was non-significant among the various planting geometry (Viorelion *et al*., 2014). Again treatment of P1 showed greater performance (34.4 and 515.1) than others with respect to number of grains/row and number of grains/cob which was statistically at par with planting geometry P2 respectively (Singh *et al.,* 1997 and Bhatt *et al*., 2012); who reported that higher values for the mentioned characters were observed at low plant density. Weight of 1,000 grains of maize was not affected significantly by different planting geometry. Babu and Mitra, 1989 Arif *et al.,* 2010. Under P2 highest grain yield (7.71 t ha^{-1}) was recorded than others while, minimum grain yield was noticed under P4 (4.96 t ha^{-1}). These findings are in line with findings of several workers like, (Abuzar *et al.,* 2011; Ramu and Reddy 2007; Arif *et al.,* 2010; Fanadzo *et al.,* 2010 and Ali *et al*., 2003). They stated that grain yield per plant is decreased in response to decreasing light and other environmental resources available to each plant. Stover yield of maize varied significantly under different planting geometry. Narrow planting geometry P4 had significantly greater stover yield (13.6 t ha^{-1}) as compared to wider planting geometry of P1 (9.00 t ha^{-1}). Difference clearly indicated that stover yield increased with decrease in planting geometry. It might be due to higher population and more numbers plants in particular unit area. Verma and Singh (1976) reported stover yield of maize was significantly improved with the increase in plant density. Planting geometry P2 showed significantly superior performance in term of harvest index (41.6%) compared to others. These results are in agreement with Arif *et al.* (2010) and Bahadori *et al.* (2015).

The significant interaction effects among the varieties and planting geometry for the yield attributes and yields revealed that, both of hybrids showed significantly greater grain yield under planting geometry P2. Hybrid AB-01 had greater performance of the stover with planting geometry of P4. The interaction effect of harvest index and planting geometry indicated that hybrid CS-200 gave significantly higher harvest index under planting geometry P2. These results indicated that planting geometry P2 showed significantly greater harvest index for the hybrid CS-200.

Economics

Economics of maize varieties under different planting geometry are presented in (Table 4). Results indicated that maize hybrid AB-01 recorded higher cost of production (55,825 Afn ha^{-1}) compared to hybrid CS-200 (55,755Afn ha^{-1}). This difference might be due to higher test weight of the grains of the particular hybrid variety. Both of varieties did not differ significantly with respect to gross returns, net returns and B:C ratio. These findings are due to their significant variation in producing grain and

stover yields. Invariably, hybrid CS-200 produced higher grain yield while hybrid AB-01 produced higher stover yield, and as both yields were taken into account for working out the economics, the net differences among the two hybrid varieties become non-significant. Among the planting geometry, cost of production increased linearly as the planting geometry decreased. Treatment of P4 recorded higher cost of production (57,350 Afn ha^{-1}) followed by P3, P2 and P1. These results may be due to higher amount of seed. Planting geometry P2 showed significantly superior and best performance in terms of gross returns, net returns and B:C ratio (255,629 Afn ha^{-1}, 200,359Afn ha^{-1} and 3.63) compared to other planting geometry. The performance of planting geometry followed the trend of P2 > P3 > P4 > P1 for the concerned parameters. These findings clearly indicated that the sustainable productivity of maize could be achieved through maintenance of optimum planting geometry P2. In this context, the present study would show the way to improve the productivity of maize in order to get more net returns. These results are supported with results reported by Bhatt, (2012).

The significant interaction effects among the varieties and planting geometry for the economics showed that, hybrid CS-200 recorded significantly greater gross return, net return and B:C ratio with planting geometry P2. These findings evaluated that hybrid CS-200 performed significantly greater gross return, net return and B:C ratio under planting geometry P2. Similarly, Saqib *et al.*, (2012) also revealed that interaction of hybrids and planting was significantly differed.

Energy relations

Energy relations of maize varieties under various planting geometry are given in (Table 4). Results showed that maize hybrid AB-01 had significantly higher input energy (20,529 MJ ha^{-1}) compared to hybrid CS-200 (20,483 MJ ha^{-1}). This difference might be due to higher test weight of the grains of the particular hybrid variety. Both the varieties did not significantly differ in terms of energy output and energy use efficiency. These differences of the results might be due to their significant variation in grain yield and stover yields. Treatment of P4 recorded greater input energy (20,835 MJ/ha) followed by P3, P2 and P1. It may be concluded that the input energy increased linearly as the planting geometry decreased due to its higher amount of seed. Planting geometry P2 showed significantly best performance (247,726 MJ/ha) regarding to output energy. The results clearly indicated that it could be due to higher grain yield production from the mentioned planting geometry. While the planting geometry P4 recorded significantly greater energy use efficiency (14.4) than P1 (10.7) which were statistically at par with planting geometry of P2 and P3. These findings showed that the energy use efficiency increased linearly as the planting geometry decreased.

The interaction effects among the hybrid varieties and different planting geometry were significant for the energy output. Maize hybrid AB-01 indicated significantly higher energy output under planting geometry P4.These findings may be due to high biomass production of the particular variety with concerned planting geometry.

CONCLUSION

It may be concluded that maize hybrid AB-01 recorded significantly greater performance in terms of growth parameters in comparison to hybrid CS-200. While maize hybrid CS-200 proved significantly superior in terms of grain yield and harvest index compared to AB-01. Both of the hybrids did not differ significantly with respect to gross returns, net returns and B:C ratio, energy output and energy use efficiency. Invariably, hybrid CS-200 produced higher grain yield while hybrid AB-01 produced higher stover yield. Among the varying planting geometries, planting geometry P2 resulted significantly greater performance in terms of grain yield, harvest index, gross return, net return, B:C ratio and output energy. Overall, hybrid CS-200 and plant population of 60,000 plants/ha keeping plant to plant geometry of P2 (75×22.2 cm) recorded batter performance for higher yield of maize, which can assure a net income of 221,371Afn ha^{-1} to the farmers of Kandahar region.

Table 2. Effect of varying planting geometry on yield attributes of two hybrids

Hybrid varieties	Plant height (cm)				Dry matter accumulation (g m^{-2})				Leaf area index		
	30 DAS	60 DAS	90 DAS	at maturity	30 DAS	60 DAS	90 DAS	at Maturity	30 DAS	60 DAS	90 DAS
Hybrid CS-200	26.1	152.6	174.0	182.1	35.1	635.4	1512.6	1688.9	0.219	3.07	3.92
Hybrid AB-01	27.7	125.6	162.1	173.1	44.9	811.3	1610.8	1798.6	0.271	4.29	5.18
SEm±	0.656	4.12	3.11	2.91	1.23	24.2	31.3	35.0	0.013	0.128	0.112
CD (P=0.05)	NS	12.5	9.45	8.84	3.72	73.4	95.0	106.1	0.029	0.388	0.341
Planting geometry											
P1 (75×33.3 cm)	27.3	157.1	181.4	187.9	29.2	527.1	1317.5	1471.1	0.149	2.29	2.82
P2 (75×22.2 cm)	25.6	142.2	174.8	179.7	40.4	730.5	1653.3	1846.1	0.199	3.47	4.39
P3 (75×16.7 cm)	27.3	136.0	157.3	172.8	41.9	758.2	1611.8	1799.8	0.282	3.88	5.25
P4 (75×13.3 cm)	27.4	120.9	156.6	169.9	48.6	877.7	1664.0	1858.0	0.351	5.07	5.79
SEm±	0.927	5.831	4.405	4.120	1.73	34.2	44.3	49.5	0.013	0.181	0.159
CD (P=0.05)	NS	17.7	13.4	12.5	5.25	103.8	134.3	150.0	0.041	0.548	0.482

Table 3. Effect of maize varieties under varying planting geometry on yields and yields attributes during spring 2015 under Kandahar situation

Hybrid varieties	No of cobs plant^{-1}	Cob length (cm)	Cob girth (cm)	No of grains/cob	1,000- grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
Hybrid CS-200	1.28	18.5	13.6	430.3	275.1	6.41	10.5	37.6
Hybrid AB-01	1.20	18.8	13.6	402.3	268.1	5.81	12.2	33.4
SEm±	0.052	0.359	0.271	18.0	4.72	0.123	0.262	0.344
CD (P=0.05)	NS	NS	NS	NS	NS	0.372	0.794	1.043
Planting geometry								
P1 (75×33.33cm)	1.65	20.15	14.2	515.1	281.3	5.71	9.00	39.0
P2 (75×22.22cm)	1.29	19.93	13.9	446.1	273.9	7.71	10.8	41.6
P3 (75×16.67cm)	1.04	17.57	13.4	386.5	265.4	6.08	11.9	34.2
P4 (75×13.33cm)	0.98	16.88	12.8	317.4	265.8	4.95	13.6	27.2
SEm±	0.074	0.508	0.383	25.4	6.67	0.174	0.370	0.486
CD (P=0.05)	0.223	1.54	NS	77.1	NS	0.526	1.12	1.48

Table 4. Effect of maize varieties under varying planting geometry on economics and energy relations during spring 2015 under Kandahar situation

Hybrid varieties	Cost of production (Afn ha^{-1})	Gross returns (Afn ha^{-1})	Net returns (Afn ha^{-1})	BCR	Input energy (MJ ha^{-1})	Output energy (MJ ha^{-1})	Energy use efficiency
Hybrid CS-200	55,755	224,886	169,131	3.04	20,483	225,221	12.7
Hybrid AB-01	55,825	225,261	169,174	3.01	20,529	237,610	14.1
SEm±	-	4,298	4298.9	0.077	_	4,590	0.529
CD (P=0.05)	-	NS	NS	NS	_	NS	NS
Planting geometry							
P1 (75×33.3 cm)	54,230	197,598	142,843	2.61	20,182	196,447	10.7
P2 (75×22.2 cm)	55,270	255,629	200,359	3.63	20,395	247,726	14.3
P3 (75×16.7 cm)	56,310	229,032	172,722	3.07	20,611	238,337	14.1
P4 (75×13.3 cm)	57,350	218,037	160,687	2.80	20,835	243,153	14.4
SEm±	-	6,079	6,079	0.109	_	6,492	0.748
CD (P=0.05)	-	18,439	18,439	0.329	_	19,690	2.29

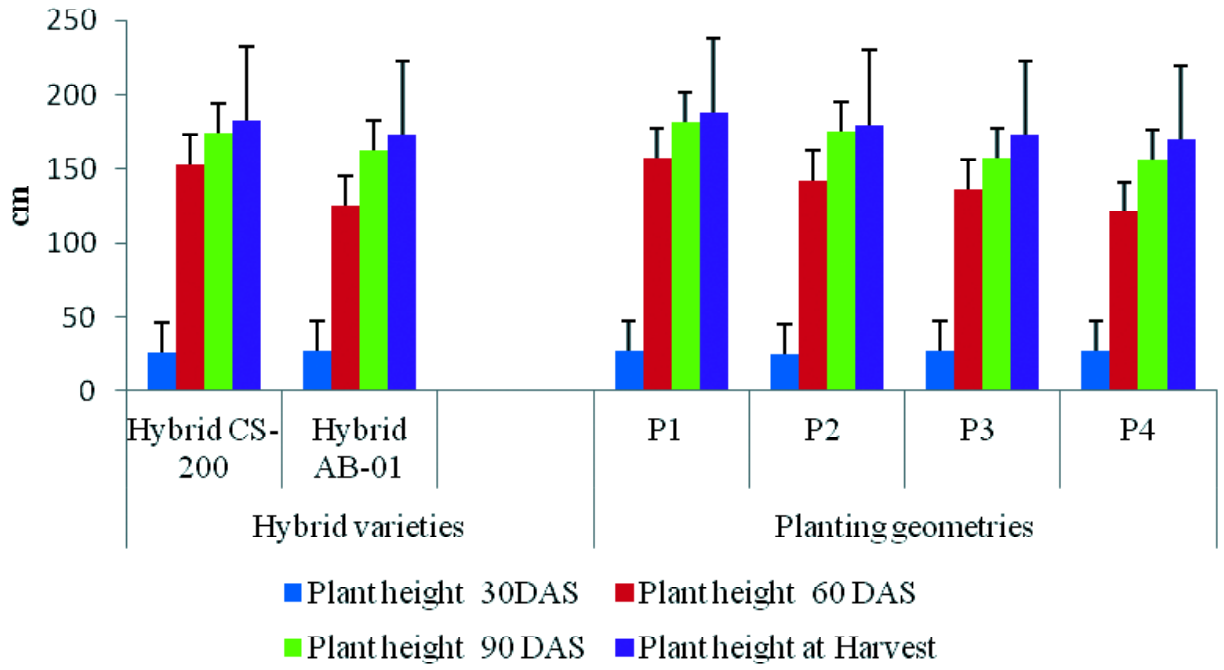

Fig. 1. Effect of varying planting geometry on plant height of Maize at different growth stages during spring 2015 of Kandahar situation

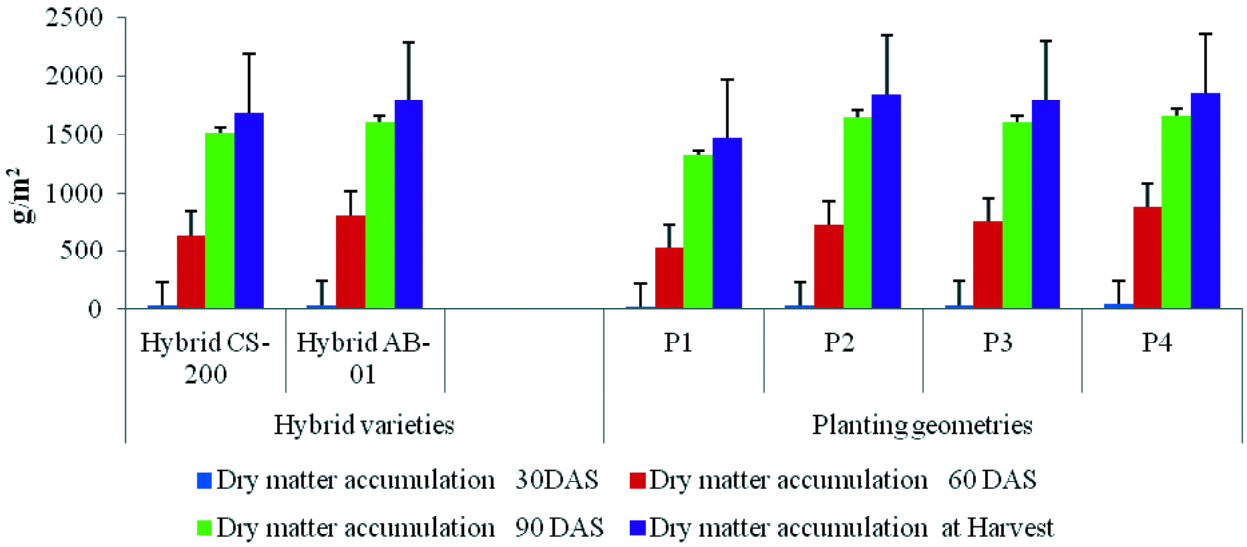

Fig. 2. Effect of varying planting geometry on plant height of Maize at different growth stages during spring 2015 of Kandahar situation

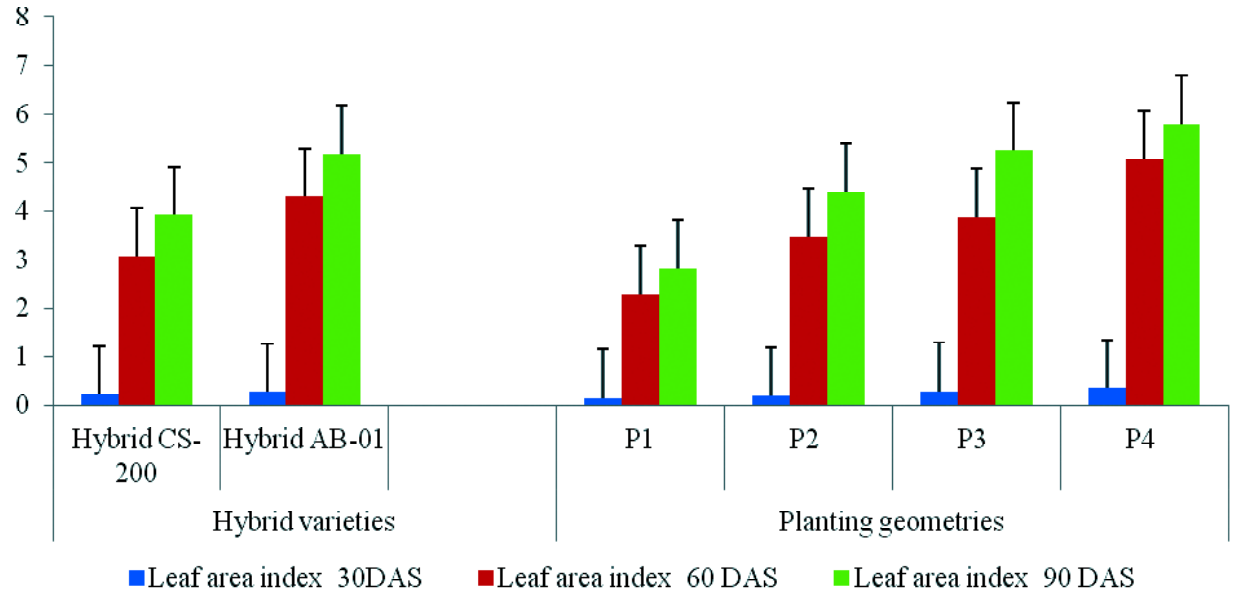

Fig. 3. Effect of varying planting geometry on leaf area index (LAI) of maize at different growth stages during spring 2015 of Kandahar situation

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e-planet **14** (1): 69-75 (June 2016)

Performance of local and improved wheat (*Triticum aestivum* L.) varieties under agro-ecological conditions of Kandahar, Afghanistan

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Date of receipt : 17. 01. 2016 Date of acceptance: 24. 06. 2016

ABSTRACT

Agriculture plays an important role in the economy of Afghanistan by contributing 28% to the total GDP and providing nearly 60% of total employment in the country. Wheat is the primary staple food crop, covering 77.5% of total area occupied by cereal crops in the country. Total annual production of wheat in Afghanistan was 5.37 million tonnes during 2014-15 with about 80% country's total cereal production, which is about 30-40% less than the demand and country is dependent on the import of wheat. Afghanistan has the potentiality not only to become self-sufficient but also to be an exporter of wheat. The present wheat productivity (2.02 t ha^{-1}) can be increased substantially by increasing the area under high yielding varieties. In view of above, a field experiment was conducted at the Research Farm of Afghanistan National Agriculture Science and Technology University (ANASTU), Kandahar during (*Rabi*) season of 2014-2015. Four wheat varieties including local (Sour Khusha and Morai) and improved varieties (PBW-154 and Shisham Bagh-08) were planted to evaluate their performance for yield, economics, and energy and water use efficiency under Kandahar conditions. Significantly maximum days (154) to maturity were taken by both the local varieties compared to improved varieties (136 days). Of the 4 varieties, Sour Khusha recorded highest growth and yield attributing parameters except grains/spike, which was highest with variety PBW 154. Use of variety PBW 154 resulted significantly more grain yield (3.55 t ha^{-1}) and harvest index (39.55%) followed by Sour Khusha. There was an increase of 19.12 and 29.09 % in grain yield with PBW 154 over Shisham Bagh-08 and morai varieties, respectively. The variety PBW-154 also recorded highest net return (96867.03 AFN ha^{-1}), B:C ratio (1.52), water use efficiency (10.14 kg ha^{-1} mm^{-1}) and production efficiency 26.18 kg ha^{-1}) and being at par with Sour Khush, found significantly superior over shisham Bagh-08 and Morai. Thus, the results indicated that variety PBW- 154 and Sour Khusha are suitable for improving average productivity, monetary benefit and water use efficiency in Kandahar condition of Afghanistan.

Key words: Economics, Kandahar, local and improved varieties, water use efficiency, wheat, yield

INTRODUCTION

Agriculture is the key driver of Afghanistan's economy and play vital role in the food and livelihood security as nearly 60% population of the country rely upon agriculture. It accounts for 28% to the total GDP and share 59% employment of overall employment in the country. Out of total land area (65.22 million ha) of Afghanistan, nearly 6% of it is used for crop production and 2.17 million ha is covered by irrigation. Wheat is the primary source of food and nourishment since per capita annual consumption is more than 170 kg in the country. Wheat contributes nearly 77.5 and 80% to the total area covered under cereal crops and total cereal production of the country, respectively. Wheat is cultivated in an area of 2.65 million ha with a production of 5.37 million tones annually and grown throughout the country in a wide variety of microclimatic environments ranging from arid desert lowlands to temperate high altitude mountain valleys. However, low average productivity of the wheat (2.02 t ha^{-1}) in Afghanistan is a major concern and country is dependent on the import of wheat. About 1.50 million tonnes of wheat grain was imported during 2013-14 which costs nearly 479 million dollar 2013-14. In Kandahar, wheat cultivation occupies an area of 66.74 thousand ha with the production of 186.89 thousand tones and productivity of 2.80 t ha^{-1}, which is 38.61% higher than national average productivity of wheat (MAIL, 2013), which is owing to more than 88% area under irrigation. However, considering the potentiality of wheat production in Kandahar, substantial increase in average productivity can be achieved by increasing the use of high yielding varieties, as local varieties dominates in the area, which have poor potentiality, while high yielding varieties have the quality of in built genetic potential.

Three types of wheat cultivars i.e. *Triticum aestivum L.*, *Triticum compactum L.* and *Triticum durum* are cultivated by the farmers in Afghanistan. The cultivation of bread wheat (*Triticum aestivum*) is common and covered maximum area, but duram wheat is also cultivated in small areas (MAIL, 2013). Rainfed wheat covered more than half area (55%) of total wheat cultivation in Afghanistan, while remaining area (45%) is irrigated. But there are substantial annual fluctuations in area depending on the amount and timing of the rainfall occurrence and average yield of rainfed wheat is very low. The highest yield (1.15 t ha^{-1}) of rainfed wheat was reported in Nangrahar province followed by Herat (1.1 t ha^{-1}). However, the average yield of rainfed wheat in all provinces during 2013 was 0.93 t ha^{-1}. Considering the demands and shortage of wheat, productivity of this crop needs to be increased to enable the country to achieve the self-sufficiency.

Among the several factors adversely influencing wheat productivity in Afganisthan, cultivation of local varieties by traditional methods are most important responsible for low yield. Yield and quality potential is largely determined by the variety, but the extent to which this potential is achieved depends upon several factors such as seasonal weather conditions and methods of crop cultivation. Improved varieties are known for higher yield, but farmers give the preference to the cultivation of local wheat varieties as these are known for the higher baking quality. In addition, there is uncertainty among the farmers about the higher water use efficiency of improved varieties compared to local varieties. In view of these facts, the present study was undertaken to evaluate the performance of local and improved varieties on growth, yield, economics and quality traits under Kandahar agro-climatic condition.

MATERIALS AND METHODS

The experiment was conducted during the *rabi* season of 2014-15 at ANASTU Research Farm, Kandahar, Afghanistan (29° and 38' N and 61° and 75' E with an altitude of 1009 m above mean sea level). The climate of the study area is semi-arid to sub-tropical with extreme cold and hot situations. July is the hottest month with the mean temperature of 31.9 °C, whereas the mean minimum temperature of the coldest month (January) falls up to 5.1°C. The average annual relative humidity and annual rainfall of the region is 38% and 190.6 mm, respectively. Soil of the experimental field was

sandy-loam with pH 7.7, having 0.490% available organic carbon and with low in available N, P and K. Four varieties (PBW-154 and Shisham Bagh-08 as improved) and (Sour Khusha and Morai as local) were evaluated in randomized block design with five replications. All the four varieties were sown in rows 20 cm apart at the depth of 3- 4 cm using the seed rate of 100 kg ha^{-1} in the last week of December, 2014 and harvested in the 1st week of May, 2015. The size of each plot was 12 m^2 (3x4 m). A recommended dose of fertilizer 120, 60 and 40 kg N, P_2O_5 and K_2O ha^{-1} in the form of urea, DAP and murate of potash was applied. Half dose of N, total P and K were applied at the time of sowing. Rest quantity of N was applied at late tillering stage. Weed control performed manually by two weeding, one at 21 and the other at 52 days after sowing (DAS). Grain yield and other agronomic data were determined by the three center rows in each plot to avoid boarder effects. Grain yield from each plot was recorded from net plot area of 10 m^2.

The energy inputs referred to both renewable and non-renewable energy. Renewable energy constituted manual, animal/bullock, kernel, grain, etc., whereas, non-renewable energy encompassed chemical fertilizer (NPK), tractor, diesel, electricity, lubricants, machinery and agro-chemicals, etc. Total physical output referred to both the grain and by-product yield. For estimation of energy inputs and outputs (expressed in MJ ha^{-1}) for each item of inputs and agronomic practices, equivalents were utilized as suggested by Mittal and Dhawan (1998); Baishay and Sharma (1990). Energy efficiency was calculated using the following formula as suggested by (Mittal and Dhawan, 1998).

Net energy (MJ ha^{-1}) = Energy output (MJ ha^{-1}) - Energy input (MJ ha^{-1})

$$\text{Energy efficiency} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

Data of related parameters were compiled and analyzed statistically as per the standard procedure prescribed for randomized block design by Gomez and Gomez (1984).

The analysis of variance (ANOVA) for the design was worked out and the significance was known by 'F' test. Standard error of mean value was computed in all cases, but critical difference values were worked out at 5% level of significance for planned pair comparison.

RESULTS AND DISCUSSION

Crop growth

The phenotypic characteristics of the wheat varieties *viz.* days to germination, days to heading and days to maturity differed significantly (Table 1). Significantly minimum days to germination (10 days) were taken by improved variety Shisham-Bagh-08, which was at par with PBW-154 (10.80 days). However, local variety Sour Khusha has taken maximum days to germination (13 days). Days to heading and maturity were significantly minimum with both the improved varieties compared to local varieties. Fast genetically make up quality of the improved varieties might have led to early germination, heading and maturity than local variety. Bakht *et al.* (2007) also observed maximum days taken to maturity by local and minimum days by improved varieties of wheat. Plant population recorded at maturity was not influenced significantly due to varieties. Plant height recorded at 30, 60, 90 days and at harvest were significantly influenced due to varieties (Table 1). Variety Sour Khusha produced tallest plant at 30, 60, 90 and at maturity, while Shisham Bagh 08 recorded lowest plant height at 30 and 60 DAS and PBW-154 at 90 and at maturity, which clearly exhibits the tall characteristics of the local variety. The effective tillers were significantly higher in variety Sour Khusha (297.8 m^2) over Shisham Bagh-08 and Morai but similar to PBW-154. The differences in tillers/plant and plant height might be due to varied genetic constitution of cultivars and adaptability to environment. The result is in agreement with Maqsood *et al.* (2000) and Tayyar (2008).

Significant difference in Leaf area index (LAI) was observed only at 30 DAS, while variety did not influence LAI recorded at 60 and 90 DAS. Maximum LAI at 30 DAS was observed from variety Sour Khusa followed by Morai and Shisham

Table 1. Growth parameters of local and improved wheat varieties under Kandahar situation

Variety	Plant height (cm)				Number of effective spikes m^{-2}	Root growth	
	30 DAS	60 DAS	90 DAS	At harvest		Root fresh weight at 90 DAS (g $plant^{-1}$)	Root dry weight at 90 DAS (g $plant^{-1}$)
PBW-154	11.12	21.53	74.00	77.66	297.20	111.28	44.08
Shisham Bagh-08	10.12	21.40	78.67	82.32	271.40	92.78	42.52
Sour Khusha	11.42	24.34	91.80	95.60	297.80	120.60	51.20
Morai	10.38	23.90	89.60	93.80	259.20	127.96	47.58
SEm±	0.31	0.64	3.44	3.43	7.28	3.34	1.19
CD (P=0.05)	0.95	1.98	10.61	10.56	22.42	10.30	3.67

Bagh-08. However, minimum LAI at 30 DAS was recorded with PBW-154. The variation in LAI could be due to differences in photosynthetic efficiency of varieties. Significantly maximum fresh root weight (127.96 g $plant^{-1}$) was recorded with variety Morai at 90 DAS, but remained at par with Sour Khusha. But both the improved varieties (PBW-154 and Shisham Bagh-08) produced significantly lower fresh root weight compared to Morai. Dry root weight was also recorded higher with local varieties compared to improved varieties. Increase in the fresh and dry root weight might be ascribed to the different varietal characters. Crop growth rate and dry matter accumulation differed significantly due to varieties at different growth stages of the crop. Variety Sour Kusha recorded maximum growth rate at all the crop stages, but remained at par with variety Morai. However, minimum growth rate was observed with variety Shisham Bagh-08 followed by PBW-154. Similarly, dry matter accumulation recorded at 30 DAS was significantly higher with variety Sour Khusha; however, thereafter it was recorded maximum with variety Morai followed by Sour Khusha. But crop growth rate recorded at all the growth stages of both the improved varieties (Shisham Bagh-08 and PBW-154) was significantly lower compared to variety Sour Khusha. This could be attributed to the efficiency of photosynthetic activity and source to sink relationship of the varieties (Hussain *et al*., 2010).

Yield attribute

Maximum number of spikes (285.6 m^{-2}) were recorded with variety Sour Khusha, which was significantly superior to Shisham Bagh-08 and PBW-154 but remained at par with PBW-154 (Table 2). Number of grains/spike were significantly influenced by different wheat varieties. However, variety PBW -154 produced maximum grains/spike, being at par with Sour Khusha recorded significantly higher over Shisham Bagh-08 and Morai. Though 1000-grain weight and spike length were non-significant, even then, variety Sour Khusha showed maximum increase in spike length and 1000 grain weight. Increase in spike length and 1000 grain weight was recorded by 12.4 and 9.7% with variety Sour Khusha and 10.5 and 5.35%, respectively with PBW-154 over Shisham Bagh-08. The variation in yield attributes might be owing to genetic makeup of the varieties (Irfan *et al.,* 2005).

Yield

Significant differences in grain yield, straw yield, biological yield and harvest index were recorded with the different varieties (Table 3). Among all the varieties, highest grain yield (3.55 t ha^{-1}) was obtained from improved variety PBW-154, closely at par with variety Sour Khusha (3.5 t ha^{-1}) and significantly superior over Shisham Bagh-08 and Morai. The increase in the grain yield with variety PBW-154 was registered by 1.43, 19.13 and 29.09% over Sour Khusha, Shisham Bagh-08 and Morai, respectively. Yield being a cumulative function of various yield attributing characters, it was recorded maximum with variety PBW-154 and Sour Khusha. Straw yield of wheat was not

Table 2. Growth parameters of local and improved wheat varieties under Kandahar situation

Variety	Dry matter accumulation (g m^{-2})				Leaf area index			Crop growth rate (g m^{-2}/day)				Phenotypic characteristics		
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	At maturity	Days to germination	Days to heading	Days to maturity
PBW-154	60.4	270.8	601.8	829	1.23	2.54	3.08	2.01	7.01	11.03	7.57	10.80	114	135.6
Shisham Bagh-08	59.6	268.4	602	823.2	1.38	2.61	3.1	1.99	6.96	11.12	7.37	10	113.8	136.2
Sour Khusha	72	290.2	664.8	870.2	1.51	2.7	3.41	2.4	7.27	12.49	6.85	13	124.2	152
Morai	64.8	297.8	665.4	879	1.46	2.86	3.26	2.16	7.77	12.25	7.12	12.60	122.8	153.6
SEm±	1.758	7.513	14.301	18.94	0.06	0.08	0.09	0.06	0.25	0.57	0.42	0.57	1.80	1.92
CD (P=0.05)	5.417	23.15	44.067	NS	0.17	NS	NS	0.18	0.76	1.77	1.30	1.74	5.54	5.91

Table 3. Yield and yield attributes of local and improved wheat varieties during *Rabi* 2015 under Kandahar situation

Variety	Number of spike m^{-2}	Spike length (cm)	Number of grains $spike^{-1}$	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
PBW-154	279.40	9.89	42.56	39.22	3.55	5.43	8.98	39.55
Shisham Bagh-08	260	8.95	35.24	37.12	2.98	5.27	8.25	36.11
Sour Khusha	285.6	10.06	40.68	40.72	3.5	5.94	9.44	37.16
Morai	244	9.3	37.8	37.1	2.75	6.16	8.91	30.92
SEm±	6.84	0.27	1.28	0.99	0.11	0.16	0.20	0.94
CD (P=0.05)	21.07	NS	3.93	NS	0.33	NS	0.62	2.88

Table 4. Economics, energy, water use efficiency and production efficiency as influenced by local and improved wheat varieties

Variety	Gross return (AFN ha^{-1})	Net return (AFN ha^{-1})	B:C ratio	Total output energy (MJ ha^{-1})	Energy Use Efficiency	Water use efficiency (kg/ha mm^{-1})	Production efficiency (kg day^{-1})
PBW-154	160784	96867	1.52	120067	5.69	10.14	26.18
Shisham Bagh-08	142103	78479	1.23	109667	5.20	8.52	21.89
Sour Khusha	157501	93899	1.48	125753	5.96	10.01	23.04
Morai	138661	75272	1.19	117435	5.56	7.87	17.92
SEm±	3675	3675	0.06	2683	0.13	0.31	0.70
CD (P=0.05)	11325	11325	0.18	8269	0.39	0.95	2.15

influenced significantly due to varieties. However, highest straw yield (6.16 t ha^{-1}) was obtained from variety Morai, which was 3.70, 16.89 and 13.44% higher over Sour Khusha, Shisham Bagh-08 and PBW-154, respectively. Biological yield was significantly affected by varieties and highest biological yield (9.44 t ha^{-1}) was recorded with variety Sour Khusha, which was at par with PBW-154 and Morai. Minimum biological yield (8.25 t ha^{-1}) was obtained with Shisham Bagh-08. Maximum harvest index (39.55%) recorded in PBW-154 followed by Sour Khusha (37.16%). The harvest index recorded with Morai and Shisham Bagh-08 was significantly inferior to the harvest index recorded with PBW-154. Harvest index is the ratio of reproductive yield to total biomass, which is a measure of in partitioning assimilated photosynthates to harvestable products. The maximum harvest index with variety PBW-154 might be owing to better portioning of photosynthates from source to sink because of genetic constitution of varieties and adoptability to environment (Maqsood *et al.* 2000; Behera *et al.* 2015).

Economics

Maximum gross return (AFN 160,784), net return (AFN 96,867) and B:C ratio (1.52) were fetched by variety PBW-154, which being at par with Sour Khusha recorded significantly higher over rest of the varieties. The variety PBW-154 fetched 23.43, 3.16 and 28.69% higher net return compared to varieties Shisham Bagh-08, Sour Khusha and Morai, respectively. The higher gross return, net returns and B:C ratio were mainly owing to production of higher grain with variety PBW-154 and Sour Khusha. Shahan *et al.* (2008) and Islam (2011) also reported higher monetary benefits with the varieties that provided higher grain yields.

Energy relations

There was significant variation in the energy outputs and energy use efficiency among varieties. Highest energy output (125,753 MJ ha^{-1}) was observed from Sour Khusha, where as it was lowest (109,667 MJ ha^{-1}) with Shisham Bagh-08. The energy use efficiency data also followed the same trend and variety Sour Khusha recorded highest energy use efficiency (5.96) followed by PBW-154. Lowest energy use efficiency (5.20) was obtained from Shisham Bagh-08. Effective energy use in agriculture is of prime importance for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction. Therefore, selection of suitable variety can play vital role to enhance energy use efficiency (Shahan *et al.*, 2008).

Water use efficiency and production efficiency

Significant increase in water use efficiency and production efficiency was observed due to different varieties (Table 4). Maximum values of water use efficiency 10.14 and 10.01 kg/ha/mm were observed with variety PBW-154 and Sour Khusha, respectively. The increase in water use efficiency with PBW-154 was 19.01 and 28.85% over Shisham Bagh-08 and Morai, respectively.

Increase in water use efficiency with PBW-154 and Sour Khusha varieties was owing to significant increase in grain yield due to better utilization of resources. These result are in the compliance with Behera *et al.* (2007) and Kaur and Behl (2010). Among all the varieties, PBW-154 resulted in significantly highest production efficiency, which showed an increase of 19.6, 13.63 and 46.09% over Shisham Bagh-08, Sour Khusha and Morai, respectively. The higher production efficiency was mainly due to production of higher grain yield and the least number of days taken to maturity by corresponding varieties.

CONCLUSION

Based on the results from the study, it could be concluded that both the local and improved varieties can be grown under Kandahar situation with reasonable level of returns. But considering the yield advantage, monetary benefit and increase of water use efficiency, improved variety PBW-154 and local variety Sour Khusha of wheat can be recommended for the cultivation under agro-ecological conditions of Kandahar, Afghanistan.

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e-planet **14** (1): 76-82 (June 2016)

A study on drought assessment and its impact on rice cropping system in Keonjhar district, Odisha

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Date of receipt : 19. 02. 2016 Date of acceptance: 24. 06. 2016

ABSTRACT

Knowledge about the amount of rainfall and its distribution and the occurrence of drought during its growth period are the prerequisite to adopt any cropping system at a particular region especially for rain fed crops. Therefore, a study was carried out to learn about the drought pattern and its impact on rice mono-cropping system in Keonjhar district of Odisha. The rainfall analysis was done based on the last 15 years (2001-2015) daily rainfall data to study monthly, seasonal and yearly drought of Keonjhar district based on the Indian Meteorological Department (IMD) protocols. The average annual rainfall of Keonjhar is 1064 mm with 59 numbers of rainy days. During the fifteen years period, no extreme and moderate drought years were experienced, but there were 4 mild (2001, 2003, 2005 and 2010) and 5 moderate (2002, 2004, 2006, 2007 and 2009) drought years. The frequency of drought month recorded for the January, February, March, November and December was 10, 7, 10, 9 and 11, respectively out of 15 years of record. This study revealed that the farmers of this region may depend on monsoon for growing rain-fed rice, as there was hardly any drought occurrence during the monsoon season. However, there is fair chance of occurrence of moderate drought during November to March due to scanty post-monsoon rainfall, hence growing of winter rice may needs assured irrigation.

Keywords: Climate change, drought year, meteorological drought, rainfall analysis, rain fed rice

INTRODUCTION

Odisha comes under humid subtropical climatic zone with average annual rainfall varying from 150 to 400 cm and has mainly rice based cropping system. Paddy being the major cereal crop during *Kharif* season, rain-fed rice cultivation is mostly practiced in Keonjhar district. Rainfall plays a pivotal role in agricultural production (Singh *et al*., 2008). Rainfall also determines the potential of any region in terms of crops to be grown in farming systems to be adopted, the nature and sequence of farming operations to be followed to achieve higher agricultural productivity as well (Singh and Dhillon, 1994). In rain-fed agriculture, the total amount of rainfall as well as its distribution affects the plant growth (Suresh *et al*., 1992). The mean global temperatures are expected to rise over the next few decades, leading to increased evaporation rates (European Environment Agency, 2004) and causing a concern in the rain fed areas. Drought is one of the major environmental stresses limiting to rain-fed agriculture system (Singh and Kumar, 2009). Out of 143 mha of India's cultivable land, 80 mha is rainfed supporting 40% human and 60% livestock population (Jat *et al*., 2013). Drought

significantly constrains rice production in India. Of the roughly 40 million hectares of harvested rice area, only about 60 percent is irrigated (AIREA, 2015), leaving the rest precariously dependent upon rainfall, and hence susceptible to drought. (Arora *et al*., 2015). About 70% of upland rice area in India are drought prone (Singh, 2002). Water scarcity and its increased competition among different sectors are forcing the planners and farmers to consider alternative practices to overcome such situations (Costa *et al*., 2007). Rainfall availability is not well assured at all the place and time. More than 60% of the cultivable rice area in India is rainfed. Rainfed agriculture still remains a voracious water user (Bhelawe *et al*., 2015). Hence, its major share has to be met from rainfall available in less than four months (Ray *et al*., 2012). Around 75% of the annual rainfall is occurring during June to September spread over 120 rainy days. Extreme conditions of rainfall are also observed in certain years and as such no general method for the drought prediction is available (Salas, 1986). Depending on the climate, the incidence of drought varies from place to place. Point rainfall has been analysed by various researchers to derive necessary conclusion on distribution characteristics of the rainfall (Jakhar *et al*., 2011; Ray *et al*., 2013), maximum probable rainfall (Ray *et al*., 2012), contingency crop planning (Sharma *et al*., 1987), trend in rainfall and impact of drought on livelihood (Singh *et al*., 2013). Several workers have done meteorological drought analysis based on rainfall data (Dhar *et al*., 1979; Shrivastava *et al*., 2008; Marathe *et al*., 2001; Tiwari *et al*., 2007; Asati., 2012 and Bhelawe et al., 2015). Sharma *et al.* (1979 and 1987) analyzed the rainfall using the definition of drought month as a month in which the actual rainfall is less than 50% of the average monthly rainfall. Drought year is the year one which receives rainfall less than or equal to the average rainfall minus twice standard deviation of the series. Shrivastava *et al*. (2008) used this definition to assess meteorological droughts in North Lakhimpur district of Assam. Assessment of meteorological drought in Keonjhar district of Odisha is necessary to quantify the extent and pattern on the production and productivity in rice based faming. In the present paper, an attempt has been made to study the frequency of drought occurrence in Keonjhar district of Odisha, on the basis of rainfall deficiency.

MATERIALS AND METHODS

Covering an area of 8240 km^2, Keonjhar district lies between 21°1' N and 22°10' N latitude and 85°11' E to 86°22' E longitude. The behavioural pattern of rainfall with reference to the amount of rainfall and number of rainy days at Keonjhar were analysed using probabilistic approach from trend of daily rainfall records from 2001 to 2015. The probability 'p' (probability) of the weekly rainfall normal value was calculated using Weibull's formula

$$p = \frac{m}{n+1}$$

Where p = probability of occurrence, m = rank number and n = number of years of data used.

The monthly rainfall, seasonal rainfall (*i.e.* June to September (monsoon), October to December (post monsoon) and January to May (pre-monsoon) and yearly rainfall were analysed. The average monthly, seasonal and yearly rainfall values were worked out. The variation of rainfall for each month, season and year from the mean was determined and the mean deviation for the seasons was calculated. Total numbers of (i) drought months (ii) drought seasons and (iii) drought year were determined using the following definition viz. (i) if the actual rainfall is less than 50% of the average monthly rainfall (Sharma *et al*., 1979), (ii) if the annual rainfall is deficient by more than twice the mean deviation of the season (Marathe *et al*., 2001) and (iii) if the annual rainfall is deficient by 20-60% of the average yearly rainfall and if the deficient is more than 60% of the average yearly rainfall it is known as drought year (Dhar *et al*., 1979) respectively. The yearly intensity of drought was also determined using the criteria suggested by IMD (1971) which is based on the percentage deviation of rainfall from its long term mean and it is given by equation:

$$Di = \left(\frac{Pi - \mu}{\mu}\right) \times 100$$

Where, D_i is the percentage deviation from the long-term mean, P_i is the annual rainfall, mm and μ is the long term mean of the annual rainfall (in mm). Drought codification based on percentage departure of rainfall from normal is presented in table1. The percentage of deviation (D_i) is then used to categorise the drought.

RESULTS AND DISCUSSION

At different probability level, the amount of rainfall that would be received was calculated and analysed. It was observed that with the increase in probability level, the amount of rainfall is reducing. The weekly extreme and normal rainfall with their standard deviation (SD), coefficient of variation (CV) and percentage of contribution was evaluated and presented in Table 1. It may be noted that the standard meteorological weeks (SMW) 1st, 3rd, 4th, 6th, 47th, and 52nd did not receive any rainfall or sometimes received a meagre amount of rainfall. During the rainy period i.e. from 23rd to 39th SMW, the CV value was almost below 200%, except in some cases, it was more. The 28th SMW received the maximum amount of rainfall with 49.63 mm, for which the extreme value was 290.7 mm. The average rainfall recedes during 42nd, and 43rd SMW. The recorded drought week was more than five for the 25th, 26^{th,} 27^{th,} 29^{th,} 32^{nd,} 35^{th,} 36th, 39th SMW during the rainy period (Table 2).

The coefficient of variation for rainfall is more than 100% for the month of January, February, March, November and December. Standard deviation was maximum for the month of September and minimum for the month of December. The highest normal rainfall of 210.41 mm was observed in the month of August and the lowest 4.64 mm occurred in the month of December. The average monthly rainfall of the study site is 30.58, 42.94, 129.16, 192.84, 210.41, 161.99 and 100.90 mm for the month of April, May, June, July, August, September and October, respectively (Table 3). The maximum average rainfall was received during the month of August to a tune of 239.7 mm and the minimum average rainfall is received during the month of December to a tune of 3.0 mm. The frequency of drought was observed to be the highest at a magnitude of 11 times in 15 years in December; while it is 10 times in 15 years during January and March and 7 and 9 times during February and November months respectively (Table 4). It indicates that, there is a need for assured irrigation in the above months.

The monsoon period contributed about 76% of rainfall, with only 11% during post-monsoon and 13% as pre-monsoon shower for Keonjhar district (Fig 1). The post-monsoon seasonal rainfall is very less, for growing winter season crops, hence further arrangement may be made for assured irrigation with proper rainwater harvesting methods. No drought was observed during the monsoon, 3 times in pre-monsoon and 4 times drought was observed in post monsoon period. The yearly intensity of drought for Keonjhar, Odisha is presented in Table 5. An increasing trend of annual rainfall was noticed for the station. The average annual rainfall of Keonjhar is 1,063.61 mm with a maximum of 1,859 mm corresponding to the year 2011 and a minimum of 590.9 mm corresponding to the year 2007(Table 5). The years are codified according to IMD specifications as described in the Table 6. It is found from the Fig 2 that, there was no severe or extreme drought occurrence. However, 4 mild drought years (2001, 2003, 2005 and 2010) and 5 moderate drought years (2002, 2004, 2006, 2007 and 2009) were observed during the course of study.

CONCLUSION

The drought analysis of Keonjhar district based on the deficiency of rainfall shows that out of fifteen years, there was no severe drought occurrence in the region. However, there were 4 mild (2001, 2003, 2005 and 2010) and 5 moderate (2002, 2004, 2006, 2007 and 2009) drought years. The seasonal drought analysis shows the monsoon period contributed around 76% of rainfall, with only 11% during post-monsoon and 13% during pre-monsoon showers. Therefore, for growing winter season crops during post monsoon season, assured irrigation facilities need to be provided simultaneously with ample emphasis on rainwater harvesting during the monsoon season, as high quantum of runoff is anticipated during rainy seasons. The farmers of this region may depend on monsoon rains for growing rain-fed rice, as there was hardly any drought occurrence.

Table 1. Weekly extreme and normal rainfall, SD, CV and per centage of contribution

Standard Meteorological Week (SWM)	Extreme Value		Normal (mm)	Standard Deviation (mm)	Coefficient of Variation (%)	Percentage of Contribution (%)
	Minimum (mm)	Maximum (mm)				
1.	0	4.2	0.73	1.4	220.6	0.08
2.	0	77.3	3.21	19.9	331.8	0.34
3.	0	0	3.40	0.0	--	0.36
4.	0	4.2	0.30	1.3	210.2	0.03
5.	0	19.6	1.30	5.7	217.2	0.14
6.	0	3.7	0.57	1.0	288.1	0.06
7.	0	73.2	5.77	20.9	192.3	0.61
8.	0	41.9	2.49	10.8	363.8	0.26
9.	0	58	3.04	15.0	341.0	0.32
10.	0	25.7	3.98	11.0	175.7	0.42
11.	0	161.2	6.66	41.6	379.0	0.71
12.	0	91.6	5.70	23.4	303.7	0.60
13.	0	11.8	4.25	4.0	136.9	0.45
14.	0	36.4	6.18	11.3	127.0	0.66
15.	0	31.2	5.11	11.1	134.6	0.54
16.	0	66.4	12.58	18.4	141.7	1.33
17.	0	38.4	6.31	12.0	144.6	0.67
18.	0	25.7	7.12	10.6	153.3	0.75
19.	0	69	12.00	17.6	297.3	1.27
20.	0	111.3	11.05	30.7	173.1	1.17
21.	0	38.8	10.41	12.8	119.9	1.10
22.	0	63.5	7.97	16.7	175.1	0.84
23.	0	76.2	23.92	24.2	87.2	2.53
24.	0	126.4	44.45	42.4	88.9	4.71
25.	0	119.7	33.42	39.1	94.6	3.54
26.	0	187.5	27.89	47.6	146.3	2.96
27.	0	103.3	37.42	32.3	98.3	3.97
28.	0	134.6	43.37	45.5	96.5	4.60
29.	0	230.6	45.54	58.7	118.1	4.83
30.	0	191.7	50.98	50.1	84.5	5.40
31.	0.6	290.7	49.63	73.4	102.3	5.26
32.	0	188.8	52.85	56.5	97.0	5.60
33.	1.2	68.6	36.74	21.0	65.9	3.89
34.	0	157.3	48.70	49.5	84.4	5.16
35.	0	190.3	43.78	53.5	103.9	4.64
36.	6.2	200.6	38.76	53.8	100.7	4.11
37.	0	139.3	37.85	39.2	92.4	4.01
38.	1.4	306.9	48.20	74.0	138.9	5.11
39.	0	112.3	25.59	39.9	106.9	2.71
40.	0	139.6	30.66	38.3	135.6	3.25
41.	0	184.7	30.48	52.9	143.0	3.23
42.	0	76.9	21.56	28.0	146.7	2.29
43.	0	79	10.69	24.1	186.9	1.13
44.	0	113.7	16.87	30.8	187.2	1.79
45.	0	11.8	3.27	3.4	259.9	0.35
46.	0	22.4	10.51	6.2	273.5	1.11
47.	0	1.2	5.39	0.4	252.0	0.57
48.	0	11.6	0.46	3.0	387.3	0.05
49.	0	10.6	2.34	2.7	387.3	0.25
50.	0	7.6	0.92	2.0	325.4	0.10
51.	0	15.8	0.67	4.1	387.3	0.07
52.	0	1.4	0.59	1.3	297.7	0.06

Table 2. Weekly rainfall analysis for drought

Standard week		Average rainfall (mm)	Half of the average Rainfall (mm)	No of drought week
23	(4th to 10th June)	27.75	13.88	5
24	(11th to 17th June)	47.71	23.86	5
25	(18th to 24th June)	41.32	20.66	6
26	(25th to 1st July)	32.56	16.28	8
27	(2nd to 8th July)	32.80	16.40	6
28	(9th to 15th July)	47.15	23.58	5
29	(16th to 22nd July)	49.73	24.87	6
30	(23rd to 29th July)	59.36	29.68	4
31	(30th to 5th August)	71.69	35.85	5
32	(6th to12th August)	58.24	29.12	7
33	(13th to 19th August)	31.86	15.93	3
34	(20th to 26th August)	58.62	29.31	5
35	(27th to 2nd September)	51.46	25.73	6
36	(3rd to 9th September)	53.44	26.72	7
37	(10th to 16th September)	42.37	21.18	4
38	(17th to 23rd September)	53.29	26.65	4
39	(24th to 30th September)	37.37	18.68	6

Table 3. Monthly extreme and normal rainfall, SD, CV and per centage of contribution

Months	Extreme Value		Normal (mm)	Standard Deviation (mm)	Coefficient of Variation (%)	Percentage of Contribution (%)
	Minimum (mm)	Maximum (mm)				
Jan	0	94.7	8.52	24.0	266.6	0.90
Feb	0	46.3	10.04	22.1	147.2	1.06
Mar	0	167.6	22.76	48.3	149.9	2.41
Apr	0	89.2	30.58	25.9	66.2	3.24
May	0	138.3	42.94	41.1	95.0	4.55
Jun	39.6	320.7	129.16	100.6	67.2	13.68
Jul	32	495.9	192.84	135.7	65.0	20.43
Aug	53.8	506.3	210.41	122.9	51.3	22.29
Sep	26.4	723.5	161.99	161.7	78.8	17.16
Oct	0	296	100.90	88.1	81.9	10.69
Nov	0	48.2	29.08	15.5	142.6	3.08
Dec	0	20.2	4.64	6.7	223.6	0.49

Table 4. Analysis of monthly and seasonal rainfall for drought

Month/Season	Name of month / season	Average rainfall mm	Half of the average rainfall	No. Of drought month/season Year	Percentage of drought months
Month	January	9	4.5	10	67
	February	15	7.5	7	47
	March	32.2	16.1	10	67
	April	39.1	19.6	4	27
	May	43.3	21.6	5	33
	June	149.7	74.8	4	27
	July	208.9	104.4	5	33
	August	239.7	119.9	2	13
	September	205.3	102.7	2	13
	October	107.5	53.8	4	27
	November	10.8	5.4	9	60
	December	3.0	1.5	11	73
Season	Pre monsoon	138.65	69.33	3	20
	Monsoon	803.58	401.79	0	0
	Post monsoon	121.37	60.69	4	27

Table 5. Yearly intensity of drought

Year	Annual rainfall (mm)	Mean Rainfall (mm)	% deviation	Category	Intensity of drought
2001	840	1063.61	-21.02	M_1	Mild drought
2002	643	1063.61	-39.55	M_2	Moderate drought
2003	1041.6	1063.61	-2.07	M_1	Mild drought
2004	768	1063.61	-27.79	M_2	Moderate drought
2005	1040.6	1063.61	-2.16	M_1	Mild drought
2006	720.3	1063.61	-32.28	M_2	Moderate drought
2007	590.9	1063.61	-44.44	M_2	Moderate drought
2008	1174.3	1063.61	10.41	M_0	No drought
2009	663.2	1063.61	-37.65	M_2	Moderate drought
2010	1045.7	1063.61	-1.68	M_1	Mild drought
2011	1859.9	1063.61	74.87	M_0	No drought
2012	1147.6	1063.61	7.90	M_0	No drought
2013	1474.5	1063.61	38.63	M_0	No drought
2014	1760.61	1063.61	65.53	M_0	No drought
2015	1183.9	1063.61	11.31	M_0	No drought

Table 6. Drought codification based on percentage departure of rainfall from normal value

% departure of rainfall from Normal	Intensity of Drought	Code
0.0 or above	No drought	M_0
0.0 to -25.0	Mild drought	M_1
-25.0 to – 50.0	Moderate drought	M_2
-50.0 to -75.0	Severe drought	M_3
-75.0 or less	Extreme drought	M_4

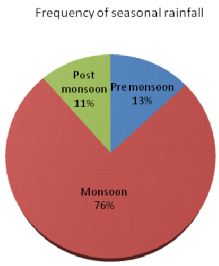

Fig. 1. Frequency of seasonal rainfall Keonjhar dist, Odisha

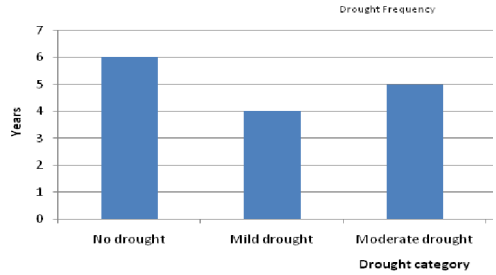

Fig. 2. Relative drought frequency in Keonjhar dist, Odisha

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e-planet **14** (1): 83-88 (June 2016)

Effect of graded level vitamin E supplementation on meat quality of male goats (*Capra hircus)*

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Date of receipt : 28. 02. 2016 Date of acceptance: 10. 06. 2016

ABSTRACT

To assess the effect of vitamin E supplementation on meat quality, fifteen male non- descriptive local kids (6.41 ± 0.37 kg BW and 2 to 3 months old) were divided into three groups and were fed on oat straw and concentrate mixture. Kids were supplemented with 0,100 and 200 IU vitamin E (á-tocopherol acetate) in group I II and III, respectively. Feeding continued for 6 months. Immediately after sacrificing the animals, carcass samples were collected to study the meat quality. Chemical composition of muscle sample of carcass showed non-significant differences between the groups for moisture, crude protein, total ash and ether extract. pH and sensory characteristics like appearance, flavor, juiciness and overall acceptability did not differ among all the groups. However, shear force values and thiobarbituric acid reactive substances decreased from group I to III. Lovibond tintometer color units for red and tenderness value showed increased trend in all the supplemented groups. It may be concluded that supplementation of 100 IU and 200 IU of vitamin E/animal/day increased the redness and tenderness of meat and reduced the shear force value and thiobarbituric acid reactive substances concentration in meat.

Key words: Goat, meat quality, supplementation, vitamin E

INTRODUCTION

Vitamin E is a generic form that includes all entities that exhibit the biological activity of á-tocopherol. Dietary supplementation with vitamin E increases the concentration of á- tocopherol in muscles and reduces the susceptibility of the muscle to the lipid oxidation (Morrissey *et al.,* 1998). Vitamin E supplementation has shown positive effect on fattening performance, carcass characteristics and meat quality (Hill *et al.,* 1987). Supplementing cattle with supranutritional levels of vitamin E (alpha-tocopherol acetate) had improved meat color and lipid stability (Arnold *et al.,* 1993). Extension of beef colour display life depends on the level and duration of supplementation with dietary vitamin E (Liu *et al.,* 1995). Alpha tocopherol becomes an intimate component of biological membranes where lipid-lipid interaction between á –tocopherol and polyunsaturated phospholipids occur (Diplock, 1971). Only prolonged dietary supplementation allows for incorporation of

á–tocopherol into sub cellular compartments (Buckley *et al*., 1995). Now a days animal nutritionists paid more attention to produce vitamin E enriched products that will increase vitamin E status of consumers. While many studies have shown the benefits of vitamin E supplementation on meat quality of poultry and cattle, but little is known on the effects of vitamin E supplementation on meat quality of goats. Therefore, aim of present study is to determine the effect of vitamin E supplementation on meat quality of male goats (*Capra hircus*).

MATERIALS AND METHODS

Animal's management and feeding

Present experiment was approved by the "Committee for the Purpose of Control and Supervision of Experiments on Animals" (CPCSEA), India, and conducted on fifteen male non- descriptive local kids (6.41 ± 0.37kg BW and 2 to 3 month old) procured from Sheep and Goat Farm of Indian Veterinary Research Institute, Izatnagar, India. These animals were adapted on the experimental diet comprising of concentrate mixture and oat straw for a period of one month during which they were treated against ecto and endo parasites and subsequently at regular intervals. All the kids were vaccinated against foot and mouth disease and *peste des petits* of ruminants (PPR). These animals were distributed into three different groups of five kids in each on the basis of their body weights following randomized block design, and were kept in a well ventilated shed with individual feeding and watering arrangements. Kids in all the three groups were fed on concentrate mixture and oat straw to meet their nutrient requirements for 50 g daily weight gain (NRC, 2007). The concentrate mixture consisted of (%) crushed maize grain 30, soybean meal 37, wheat bran 30, mineral mixture 2 and common salt 1.Treatments were: group I (control), without any supplementation, group II supplemented with 100 IU and group III supplemented with 200 IU vitamin E (DL-á-tocopheryl acetate) respectively through the concentrate mixture. Oat straw was provided to the animals after total consumption of concentrate mixture. All the kids were offered about 100 g of the available green berseem (*Trifolium alexandrium*) fodder once a week to meet their vitamin A requirements. Clean and fresh drinking water was provided twice a day to all the animals.

Slaughter of the animals

This experimental feeding practice lasted for 180 days. Twenty-four hr prior to slaughter, the body weight of the animals was recorded. The feed was withdrawn and only *ad lib* water was provided twice during the day. The slaughter of animals was carried out following proper ethical standards using ritual 'halal' method. About one kg of *semitendinosus* (ST) muscle was collected immediately after slaughter of each animal. After removing the separable fat and connective tissues, the samples were brought to laboratory for further analysis.

Analytical Techniques

Feed and meat of the experimental animals were analysed for proximate constituents (AOAC, 2001). pH of meat samples was determined after 4 hr of slaughter of the animals (Strange *et al*., 1977). Shear Force Value (SFV) of muscle sample was estimated by placing the cores of meat samples in the blade attached to the Warner-Bratzler shear force apparatus. The distillation methods of Witte *et al*. (1970) were followed for the estimation of Thio Barbituric Acid Reactive Substances (TBARS) number which was expressed as mg malonaldehyde/kg of meat sample. The color units were determined by using Lovibond Tintometer (Model F, UK) as per the method of Conforth (1994).

Organoleptic evaluation

Pooled ST muscle samples from each group were pressure cooked with salt (1.5%; w/w) and subjected to organoleptic evaluation on 8 point Hedonic scale by a panel of six semi-trained judges to evaluate appearance, flavor, juiciness, tenderness and overall acceptability (Keeton, 1983).

Statistical analysis

The data obtained from above studies was subjected to one way analysis of variance as per Snedecor and Cochran (1989). Difference among

means was tested by using SPSS (1999) computer package.

RESULTS AND DISCUSSION

Chemical composition of the ration

The chemical composition of the feeds offered to experimental goats is presented in Table 1. The crude protein content in concentrate mixture and oat straw was 20.40 % and 4.30%, respectively. Vitamin E concentration in concentrate mixture and oat straw was 13.75 and 1.90 mg kg^{-1} feed, respectively.

Chemical composition of meat

Moisture, crude protein (CP), ether extracts (EE) and total ash content in meat sample is presented in Table 2. No significant difference could be noticed with respect to moisture, protein, fat and total ash content of ST muscle due to different dietary treatments. Similarly Houben *et a*l. (2000) Arnold *et al.*(1992) did not find any significant effect on moisture percent of beef supplemented with vitamin E. Similarly, Yang et al. (2002) also showed non-significant (P>0.05) difference for lipid concentration in muscles of animals given vitamin E in comparison to non-supplemented animals. Dass *et al*. (2011) also observed non significant (P> 0.05) change in moisture, CP, lipid concentration in muscle of buffaloes supplemented with 300 and 600 IU of vitamin E for 180 days.

Sensory attributes of cooked meat

The scores for appearance, flavor, juiciness, tenderness and overall acceptability for ST muscle is presented in Table 2.The organoleptic evaluation of pressure cooked meat with salt by semi trained judges for sensory attributes viz., appearance, flavor, juiciness and overall acceptability did not show any appreciable variation (P>0.05) due to dietary treatments, as they were found statistically comparable. Similarly, Garber *et al*. (1996) did not find any effect of vitamin E supplementation on flavour, juiciness of beef. The tenderness value in different group of animals are 5.65, 6.11 and 6.23 respectively which differ significantly (P<0.05) in supplemented groups than un supplemented group. Contrarily Svedaite *et al*. (2009) observed that feeding a diet containing 0.1 ppm Se and 20 IU of vitamin-E to pigs for 4 months had no effect on tenderness of the meat. Similarly, Dass *et al.* (2011) observed non significant difference in flavor, tenderness, juiciness in Longismus dorsi muscle of buffaloes supplemented with 300 IU of vitamin E/D. Increased tenderness value may be due antioxidant effect of vitamin E on the muscle cells.

Physiochemical properties of meat

Meat pH, water holding capacity, shear force value, thiobarbituric acid reactive substance (TBARS) and Lovibond tintometer color unit number are presented in Table 3. Non-significant (P>0.05) differences were observed among three groups of goats for meat pH and water holding capacity of meat. Similarly, Svedaite *et al*. (2009) observed that feeding a diet containing 0.1 ppm Se and 20 IU of vitamin E to pigs for 4 months had no effect on meat pH and water holding capacity.

Table 1. Chemical composition (%) of concentrate mixture and oats straw

Nutrients	Concentrate mixture	Oat straw
Crude protein	20.40	4.30
Ether extract	2.30	1.20
Neutral detergent fiber	34.50	78.30
Acid detergent fiber	11.60	57.10
Hemicelluloses	22.90	21.20
Cellulose	9.50	43.90
Total ash	9.10	6.70
Calcium	1.57	0.85
Phosphorus	0.86	0.14
α-tocopherol, mg kg^{-1}	13.75	1.90

Table 2. Chemical composition and organoleptic evaluation of *semi tendinosus* muscle on eight point Hedonic scale

Attributes	Group			
	I	II	III	SEM
Moisture (%)	75.90	74.50	75.00	0.49
Total Ash (%)	1.70	1.60	1.58	0.06
Crude protein (%)	18.20	19.12	18.50	0.32
Ether extract (%)	4.01	3.96	3.81	0.17
Organoleptic evaluation score				
Appearance	6.50	6.72	6.95	0.28
Flavor	6.60	6.82	6.91	0.15
Juiciness	6.50	6.67	6.71	0.16
Tenderness*	5.65 [a]	6.11 [b]	6.23 [b]	0.13
Overall acceptability	6.50	6.81	6.73	0.14

[ab]Means bearing different superscripts in a row differ significantly ($P < 0.05$)

Table 3. Physiochemical properties of *semi tendinosus* muscle in goats supplemented with vitamin E

Attributes	Group			
	I	II	III	SEM
pH	6.30	6.20	6.20	0.11
WHC (%)	29.25	30.52	31.00	0.82
SFV (kg/cm^2)	3.45^b	3.11^a	3.11 ^{a}	0.02
TBARS (mg malonaldehyde/ kg)	0.53^c	0.42^b	0.51^{ab}	0.04
Lovibond Tintometer color unit				
Red (a)	2.11 ^{a}	2.52^{ab}	3.21^b	0.12
Yellow (b)	2.50 ^{a}	3.25^a	3.92^{ab}	0.29

Contrary to these findings, Lynch *et al.* (2000) reported higher ($P<0.01$) pH values of meat from the vitamin E supplemented bulls, which may be due to very high dose of vitamin E (2000 IU) given to bulls in comparison to present study.

Shear force values (kg cm^{-2}) in muscles of goats given vitamin E were significantly lower in comparison to control group. Contrary to this, no treatment effect on the force required to shear the meat was observed in beef cattle (Arnold *et al.*, 1992; Garber *et al.*, 1996). Lower SFV in meat samples of vitamin E treated animals could be due to non-significant lower growth rate and increased tenderness of the muscle.

The TBARS (thiobarbituric acid reactive substances) number, which indicates the oxidative stability and keeping quality of meat, were significantly ($P < 0.05$) differed among the four groups, being lowest in vitamin E supplemented group. Similar observations were reported by Stubbs *et al*. (2002) in top loin steaks of vitamin E supplemented steers as compared to control group. Similarly, Arnold *et al.* (1992) also reported delayed lipid oxidation by vitamin E supplementation. These results revealed that vitamin E supplementation was effective in reducing the lipid oxidation of the meat samples. Contrary to present findings, Yang *et al*. (2002) did not observe increased in TBARS values in the meat of steers supplemented with 2500 IU of alpha-tocopheryl acetate/d.

The result of this experiment indicated that supplementation of Vitamin E in the diet of goats had positive effect on Lovibond tintometer colour units. Meat Redness and yellowness value of vitamin E supplemented animals was significantly ($P < 0.05$) higher than control. Similarly, Lynch *et al*. (1999)

observed that dietary vitamin E supplementation (2000 mg á- tocopheryl acetate/ kg feed) for approximately 50 days prior to slaughter improved the colour in fresh beef than un supplemented beef. Similarly, Muhlis *et al.* (2003) reported that vitamin E supplementation (45 mg vitamin E per lamb per day for 75 days) in the diet of Morkaraman male lambs significantly reduced lipid oxidation and tended to maintain meat redness. Similarly, Dass *et al.* (2011) observed increased redness and yellowness value in muscles of buffaloes supplemented with 600 IU of vitamin E. Contrary to these, Guo *et al.* (2006) observed that supplementation of vitamin E @ 40 IU to 200 IU/kg for 63 days in finishing pigs had no effect on color intensity of meat. Svedaite *et al.* (2009) observed that feeding a diet containing 0.1 ppm Se and 20 IU of vitamin-E for 4 months had no effect on meat colour of pigs . Extension of color display of the meat depends on level and duration of supplementation of vitamin E and Se (Liu *et al.,* 1995).

CONCLUSION

It may be concluded that supplementation of 100 IU and 200 IU of vitamin E improved the redness, tenderness and keeping quality of meat of male goats.

ACKNOWLEDGMENT

First author is thankful to Indian Council of Agricultural Research, Krishi Bhawan, New Delhi, India for providing financial assistance in the form of Senior Research Fellowship. Authors are also thankful to the Director, Indian Veterinary Research Institute, Izatnagar, India for providing the necessary facilities to carry out this work.

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e-planet **14** (1): 89-92 (June 2016)

In-vitro evaluation of acaricidal property of *Cymbopogon citratus*, *Nicotiana tabacum* and deltamethrin against *Rhipicephalus* sp. ticks

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Date of receipt : 21. 03. 2016 Date of acceptance: 24. 06. 2016

ABSTRACT

In vitro acaricidal property of lemon grass oil, tobacco leaves along with deltamethrin was evaluated on cattle ticks using emulsion test. The ticks collected from rural and urban areas of Odisha were identified as i.e., *Rhipicephalus* sp. Essential oil of *Cymbopogon citratus* commonly known as lemon grass oil and deltamethrin, a commercially available acaricidal agent, at 0.3 % concentration showed efficacy of 97.77 and 97.77 % in urban ticks and 92.2 and 100 % in rural ticks with a contact period of 24 hours, respectively. Tobacco (*Nicotiana tabacum*) leaves exhibited visibly poor action. Though deltamethrin and lemon grass oil found equipotent, the former need to be used properly for its toxic property.

Key words: Cattle, *Cymbopogon citratus,* deltamethrin, *Nicotiana tabacum, Rhipicephalus,* ticks

INTRODUCTION

Ticks rank second to mosquitoes among arthropod vectors for transmission of disease causing protozoa, bacteria and viruses in nonhuman vertebrates (Zhou *et al.*, 2009). Ectoparasitic pests require blood meal from the host not only for their development and survival (Ribeiro, 1995) but help spread of tick-borne disease (Jonsson, 2006). *Rhipicephalus* sp. tick is considered harmful for cattle in sub-tropical areas of the world (Evans *et al.*, 2000). Tick and tick-borne disease (TBD) control predominantly focus on repeated use of various acaricides like organophosphates, carbonates, pyrethroids, cyclodines, amidines and macrocyclic lactones. Besides high cost of treatment, it may lead to drug resistance, residual deposition and environmental pollution. In order to overcome such undesirable consequences, a study was undertaken to reveal *in vitro* acaricidal effect of two available plant products i.e. lemon grass (*Cymbopogon citratus*) oil and tobacco (*Nicotiana tabacum*) leaves on ticks collected from cattle.

MATERIALS AND METHODS

Adult female ticks were collected during morning hours from the cattle of different dairy farms located within Bhubaneswar city and nearby rural areas. Ticks were kept in transparent plastic bottles with numerous small openings. Small pieces

of blotting papers dipped in water were kept inside those bottles and were carried to the laboratory of the Department of Epidemiology and Preventive Medicine, College of Veterinary Science and Animal Husbandry, Bhubaneswar for identification and *in vitro* study. Collected ticks were identified on the basis of their anatomical features i.e., anal groove, coxa-1, coxa-4, pedipalp, basis-capitulum, presence or absence of festoons, adannal shields and designs of the colours present on the scutum (Soulsby, 1982). Ticks collected from the Bhubaneswar city was considered as rural ticks and that of the village areas about approximately 50 km aerial distance away from Bhubaneswar were grouped as rural ticks.

The essential oil extracted using Clevenger's apparatus from the freshly collected leaves of *Cymbopogon citratus* (lemon grass) through steam distillation was used in the study. Desired concentration of lemon grass oil were prepared by taking 0.3ml of lemongrass oil in 100 ml of distilled water to which 0.3 ml of Tween 80 (Polyoxyethy-lenesorbitan mono-oleate) was added as emulsifier. Dry leaves of *Nicotiana tabacum* (Tobacco) procured from the local market were ground to powder using pestle and motor of which 0.3 g was added to 100 ml of distilled water and kept overnight for subsequent use. For *in vitro* comparison, commercially available deltamethrin (Butox; Manufactured by M/S Intervet India Pvt. Ltd contains deltamethrin 1.25 %) was used by taking 0.3 ml in 100 ml of water. Ten live ticks were placed in a petridish of 10 cm diameter to which 10 millilitres of prepared solution was poured. Besides, equal numbers of ticks were treated in two petridsh containing either water or Tween-80 emulsion alone as control.

The entire set of experiment was left in the room temperature for 1 day or 24 hours with a porous covering on the petridish. After desired contact period, the ticks were transferred to a piece of blotting paper so as to make them dry off the solutions that were adhering to. Absence in the movement of the tick's legs and/or body as a whole within the period of observation was considered as paralyzed/dead and the number of such ticks within 24 hour of exposures to the solutions was recorded. Tests for rural and urban ticks were undertaken separately in similar conditions. Each set of experiment was repeated thrice under similar conditions.

Efficacy of the preparations was calculated by the following formula:

$$\% \text{ of efficacy} = \frac{(A - B)}{C} \times 100$$

Where, A- Number of ticks died in test solution
B- Number of ticks died in water
C- Total number of ticks

RESULTS AND DISCUSSION

Based on the anatomical characters, the ticks collected from the cattle were classified as *Rhipicephalus* sp. (Fig. 1) and the live ticks were subjected to *in vitro* trial. Effects of lemon grass oil, tobacco leaves and deltamethrin on cattle ticks collected from urban and rural were presented in table 1 and 2, respectively.

Effectiveness of lemon grass oil at a concentration of 0.3 ml in 100 ml of water in paralyzing or killing of live ticks collected from urban areas was found to be 16.6% within 1 hour of exposure and 92.22% within 24 hours of exposure but such effect was slightly better i.e., 33.3 % within 1 hour and 97.77% within 24 hours of contact of the ticks collected from different dairy units located in rural areas. The variation in the acaricidal property may be due to lesser degree of exposure of rural ticks to chemical acaricides than that of urban areas. It was interesting to observe that more than 90% of ticks could not survive in either deltamethrin or lemon grass oil within 24 hours of exposure. Tobacco leaf powder also acted as an acaricides, but it had lesser effect than deltamethrin and lemon grass. Of the 30 ticks from urban and rural areas each exposed to tobacco leaves, 3 (10.0%) and 19 (62.2%) ticks showed paralytic or lethal effects within 24 hours. Ticks placed in either Tween-80 or water remained alive during the entire observation period of 24 hours thereby ruled out the toxic effects on ticks.

Cymbopogon citratus (lemon grass) oil has been known to have insect repellent effects (Ansari *et al.* 1995) and also is an effective insecticide against various insects like dust mites, termites and ticks (Sigma-Aldrich Plant Profiler). *Nicotiana tabacum* contains a higher concentration of nicotine, a powerful neurotoxin to insects. Such literature triggered mind to assess the acaricidal property of these two indigenous plant preparations. Deltamethrin is a widely used effective acaricide at a recommended dosage of 3.0 ml L^{-1}.In the present *in vitro* study, efficacy of the selected plant preparations were compared at such concentration.

Deltamethrin causes multiple system toxicity in wild and domesticated animals as well as human beings. It temporarily attacks the nervous system of any individual that comes into contact. Skin contact can lead to tingling or reddening of the skin local to the application. If comes in contact of conjunctiva or oral mucous membrane, a common symptom is facial paraesthesia, which can feel like many different abnormal sensations, including burning, partial numbness, skin crawling, etc. Besides neurotoxicity, it induces hepatotoxicity, nephrotoxicity, reproductive toxicity, genotoxicity and immunotoxicity (Doi *et al*., 2006, Sharma *et al*., 2013). Hence, deltamethrin-induced toxicity is a matter of concern especially during its therapeutic use against ecto-parasitic infestation.

It is inferred that lemon grass oil and deltamethrin are somehow equipotent in inhibiting the survival of cattle ticks. However, as deltamethrin has various toxic effects, lemon grass oil may be preferred to control tick infestation. Further work may be carried out on its pharmacokinetic action so as to replace the chemical acaricide.

Table 1. Effect of lemon grass oil, tobacco and deltamethrin on cattle ticks collected from urban areas of Odisha

Name of the herbal and chemical product	Conc./ 100ml of water	No. of sets	No. of ticks treated	No. of ticks paralyzed/died during different hour of contact	
				1 hour	24 hours
Lemon grass Oil	0.3ml	03	30	5 (16.6)	28 (92.22)
Tobacco	300mg	03	30	1 (0.03)	3 (10.0)
Deltamethrin	0.3ml	03	30	6 (20)	29 (97.77)
Water	0.3ml	03	30	0 (0)	0 (0)
Tween 80	0.3ml	03	30	0 (0)	0 (0)

N.B. Figures in parentheses indicate percentage

Table 2. Effect of lemon grass oil, tobacco and deltamethrin on cattle ticks collected from rural areas of Odisha

Name of the herbal and chemical Product	Conc./ 100ml of water	No. of sets	No. of Ticks treated	No. of ticks paralyzed/died during different hour of contact	
				1 hour	24 hours
Lemon grass Oil	0.3ml	03	30	10 (33.3)	29 (97.7)
Tobacco	300mg	03	30	5 (16.6)	19 (62.2)
Deltamethrin	0.3ml	03	30	18 (60)	10 (100)
Water	0.3ml	03	30	0 (0)	0 (0)
Tween 80	0.3ml	03	30	0 (0)	0 (0)

N.B. Figures in parentheses indicate percentage

SUMMARY

Deltamethrin at a concentration of 0.3% showed highest degree of *in vitro* efficacy against ticks collected from the urban and rural areas where about 97- 100 % ticks showed paralytic and/or lethal effects within a contact period of 24 hours. Comparable degree of action was recorded in lemon grass oil at similar concentration. However, aqueous solution of tobacco leaves and exhibited lower degree of acaricidal property. When lemon grass oil vs. deltamethrin is debated on the issue relating to their acaricidal properties, the former is considered as more ideal for control of tick infection to get rid of toxic effects of later.

ACKNOWLEDGEMENT

Authors are thankful to the Dean, College of Veterinary Science and Animal Husbandry and Director, College of Basic Science and Humanities, both under the Orissa University of Agriculture and Technology, Bhubaneswar for extending necessary support to carry out the research work.

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