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IDENTIFICATION AND *IN SILICO* CHARACTERIZATION OF *TaGSTU30* AND *TaTPS1* GENES IN BREAD WHEAT

AMARDEEP* **and T. SINGH**

Department of Genetics and Plant Breeding, Kisan (P.G.) College, Chaudhary Charan Singh University, Simbhaoli, Hapur, Uttar Pradesh-245207

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ABSTRACT

In case of rice, *OsGSTU30* and *OsTPS1* genes play a critical role in development, metabolism, and abiotic stress responses.In the study, it was aimed to identify and characterize*OsGSTU30* and *OsTPS1*genes in wheat reference genomic data. Functional domains, physicochemical properties and subcellular localization of both genes were identified. The homology modeling method was used to predict the 3D structures and Ramachandran plots were also predicted to evaluate protein structures. *In silico* expression profiles of wheat,*TaGSTU30* and *TPS1* genes at different development tissues were also identified. Most members of *TaGSTU30* and *TaTPS1* genes shared similar patterns of exon/intron structures, including intron phase, intron number, and exon length. Drought responsive orthologous genes were also identified in recently released reference genomic data of wheat (available on Ensembl Plants), which were previously identified in rice and *Arabidopsis* plants. The results of the study would permit a better understanding of the structure and advancement of the genes and the encoded proteins and also provide information for the exploitation of variability for the engineering of these genes.

Keywords: Wheat, Drought, *GSTU30*, *TPS1*, *In silico*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important food crop cultivated throughout the world and is the major source of proteins and calories (which are almost 72% in an average diet). It supplies one-third of the world's population with more than half of their calories and proteins. The current production of wheat is not sufficient to meet the demands of rapidly growing population. Although, breeders are working hard to improve wheat production, increasing wheat production in drought environmentshowever has been more complex to achieve (Jatoi *et al*., 2011).

Drought stress is one of the most important environmental stresses affecting agricultural productivity around the world and may result in considerable yield reductions(Boyer, 1982). Reduced plant size, leaf area and leaf area index are major mechanism for moderating water use

*Corresponding Author E-mail i.d: amar92home@gmail.com; PhD thesis submitted to Chaudhary Charan Singh University, Uttar Pradesh

and reducing injury under drought stress(Mitchell *et al*., 1998). In India, there is a big gap between wheat production and consumption, and water stress that affects growth, physiological process, and yield is one of the reasons.

Various drought responsive genes have been distinguished (Ingram and Bartels,1996). There are several genes which are responsible for drought stress tolerance and produce different types of enzymes, proteins and carbohydrates during drought stress. Drought stress can also influence plants in terms of proteomic changes, antioxidant production, osmotic adjustment, hormone composition, root depth and extension, opening and closing of stomata, cuticle thickness, inhibition of photosynthesis, decrease in chlorophyll content, reduction in transpiration and growth inhibition (Zhu, 2002; Lawlor and Cornic,2002; Yordanov,2000) to stand with some osmotic changes in their organs.

GSTU30 and *TPS1* genes play significant roles in development, metabolism,and abiotic stress responses in a variety of organisms Glutathione transferases (GSTs; EC 2.5.1.18) are multi-functional protein superfamily (Wilce and Parker,1994)confer resistance against several abiotic stresses(Tiwari *et al*., 2020). Soluble GSTs have been divided into several classes based on their degree of sequence identity but there are only four classes, phi, tau, lambda, and DHAR that are specific to plants. Plant GSTs are additionally associated with abiotic stress resilience, for example, drought(Yang *et al*., 2014; George *et al*., 2010) salt (Xu *et al*., 2016; Ji *et al*., 2010) heavy metals (Kumar *et al*., 2013; Tripathi *et al*., 2014) and cold (Seppa¨nen*et al*., 2000). The root-specific tau class GST from rice (*OsGSTU30*) showed drought (Srivastava *et al*., 2019) as well as heavy metal Cr(VI) stress tolerance (Tripathi*et al*., 2014) through overexpression in *Arabidopsis thaliana*. Biochemical and physiological examinations uncovered that *OsGSTU30* overexpression lines have improved tolerance against both stresses when compared with wild-type plants.

Trehalose-6-phosphate synthase (*TPS1*) gene helps in overcoming cold, drought stress and maitainance of osmoregulation in plants (Garg *et al*., 2002; Jang *et al*., 2003). Overexpression of *TPS1* gene isolated from *Arabidopsis* and rice conferred abiotic stress tolerance in transgenic *Arabidopsis* and rice plants without causing any morphological changes. These data firmly propose that plant *TPS1* additionally has a high potential in providing abiotic stress resistance (Avonce*et al*., 2004; Li *et al*., 2011).

The products of stress-inducible genes identified in one plant can present in other plants also and may be categorized into functional proteins and regulatory proteins. Comparative analysis of some stress-inducible genes revealed a considerable degree of similarity in stress responses between the two genomes at the molecular level. These outcomes confirm that two plants share common stress-inducible genes, even though these two plants evolved separately more than a million years ago. Therefore, in the current study, we identified drought-inducible orthologous genes in wheat which were previously identified in rice and *Arabidopsis* plants.

MATERIAL AND METHODS

Identification of *GSTU30* and *TPS1* genes in wheat reference genomic data

In order to get gene sequences of wheat that encode *GSTU30* and *TPS1* proteins, sequences of known *OsGSTU30* and *OsTPS1* genes from the rice crop (a closely related species to wheat) were utilized. Protein sequences of rice genes were retrieved from Ensembl Plants (http://plants.ensembl.org) and used in BLASTp analysis against the recently released reference genomic data (IWGSC RefSeq v1.0) available on Ensembl Plants. Following criteria was utilized for the identification of wheat orthologs (Kumar *et al*., 2016; Kumar *et al*., 2018-I; Kumar *et al*., 2018-II): (i) high level (>60%) of sequence identity and query coverage along the protein length; (ii) presence of all the functional domains available in query sequences. A flowchart of whole process utilized to identify genes in the present study is summarized in Fig. 1.

Prediction of intron/exon boundaries

In order to predict the intron/exon structures of *TaGSTU30* and *TaTPS1* genes, Gene Structure Display Server (GSDS version 2.0) (http://gsds.cbi.pku.edu.cn/) was utilizedby aligning the CDS sequences to their corresponding genomic DNA sequences obtained from Ensembl Plants.

Functional domains, physicochemical properties and subcellular localization

NCBI (www.ncbi.nlm.nih.gov) and PROSITE (https://prosite.expasy.org/)databases were utilized to predict the functional domains of

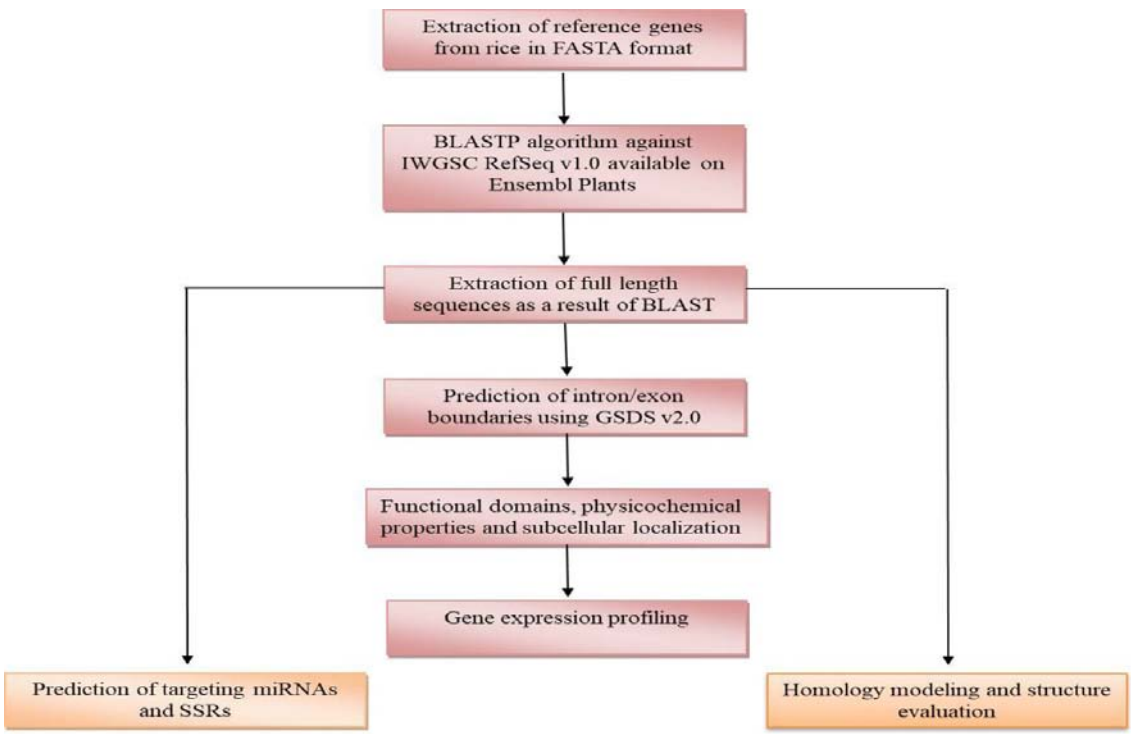


Fig. 1. Flowchart of pipeline used for identification and annotation of *TaGSTU30* and *TaTPS1* genes in wheat genome

identified wheat *TaGSTU30* and *TaTPS1* genes. All the identified genes were studied for various physicochemical properties using Prot-Param (Gasteiger *et al*., 2005). Prot-Param computes different physicochemical properties including molecular weight (Mw), theoretical pI, instability index, aliphatic index (AI), and grand average of hydropathicity (GRAVY). While, subcellular localization was predicted by using BUSCA (http://busca.biocomp.unibo.it/).

Occurrence of molecular markers and miRNAs targeting *TaGSTU30* and *TaTPS1* genes

The genomic transcripts of identified wheat *TaGSTU30* and *TaTPS1* genes were utilized to predict the simple sequence repeats (SSRs) by using BatchPrimer3 version 1. (http://probes.pw.usda.gov/batchprimer3/). In order to predict the potential miRNAs targeting the *TaGSTU30* and *TaTPS1* genes, psRNA Target platform (http://plantgrn.noble.org/psRNATarget/) was utilized with default parameters.

Gene expression analysis complemented by protein-protein interaction network

Expression profiling of *TaGSTU30* and *TaTPS1* genes was performed using WheatExp (http://wheat.pw.usda.gov/WheatExp/) database. Expression profiling of individual genes was conducted in different wheat tissues at different developmental stages including grain, leaf, root, spike and stem.To predict the functional regulatory partners of *GSTU30* and *TPS1* proteins, automated GeneMANIA (Warde-Farley *et al*., 2010) (https://genemania.org/) server was used with default parameters.

Identification of *cis*-elements in the promoter region of the *TaGSTU30* and *TaTPS1* genes

In order to determine *cis*-elements in the promoters region of *TaGSTU30* and *TaTPS1* genes, 1500 bp upstream sequences relative to the translation start codon (ATG) (*i.e.* promoter region) were obtained from EnsemblPlants (http://plants.ensembl.org) in FASTA format. The PLACE server (Higo *et al.,* 1999) was utilized to identify and annotate the *cis*-regulatory elements associated with development response and abiotic stresses.

Homology modeling

The prediction of 3D structure of proteins play an important role in functional annotation of the key regulators associated with many cellular processes. Crystal structures ofallplantproteins are not available in structure databases such as Protein Data Bank (PDB) (https://www.rcsb.org/). Moreover, protein structure prediction of abiotic stress responsive proteins is a challenging task. Therefore, comparative modeling for predicting wheat *TaGSTU30* and *TaTPS1* proteins structure can provide alternative solutions. Since last decade, the homology modeling method has become an important method to predict the 3D structure of proteins based on significant sequences similarity with template structure available in PDB. In the study, 3D structures of *TaGSTU30* and *TaTPS1* proteins were modelled using homology modeling based method. The position specific iterated BLAST (PSI-BLAST) was carried out to obtain the homologous template structures of *TaGSTU30* and *TaTPS1* proteins (Altschul *et al*.,1997). Whereas, 3D structures were predicted using automated Swiss-Model server (Biasini *et al*., 2014; Arnold *et al*., 2006) (https://swissmodel.expasy.org/). Furthermore, UCSF CHIMERA 1.10 (Pettersen *et al*., 2004)(https://

www.cgl.ucsf.edu/chimera/) was used to visualize different chemical coordinates of predicted *TaGSTU30* and *TaTPS1* proteins.

Structure evaluation

Ramachandran plots were predicted to evaluate protein structures with the calculations of phi (Ö) and psi (ø) torsion angles. The geometric validation of the modeled 3D structures of *TaGSTU30* and *TaTPS1* proteins were performed using PROCHECK and protein structure verification server (PSVS) (https://nihserver.mbi.ucla.edu/SAVES/).

RESULTS AND DISCUSSION

Identification of *GSTU30* and *TPS1* genes in wheat genome

In order to identify *TaGSTU30* and *TaTPS1* genes in the wheat genome, the researchers performed a homologous BLASTp algorithm against wheat genome assembly IWGSC RefSeq v 1.0 available on EnsemblPlants, based on *OsGSTU30* and *OsTPS1* genes reported in rice. Based on the sequence similarity, BLASTp search obtained the homologous transcripts associated with queried genes. The transcripts of wheat *TaGSTU30* and *TaTPS1*were found to have 73.6% to 95.5% identity with query sequences on lower e-value(Table 1).Out of total six genes, three *TaGSTU30* genes (*TaGSTU30-1A, TaGSTU30-1B, TaGSTU30-1D*) and three *TaTPS1* genes (*TaTPS-1A, TaTPS-1B, TaTPS-1D*) were identified in the wheat genome using the BLAST algorithm. These identified six genes were found to be scattered on wheat homoeologous chromosome group 1 (1A, 1B, and 1D). Table 1 shows the chromosomes and genomic locations of identified*TaGSTU30* and *TaTPS1* genes. The CDS length of *TaGSTU30* genes ranged from 708 to 711bp, while CDS of *TaTPS1* genes ranged from 2964 to3015bp. The corresponding amino acid length of *TaGSTU30* ranged from 235 to 236aa, while amino acid length of *TaTPS1* ranged from 987 to 1004aa. In comparision to *TaGSTU30* genes the *TaTPS1* genes were found longer in length.

Predicted intron/exon boundaries

To examine the evolutionary gene relationship and functional diversification within a gene family, analysis of intron and exon structure boundaries is an important step. In the study, the intron/exon composition and upstream (52 UTR)/downstream (32 UTR) sequences of *TaGSTU30* and *TPS1*genes predicted using the GSDS v2.0 server. The number of introns is highly divergent, from zero to 16,which is consistent with *GSTU30* and *TPS1* genes in rice and *Arabidopsis* suggesting a common ancestralorigin of different genes (Fig. 2). It has been found that all three *TaTPS1*genes (*TaTPS-1A, TaTPS-1B, TaTPS-1D*) contain the 16 introns, while*TaGSTU30* genes not having introns in their structure arrangements. Most members of *TaGSTU30* and *TaTPS1*genes shared similar patterns ofexon/intron structures, including intron phase, intron number, and exon length. Candidate genes reported from *Arabidopsis* and rice also revealed the same bimodal distribution of intron, suggesting that this trend is evolutionary conserved.

Conserved domains, physicochemical properties, and subcellular localization of *TaGSTU30* and *TaTPS1* proteins

To verify the reliability of identified *TaGSTU30* and *TPS1* genes, the amino acid

sequences of identified genes were analyzed for the prediction of functional domains using by CDD and PROSITE databases. Conserved domains analysis revealed that *TaGSTU30* proteins possess the GST_C_family and thioredoxin_like superfamily domains, while *TPS1*proteins belong to glycosyltransferase family 20 and trehalose-phosphatase (Fig. 3). Members of these superfamilies play a principal role in response to abiotic stresses in crop plants.

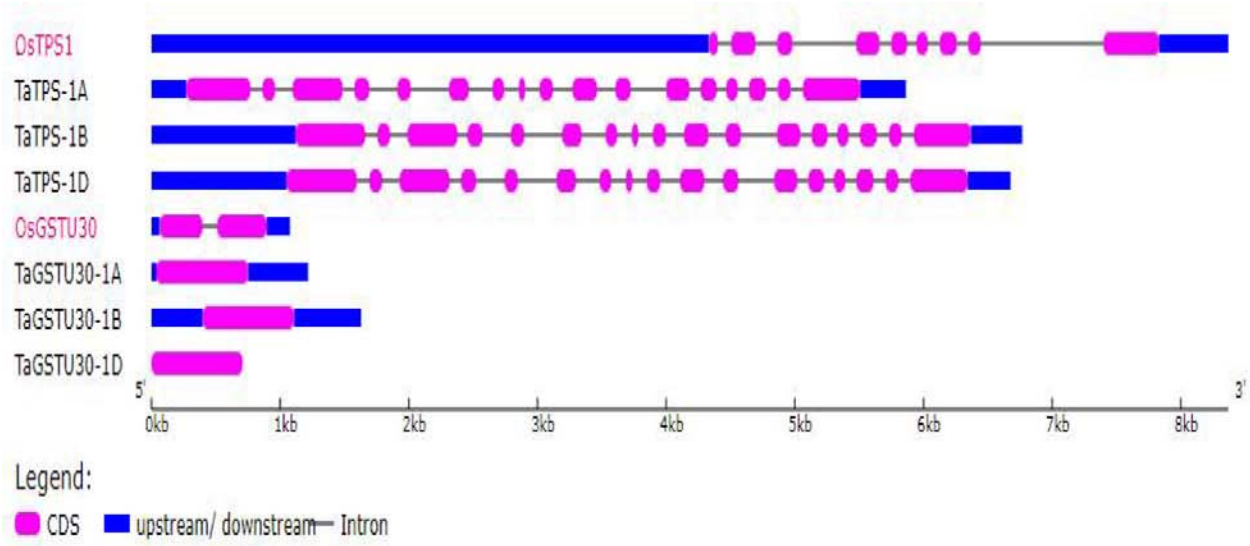


Fig. 2. Predicted distribution of exons and introns, along with upstreamand downstream regions in identified wheat *TaGSTU30* and *TPS1*genes, which illustrates the gene structure, predicted by GSDS 2.0 server

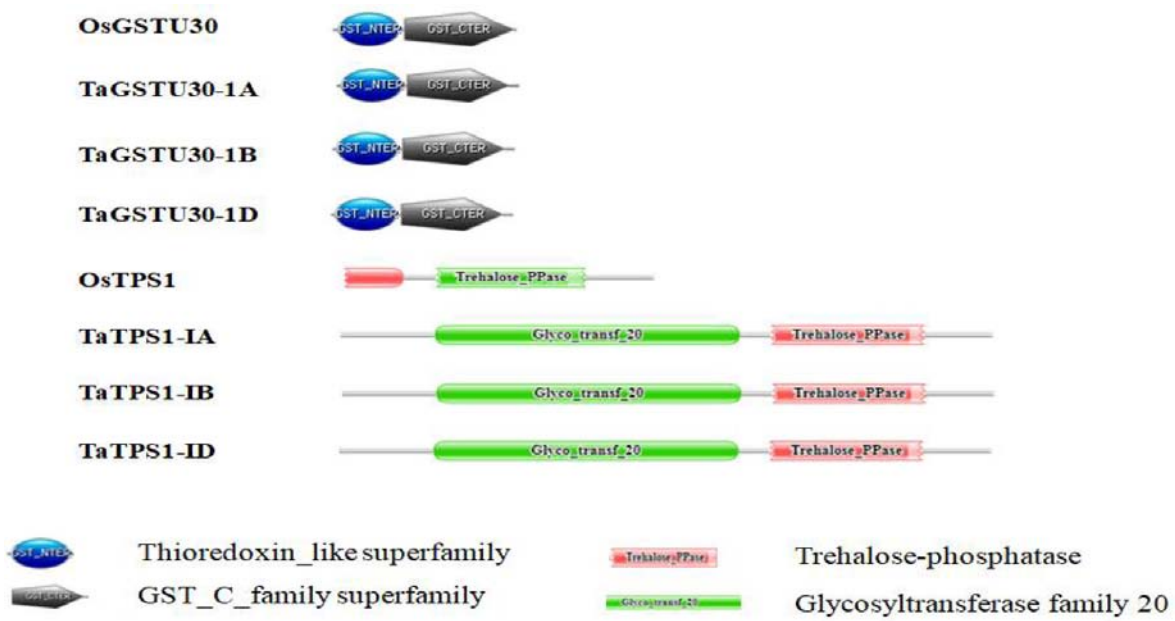


Fig. 3. Predicted functional domains in peptide sequences of *TaGSTU30* and *TaTPS1* proteins

Table 1. Catalouge of identified *TaGSTU30* and *TaTPS1* genes using BLASTp algorithm and physicochemical properties of identified genes in wheat genome

Query gene	Wheat gene hit	Ensembl Plants Id	Genomic location	CDS length (bp)	Protein length (aa)	E-value	%ID	Mol. wt. (g/mol)	pI	Instability index (II)	Aliphatic index	GRAVY	Stability
OsGSTU30	TaGSTU30-1A	TraesCS1A02G186500	1A:337658081-337658524	711	236	1.5E-73	74.3	25777.58	5.23	28.43	96.36	-0.013	Yes
	TaGSTU30-1B	TraesCS1B02G194300	1B:349546852-349547295	708	235	2.7E-72	75.0	25861.62	5.14	28.57	96.30	-0.026	Yes
	TaGSTU30-1D	TraesCS1D02G190100	1D:262287843-262288286	708	235	2.7E-72	73.6	25758.49	5.02	28.41	95.06	-0.046	Yes
OsTPS1	TaTPS-1A	TraesCS1A02G339300	1A:529244778-529246859	2964	987	0.0	95.5	109695.45	6.01	48.34	79.65	-0.407	No
	TaTPS-1B	TraesCS1B02G351600	1B:582093244-582095309	3009	1002	0.0	95.2	111295.25	6.10	49.54	78.16	-0.425	No
	TaTPS-1D	TraesCS1D02G341100	1D:430977409-430979493	3015	1004	0.0	95.5	111323.24	6.11	49.50	77.91	-0.419	No

The molecular weight of predicted *TaGSTU30* proteins varied from 25758.49 to 25861.62 g/mol that of *TaTPS1* proteins ranged from 109695.45 to 111323.24 g/mol.The isoelectric point (pI) of all *TaGSTU30* proteins ranged from 5.02 to 5.23, while the plof *TaTPS1* proteins ranged from 6.01 to 6.11 (Table 1). All three *TaGSTU30* proteins (*TaGSTU30-1A*, *TaGSTU30-1B*, *TaGSTU30-1D*) had an unstable nature, while all three *TaTPS1* proteins (*TaTPS-1A*, *TaTPS-1B*, *TaTPS-1D*) found stable at the sequence level. Unstable nature of *TaTPS1*proteins making it difficult to obtain the crystal structure of these proteins using x-ray methods. However, the higher aliphatic index of the *TaGSTU30* proteins (range: 95.06 to 96.36) relative to that of *TaTPS1*proteins (range: 77.91 to 79.65), suggests relatively higher stability of *TaGSTU30* proteins at wider range of temperatures. Grand Average of Hydropathy (GRAVY) ranged from -0.013 to -0.046 for *TaGSTU30* proteins and from -0.407 to -0.425 for *TaTPS1* proteins suggesting hydrophilic nature of these proteins. BUSCA algorithm predicted nucleus location for *TaGSTU30* and *TPS1* proteins.

Molecular markers and miRNAs targeting *TaGSTU30* and *TaTPS1*genes

As many as 7 gene-specific SSRs (one of *TaGSTU30*and six of *TaTPS1*) were identified in *TaGSTU30 and TaTPS1* genes. The different classes of identified markers(dinucleotide, trinucleotide, tetranucleotide, pentanucleotide and hexanucleotide) are presented in Table 2. Penta SSRs (3/7) outnumbered the other repeats, while di and tri SSR repeats (1/7) were found to be less than tetra SSRs (2/7). Infuture, after due validation, these markers may be utilized for the selection of genotypes exhibiting improved abiotic stresses using marker-assisted selection (MAS) molecular breeding program (Kumar *et al*., 2018-I; Kumar *et al*., 2019).

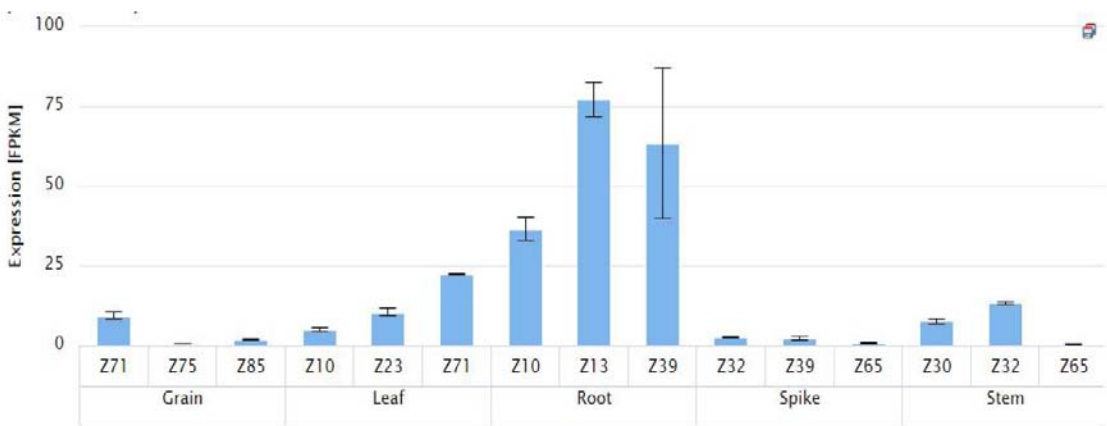
Table 2. **Identified SSRs markers among genomic sequences of *TaGSTU30* and *TaTPS1* genes**

Gene	Motif	Primer Seq (F)	Primer Seq (R)	Product size
TaGSTU 30-1A	(GGTG)3	CGACAGGGTGGTTGAGTA	GTAATTCCAGCTAATTCCACA	148
TaTPS-1A	(TAC)4	CACTACGGTTATCGTTCTCAG	AAAATTCTGCAAAGGGTAGAG	143
	(GCGG)3	GAAAGCAGCGCAATTAAG	AGACGGCCCATCATCACT	147
	(CCCGC)3	GCTGATTACATGTTCTTGGAT	GTACAGGGAACACCAATGTTA	135
TaTPS-1B	(CCGCC)4	TGTTCTTGGATAGGCAGTAGA	TTTGTACAGGATTGTACACCAC	164
TaTPS-1D	(TG)18	TAGGGAAAAGTAGAACGGAAC	CGCAGAAAATCCTCTTTTATT	144
	(CCGCC)4	CGGACTACATGTTCTTGG ATA	AGGGCTGTTGTTAACTCT TCT	110

Table 3.Predicted miRNA targets in genomic sequences of*TaGSTU30* and Ta*TPS1* genes.

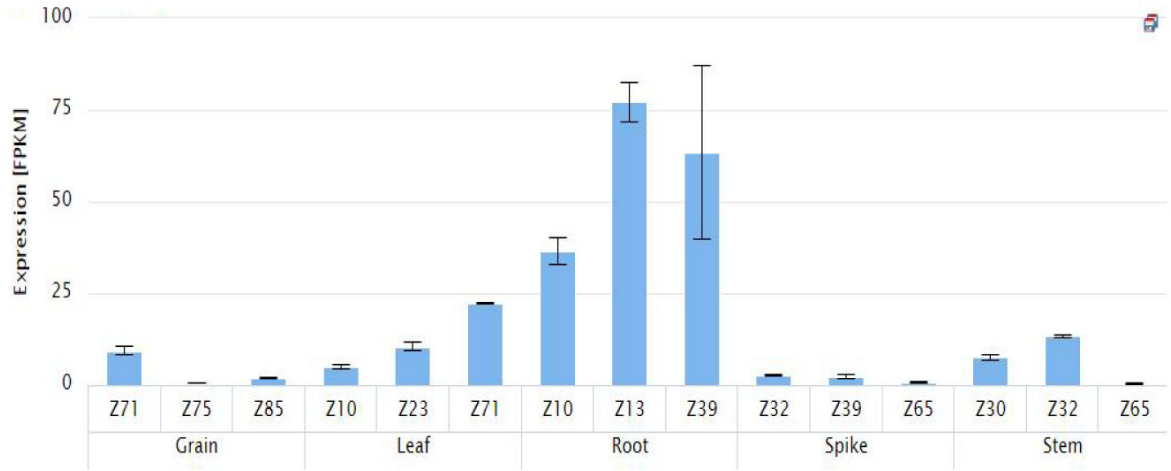
Gene name	miRNA	E-value	miRNA length	Target site	Inhibition
TaTPS-1A	mtr-miR2650	2.5	22	3222-3243	Cleavage
TaTPS-1B	cca-miR6112	1.5	24	661-684	Cleavage
	mtr-miR2650	2.0	22	4088-4109	Cleavage
	aqu-miR-2017-5p	3.5	21	3747-367	Cleavage
TaTPS-1D	cca-miR6112	2.5	24	629-652	Cleavage
	gma-miR1510a-5p	2.5	24	2635-2658	Cleavage
	bdi-miR5185m-3p	3.0	21	5838-5858	Cleavage
	bra-miR9563a-3p	3.0	21	1340-1360	Cleavage
	gma-miR4364b	3.0	24	537-560	Cleavage
	mtr-miR2650	3.0	22	4057-4068	Cleavage
	mtr-miR5282	3.0	24	5829-5852	Cleavage
TaGSTU30-1A	ath-miR5021	2.5	20	838-857	Cleavage
TaGSTU30-1B	ath-miR5021	2.5	20	1191-1210	Cleavage
	ptc-miR473b	2.5	20	821-840	Cleavage

For post-transcriptional regulation, targeting sites for nine miRNAs (aqu-miR-2017-5p, ath-miR5021, bdi-miR5185m-3p, cca-miR6112, gma-miR1510a-5p, gma-miR4364b, mtr-miR2650, mtr-miR5282, and ptc-miR473b) were predicted in five genes (*TaTPS-1A, TaTPS-1B, TaTPS-1D, TaGSTU30-1A,* and *TaGSTU30-1B*) with an e-value ranging from 1.5 to 3.0 (Table 3).



(a) *TaTPS1-1A*

(Fig. 4 continued)



(b) *TaGSTU30-1A*

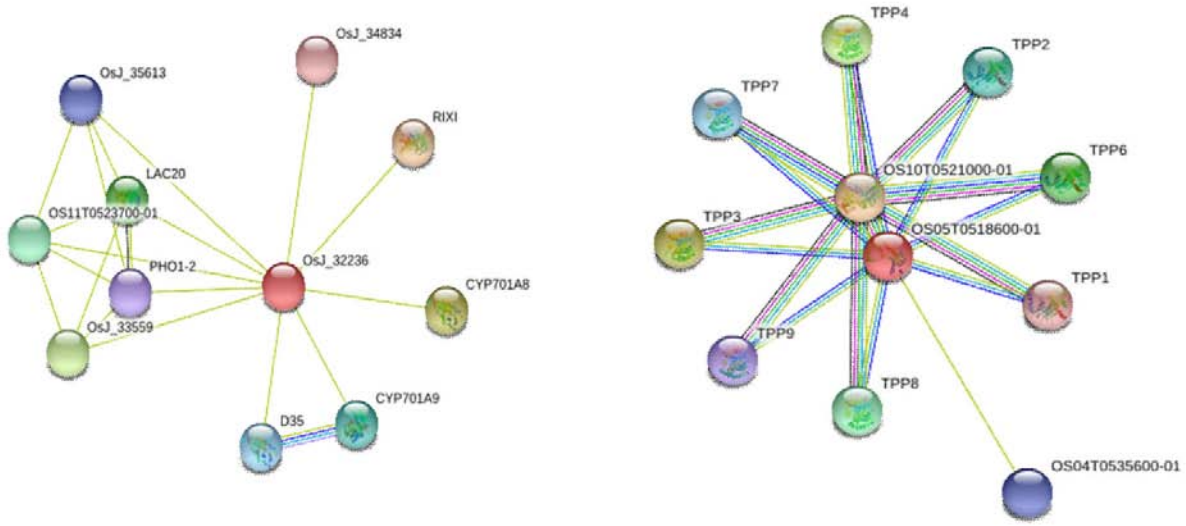
Fig.4. Expression profiling (a and b) of wheat genes in different tissues

Gene expression and protein-protein interaction network analysis

Digital expression profiling conducted by using WheatExp showed that wheat *TaGSTU30* and *TaTPS1* genes have variable expression profiling at different development tissues including grain, leaf, root, spike, and stem (Fig.4). Expression profiling of these genes revealed that these are the key players in response to the drought stress and as well as important to plant development. This is also a confirmation of protein-protein interaction results where a set of co-regulated abiotic stresses responsive genes,viz. *CY701A8*, *CY701A9*, *D35*, *RIXI, LAC20*, *PHO1-2*, *TPP* proteins (*TPP*1 to 9) are known to be co-expressed from the edges (Fig. 5). These interacted partners play a principal role in response to abiotic and biotic stress in plants. In future, molecular interaction between *GSTU30* and *TPS1* and their functional partners can be evaluated by using Co-immuno precipitation (Co-IP) and in-situ hybridization methods.

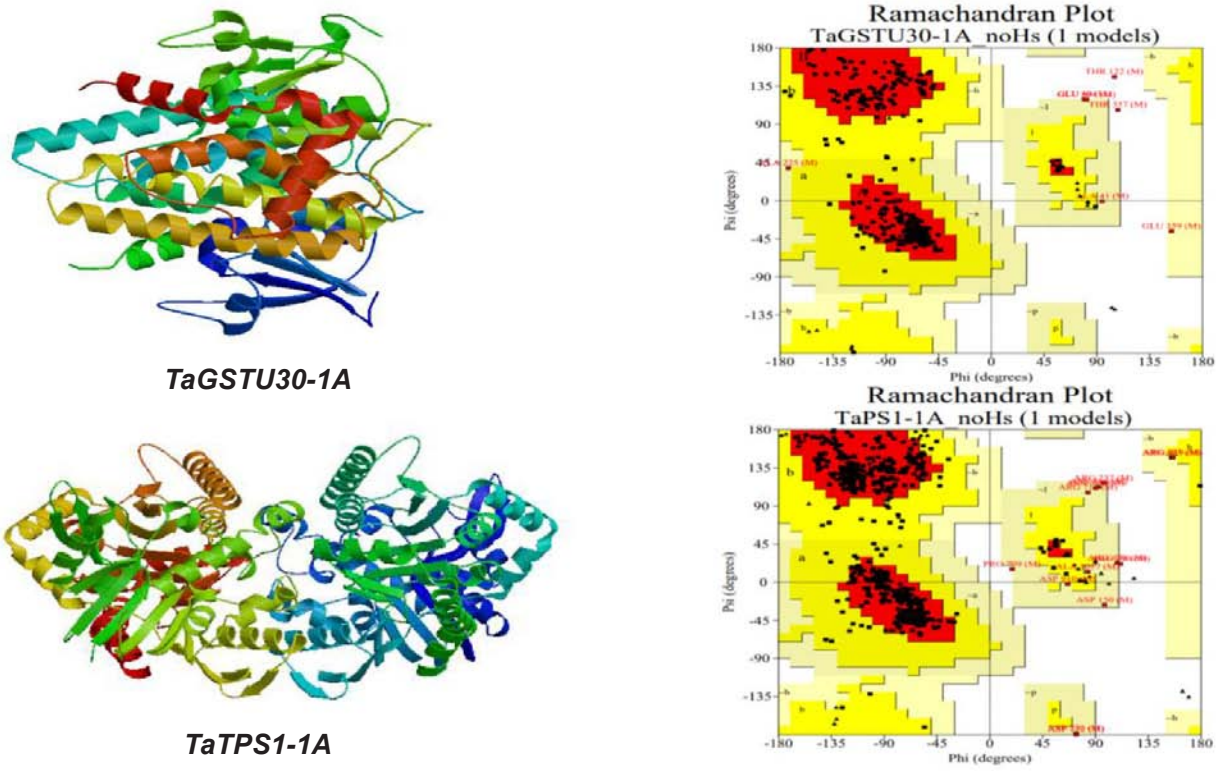
Potential of *cis*-regulatory motifs in the promoters of *TaGSTU30* and *TaTPS1* genes

The promoter analysis of *TaGSTU30* and *TaTPS1* genes demonstrated that these genes have potential of various *cis*-regulatory elements responsive to several abiotic stresses and developmental response. The *cis*-elements responsive to drought *i.e* AP2, ERF, B3, ARF have been found distributed in these genes. Beside these drought responsive elements, *GSTU30* and *TPS1* genes also found to possesses the hormone responsive (Abscisic acid, Gibberellic acid and ethylene)and development-related elements (pollen, and endosperm), As per the previous reports, the AP2, ERF, B3, ARF elements are most conserved elements found in many gene families (Kumar *et al*., 2019). These regulatory motifs are well studied for their important roles in different biological activity and response to wide range of abiotic stresses (Singh *et al.,* 2015).



GSTU30 ***TPS1***

Fig. 5. Predicted protein-protein interaction networks of *GSTU30* and *TPS1* proteins



TaGSTU30-1A

TaTPS1-1A

Fig. 6. Predicted protein structures and calculated Ramachndran plots of *TaGSTU30-1A* and *TaTPS1* proteins

Protein structure prediction and evaluation

Protein structures were predicted using homology modeling based approach with the parameters previously described (Kumar *et al*., 2016; Kumar *et al*., 2013). Protein structures of *TaGSTU30-1A* and *TaTPS1* proteins were modeled using a homology modeling based method. Aminoacid sequences of *TaGSTU30-1A* shared the 43.30% sequence identity with PDB ID: 5KEJ.1.A (Tau class glutathione S-transferase), while *TaTPS1-1A* shared the 51.97% sequence identity with PDB ID: 5HUT.1.A [Alpha, alpha-trehalose-phosphate synthase (UDP-forming)]. These solved structures namely, PDB ID: 5KEJ.1.A and PDB ID: 5HUT.1.A,were used as template for modeling of *TaGSTU30-1A* and *TaTPS1* proteins, respectively. Predicted 3D structures deduced using the Swiss-Model tool, were further visualized in CPK by UCSF CHIMERA (Fig.6).The predicted 3D structures of *TaGSTU30-1A* and *TaTPS1* proteins showed<1A^{0}RMSD with respect to the corresponding homologtemplates upon superposition.Thecalculations of Ramachandran plots for the phi (Ö) and psi (ø) torsion angles analysis represented the excellent geometry of the modelled 3D structures of *TaGSTU30-1A* and *TaTPS1* proteins (Fig.6). As evident from the calculated plots, predicted 3D structures have shown that up to 92.7% of residues belong to most favoured regions. According to the PROCHECK algorithm, a good model should have over 90% residues in most favoured regions.

CONCLUSION

The study identified the orthologs of *OsGSTU30* and *OsTPS1* genes in recently released reference genomic data of wheat. *In silico* analysis revealed that identified genes have structural and functional similarity with their related rice genes. These genes can play a significant role in response to drought stress in crop plants.

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SURVEY ON THE INCIDENCE OF *SESAMIA INFERENS* (WALKER) IN MAIZE IN GUNTUR AND KRISHNA DISTRICTS OF ANDHRA PRADESH

K. ANIL KUMAR*, T. MADHUMATHI, D.V. SAI RAM KUMAR, N. RAJ KUMAR and SK. NAFEEZ UMAR

Department of Entomology, Agricultural College,
Acharya N.G. Ranga Agricultural University, Bapatla- 522 101

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ABSTRACT

The cumulative results of roving survey was conducted during (*rabi* 2017-18 and 2018-19) in maize growing mandals of Guntur and Krishna districts for recording *Sesamia inferens* infestation in farmer fields.The results showed that Narasaraopet mandal recorded the least infestation by *S. inferens* in terms of percentage leaf infestation (18.28), dead heart percentage (15.16), stem tunneling length (2.66 cm) and found less no. of larvae (0.39 plant^{-1}), no. of pupae (0.22 plant^{-1}) and Battiprolu mandal recorded the least number of exit holes (0.48 plant^{-1}). While, Ponnur mandal recorded the highest percent leaf infestation (28.05) with stem tunneling length (5.71 cm).In Krishna district, Veerullapadu mandal recorded the least infestation of maize by *S. inferens* in terms of percent leaf infestation (15.33), dead heart percentage (12.97), stem tunneling length (2.10 cm) and found less no. of larvae (0.24 plant^{-1}), no. of pupae (0.18plant^{-1}) and no. of exit holes (0.17 plant^{-1}). Highest percentage leaf infestation (24.28) and dead heart percentage (21.26) was recorded from Mylavaram mandal;highest tunnel length (3.81 cm) from Musunnuru mandal. In case of Guntur district, highest number of spiders were recorded in Battiprolu (2.42) and least in Narasaraopet (1.39), while highest number of coccinellids were recorded in Ponnuru (4.74) and least in Battiprolu (3.54) mandals. Furthermore, more number of spiders (2.69) were recorded in Mylavaram mandal, more number of coccinellids (7.12) in Musunnuru mandal, and least number of spiders (1.18) and least number of coccinellids (2.58) in Veerullapadu mandal of Krishna district.

Key Words: *Sesamia inferens,* Maize*,* Survey, Incidence, Guntur and Krishna districts

INTRODUCTION

Maize, an important cereal crop plays a prominent role in contributing to the Gross Domestic Product (GDP) of our country. It is used as food, feed and as an industrial crop globally.Maize grains have great nutritional value as they contain 72% starch, 10% protein, 4.8% oil, 8.5% fibre, 3.0% sugarand 1.7% ash. (Bushra *et al.,* 2019). Maize is a versatile crop and can be grown in all the seasons. The predominant maize growing states that contributes more than 80 % of the total maize production are Andhra

*Corresponding Author E-mail i.d: anilento3@gmail.com; PhD thesis submitted to Acharya N.G. Ranga Agricultural University, Guntur

Pradesh (20.9 %), Karnataka (16.5 %), Rajasthan (9.9 %), Maharashtra (9.1 %), Bihar (8.9 %), Uttar Pradesh (6.1 %), Madhya Pradesh (5.7 %), Himachal Pradesh (4.4 %). (GoI, 2020). Andhra Pradesh ranks 5th in area (0.79 m ha) having the highest production (4.14 m t) and productivity (5.26 t ha^{-1}) in the country.*Sesamia inferens*is the key*rabi* pest causing grain yield losses ranging from 18.0% to 49.0%.It is a polyphagous pest attacking various graminaceous crops such as sorghum, pearl millet, finger millet, wheat, rice, sugarcane, barley, and some grasses. It attacks on all parts of plant *viz.,* leaves, stems, tassels and cob.Adequate knowledge of the pest incidence, distribution and economic importance of an insect pest plays a pivotal role both in determining its pest status and in development of a research agenda towards viable management options. Compilation of such information requires quantitative data through diagnostic visits to farm, assessment of pest incidence, associated natural enemies, crop damage and losses with direct farmer participation inputs. Hence, an attempt was made to record percent incidence of pink stem borer, *Sesamia inferens* in two maizegrowing districts of Andhra Pradesh through roving survey.

MATERIALS AND METHODS:

Field surveys were conducted in two consecutive years during *rabi*, 2017-18 and 2018-19 in maize growing fields covering four mandals each of Guntur and Krishna districts of Andhra Pradesh at vegetative and harvesting stages of the crop. The aim of the survey is to ascertain the infestation levels of *S. inferens* in the surveying districts. Four maize growing villages were randomly selected in each mandal of a district and four fields were selected at random in each village. In each field 40 plants were selected at random to record the infestation of *S. inferens.*The infestation was recorded on the basis of damage caused by *S. inferens* and symptoms expressed by plants in expose for pest attack. Accordingly, the damage was recorded interms of percent infestation of leaves and dead hearts during vegetative stage. Simultaneously the natural enemies were also recorded in the same fields.

The percent leaf infestation was calculated by using the formula:

Percent Leaf infestation =

$$\left(\frac{\text{No.of leaves infested}}{\text{Total no.of leaves}}\right) \text{X } 100$$

The percentdead heartswas calculated by using the formula:

Percent dead hearts =

$$\left(\frac{\text{No.of dead hearts}}{\text{Total no.of plants}}\right) \text{X } 100$$

After harvest, the stems were split opened to count the number of larvae, pupae and exit holes per plant and measured the stem tunnel length caused by larvae.

The percentage stem tunneling of the larva was calculated using the formula:

$$\% \text{ stem tunneling} = \frac{\text{Length of tunneling (cm)}}{\text{Length of stem upto cob height (cm)}} \text{ X } 100$$

Data collected on the field infestation of *S. inferens* and its associated natural enemies at different locations were pooled to obtain district averages.

RESULTS AND DISCUSSION

In Guntur district, *S. inferens* infestation was noticed in all the surveyed mandals during *rabi* 2017-18 and 2018-19. The results showed that during *rabi*, 2017-18 the percent leaf infestation varied between 20.5 and 34.0, with a variation of percent dead hearts between 17.3 and 33.4 percentdead hearts and tunnel length between 2.9and 9.4 cm (Table 1) in Narasaraopet and Ponnur mandals, respectively. The number of larvae ranged from 0.4 to 0.9 plant^{-1}, no of pupae from 0.3 to 0.4 plant^{-1}and no of exit holes from 0.5 to 0.7 plant^{-1} among the mandals surveyed (Table 2). During *rabi*, 2018-19 the percent leaf infestation varied between 15.7 and 25.3, with a variation of percentdead hearts between 10.9and 20.8and tunnel length between 1.9and 2.6 cm (Table1). The number of larvae ranged from 0.2 to 0.4plant^{-1}, no of pupae from 0.1 to 0.3 plant^{-1} and no of exit holes from 0.1 to 0.3 plant^{-1} in different mandals surveyed with a district mean of 0.3, 0.1 and 0.2 per plant respectively(Table 2).

The cumulative survey results of two seasons *i.e., rabi,* 2017-18 and *rabi* 2018-19 showed that Narasaraopet mandal recorded the least *S. inferens* infestation in terms of percent leaf infestation (18.2), dead heart percentage (15.1), stem tunneling length (2.6 cm) (Table 1) (Fig. 1) and found less no. of larvae(0.3 plant^{-1}), no. of pupae (0.2 plant^{-1}) and Battiprolu recorded the least no. of exit holes (0.3 plant^{-1}) (Table 2). While, Ponnur mandal recorded highest percent leaf infestation (28.0) and stem tunneling length (5.7 cm), Battiprolu mandal recorded highest dead heart percentage (22.6) (Table 1) and no. of pupae (0.3 plant^{-1}), Pedanandipadu recorded highest no. of larvae (0.6 plant^{-1}), and no. of exit holes (0.4 plant^{-1}) (Table 2) compared to other mandals surveyed. These results are in conformity with Jyothi (2016) who reported highest dead hearts (21.9%) in ponnur district of Andhra Pradesh during her survey. Camerini *et al.* (2014) reported 0.02% stem borer larvae in Brigga and 0.01% in Cargo districts confirmed the lower record of larvae from the infested plants in surveyed mandals.

In Krishna district, *S. inferens* infestation was noticed in all the surveyed mandals during *rabi* 2017-18 and 2018-19. The results showed that during *rabi*, 2017-18 the percent leaf infestation in different mandals was ranged from 17.6 to 28.7, with 16.5 to 26.2 percent dead hearts and the tunnel length was ranged from 2.4 to 5.4 cm with a distinct mean of 23.6%, 21.8% and 3.3 cm respectively (Table 1). The number of larvae ranged from 0.3 to 0.7plant^{-1}, no of pupae from 0.2 to 0.4plant^{-1} and no of exit holes from 0.2 to 0.5 plant^{-1} (Table 2). During *rabi*, 2018-19 the percent leaf infestation ranged from 12.9 to 25.3, with a range of percent dead hearts from 9.4 to 21.8and the tunnel length ranged from 1.6 to 3.1 cm (Table 1). The number of larvae ranged from 0.1 to 0.5 plant^{-1}, no of pupae from 0.1 to 0.3plant^{-1} and no of exit holes from 0.1 to 0.6plant^{-1} with a distinct mean of 0.2, 0.1 and 0.3 plant^{-1} respectively (Table 2).

The cumulative results of two seasons *i.e., rabi,* 2017-18 and *rabi* 2018-19 showed that Veerullapadu mandal recorded the least *S. inferens* infestation in terms of percent leaf infestation (15.3), dead heart percentage (12.9), stem tunneling length (2.1 cm) (Table 1)(Fig. 2) and found less no. of larvae (0.2plant^{-1}), no. of pupae (0.1 plant^{-1}) and no. of exit holes (0.1 plant^{-1}) (Table 2).Highest percent leaf infestation (24.2), dead heart percentage (21.2) was recorded from Mylavaram mandal, highest tunnel length (3.8 cm) from Musunnuru (Table 1) more no. of larvae (0.5 plant^{-1}) from G. konduru mandal,

Table 1. Survey on *Sesamia inferens* infestation during *rabi* 2017-18 and 2018-19 in Guntur and Krishna districts

S. No.	Guntur district	Stem borer infestation (Mean data of four villages)								
		Leaf infestation (%)			Deadhearts (%)			Tunnel length (cm)		
	Name of the Mandal	*rabi* 2017-18	*rabi* 2018-19	Pooled Mean	*rabi* 2017-18	*rabi* 2018-19	Pooled Mean	*rabi* 2017-18	*rabi* 2018-	Pooled Mean
1.	Narasaraopet	20.5	16.0	18.2	17.3	12.9	15.1	2.9	2.4	2.6
2	Pedanandipadu	31.8	15.7	23.7	28.4	14.2	21.3	7.8	2.0	4.9
3	Ponnuru	34.0	22.0	28.0	33.4	10.9	22.1	9.4	1.9	5.7
4	Bhattiprolu	28.2	25.3	26.7	24.5	20.8	22.6	3.2	2.6	2.9
	Mean	28.6	19.7	24.2	25.9	14.7	20.3	5.8	2.2	4.0
	SD	5.9	4.6	4.3	6.7	4.2	3.4	3.3	0.3	1.5
Krishna district										
1.	G konduru	25.1	18.4	21.7	23.9	13.2	18.5	2.9	1.6	2.3
2	Mylavaram	23.2	25.3	24.2	20.6	21.8	21.2	2.4	3.1	2.7
3	Musunnuru	28.7	19.2	23.9	26.2	11.1	18.6	5.4	2.2	3.81
4	Veerullapadu	17.6	12.9	15.3	16.5	9.4	12.9	2.4	1.8	2.1
	Mean	23.6	18.9	21.3	21.8	13.9	17.8	3.3	2.1	2.7
	SD	4.6	5.0	4.1	4.2	5.5	3.4	1.4	0.6	0.7

SD- Standard deviation

more no. of pupae (0.3 plant^{-1}) and no. of exit holes (0.5plant^{-1}) from Mylavaram mandal (Table 2). These results are similar withthe survey results of Reddy *et al.* (2003) who reported 1-6 cm tunneling length by *S. inferens* in infested maize stems.

Among the natural enemies, the generalist predator's*viz.,* spiders and coccinellids associated with maize stem borers were recorded during the survey made in Guntur and Krishna districts during 2017-18 and 2018-19. In Guntur district, the data on number of spiders and coccinellids per 40 plants from farmer's fields ranged from 1.1 to 2.4 spiders and 2.6 to 5.2respectively during *rabi* 2017-18 and 1.6 to 2.7and 3.5 to 4.4, respectively during *rabi* 2018-19. The pooled data of two seasons *i.e., rabi,* 2017-18 and *rabi* 2018-19 illustrated highest number of spiders were recorded in Battiprolu (2.42) and least in Narasaraopet (1.3), while highest number of coccinellids were recorded inPonnuru (4.7) and leastin Battiprolu (3.5) (Table 3) (Fig. 1).

In Krishna district, the data on number of spiders and coccinellids per 40 plants from farmer fields ranged from 1.1 to 2.9and 2.3 to 6.4, respectively during *rabi* 2017-18 and 1.2 to 3.1, 2.8 to 7.8 respectively during *rabi* 2018-19. The pooled data of two seasons *i.e., rabi,* 2017-18

Table 2. *Sesamia inferens* infestation during *rabi* 2017-18 and2018-19 in Guntur and Krishna districts of Andhra Pradesh

S. No.	Guntur district	Stem borer infestation (Mean data of 4 villages)								
		No. of larvae			No. of pupae			No. of exit holes		
	Name of the Mandal	*rabi* 2017-18	*rabi* 2018-19	Pooled Mean	*rabi* 2017-18	*rabi* 2018-19	Pooled Mean	*rabi* 2017-18	*rabi* 2018-	Pooled Mean
1.	Narasaraopet	0.4	0.3	0.3	0.3	0.1	0.2	0.6	0.3	0.4
2	Pedanandipadu	0.8	0.3	0.6	0.4	0.1	0.30	0.6	0.2	0.4
3	Ponnuru	0.9	0.2	0.5	0.4	0.1	0.2	0.7	0.1	0.4
4	Bhattiprolu	0.7	0.4	0.5	0.3	0.3	0.3	0.5	0.2	0.3
	Mean	0.7	0.3	0.5	0.4	0.1	0.2	0.6	0.2	0.4
	SD	0.2	0.09	0.1	0.06	0.09	0.04	0.08	0.07	0.04
Krishna district										
1.	G konduru	0.6	0.3	0.5	0.3	0.1	0.2	0.5	0.4	0.4
2	Mylavaram	0.4	0.0	0.4	0.3	0.3	0.3	0.5	0.6	0.5
3	Musunnuru	0.7	0.1	0.4	0.4	0.1	0.2	0.4	0.1	0.3
4	Veerullapadu	0.3	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.1
	Mean	0.5	0.2	0.4	0.3	0.1	0.2	0.4	0.3	0.3
	SD	0.19	0.17	0.12	0.06	0.11	0.05	0.14	0.24	0.17

SD- Standard deviation

and *rabi* 2018-19 illustrated more number of spiders (2.6) was recorded in Mylavaram mandal, coccinellids (7.1) in Musunnuru mandal and least spiders (1.1) and least coccinellids (2.5) in Veerullapadu mandal (Table 3) (Fig 2).

Overall results of Guntur and Krishna district show that Krishna have low infestation levels than the Guntur district which might be due to early plantings in Krishna district that might have resulted in escape of the plants from *S. inferens* incidence compared to Guntur district where sowings were late (due to late release of canal water,a major source of water for both the districts).

CONCLUSION

The results showed that Guntur district has high infestation levels of *S. inferens* compared to Krishna district and also the fields have more number of spiders and coccinellids resulted in less damage by the stem borer indicating their effect in suppressing the pest damage. The decrease of *S. inferens* infestation in most of the fields during *rabi*, 2018-19 compared to 2017-18,may be due to the

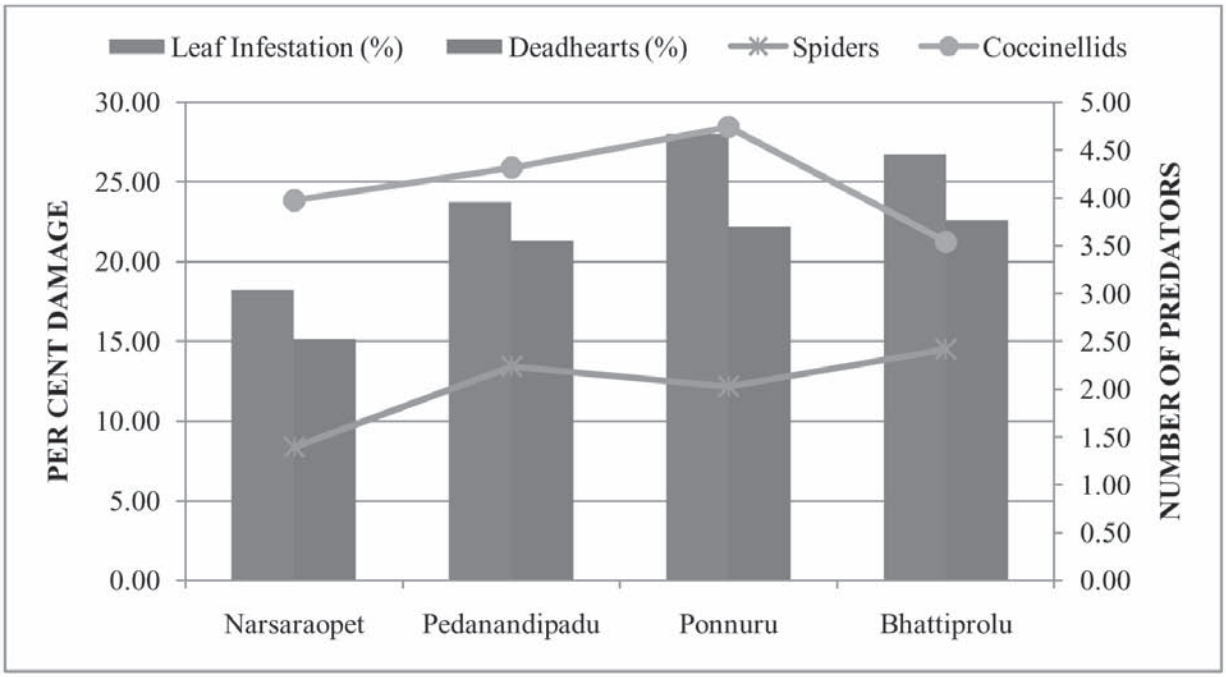

Fig.1. Cumulative occurrence of *S. inferens*in Guntur district during*rabi*2017-18 and 2018-19

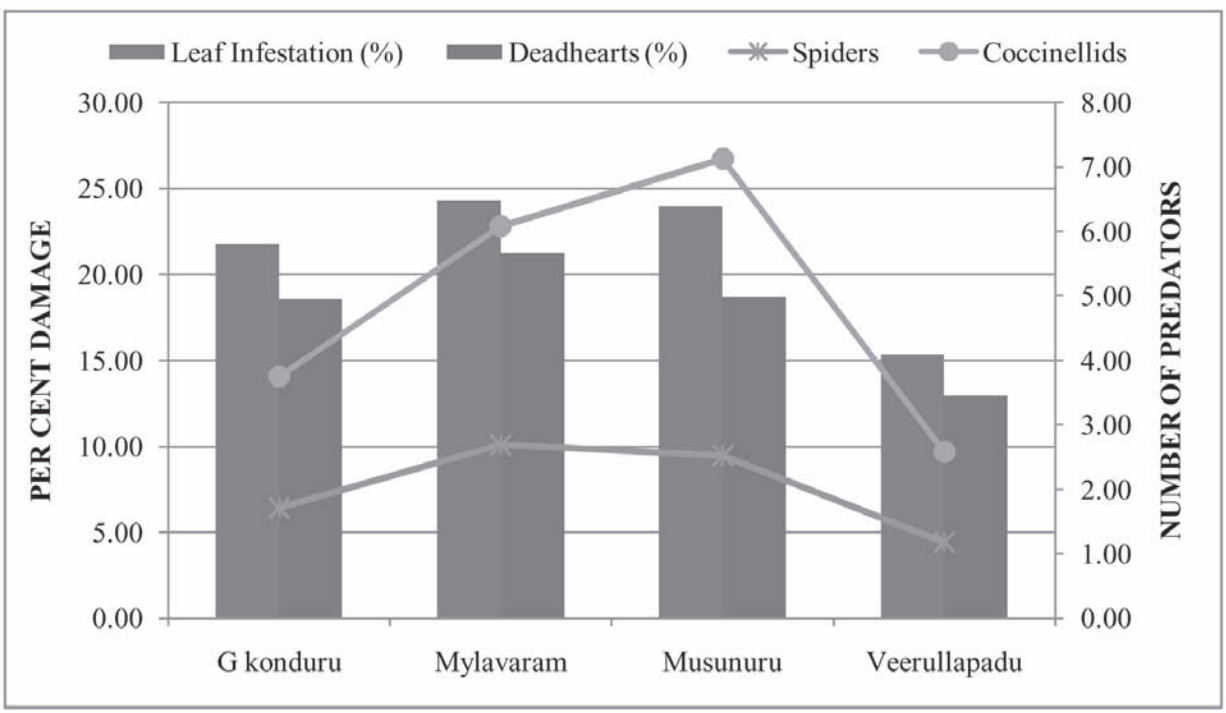

Fig. 2. Cumulative occurrence of *S. inferens*in Krishna district during*rabi* 2017-18 and 2018-19

Table 3. Survey on natural enemies fauna on maize in Guntur and Krishna districts of Andhra Pradesh during*rabi* 2017-18 and 2018-19

S. No.	Guntur district	Natural enemies 40 plants^{-1}(Mean data of 4 villages)					
		Spiders			Coccinellids		
	Name of the Mandal	*rabi* 2017-18	*rabi* 2018-19	Pooled Mean	*rabi* 2017-18	*rabi* 2018-19	Pooled Mean
1.	Narasaraopet	1.1	1.6	1.3	4.4	3.5	3.9
2	Pedanandipadu	2.4	2.0	2.2	4.9	3.6	4.3
3	Ponnuru	1.9	2.1	2.0	5.2	4.2	4.7
4	Bhattiprolu	2.1	2.7	2.4	2.6	4.4	3.5
	Mean	1.8	2.1	2.0	4.3	3.9	4.1
	SD	0.53	0.45	0.44	1.13	0.44	0.50
Krishna District							
1.	G konduru	1.1	2.2	1.7	2.6	4.8	3.7
2	Mylavaram	2.2	3.1	2.6	4.7	7.4	6.0
3	Musunnuru	2.9	2.1	2.5	6.4	7.8	7.1
4	Veerullapadu	1.1	1.2	1.1	2.3	2.8	2.5
	Mean	1.8	2.2	2.0	4.0	5.7	4.8
	SD	0.87	0.77	0.7	1.92	2.33	2.08

SD- Standard deviation

incidence of new invasive pest on maize *i.e., Spodoptera frugiperda* which was reported during May, 2018 in Andhra Pradesh.

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COMPARATIVE ANALYSIS OF CHEMICAL COMPOSITION AND SPECTRAL PROPERTIES OF BIOCHAR PRODUCED FROM PIGEONPEA AND COTTON RESIDUES

K.C. NATARAJA*, D. BALAGURAVAIAH, CH. SRINIVASA RAO, T. GIRIDHARA KRISHNA, Y. REDDI RAMU and P. LAVANYA KUMARI

Department of Soil Science and Agricultural Chemistry
S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati – 517 502

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ABSTRACT

The study was conducted during 2018-19 to characterize the biochar. Biochar from two different agricultural crop residues viz., pigeonpea (*Cajanas cajan (L.) Millsp*.) and cotton (*Gossypium spp*) were produced under the slow pyrolysis process and studied for their physico-chemical properties, carbon stability, recovery and spectral properties. The proximate analysis of biochars recorded higher biochar yield (24.5%), higher fixed carbon (63.84%), lower volatile matter (5.85%) and ash (16.2%) in pigeonpea compared to cotton biochar (yield 22.6%; fixed carbon 62.69%; volatile matter 6.90%; and ash 18.5%). The pH of biochar from pigeonpea and cotton was 9.86 and 9.82, respectively. Electrical conductivity (EC) values of biochar from pigeonpea and cotton are 2.04 and 2.53 dS $m^{-1,}$ respectively. The nutrient concentration of derived biochar indicates enrichment of carbon and depletion of nitrogen and other nutrient elements after slow pyrolysis process. The pigeonpea biochar had lower bulk density (0.26 g cm^{-3}) compared to cotton biochar (0.29 g cm^{-3}). The CEC of pigeonpea and cotton biochar is 44.33 and 33.86 cmol (P^{+}) $kg^{-1,}$ respectively; the carbon recovery level after conversion of the pigeonpea and cotton residues to biochar was 27.6 and 29.0 %, respectively. The typical honey-comb like structure of pigeonpea biochar analysed through SEM micrographs revealed the relatively porous nature of pigeonpea biochar. The study demonstrates that both pigeonpea and cotton biochars are substantially different despite being produced under the same slow pyrolysis process.

Key Words: Biochar, Pigeonpea, Cotton, pH, CEC, Carbon recovery, Spectral properties

INTRODUCTION

Biochar has earned the profound importance in modern agriculture. The basis for growing interest in biochar is manifold. The unique quality of biochar that makes it attractive as a soil amendment is its highly porous structure, which is potentially responsible for improved water andnutrient retention, amelioration of soil acidity, carbon sequestration *etc.* Biochar is a fine-grained, carbon-rich,

*Corresponding Author E-mail i.d: natarajkc2014@gmail.com; PhD thesis submitted to Acharya N.G. Ranga Agricultural University, Guntur

porous product transformed after plant biomass has been subjected to thermo-chemical conversion (pyrolysis) with little or no oxygen (Amonette and Joseph, 2009). Biochar offers a significant, multidimensional opportunity to convert excess agricultural waste into valuable soil amendment (Bera *et al.,* 2018). Use of biocharas soil amendment is a viable option which enhances the natural rates of carbon sequestration and reduces the excessive crop residues into useful material for enhancing soil health and crop productivity (Srinivasarao *et al.,* 2013; Purakayastha *et al.,* 2015).

Biochar plays a vital role in rainfedagriculture for improvement of soil physical properties, retention of nutrients and soil moisture, consequently enhancing crop yields (Venkatesh *et al.,* 2018). Biochars made from different materials vary in their composition which ultimately influences the crop growth after field application. Little published information is available on comparative analysis of biochars obtained from pigeonpea and cotton residues.Hence,the study was carried out to characterize the properties of biochars obtained from pigeonpea and cotton residues.

MATERIAL AND METHODS

The study was conducted during the year 2018-19 at Agricultural Research Station, (14º 41' E Latitude; and 77º 40' N Longitude), Anantapur, Acharya N.G. Ranga Agricultural University, Andhra Pradesh. The pigeon pea and cotton stalks were manually chopped separately and screened to appropriate size (approximately 15 - 20 cm long and 1.0 - 2.0 cm diameter)for loading into drum kiln. The charring of the biomass was taken up in a cylindrical metallic drum fabricated for the purpose of biocharpreparation. The biochar was prepared using slow pyrolysis process at 350 ºC to 400 ºC temperature range.The prepared biochar was grounded and passed through 2 mm sieve for subsequent laboratory analysis.

The pH of biochar was determinedusing pH meter in 1:20 (biochar: water) ratiosuspension after shaking for 1 hour.The pH of biochar in 1 N KCl solution was also determined same as pH in water (Cheng *et al.,* 2006). The EC of the biochar was determined using electrical conductivity meter.Total carbon and total nitrogen concentration of biochar was determined by dry combustion method in CN analyser (Vario EL Cube, Elementar). The concentrations of total P, K, Ca, Mg, S, Na, and the micronutrients such as Cu, Mn, Fe and Zn were analysed with an inductively coupled plasma spectrometer. The cation exchange capacity of the biochar was measured by following ammonium acetate method as outlined by Yuan *et al.* (2011).The maximum water holding capacity of biochar samples were determined by Keen's cup method (Keen and Raczkowski, 1921). The bulk density of biochar was measured by Core Method (Veihmeyer and Hedrickson, 1948) and particle by pycnometer method (Hernandez-Mena *et al.,* 2014). The pore space (%) was calculated by using the formula:

$$\text{Pore space (\%)} = (1- (BD / PD)) \times 100$$

The biocharyield (%) produced from the carbonizedbiochar was calculated by taking the difference of masses before and after conversion using the equation:

$$\text{Biochar Yield (\%)} = (m_{biochar} / m_{straw}) \times 100$$

(Antal and Gronli, 2003).

Where, $m_{biochar}$ wasthe mass of biochar obtained after thermo - conversion process and m_{straw} was the dry mass of raw crop residue loaded into the drum kiln. The proximate analyses were conducted for biochar. The ash content, volatile matter (%) and fixed carbon (%) were determined as outlined by Yuan *et al.* (2011). The ash content was determined by the following equation:

Ash (%) = (Wt. ash / Wt. biochar) x 100

The Volatile Matter (VM) was determined by heating the biochar in covered crucible at 700 ºC for 20 minutes under muffle furnace. The sample weight was measured and weight loss from initial dry biochar was considered as volatile matter and the residual solid was carbonized biochar. The volatile matter content was determined using the formula:

Volatile matter (%) = $(m_{biochar}-m_{cc})$ / $m_{biochar}$ x 100

Where, $m_{biochar}$ was initial dry mass of biochar, m_{cc} was dry mass of carbonized biochar which remained after heating under muffle furnace. The fixed carbon content was calculated by using the following equation:

Fixed carbon (%) = 100 – VM (%) – Ash (%)

in which, VM was the volatile matter content of biochar.

The biocharmorphology was studied by scanning electron microscopy (SEM) performed with the model Zeiss Evoma10.The samples were coated with 24 mm alloy of palladium and gold, then the SEM scanning was performed at resolution of 100 µm; 1.0 k magnification for pigeonpea and resolution of 30µm; 2.5 k magnification for cotton biochar.The biochar particles were analysed through transmission electron microscopy (TEM) at accelerating voltage of 50 keV using a model Hitachi TEM HT 7700. The biochar samples were dispersed in warm millipore water by ultrasonic mixing. Samples were deposited onto a carbon coated grid. The biochar samples were examined at the magnification of 50 k for pigeonpea and magnification of 10 k for cotton biochar.

RESULTS AND DISCUSSION

Proximate analysis of biochar produced from pigeonpea and cotton

The biocharyield and corresponding ash content, volatile matter and fixed carbonwere studied as the proximate parameters of biochar.Proximate analysis results are presented in Table 1.The results revealed that, yield of biochar from pigeonpea stalks (24.48%) were higher than cotton stalks (22.60 %). The varying yield among two biochars obtained may be attributed to feedstock type used (Shaon Kumar Das*et al.,* 2018). Previous studies also described that, the varied concentration of cellulose, hemi-cellulose and lignin content in the feedstock influences the conversion of residue into biochar yield.

The crucial part of the production process is its ash content. Ash quantity alters the product distribution in terms of yield of gas, char and bio-oil (Patwardhan *et al.,* 2010). The cotton biochar had higher ash content (18.5%) than pigeonpea biochar (16.2 %). However, in the study (Table 1), the ash content in both biochars produced is in the range of acceptability, particularly, biochar produced from the non woody feedstock for use as soil amendment (Ronsse *et al.,* 2013). The moisture content of pigeonpea biochar was 4.48per cent compared to 3.91 per cent of cotton

biochar. Bera *et al.* (2018) reported that, ash content less than 20 per cent under low temperature influences the volatile matter. The similar results were obtained in the study as indicated by volatile matter content of pigeonpea (5.85 %) and cotton (6.90 %).

According to Bera *et al.* (2018) under the slow pyrolysis process at temperature of 350 to 400 ºC, poly-aromatic graphene sheets with greater carbon concentration begins to increase at the expense of amorphous carbon pool in the process. However, the fixed carbon content of pigeonpea (63.84%) and cotton (62.69%) does not change muchbut it may increase slightly as per the temperature range (Table 1). Hence, under the slow pyrolysis process a series of de-volatilization reactions occur whichleads to more condensed carbonaceous matrix in the resulted biochar (Ronsse *et al.,* 2013).

Table 1. **Yield and proximate analysis of biochar derived from pigeonpea and cotton stalks**

Biochar properties	Pigeonpea Biochar	Cotton Biochar
Biochar yield (%)	24.48 ± 0.06	22.60 ± 0.15
Ash (%)	16.20 ± 0.04	18.50 ± 0.02
Volatile Matter (%)	5.85 ± 0.01	6.90 ± 0.01
Fixed Carbon (%)	63.84 ± 0.01	62.69 ± 0.01

Values are given as mean ± standard deviation for triplicate measurements

Physico-chemical characteristics of biochar

In the study,the pH values of two biochars were compared in both aqueous and KCl solution (Table 2). The pH of pigeonpea biochar was 9.86and 9.41 in aqueous and suspension, respectively, wherein for the cotton the values were 9.82 and 9.30.This differences in pH values could be attributed to the feedstock type. Further, the deprotonation of acidic groups results in conjugation of bases and leads to alkaline pH of biochar (Ronsse *et al.,* 2013). The EC was also higher in both pigeonpea (2.04 $dSm^{-1)}$ and cotton (2.53 dSm^{-1}) biochar. The reason for the alkaline pH and higher electrical conductivity is the relative increase of ash content in thebiochars (Bera *et al.,* 2014).

The CEC of pigeonpea biochar was 44.33 and cotton 33.86 cmol(P^+) kg^{-1}(Table 2). The higher CEC values indicates that, the biochars has greater potential to hold more nutrients particularly K^+ and NH_4^+ in the rhizosphere. Our study results are also in tune with the results of Bera *et al.* (2018); Shaon Kumar Das *et al.* (2018).

The C/N ratio is considered as the indicator of biochar stability in soils. The C/N ratio of pigeonpea and cotton biochars produced was 67.10 and 67.59, respectively (Table 2). During pyrolysis, the increased temperature leads to dehydration, alkalization and demethylation through volatililization of light organic structures resulting in increased stability. Generally, the C/N ratio greater than 20 had been considered as more stable and presence of recalcitrant pool of carbon in biochar and it may last for more than 1000 years against the microbial decomposition in soils as explained by Spokas *et al.* (2012) and Enders *et al.*(2012).

Table 2.Physico-chemical properties of biochar derived from pigeonpea and cotton residues

Biochar properties	PigeonpeaBiochar	Cotton Biochar
pH (H_2O)	9.86 ± 0.03	9.82 ± 0.04
pH (KCl)	9.41 ± 0.03	9.30 ± 0.01
EC (dSm^{-1})	2.04 ± 0.04	2.53 ± 0.01
CEC ($cmol(P^{+})kg^{-1}$)	44.33 ± 0.13	33.86 ± 0.34
C/N Ratio	67.10 ± 1.48	67.59 ± 1.00

Note: Values are given as mean ± standard deviation for triplicate measurements

Physical properties and moisture retention capacity of pigeonpea and cotton biochar

The bulk density of pigeon pea was 0.26g cm^{-3} and cotton biochar was 0.29 g cm^{-3} (Table 3). The pigeonpea and cotton residues are semi woody in nature and biocharprepared under drum kiln method might influence the bulk density of biochar. In contrast to the findings of Shaon Kumar Das *et al.* (2018), the bulk density increased with increasing ash content of biochar. The amount of total carbon and ash content in biochar along with temperature range influence the bulk density. Similar bulk density results were also reported by Bera *et al.* (2018).The pigeonpea biochar recorded lower BD as compared to cotton, and, hence, pigeonpea biochar could be of great benefit as soil amendment. Lower BD indicates more porosity, which enhances the potential for better soil aeration and increased water holding capacity (Shaon Kumar Das *et al.*, 2018).

The particle density of pigeonpea biochar was 0.54 g cm^{-3} and cotton biochar was 0.53 g cm^{-3}. The ash content has major contribution towards particle density. Similar results reported by Bera *et al.* (2018). The lower bulk density increases the pore spaces which was confirmed by higher porosity of pigeonpea biochar (52.7%) as compared to cottonbiochar (45.5%).The increased porosity of biochar under slow pyrolysis temperature may be attributed to progressive removal of volatiles from pores. In addition, chemical and physical condensation of remaining skeletal structure occurs under 350 to 400 ºC of slow pyrolysis (Brewer *et al.,* 2011).

Among two biochars, pigeonpea biochar showed higher WHC (318 %) as compared to cotton (280 %). WHC of biochar is a function of pore structure connectivity and sizeof pores. The narrow pore throats lead to improved water retention capacity of biochar produced under slow pyrolysis. The pore structure significantly influences the moisture retention capacity of the biochar. The similar observation was also made by Kinney *et al.* (2012) and Venkatesh *et al,* (2013a).

Carbon and Nitrogen recovery levels under thermo - chemical conversion

The recovery of total carbon and total nitrogen content in pigeonpea and cotton biochars were found to be 27.6 and 29.0 per cent respectively (Table 4). This recovery of carbon is inversely proportional to the ash

Table 3. Physical properties and moisture retention capacity of pigeonpea and cotton biochar

Biochar properties	Pigeonpea Biochar	Cotton Biochar
Bulk density (g cm^{-3})	0.26 ± 0.01	0.29 ± 0.01
Particle density (g cm^{-3})	0.54 ± 0.01	0.53 ± 0.01
Moisture content (%)	4.48 ± 0.08	3.91 ± 0.05
Pore space (%)	52.7 ± 1.56	45.5 ± 2.26
Water holding Capacity (%)	318 ± 0.02	280 ± 0.10

Note: Values are given as mean ± standard deviation for triplicate measurements

content of the corresponding biochars produced at the temperature range of 350 to 400 ºC under slow pyrolysis (Fig.1). During carbonization process, the volatilization of compounds occurs which are in conjunction with volatile matter. The loss of carbon also might have occurred but largely the carbon was conservedwith increasing temperature as recalcitrant carbon in biochar as indicated by carbon recovery (%) and C/N ratio which was in accordance with the findings of Venkatesh *et al.* (2013 a); Kloss *et al.* (2011).

Similarly, the recovery of total N in the pigeonpea and cotton biochar was 20.3 and 18.8 per cent, respectively. Previous studies revealed that, N recovery slightly decreases or stabilizes

Table 4. Carbon and nitrogen recovery levels during conversion to biochar

Particulars	PigeonpeaBiochar	Cotton Biochar
Stalk load (kg)	25.00	25.00
Biochar yield (kg)	6.12	5.65
Biochar yield (%)	24.48	22.60
Total C instalk (%)	40.21	32.92
Total C inbiochar (%)	45.39	42.25
Total C in stalk (kg)	10.05	8.23
Total C in biochar (kg)	2.78	2.39
C Recovery in biochar (%)	27.60	29.00
Total N instalk (%)	0.82	0.65
Total N inbiochar (%)	0.68	0.54
Total N in stalk (kg)	0.21	0.16
Total N in biochar (Kg)	0.04	0.03
N Recovery in biochar (%)	20.30	18.80

Note: Values are given as mean for triplicate measurements

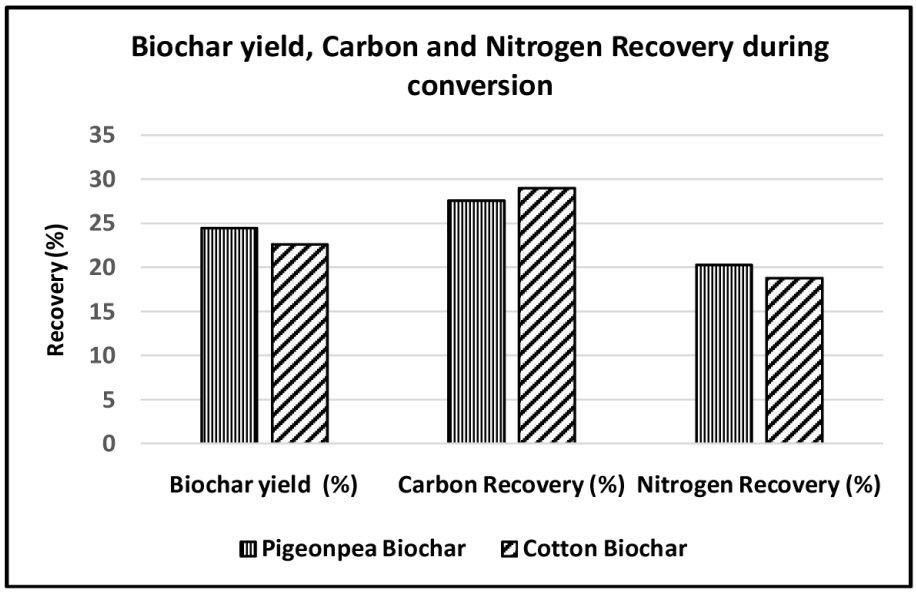

Fig. 1. Carbon and nitrogen recovery during conversion to biochar

as the temperature increases under pyrolysis process (Fig.1). Similar findings were reported by Venkatesh *et al.* (2013ab). The reasons for decreased N recovery in the study could be attributed to the aromatization and condensation of N- containing structures in biocharat the temperature prevailing during pyrolysis into a recalcitrant heterocyclic N rather than more bioavailable amoniacal nitrogen as explained by Novak *et al.* (2009).

Elemental composition of pigeonpea and cotton stalks and their derived biochar

Previous studies revealed thatfeedstock composition influences the elemental composition of biochar materials (Venkatesh *et al.,* 2013a). The results pertaining to elemental composition of raw pigeonpea and cotton feed stocks and their derived biochar are presented in the table 5. The raw pigeonpea stalk used in the study contained 40.21 and 0.82 percent of total C and N, while the corresponding carbon in biochar was 45.39 and nitrogen is 0.68 percent. Similarly, the raw cotton utilized for the biochar preparation in the study contained32.92per centtotal C, 0.65 per cent total N and the corresponding carbon in biocharwas43.25 and nitrogen is 0.64 per cent.The increase in carbon concentration of biochar after subjecting feedstock to slow pyrolysis (350 to 400 ºC) can be attributed to loss of hydrogen and oxygen in greater proportion than C (Bera *et al.,* 2014).

The other nutrient element concentrations (Ca, Mg, S, Na, and micronutrients such as Cu, Mn, Fe and Zn) of both pigeonpea and cotton residues and the respective derived biochar are presented in Table 5. The results revealed that the nutrient compositions of the feedstock influence thenutrient concentrations of resulting biochar during the process of pyrolysis.

Higher phosphorus content in biochar produced under the Pyrolysis temperature range 350 to 400 ºC lead to loss of C and presence of less crystallized P associated minerals, similarly, the higher amount of K in biochar is due to the greater solubility of K associated minerals in

Table 5.Elemental composition of pigeonpea and cotton stalks and their derived biochar

Nutrient element	Pigeonpea stalk	Cotton stalk	Pigeonpea Biochar	Cotton Biochar
Carbon **(%)**	40.21 ± 0.61	32.92 ± 0.04	45.39 ± 0.03	43.25 ± 0.04
Nitrogen **(%)**	0.82 ± 0.01	0.65 ± 0.02	0.68 ± 0.02	0.64 ± 0.01
Phosphorus **(%)**	0.38 ± 0.02	0.34 ± 0.02	0.47 ± 0.02	0.43 ± 0.01
Potassium **(%)**	0.59 ± 0.01	0.55 ± 0.02	0.68 ± 0.01	0.51 ± 0.02
C/N Ratio	49.24 ± 0.51	50.59 ± 0.64	67.10 ± 1.48	67.59 ± 1.00
Calcium (mg/kg)	0.13 ± 0.01	0.12 ± 0.01	2.12 ± 0.03	2.08 ± 0.02
Magnesium (mg/kg)	0.42 ± 0.01	0.39 ± 0.01	0.19 ± 0.04	0.17 ± 0.03
Sulphur (mg/kg)	0.01 ± 0.00	0.01 ± 0.00	0.02 ± 0.00	0.07 ± 0.10
Sodium (mg/kg)	0.06 ± 0.01	0.08 ± 0.02	2.39 ± 0.07	1.94 ± 0.04
Copper (mg/kg)	0.03 ± .00	0.02 ± 0.00	0.03 ± 0.02	0.01 ± 0.01
Manganese (mg/kg)	0.11 ± 0.01	0.06 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
Iron (mg/kg)	0.62 ± .02	0.58 ± 0.02	0.30 ± 0.01	0.29 ± 0.01

biochar formed during pyrolysis process (Bera *et al.,* 2014). With respect to increase of Ca, Mg, S, Na and micronutrient concentrations such as copper, manganese, iron and zinc inbiochar indicates compositional relationship between bio-residue and their corresponding biochar produced at temperature range of 350 ºC to 400 ºC pyrolysis process (Venkatesh *et al.,* 2013a). The C/N ratio of the raw pigeonpea and cotton was 49.24 and 50.59 respectively, while the corresponding biochar was67.10 and 67.59, respectively. The C/N ratio is higher in cotton biochar compared to pigeon biochar, which indicates the more carbon stability of cotton derived biochar. The C/N ratio also indicates the carbon sequestration potential of the feedstock type *i.e.* legume and non-legume in the study.

Spectral analysis of pigeonpea and cotton biochar

The morphology of the pigeon pea and cotton biocharwas characterized by Scanning electron microscopy (SEM) and particle structure images of the biochar was examined through Transmission electron microscopy (TEM).The clear visibility of biochar morphology depends on the particle size of respective biochar. Hence, suitable magnification and resolution of SEM and TEM for each biochar was used for more clarity of micrographs. The SEM and TEM micrographs are presented in Fig. 2 and Fig. 3.

The SEM micrographs of pigeonpea and cotton biochar clearly illustrate the unique honey-comb like structure of biochar produced from pigeonpea compared to its counterpart cotton biochar. The existence of porous tubular

structures of pigeon pea biochar inherits the architecture of feedstock material used (Sohi *et al.,* 2010). The macro and micro porous structures (pores of approximately 1 mm diameter) of pigeonpea biochar are potentially important for water holding capacity and nutrient adsorption capacity in soil system (Bera *et al.,* 2014; Vijayaraghavan and Ashok Kumar, 2019). The capillary movement of soil solution through these tubular structures dissolves minerals in these pores by the process of diffusion and mass flow.The pore structure of biochar seen under SEM provides physical refuge, resulting in increased abundances of beneficial microorganisms (Sohi *et al.,* 2010; Bera *et al.,* 2018), In contrast, the SEM micrograph of cotton biochar exhibit the flat surface and less porous structure (Fig.2). However, the cotton biochar exhibit tiny holes on surface that hold water and provide habitat for microorganisms (Vijayaraghavan and Ashok Kumar, 2019).

The TEM images shows tiny, some-what spherical primary particles in pigeonpea biochar at high magnification (Fig. 3A) in comparision to cotton biochar (Fig. 3B). This might be related to ash content spreading on surface along with

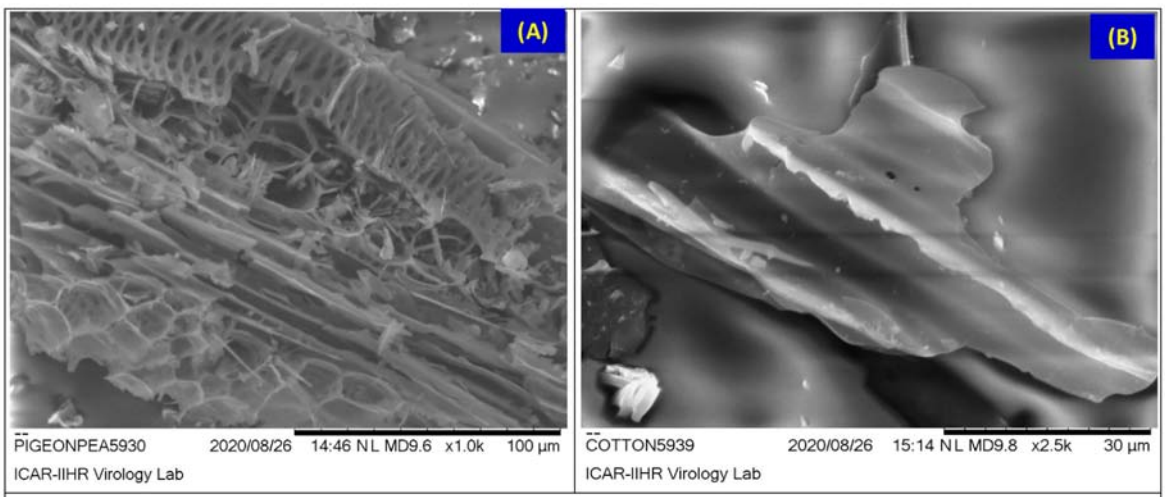

Fig. 2. Scanning electron micrographs (SEM) (A) Pigeonpea biochar at 1.0 k magnification; 100 µm resolution (B) Cotton biochar at 2.5 k magnification; 30µm resolution

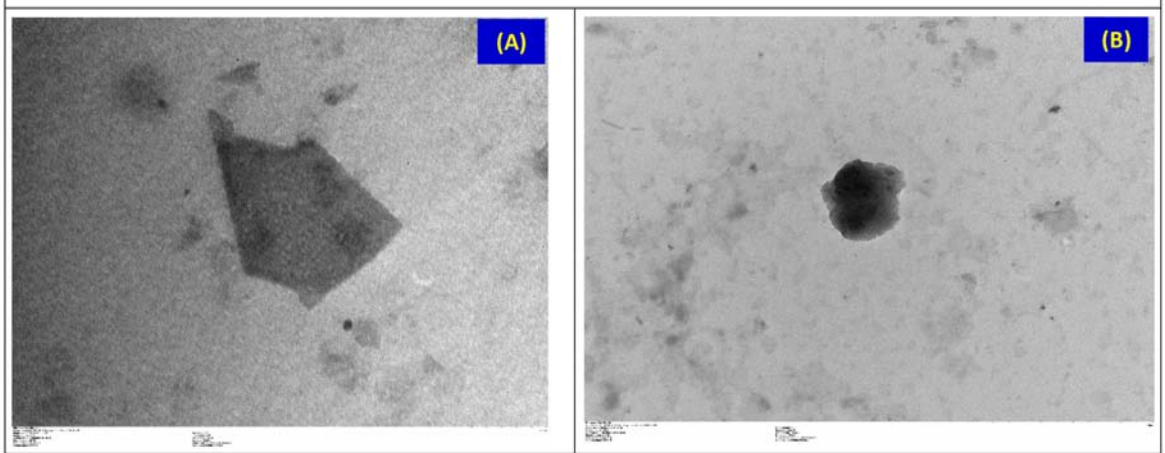

Fig. 3. Transmission electron micrograph (TEM) (A) Pigeonpea biochar at 50k magnification (B) Cotton biochar at 10k magnification

constituent elements adsorbed on the surface (Dinesh Mohan *et al.,* 2018). However, these images indicate the high surface adsorptive potential of pigeonpea over cotton biochar for constituent elements adsorption.

CONCLUSION

The comparative analysis of biochars derived from pigeonpea and cotton residues revealed that, physico-chemical, physical, nutrient, and spectral properties of biochar were strongly influenced by residue type and the pyrolysis process. The pigeonpea biochar recorded the greatest pH of both aqueous and suspension measurement making it most suitable for soil acidity amelioration. However, the cotton is also equally suitable for the purpose of acid neutralization. Both the biochars produced under the temperature range of 350 to 400 ºC, derives higher yield, fixed carbon, lower ash and volatile matter indicated the suitability of both residue type for biochar making. The physical and moisture retention properties of pigeonpea biochar resulted in lower bulk density and higher water holding capacity than cotton. The higher CEC and total nutrient concentration of pigeonpea biochar as compared to cotton signifies the impact of legumeover non-legume residue types. On the contrary, carbon stability and recovery of carbon in cotton biochardepicted that, the cotton biochar is the premium carbon sequestering agent compared to pigeonpea. The spectral properties of pigeonpea and cotton biochar compared in the study clearly depicted the requiredpurpose of biochar use such as honey-comb like porous structure.

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CULTURAL AND MORPHOLOGICAL VARIABILITY OF *CORYNESPORA CASSIICOLA* (BERK. AND CURT.) WEI. CAUSING TARGET SPOT DISEASE IN COTTON

B. MOHAN VENKATA SIVA PRASAD, BHATTIPROLU, S.L*., V. MANOJ KUMAR, K. JAYALALITHA and D.V. SAI RAM KUMAR

Department of Plant Pathology, Agricultural College,
Acharya N.G. Ranga Agricultural University, Bapatla- 522 101

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ABSTRACT

Cultural and morphological variability of *Corynespora cassiicola* (Berk. and Curt.) Wei. causing target spot of cotton, was studied on different growth media. Ten different media *viz*., Potato Dextrose Agar (PDA), Potato Sucrose Agar (PSA), Carrot Dextrose Agar (CDA), Carrot Sucrose Agar (CSA), Oat Meal Agar (OMA), Lactose Casein Agar (LCA), Lactose Peptone Agar (LPA) and different leaf extract media *viz.,* Cotton Leaf Extract Agar (CLEA), Blackgram Leaf Extract Agar (BgLEA), Greengram Leaf Extract Agar (GgLEA) were used to find out the media which enables pathogen to grow fast and to identify the best media for good sporulation. Among the different media tested,CLEA media promotedthe highest radial growth (7.83cm) having more growth rate (0.54 mm per hr) followed by BgLEA with radial growth of 6.80cm and growth rate of 0.47mm per hr; lowest radial growth observed in CAS (4.20 cm) with growth rate of 0.29 mm per hr. Highest sporulation observed in CLEA (394 $x10^4$±10.8) followed by LPA (132 $x10^4$±22.1) and lowest was observed in GgLEA (11.2 $x10^4$±2.8). Conidial morphology varied in the different media tested, lowest conidial length was observed in CLEAmedium(32.83 ±3.33µm) whereas highest in LPA medium(91.58±3.50µm);narrowest conidial width in CLEA medium (7.36±1.79µm) and broadest conidial length in BgLEA medium (12.42±2.02µm).

INTRODUCTION

Cotton (*Gossypium* spp.) is the most important commercial crops of the world, which belongs to the botanical family "*Malvaceae*". India is the largest cotton growing country in the world with 37.56% (13 Mha) of the world's cotton area and produces 24.2% (29.5 M bales) of the world cotton production followed by China (3.45 Mha; 27.2 M bales) and USA (4.77 Mha; 19.8 M bales). In case of India, Andhra Pradesh stood in the seventh position with 5.86 Lakh ha (4.64%) area under cultivation and production of 20 Lakh bales (5.5%) (ICAR - AICRP, 2020).

Cotton crop is affected by fungal, bacterial and viral diseases. In India, foliar diseases have been estimated to cause yield

*Corresponding Author E-mail i.d: bhattiprolu2023@gmail.com; M.Sc thesis submitted to Acharya N.G. Ranga Agricultural University, Guntur

losses up to 20% to 30% (Mayee and Mukewar, 2007). Among all fungal foliar diseases, Corynespora leaf spot caused by *Corynespora cassiicola* has been increasing its prevalence and severity in cotton growing areas of south central United States and Central India (Butler *et al.,* 2016 and Salunkhe *et al.,* 2019). In Andhra Pradesh, the disease was observed in farmers' fields as well as at RARS, Lam, Guntur during 2017 and it dominated Alternaria leaf spot during 2019 and 2020 (ICAR - AICRP, 2020). It was also observed in Maharashtra and Gujarat during recent years (ICAR - AICRP, 021). As Corynespora target leaf spot is emerging as a major disease in cotton, it is necessary to conduct certain basic studies about the pathogen. Potato dextrose agar medium was found suitable for optimum growth and sporulation of *C. cassiicola* infecting okra (Ahmed *et al*., 2013; Sajili *et al*., 2019). Variation in length, width and number of pseudosepta in conidia of *Corynespora* was reported by different workers (Kwon *et al*., 2005; Conner *et al*., 2013; Fulmer *et al*., 2012).The present investigation reports the effect of different media on the growth and sporulation of *Corynespora cassiicola* (Berk. and Curt.) Wei. causing target spot of cotton.

MATERIAL AND METHODS

Isolation and purification of the pathogen

Corynespora cassiicola, was isolated from the infected cotton leaves collected from the field. Small bits of the infected leaves of 3 mm to 5 mm size were cut from the diseased area along with some healthy portion, surface sterilized with 1% sodium hypochlorite for 30 seconds and rinsed in three changes of sterilized distilled water. The surface sterilized bits were transferred on to potato dextrose agar medium plate aseptically and incubated at 27± 1^0C for three days.Initial growth of the pathogen was sub-cultured in to agar slants and the pathogen was purified by single conidial isolation. After purification the culture slants were stored at 2^oC temperature (Dhingra and Sinclair, 1985).

Cultural variability on different media

Ten different media *viz*., Potato Dextrose Agar (PDA), Potato Sucrose Agar (PSA), Carrot Dextrose Agar (CDA), Carrot Sucrose Agar (CSA), Oat Meal Agar (OMA), Lactose Casein Agar (LCA), Lactose Peptone Agar (LPA) and different leaf extract media like Cotton Leaf Extract Agar (CLEA), Blackgram Leaf Extract Agar (BgLEA), Greengram Leaf Extract Agar (GgLEA) were tested against the pathogen (Dhingra and Sinclair,1985; Ahmed *et al*., 2013; Sajili *et al*., 2019)

All the media except LCA and LPA, contents (Potato, Carrot and Leaf extracts) 200:20:20 proportionateof respected material: dextrose:agar, were used to make 1 litre. For LCA and LPA media: Lactose-38g; Agar-20g; Casein/Peptone-4g; KH_2PO_4-1g; $MgSO_4$-4g and micronutrient solution- 2ml for 1 litre were used for media preparation.

Radial growth on different media were recorded upto 10 days after inoculation (DAI) followed by spore count at 10 DAIusing Neaubaur Haemocytometer (0.1 mm depth). Growth rate was calculated at 6 DAI. Spores were collected by adding 10 ml of sterilized distilled water to culture plate and shaking gently with camel brush. Micrographs of the pathogen were taken using image capturing microscope and conidial dimensions were recorded.

Table 1. Cultural variability of *Corynespora cassiicola* on different media

S.No.	Media	Radialgrowth (cm)				
		2DAI	4DAI	6DAI	8DAI	10DAI
1	Potato Dextrose Agar	1.73^{c}	3.27^{ef}	4.83^{f}	6.33^{f}	7.70^{d}
2	Potato Sucrose Agar	1.83^{b}	3.33^{def}	4.90^{ef}	6.47^{e}	7.87^{c}
3	Carrot Dextrose Agar	1.57^{ef}	3.13^{f}	4.43^{g}	5.77^{g}	7.17^{e}
4	Carrot Sucrose Agar	1.63^{de}	2.87^{g}	4.20^{h}	5.33^{h}	6.73^{f}
5	Oat Meal Agar	2.00^{a}	3.50^{de}	4.77^{f}	6.33^{f}	7.60^{d}
6	Lactose Casein Agar	1.50^{g}	3.60^{d}	5.03^{e}	6.93^{d}	8.43^{b}
7	Lactose Peptone Agar	2.00^{a}	3.87^{c}	5.53^{d}	7.17^{c}	8.97^{a}
8	Cotton Leaf Extract Agar	2.00^{a}	5.50^{a}	7.83^{a}	9.00^{a}	9.00^{a}
9	Blackgram Leaf Extract Agar	1.93^{a}	5.33^{a}	6.80^{b}	9.00^{a}	9.00^{a}
10	Greengram Leaf Extract Agar	1.67^{cd}	4.33^{b}	5.73^{c}	8.50^{b}	9.00^{a}
	SEM±	0.03	0.09	0.06	0.11	0.04
	CV%	3.07	3.94	1.97	2.58	0.92
	CD @ 5 %	0.09	0.26	0.18	0.64	0.13

RESULTS AND DISCUSSION

Growth of *C. cassiicola* (Berk. and Curt.) Wei. on different media

Variation in the radial growth of the pathogen was observed from 2DAI to 10 DAI. There was a significant variation in the radial growth of the pathogen observed among the different media tested. At 6 DAI radial growth was highest with CLEA (7.83cm) followed by BgLEA (6.80cm), GgLEA (5.73cm), LPA (5.53cm) and lowest radial growth observed in CSA (4.20cm). At 8DAI, full growth of the pathogen observed in CLEA (9.0cm) and BgLEA (9.0cm) media (Table 1 and Fig. 1).

At 6DAI, growth rate was highest in CLEA (0.54 mm/hr) followed by BgLEA (0.47 mm/hr), GgLEA (0.40 mm/hr), LPA (0.38 mm/hr) and lowest radial growth observed in CSA (0.29 mm/hr). At 10 DAI, conidial count was recorded and the highest sporulation observed in CLEA ($394x10^4$±10.8) followed by LPA ($132x10^4$±22.1) and lowest observed in GgLEA ($11.2x10^4$±2.8) (Fig. 3).Highest number of pseudosepta observed in LCA media (7.6±0.54) whereas lowest in BgLEA media (2.4±0.55) (Table 3).

There was also a corresponding variation observed in different characters *viz.,* colony colour, colony growth, colony margin, surface appearance and conidia measurement (Table 2). Population mean with respect to conidial length was observed as 57.71±2.01(2.84). Upper limit was 63.42 µm and lower limit was 52.01 µm. There was significant variation observed in the conidial dimensions with respect to length of

Table 2. Variation in cultural characters of *Corynespora cassiicola* on different media

Media	Colony colour	Colony growth*	Colony margin	Surface appearance
Potato Dextrose Agar	Light Grey to Green	Moderate	Smooth and circular	Fibrous and aerial mycelium
Potato Sucrose Agar	Grey to Olive Green	Moderate	Circular	Fibrous and aerial mycelium
Carrot Dextrose Agar	Grey to Olive Green at centre and light grey at margin	Moderate	Circular and sparse	Fibrous, aerial at centre and velvety and smooth at margin
Carrot Sucrose Agar	Light Grey to Grey	Slow	Circular and sparse	Fibrous and aerial mycelium in concentric rings
Oat Meal Agar	Milky white to Light Grey	Moderate	Circular	Fluffy and raised mycelium
Lactose Casein Agar	Light Grey	Moderate	Smooth and circular	Smooth with raised aerial mycelium
Lactose Peptone Agar	Milky white to light Grey	Fast	Circular and raised	Fluffy and raised mycelium
Cotton Leaf Extract	Light Grey	Fast	Circular	Fluffy and raised mycelium
Blackgram Leaf Extract	Grey to Dusky Grey	Fast	Circular	Fluffy and raised mycelium
Greengram Leaf Extract	Light Grey	Fast	Circular and sparse	Smooth and aerial mycelium

*Slow: 0.1 to 0.2 mm/hr; Moderate: 0.2 to 0.4 mm/hr; Fast: >0.4 mm/hr

Table 3. Population means of *C. cassiicola* conidial dimensions in different media

Characters	Population mean (µm)	Upper limit (µm)	Lower limit (µm)	Range (µm)
Conidial length	57.71±2.01(2.84)	63.42	52.01	52.01-63.42
Conidial width	8.68±2.01(0.33)	9.41	8.03	8.03-9.41
No. of pseudosepta	5.12±2.01(0.25)	5.63	4.61	4.61-5.63

Table 4. Variability in conidial dimensions of *C. cassiicola* in different media

Media	Length (µm)	Width (µm)	No. of Pseudosepta
PDA	76.94±4.92	8.19±0.16	6.4±1.14
PSA	47.78±4.12	6.76±1.18	6.2±0.84
CDA	44.30±4.35	9.88±2.82	5.2±0.45
CSA	60.50±2.88	8.10±1.80	4.4±0.55
OMA	48.45±1.98	9.26±2.31	3.4±0.55
LCA	84.99±5.80	7.51±1.14	7.6±0.54
LPA	91.58±3.50	8.68±2.88	7.2±0.45
CLA	32.83±3.33	7.36±1.79	3.2±0.45
BGLA	33.60±3.60	12.42±2.02	2.4±0.55
GGLA	56.11±4.12	8.8±2.17	5.2±0.45
SEm±	1.78	0.89	0.28
CV (%)	6.9	22.85	12.35
CD @ 5 %	5.1	2.54	0.81

conidia. The length of conidia was maximum in LPA medium (91.58±3.50µm), while, the shortest (32.83±3.33µm) in CLEA medium. Broadest conidial width in BgLEA medium (12.42±2.02µm) and narrowest conidial width in CLEA media (7.36±1.79 µm) were noticed (Table 3 and 4)(Fig. 2)

Melendez and Pinero (1971) reported that PA and V-8A media were the best media for radial growth of *C.cassiicola*isolated from papaya followed by BPA, XA, PDA, OMA and CMA. Potato dextrose agar medium was found tobe most suitable for optimum growth and sporulation of *C.cassiicola* infecting okra (Ahmed *et al*., 2013; Sajili *et al*., 2019). Conidia of the fungus varied **from 36-186 ìm long and 8-19 ìm wide to 50-209 ìmlong and 7 to 15 ìm wide with 4-15 pseudosepta when grown on PDA and V8 media (Kwon *et al*., 2005; Conner *et al*., 2013; Fulmer *et al*., 2012).**

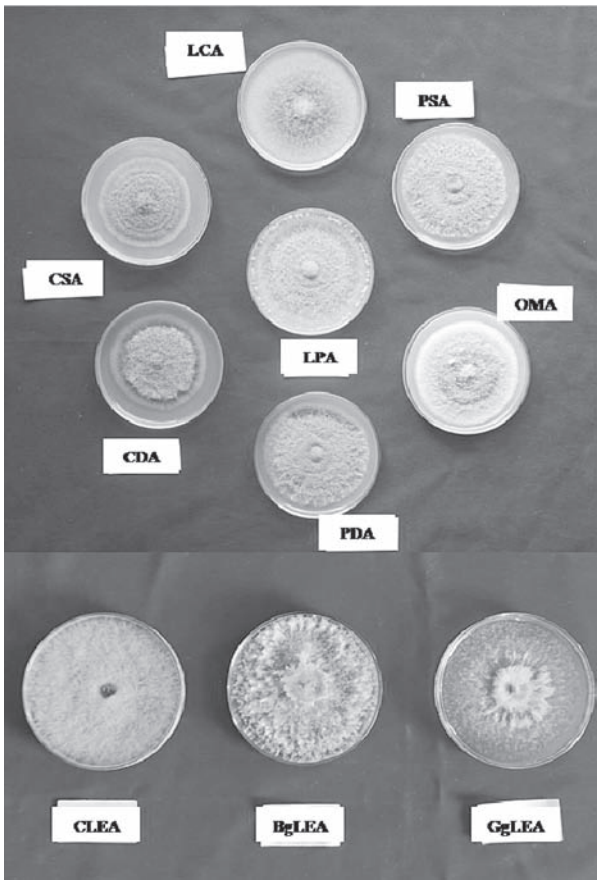

Fig. 1. Cultural variability of *Corynespora cassiicola* on different media

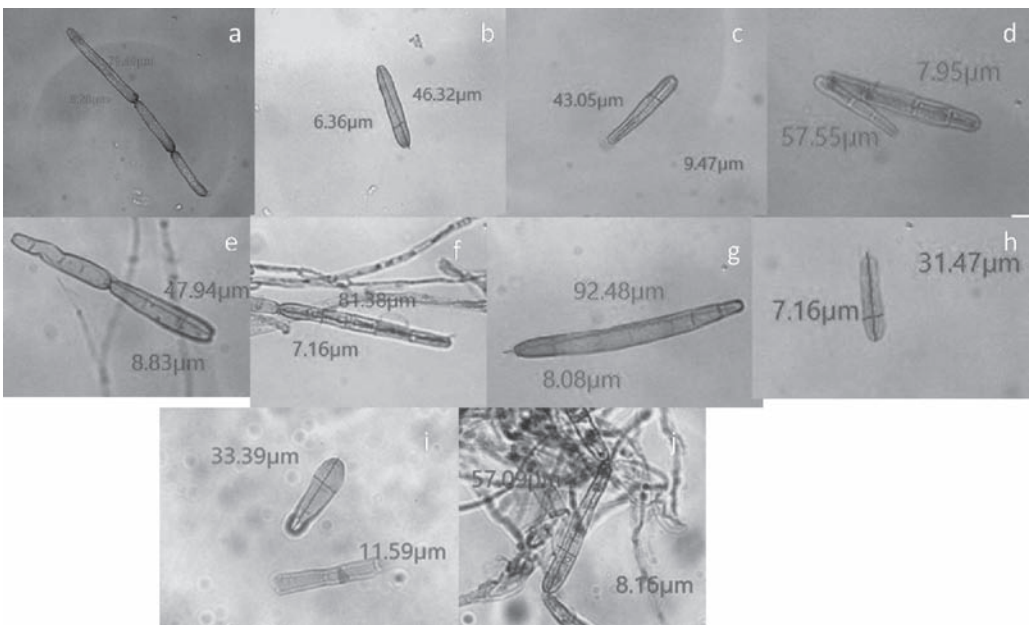

Fig. 2. Morphological variability of *Corynespora cassiicola* in different media

a-PD A b-PSA c-CDA d-CSA e-OMA

f-LCA g- LPA h-CLEA i-BgLEA j-GgLEA

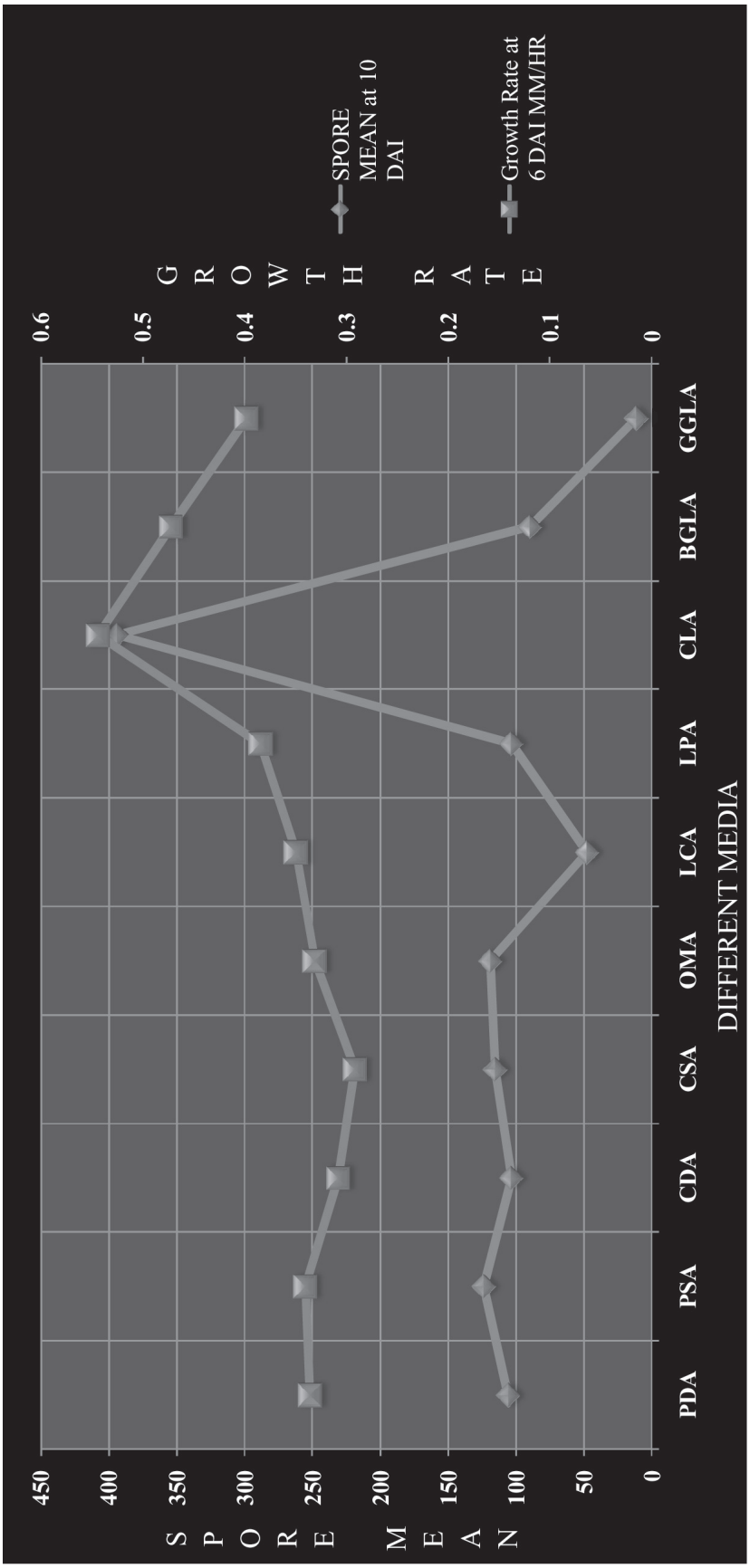

Fig. 3. Spore mean at 10 DAI and Growth rate at 6 DAI in different media

CONCLUSION

Among the different media tested, CLEA media showedthe highest radial growth with highest growth rate @ 6DAI and spore count @ 10 DAI (7.83.0 cm; 0.54 mm/hr;394x10^4±10.8) respectively.

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EVALUATION OF INTEGRATED MANAGEMENT STRATEGIES AGAINST STEM ROT OF GROUNDNUT (*Sclerotium rolfsii*) UNDER POT CULTURE

P. ARUNASRI*, B. PADMODAYA, M.REDDI KUMAR, S.R. KOTESWARA RAO, B. RAVINDRA REDDY and S. TIRUMALA REDDY

Department of Plant Pathology, S.V. Agricultural College,
Acharya N.G. Ranga Agricultural University, Tirupati - 517 502

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ABSTRACT

The study is aimed at determining the viability of sclerotia of *S. rolfsii* under pot culture studies. Eight combination fungicides were used. The fungicides were applied to soil by soil drenching (0.01%). Furthermore, 10 *Trichoderma* isolates (*T.asperellum* GT_1, GT_4, GT_{15}, GT_{23}, GT_{25}, GT_{60}, GT_{61},GT_{NT} and $GT_{w38(2)}$), five organic amendments and five ITK inputs (Modified Panchagavya, beejamrutham, jeevamrutham, cow urine and butter milk) were evaluated on sclerotial viability. Out of the eight fungicides, Hexaconazole 4% + Zineb 68% WP has inhibited sclerotial viability or germination to 98.88% (Overall mean). Talc based formulations of *Trichoderma* isolates were applied to soil @5g/kg soil. Organic amendments were ground into powder and applied to soil @30g/kg, whereas, ITK inputs applied as soil drenching. Results indicated that, at 5 cm depth of soil. Hexaconazole+Zineb has inhibited sclerotial germination to cent percent. At 10 cm and 20 cm also this combi fungicides has shown highest inhibition of germination or viability of sclerotia. In the case of *Trichoderma* isolates (*T.asperellum* GT_1, GT_4, GT_{15}, GT_{23}, GT_{25}, GT_{60}, GT_{61},GT_{NT} and $GT_{w38(2)}$.*Trichoderma asperellum* GT_4 has shown overall mean inhibition of sclerotial germination or viability to 100% with efficacy at all the three depths. Neem cake (3%) and gingelly cake have inhibited sclerotia to maximum extent but neem cake was proved to be effective in percent inhibition of sclerotia (97.78%). Out of the five ITK inputs, modified Panchgavya (10 dilution) was effective with overall mean inhibition of 96.66% and showed highest percentage of sclerotial inhibition at 5cm,10cm and 20cm when compared to the Control (untreated plot). The results showed the efficacy of ITK inputs, organic amendments and *Trichoderma* isolates in inhibiting sclerotial viability of *S. rolfsii* under pot culture in greenhouse conditions.

Key Words: *Sclerotium rolfsii,* stem rot, viability of sclerotia, combi fungicides, ITK inputs, Organic amendments, *Trichoderma*

*Corresponding Author E-mail i.d: PhD thesis submitted to Acharya N.G. Ranga Agricultural University, Guntur

INTRODUCTION

Sclerotium rolfsii Sacc. is a facultative soil borne fungal pathogen of major importance causing huge economic losses in various crop plants. This fungal pathogen is widely spread globally, infecting more than 500 plant species (Aycock,1966 and Punja,1965) including tomato, cucumber, brinjal, soybean, maize, groundnut, bean, watermelon. Diseases incited by *S.rolfsii* include collar rot, *Sclerotium* wilt, stem rot, charcoal rot, seedling blight, damping-off, foot-rot, stem blight and root-rot in different crop plants (Gopalakrishnan *et al.,* 2005). Groundnut (*Arachis hypogaea* L.) is an important edible oil legume in the semi-arid tropics. In recent years, *S. rolfsii* induced stem rot disease is causing significant yield losses to a tune of over 80% (Baskey *et al.,* 2020). The fungal pathogen perpetuates through sclerotia that play a major role as primary source of inoculum (Shoeraj Singh *et al.,* 2007). Sclerotia are the hyphal modifications that help the pathogen to mitigate unfavorable conditions. Mature sclerotia comprises three layers (Outer rind, cortical layer and a medullary layer at the centre (Deacon, 2006). Indiscriminate usage of chemical fungicides often lead to hazardous effects on human and animal health and also facilitates entry of chemicals into food chain. In this context, an Integrated and sustainable strategy for managing stem rot that juxtaposes using inputs like organic farming, natural farming, combi molecules that make use of organic amendments, botanical preparations, non chemical preparations and new chemicals can yield desirable results (Rajeswari *et al.,* 2018). Keeping this in view, the study was conducted to evolve an Integrated Disease Management strategy through application of fungicides, *Trichoderma* spp., ITK inputs and organic amendments.

As literature on survival sclerotia of *S.rolfsii* that causes stem rot of groundnut at different depths and at different conditions *viz.*, fungicides, *Trichoderma* spp., ITK inputs and organic amendments is scanty, the study was taken up to screen the viability of sclerotia at different depths and in the presence of various inputs.

MATERIAL AND METHODS

The experiment was conducted in the green house of Department of Plant Pathology, S.V. Agricultural College, Tirupati between 2018 and 2019.

Isolation and mass multiplication of *S. rolfsii*

The stem rot pathogen was isolated from stem rot affected groundnut plants by tissue segment method. The pathogen was purified by hyphal tip method and identified as *Sclerotium rolfsii* Sacc.(Rangaswami and Mahadevan, 1999) For screening fungicides, *Trichoderma* isolates, organic amendments and ITK inputs on sclerotial viability *S. rolfsii* was multiplied on sorghum grains (200 g) soaked overnight in water for pot experiment. About 100 g of soaked sorghum grains were taken in 500 ml capacity saline bottles tightly plugged. The bottles were then sterilized for 20 min at 121°C. After sterilization the sorghum seeds in saline bottles were inoculated with 5 mm mycelial disc from 7-day-old pure culture of *S. rolfsii* in each bottle and bottles were incubated for a 15 days at 27°C ± 2°C for proper mycelial growth and sclerotial population.

The following combination fungicides were used:

S. No.	Fungicide	Trade Name	Percent a.i.	Source of supply
1.	Azoxystrobin 11%+ Tebuconazole 18.3 %SC	Custodia	29.3%	Adama Pvt Ltd
2.	Azoxystrobin 7.1%+ Propiconazole 11.9% SE	Apropo	19%	Adama Pvt.Ltd
3.	Azoxystrobin 18.2% +Difenoconazole 11.4 %SC	Amistar top	29.6%	Syngenta
4.	Tebuconazole 50% + Trifloxystrobin 25% WG	Nativo	75%	Bayer
5.	Mancozeb 63% + Carbendazim 12%WP	Saaf	75%	UPL
6.	Flusilazole 12.5% + Carbendazim 25%WP	Lustre	37.5%	Dhanuka Agritech Ltd
7.	Hexaconazole 4% + Zineb 68% WP	Avtar	72%	Indofil industries Ltd
8.	Captan 70% + Hexaconazole 5% WP	Taqat	75%	Rallis India Ltd

Soil drenching with eight fungicides Azoxystrobin 11%+ Tebuconazole 18.3 %SC (Custodia); Azoxystrobin7.1%+ Propiconazole 11.9% SE (Apropo); Azoxystrobin 18.2% +Difenoconazole 11.4 %SC (Amistar top); Tebuconazole 50% + Trifloxystrobin 25% WG (Nativo); Mancozeb 63% + Carbendazim 12%WP (Saaf); Flusilazole 12.5% + Carbendazim 25%WP (Lustre); Hexaconazole 4% + Zineb 68% WP (Avtar) and Captan 70% + Hexaconazole (Taqat) were used with 0.01% concentration that was found effective on *S.rolfsii* in our previous studies were screened on viability of sclerotia in pot soil at different depths (5cm,10cm and 20 cm).

Trichoderma spp were isolated from rhizophere soil of groundnut on *Trichoderma* selective medium. They were identified as *Trichoderma* based on mycological keys (Barnett and Hunter, 1972). Talc based formulation of 10 native *Trichoderma* spp. which were found effective against *S.rolfsii* in our previous studies were prepared. *Trichoderma* spp were mass multiplied in potato dextrose broth medium incubated for 15 days, then the mycelial growth was used to prepare talc formulation which was applied @ 5g/kg soil.

Neem cake, Castor, Karanj, Cotton and gingelly cake were procured locally and ground to powder and applied to the soil @30g/kg soil.

Soil drenching with ITK inputs (by utilizing raw materials available at RARS Farm, Tirupati) was done in pot. Modified Panchagavya (10 dilution) beejamrutha, jeevamrutha, cow urine and butter milk (15%) were used.

Sclerotia produced in culture or soil subjected to the drying-washing treatments were placed in 30mm x 30 mm nylon mesh bags. Each bag contained 10 sclerotia from a single source after drying for treatment combination. Bags containing sclerotia were stapled to un-paint wooden stakes and positioned at three depths (5 cm, 10 cm and 20 cm), parallel to the soil surface .Stakes with attached bags containing sclerotia were lowered into pots and soil was packed by hand around the bags. The soil

surface was smoothed and levelled by hand. Sclerotia from each drying treatment were placed in each pot. Pots were arranged in a randomized complete-block design and replicated thrice. Treatments were imposed and moisture maintained upto saturation. Retrieval of sclerotia was completed after 10 days. These were washed with tap water then surface sterilized with 1% sodium hypochlorite ,placed over PDA plates and incubated at 26±2^{0}C for 24 hours. Number of germinated sclerotia in different treatments including control were recorded (Smith,1989). The percent inhibition of germination of sclerotia was calculated using the following formula.

$$\text{Percent inhibition} = \frac{\text{Total no. of sclerotia - No.of germinated sclerotia}}{\text{Total No. of sclerotia}} \times 100$$

Data was analsed statistically as per the procedures (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Efficacy of fungicides in soil application in inhibiting sclerotial viability

Among eight combination fungicides screened for efficacy on viability of sclerotia of *S.rolfsii* Hexaconazole+Zineb (Avtar) has inhibited the germination of sclerotia to maximum extent of inhibition (98.88%) (Table 1). At 5 cm and 10 cm depths all the fungicides Azoxystrobin 11%+ Tebuconazole 18.3 %SC; Azoxystrobin 7.1%+ Propiconazole 11.9% SE; Azoxystrobin 18.2% +Difenoconazole11.4 %SC; Tebuconazole 50% + Trifloxystrobin 25% WG,; Mancozeb 63% + Carbendazim 12%WP; Flusilazole 12.5% + Carbendazim 25%WP; Hexaconazole 4% + Zineb 68% WP have inhibited sclerotial germination to 100% , whereas, Captan 70% + Hexaconazole 5% WP has inhibited to 96.66%. at 20 cm depth. Hexaconazole 4% + Zineb 68% WP has inhibited sclerotial viability to a maximum of 96.66% (83.85) which is statistically significant when compared with other fungicides and this combination fungicide was found to be superior and least sclerotial inhibition of 90% was recorded with Captan 70% + Hexaconazole 5% WP when compared to other fungicides. In case of control (untreated), germination or viability of sclerotia was 100% at all the three depths under study (Table 1).

In the study, Hexaconazole 4% + Zineb 68% WP was found to be superior in inhibiting the sclerotial germination of *S.rolfsii.* Carbendazim and Mancozeb inhibited 100% sclerotial germination at 5 cm and 10 cm depths and 90% at 20 cm depth. Similar findings were reported by Madhavi and Bhattiprolu (2011) in chilli with hexaconazole, propiconazole and difenoconazole at 10 and 15 cm depths at 1000, 2000ppm and 3000ppm concentrations. Carbendazim and Mancozeb 0.2% has inhibited to an extent of 80 % at both depths at 1000 ppm. These findings were in accordance with Prabhu and Hiremath (2003) who proved that efficacy of systemic and non-systemic fungicides through soil drenching depends on the percolation of fungicides and they recorded decreased efficacy of fungicides with increase in depths. Theresearchers aslo reported that propiconazole and hexaconazole were effective at 2.5 cm but efficacy decreased with increase in depth but hexaconazole was found to be very effective even at 12.5 cm.

Efficacy of talc based formulation of *Trichoderma* spp. in inhibiting sclerotial viability

Among the 10 isolates of *T.asperellum* GT1,

GT4, GT15, GT23, GT25, GT60, GT61, GTNT and GTw38(2), the isolate *T.asperellum* GT4 has inhibited sclerotia of *S.rolfsii* to 100% at all the depths of 5cm,10cm and 20cm (Table 2). At 5 cm depth of soil in pot, all the ten isolates have inhibited sclerotial germination to maximum extent. At 10 cm depth only *T.asperellum* GT4 has inhibited sclerotia to 100 per cent whereas other isolates showed decline in inhibition. At 20cm depth of soil only *T.asperellum* GT4 has inhibited sclerotia to 100 percent, whereas, least inhibition of sclerotia was obtained by *T.asperellum* GT1 (73.33%) and *T.asperellum* GT11 (76.66%). Next best isolates in inhibiting the sclerotial germination were *T.asperellum* GT23,GT60 and GT61 (Table 2). Statistically, the inhibition of sclerotial germination by all the 10 *Trichoderma* isolates were on par with one another at 5cm depth. However, at 10cm depth, *T.asperellum* GT4 was on par with *T.asperellum* GT61 when compared to other eight isolates. Also, at a depth of 20 cm, *T.asperellum* GT4 has inhibited sclerotial germination to 100% and is statistically significant when compared to all other isolates.

T.asperellum GT4 was proved to be a potential isolate over others in inhibiting sclerotial germination showing 100% inhibition at all three depths. The other isolates have also shown significant inhibition. The findings are in accordance with the findings of Bhagat and Pan (2011) who reported that *Trichoderma* isolates ThrWB-1, ThrAN- 5, ThrAN-7, TvAN-3 and TVAN-5 have high competitive colonization of *S.rolfsii.* They also observed chlamydospore producing *Trichoderma* performed well and able to withstand soil mycostasis/fungistasis. Khattabi *et al.*(2004) who investigated on efficacy of seventy isolates of *Trichoderma* spp. on sclerotial viability of *S.rolfsii* and reported that all were found to be effective. Also, Raghavendra (2018) reported that *T.viride* isolate Tr-DM 66.6% has recorded highest sclerotial inhibition of *S.rolfsii* at $1X10^8$ conidia concentration. Furthermore, Jebaraj *et al.* (2012) also revealed that *T.viride* inhibited sclerotial germination of 58.16%. Kattabi *et al.* (2001) also reported that isolates ES, KB, NZ and KF1 of *Trichoderma harzianum* applied @ 10^7 conidia with per gram of soil inhibited viability of sclerotia placed at a depth of 15cm in a plastic bag to an extent of 53.3 % ,70.8 % ,65% and 49.2 per cent. Effect of fungicides and bioagent *T.viride* on sclerotial germination was studied by Raghavendra (2018). Ten sclerotia were placed in plastic cups filled with soil treated with the fungicides and *T.viride*, they observed that *T.viride* at $1x10^8$ conidia per ml was effective in inhibiting the scleriotial germination (33.33%) which was 66.66 per cent inhibition over control, whereas, among different fungicides mancozeb, tebuconazole and hexaconazole had completely inhibited the germination of sclerotia.

Efficacy of soil application of organic amendments in inhibiting sclerotial viability

At 10 cm depth, neem cake has inhibited sclerotial germination to cent percent at 3% concentration followed by karanj cake (93.33%). These are followed by gingelly cake that inhibited to 90% when compared to control (Table 3). Cotton and castor have inhibited to 80% and 70%. Statistically, neem cake was significantly effective to all other cakes whereas karanj and gingelly cake were on par with each other. At 10 cm depth neem cake has inhibited sclerotial germination to 96.66% and statistically also

significant when compared to all other cakes. Gingelly cake has inhibited to 83.33% followed by karanj cake that inhibited to 76.66% and least inhibition was obtained with cotton cake. Remaining cakes except neem cake were on par with each other. Even at 20 cm depth neem cake has significantly inhibited sclerotial germination to a maximum of 96.66% (Table 3), whereas, all other cakes were statistically on par with each other.

In the study, neem cake was found to be effective at all three depths in inhibiting the viability of sclerotia with mean inhibition of 97.78%. Gingelly cake was found to be the next best in inhibiting sclerotial germination with mean inhibition of 81.11%. These findings are in accordance with Rajeswari *et al.*(2018) who reported that neem cake was significantly superior to all other treatments by recording the lowest sclerotial germination of *Rhizoctonia solani* (23.33%) followed by groundnut (30%), gingelly (40%) and sunflower (50%) cakes at 15 percent concentration. Dubey and Pandey (2009) investigated on the mode of action of neem cake extracts or amendments (5%) on the sclerotial viability of *Macrophomina phaseolina* in soil. They concluded that volatile fungistasis inhibited sclerotial viability to a maximum of 97% than non-volatile fungistasis which inhibited to 77%. On decomposition, amendments such as neem cake release ammonia which make soil alkaline that act in mycostasis. Jebaraj *et al.*(2012) reported that among different organic amendments, maximum inhibition of sclerotia of *Macrophomina phaseolina* was recorded with 10% concentration of neem cake (62.48%) when compared to control under *in vitro* conditions. Blum and Kabana (2004) revealed that soil organic amendments such as benzaldehyde and velvetbean inhibited mycelial growth and viability of sclerotia of *S.rolfsii.*

Efficacy of soil drenching with ITK inputs in inhibiting sclerotial viability

Influence of ITK inputs MPG (10 dilution) beejamrutham, jeevamrutham, cow urine and butter milk (15%) on inhibition of sclerotial germination was investigated at 5 cm, 10 cm and 20 cm depth. Modified Panchagavya was found to be effective at all the three depths with overall mean inhibition of sclerotial germination of 96.66% (Table 4). At 5 cm depth MPG has inhibited sclerotia to cent percent but statistically on par with jeevamrutham which was next effective as inhibited sclerotia to 96.66%. At 10 cm depth MPG has inhibited sclerotia to an extent of 93.33%, whereas, jeevamrutham has inhibited to 86.66%. Least inhibition of sclerotial germination at 10 cm was recorded in case of cow urine. At 20 cm depth, inhibition of sclerotial germination was further increased to 96.66% which might me due to more penetration or activity of micro-organisms developed in MPG (Table 4).

In the study, MPG was proved to be effective in inhibiting the germination of sclerotia of *S.rolfsii.* This was in accordance with the findings of Karthika *et al.*(2017) who reported that dipping the sclerotia is the most effective treatment over fermented egg-lemon juice extract (10%), fermented weed extract (100%), lime solution (12.5%) and panchagavya (5%) that completely inhibited the mycelial regeneration from sclerotia of *S.rolfsii* at 24 h after dipping.

Table 1. Screening of combination fungicides on sclerotial viability of S. rolfsii (groundnut stem rot disease) under pot culture

Efficacy of new combination fungicides on sclerotial viability of *S.rolfsii*								
Fungicides	Depth						Overall mean no. of sclerotia germinated	Overall mean inhibition of sclerotia(%)
	5 cm		10 cm		20 cm			
	No.of sclerotia germinated*	Inhibition of sclerotia(%)	No.of sclerotia germinated*	Inhibition of sclerotia(%)	No.of sclerotia germinated*	Inhibition of sclerotia(%)		
Azoxystrobin 11%+ Tebuconazole 18.3 %SC	0.00	100.00 (90.00)	0.00	100.00 (90.00)	1.33	86.66 (68.82)	0.44	95.55
Azoxystrobin 7.1%+ Propiconazole 11.9% SE	0.00	100.00 (90.00)	0.00	100.00 (90.00)	1.33	86.66 (68.82)	0.44	95.55
Azoxystrobin 18.2%+ Difenoconazole 11.4 %SC	0.00	100.00 (90.00)	0.00	100.00 (90.00)	2.33	76.66 (61.19)	0.78	92.22
Tebuconazole 50% + Trifloxystrobin 25% WG	0.00	100.00 (90.00)	0.00	100.00 (90.00)	1.00	90.00 (71.53)	0.33	96.66
Mancozeb 63% + Carbendazim 12%WP	0.00	100.00 (90.00)	0.00	100.00 (90.00)	1.00	90.00 (71.53)	0.33	96.66
Flusilazole 12.5% + Carbendazim 25%WP	0.00	100.00 (90.00)	0.00	100.00 (90.00)	1.00	90.00 (71.53)	0.33	96.66
Hexaconazole 4% + Zineb 68% WP	0.00	100.00 (90.00)	0.00	100.00 (90.00)	0.33	96.66 (83.85)	0.11	98.88
Captan 70% + Hexaconazole5% WP	0.33	96.66 (83.85)	0.33 (83.85)	96.66	2.33	76.66 (61.19)	1.00	90.00
Control	10.00	0.00(0.00)	10.00	0.00(0.00)	10.00	0.00(0.00)	10.00	0.00
Overall mean	1.14	88.51	1.14	88.51	2.29	77.02	1.53	

* Mean of three replications; Figures in parenthesis are arc sine transformed values

C.D. 6.131	C.D. 6.143	C.D.7.882
SE(m) 2.048	SE(m) 2.052	SE(m)2.632
C.V. 4.472	C.V. 4.48	C.V.7.347

Table 2. Screening of *Trichoderma* isolates on sclerotial viability of S. rolfsii (groundnut stem rot disease) in under pot culture

Efficacy of new combination fungicides on sclerotial viability of *S.rolfsii*								
Trichoderma isolate	Depth						Overall mean no. of sclerotia germin-ated	Overall mean inhibition of sclerotia(%)
	5 cm		10 cm		20 cm			
	No.of sclerotia germinated*	Inhibition of sclerotia(%)	No.of sclerotia germinated*	Inhibition of sclerotia(%)	No.of sclerotia germinated*	Inhibition of sclerotia(%)		
T.asperellum GT1	0.00	100.00(90.00)	0.67	93.33(77.69)	2.67	73.33(58.98)	1.11	88.89
T.asperellum GT4	0.00	100.00(90.00)	0.00	100.00(90.00)	0.00	100.00(90.00)	0.00	100.00
T.asperellum GT11	0.33	96.66(83.84)	1.00	90.00(71.53)	2.33	76.66(61.19)	1.22	87.78
T.asperellum GT15	0.00	100 .00(90.00)	1.00	90.00(71.53)	2.33	76.66(61.19)	1.11	88.89
T.asperellum GT23	0.00	100.00(90.00)	1.00	90.00(71.53)	1.33	86.66(68.82)	0.78	92.22
T.asperellum GT25	0.33	96.66(83.84)	0.67	93.33(77.69)	2.33	76.66(61.19)	1.11	88.89
T.asperellum GT60	0.00	100.00(90.00)	1.00	90.00(71.53)	1.33	86.66(68.82)	0.78	92.22
T.asperellum GT61	0.33	96.66(83.84)	0.33	96.66(83.84)	1.67	83.33(66.11)	0.78	92.22
T.asperellum GTNT	0.00	100.00(90.00)	1.00	90.00(71.53)	1.67	83.33(66.11)	0.89	91.11
T.asperellum GTW38(2)	0.33	96.66(83.84)	1.00	90.00(71.53)	1.33	86.66(68.82)	0.89	91.11
Control	10.00	0.00(0.00)	10.00	0.00(0.00)	10.00	0.00(0.00)	10.00	0.00
Overall mean	1.26	87.41	1.89	81.11	2.70	72.96	1.95	80.49

* Mean of three replications. Figures in parenthesis are arc sine transformed values

C.D.10.955 C.D.9.488 C.D.6.678

SE(m)3.711 SE(m)3.214 SE(m)2.262

C.V.8.078 C.V.8.074 C.V. 6.421

Table 3. Screening of organic amendments on sclerotial viability of S. rolfsii (groundnut stem rot disease) under pot culture

Efficacy of organic amendments on sclerotial viability of *S.rolfsii*								
Organic amendments	Depth						Overall mean no. of sclerotia germinated	Overall mean inhibition of sclerotia(%)
	5 cm		10 cm		20 cm			
	No.of sclerotia germinated*	Inhibition of sclerotia(%)	No.of sclerotia germinated*	Inhibition of sclerotia(%)	No.of sclerotia germinated*	Inhibition of sclerotia(%)		
Neem cake	0.00	100.00 (90.00)	0.33	96.66 (83.84)	0.33	96.66 (83.84)	0.22	97.78
Castor cake	2.67	70.00 (56.76)	3.33	66.66 (54.76)	5.33	50.00 (44.98)	3.78	62.22
Karanj cake	0.33	93.33 (77.69)	2.33	76.66 (61.19)	4.33	56.66 (48.82)	2.33	75.56
Cotton cake	2.67	80.00 (63.40)	4.33	56.66 (48.82)	4.33	60.00 (50.74)	3.78	65.56
Gingelly cake	0.67	90.00 (71.53)	1.67	83.33 (66.11)	2.67	70.00 (56.76)	1.67	81.11
Control	10.00	0.00(0.00)	10.00	0.00(0.00)	10.00	0.00(0.00)	10.00	0.00
Overall mean	2.72	65.83	3.67	63.33	4.50	55.00	3.63	

* Mean of three replications; Figures in parenthesis are arc sine transformed values

C.D.	7.813	C.D.	9.673	C.D.	8.201
SE(m)	2.508	SE(m)	3.105	SE(m)	2.632
C.V.	7.25	C.V.	10.25	C.V.	9.59

Table 4. Screening of ITK inputs on sclerotial viability of S. rolfsii (groundnut stem rot disease) under pot culture

Efficacy of ITK inputs on sclerotial viability of *S.rolfsii*								
ITK inputs	**Depth**						Overall mean no. of sclerotia germinated	Overall mean inhibition of sclerotia(%)
	5 cm		**10 cm**		**20 cm**			
	No.of sclerotia germinated*	Inhibition of sclerotia(%)	No.of sclerotia germinated*	Inhibition of sclerotia(%)	No.of sclerotia germinated*	Inhibition of sclerotia(%)		
Modified Panchagavya(MPG)	0.00	100.00 (90.00)	0.67	93.33 (77.69)	0.33	96.66 (83.84)	0.33	96.66
Beejamrutham	1.00	90.00 (71.53)	1.67	83.33 (66.11)	2.33	76.66 (61.19)	1.67	83.33
Jeevamrutham	0.33	96.66 (83.84)	1.33	86.66 (68.82)	2.00	80.00 (63.40)	1.22	87.78
Cow urine	1.33	86.66 (68.82)	2.67	73.33 (58.98)	3.00	70.00 (56.76)	2.33	76.67
Butter milk	1.33	86.66 (68.82)	2.00	80.00 (63.40)	3.00	70.00 (56.76)	2.11	78.89
Control	10.00	0.00(0.00)	10.00	0.00(0.00)	10.00	0.00(0.00)	10.00	0.00
Overall mean	2.33	76.67	3.06	69.44	3.44	65.56	2.94	

* Mean of three replications; Figures in parenthesis are arc sine transformed values

C.D.	9.22	C.D.	9.641	C.D.	8.319
SE(m)	2.96	SE(m)	3.095	SE(m)	2.67
C.V.	8.03	C.V.	9.599	C.V.	8.619

CONCLUSION

Sclerotial viability of *S.rolfsii* (groundnut stem rot) based on sclerotial germination in presence of combi fungicides, *Trichoderma* isolates, organic amendments and ITK inputs was found at different depths of soil tested in pot culture as sclerotia play a major role as dormant survival structure in case of soil borne pathogens like *S.rolfsii.*

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PROPERTIES OF TANK SILTS OF SRIVAIKUNTUM BLOCK IN THOOTHUKUDI DISTRICT OF TAMIL NADU

M. PARAMASIVAN* and N. SENTHIL KUMAR

ICAR – KVK, Tamil Nadu Agricultural University, Virinjipuram – 632 104

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ABSTRACT

Tank silt samples (0-30 cm) fifteen each from the tanks of non system and system in Srivaikuntum block of Thoothukudi district were collected to assess the physico-chemical properties and fertility status of. Majority of the samples showed neutral to slightly saline in reaction non saline in both non system and system tanks. Organic carbon content was found to be higher in tank silts of system tanks as compared to non system tanks. Both silts were high in available nitrogen, phosphorus and potassium. How ever, the clay, silt, water holding capacity and the macro nutrients were also high in tank silts of system. Available micronutrients in all the tank silt samples of non system and system were found adequate. The macro and micronutrients were found to be significantly and positively correlated with pH, EC and organic carbon.

Key words: Tank silt, non system, system physico-chemical properties, fertility, macro and micronutrients

INTRODUCTION

Tank silt application to agricultural field is the age old traditional practice of southern India. Removal of tank silt and its application on agricultural lands is a traditional activity done by farmers for sustainability and productivity. Application of tank silt as an organic amendments to the sandy soil is economically viable for improving the soil physico-chemical properties. This is a common practice to maintain soil productivity in southern district of Tamil Nadu. Tank silt application is more in rainfed and garden lands than the alluvial soils of river basin.

Continuous intensive cultivation, imbalanced application of chemical fertilizers prevalent in the area coupled with erratic rainfall in semi arid region is resulting in soil health deterioration. Tank silt application is the age old traditional practice in this region aimed at sustaining soil health and productivity. Despite large scale adoption of this practice, here is no systematic study to characterize the physico-chemical properties and fertility status of tank silt. Detailed study on tank silt characterization is essential to recommend as a organic

*Corresponding Author E-mail i.d: paramusoil@gmail.com

amendment to constrained soils,. Keeping this in view, an attempt was made to assess the physico-chemical properties and fertility status of the tank silt of Srivaikuntum block of Thoothukudi district.

MATERIAL AND METHODS

Study area

Srivaikuntum block is located at 9^0 16' of North latitude and 77^0 92' of East longitude with an altitude of 90 m above mean sea level (MSL) in Thoothukudi district of Tamil Nadu. Geologically the area comprises of recent alluvium of Tambiraparani river basin. The major landform is very gently sloping (1-3%) and nearly level (0-1). The climate is semi arid with hot summer and cool winter with mean a annual rainfall of 740 mm and average annual temperature of 37^oC.

In Srivaikuntum block, two types of tanks *viz.,* non-system and system were identified for this study. Non-system tanks receive water from annual precipitation only, whereas the system tanks receive water from the source of river, dam and canals in addition to annual precipitation. Based on its geography and water sources, the tanks were selected for this study. Fifteen (15) tanks each from non-system and system categories were identified for the collection of silt samples. In non-system tanks, the water is available during 3-5 months in monsoon season. In the study area, the system tanks, the tanks will receive water from both rainfall, river (Tambiraparani) and dams (Papanasam and Manimutharu) through the canal. In these tanks, water storage is witnessed for a longer period and they become dry only once in three to five years.

Tank silt samples (0-30 cm) from thirty village tanks of non system and system were collected in the mid of April 2017 - 2018 in Srivaikuntum block. After drying at room temperature, broken clods were crushed into smaller particle with the help of wooden roller and finally passed through 2 mm sieve. The physical properties *viz.,* bulk density, particle density and pore space were determined (Hillel, 1971 and Jackson 1973). The tank silt reaction (pH) and electrical conductivity (EC) were determined in 1:2.5 (silt : water) suspension by standard procedure described by Jackson (1973). Soil texture was determined by the method prescribed by Keen and Raczkowski (1921). Organic carbon was determined by wet oxidation method (Walkley and Black 1934). Available N was determined by alkaline permanganate oxidizable N as described (Subbaiah and Asija 1956), available phosphorus (Olsen *et al.,* 1954) and available potassium by flame photometry after extracting 1 N NH_4OAC (Jackson 1973). The available Zn, Cu, Mn and Fe were extracted with DTPA extractant (Lindsay and Norvell 1978) and the concentration of nutrients were determined on Atomic Adsorption spectrophotometer (AAS).

RESULTS AND DISCUSSION

The physico-chemical properties of tank silt of both area are presented in table 1-4. The non-system tank silt exhibited clay loam texture and clay content varied from 63.6 to 72.7% with a mean value of 69.3%, silt content ranged from 18.1 to 23.3% with a mean value of 20.3% and sand content ranged from 7.3 to 14.6% with a mean value of 10.42%. On the other hand, system tank silt also showed clay loam texture. Its clay content varied from 59.6 to 72.4% with a

mean value of 65.3%, silt content ranged from 24.8 to 33.5% with a mean value of 29.4% and sand content ranged from 2.1 to 10.1 % with a mean value of 5.3%. The bulk density and particle density of the non system tank silt ranged from 1.22 to 1.34 and 2.32 to 2.57 Mg m^{-3} with a mean value of 1.29 and 2.43 Mg m^{-3}, while in the system tank silts it ranged from 1.17 to 1.28 and 2.14 to 2.42 Mg m^{-3} with a mean value of 1.23 and 2.29 Mg m^{-3}, respectively. Granulometric data revealed that the distribution of particles vary from tank to tank depending on their physiographic locations, climatic condition and soil parent materials (Srinivasan *et al.,* 2015). The mean values of water holding capacity, pore space and volume expansion in the non system tank silt were 46.2, 46.7 and 9.8 %, respectively. In system tank silts its mean values were 57.3, 46.5 and 13.5 %, respectively (Tables 1&3). These indicated that the sediments eroded from the fine grained soil such as alluvial clay and heavy textured soil. The rate of deposition depended upon the flow velocity of water. The tank silt of arid non system tanks showed varied properties in its particle size distribution. The mechanical component of tank silt was mainly by the soil type from which it is eroded. Similar results were observed by Rakesh Tiwari *et al.,* (2014).

The pH of tank silt from non-system ranged from 6.8 to 8.2 and it ranged from 6.7 to 7.8 in system tanks. The EC varied from 0.18 to 0.62 dSm^{-1} in non-system tank silt and in system tanks it varied from 0.18 to 0.73 dSm^{-1}. The pH and EC of these tank silts varied from tank to tank with lowest of 0.18 dSm^{-1} to the highest of 0.73 dSm^{-1} (Tables 2&4). This might be due to collection from different landforms with different soil parent materials of the two areas Binitha, (2006) and Osman *et al.,* (2007).

In non-system tank silt, the organic carbon content ranged from 0.55-1.21 % and in system tanks, it varied from 0.74 to 1.75 %. The organic carbon content in the tank silt depend upon the weather and ecosystem of the region. The high organic carbon content in the tank silt might be due to well decomposition of settled residue under the water of tanks (Anil Kumar *et al.,* 2015).

The range and mean values of available N, P, K and cationic micronutrients are presented in Table 2 &4. The available N, P and K in non-system tank silt varied from 315 to 540, 17 to 38 and 197 to 573 kg ha^{-1}, respectively with the mean values of 408, 35, 362 kg ha^{-1}, respectively. In the system tank silt the available macronutrients ranged from 491 to 848, 18 to 47 and 252 to 388 kg ha-^{1}, respectively with the mean values of 635,38 and 312 kg ha^{-1}, respectively. The available Zn content of non-system tank silt ranged from 1.38 to 2.61 mg kg^{-1} with an average value of 1.79 mg kg^{-1} while in system tank silt the content ranged from 1.76 to 3.53 mg kg^{-1} with a mean value of 2.53 mg kg^{-1}. Available Cu, Mn and Fe content were found at sufficient level in non-system tank silts with mean values of 2.15, 2.91, 9.56 mg kg^{-1}, respectively and 3.11, 3.90, 10.11 mg kg^{-1}, respectively in system tank silts. The high level of available macronutrients in non-system tank silt may be due to silt collected from rainfed soils having parent materials with apatite, monmorillonite and smectite minerals. The high content of N, P, K and cationic micronutrients might be due to soil, topography, rainfall, quantity of water in tank, period of water storage, activities of micro

Table 1. Physical properties of tank silt of non-system tanks

Sl.No.	Tank / Village	Clay(%)	Silt (%)	Sand (%)	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Pore space (%)	Water holding capacity (%)	Volume expansion (%)
1.	Srimoolakkarai	66.2	20.4	13.4	1.28	2.48	48	47.6	9.2
2.	Manakkkarai	72.5	19.4	8.1	1.31	2.55	49	46.3	10.1
3.	Aniyaparanalluir	72.7	19.4	7.9	1.32	2.57	49	47.8	9.7
4.	Vallanad	71.4	20.3	8.3	1.26	2.46	49	48.8	11.5
5.	Vadavallanad	69.3	20.7	10.0	1.27	2.48	49	45.5	10.6
6.	Alwarkarkulam	63.6	21.8	14.6	1.27	2.45	48	44.6	9.1
7.	Uzhakkudi	70.2	22.5	7.3	1.22	2.46	51	50.4	8.7
8.	Kaliyavoor	69.1	19.3	11.6	1.33	2.32	43	44.2	9.8
9.	Poovani	71.7	18.7	9.6	1.34	2.35	43	40.5	11.8
10.	Deivaseyalpuram	65.3	21.0	13.7	1.26	2.35	46	44.7	8.8
11.	Singathakkuruchi	69.4	18.1	12.5	1.31	2.38	45	46.6	9.3
12.	Sawyerpuram	68.4	20.4	11.2	1.27	2.34	46	45.8	9.6
13.	Sekkarakudi	68.4	23.3	8.3	1.38	2.49	45	50.2	10.1
14.	Vadakku karaseri	69.5	19.2	11.3	1.32	2.34	44	44.4	9.5
15.	Meenakshipetti	71.2	20.3	8.5	1.28	2.38	46	45.7	8.9
	Range value	63.6–72.7	18.1–23.3	7.3–14.6	1.22–1.34	2.32–2.57	44-51	40.5–50.4	8.7–11.8
	Mean value	69.26	20.32	10.42	1.29	2.43	46.7	46.2	9.8

Table 2. Chemical properties and available nutrient content in tank silt of non-system tanks

Sl.No.	Tank / Village	pH	EC (dSm^{-1})	Organic carbon	Available macro nutrients(mg kg^{-1})			Available micronutrients(mg kg^{-1})			
				(%)	N	P	K	Zn	Cu	Mn	Fe
1.	Srimoolakkarai	7.6	0.62	0.78	368	22	197	1.38	1.54	2.82	08.60
2.	Manakkkarai	6.9	0.31	1.13	436	27	202	1.53	1.82	3.46	07.25
3.	Aniyaparanalluir	8.2	0.44	1.11	540	21	552	1.78	2.42	2.86	06.55
4.	Vallanad	7.3	0.28	1.16	391	30	265	1.88	1.61	2.04	10.14
5.	Vadavallanad	7.6	0.22	0.69	356	25	275	1.56	1.47	2.16	11.24
6.	Alwarkarkulam	7.1	0.29	0.91	315	28	215	1.41	1.43	2.12	10.80
7.	Uzhakkudi	7.8	0.25	0.55	451	25	443	1.74	2.36	3.61	07.82
8.	Kaliyavoor	7.6	0.23	0.94	456	20	487	2.02	2.17	3.02	08.33
9.	Poovani	7.8	0.55	1.02	444	17	427	1.43	2.06	3.28	09.42
10.	Deivaseyalpuram	7.4	0.23	0.63	376	32	281	1.75	2.55	2.69	13.23
11.	Singathakkuruchi	7.2	0.37	0.71	297	28	355	2.05	2.13	3.14	09.44
12.	Sawyerpuram	6.8	0.18	1.06	423	38	224	1.92	2.83	3.42	17.64
13.	Sekkarakudi	8.2	0.31	1.21	521	23	573	2.61	3.05	4.57	08.26
14.	Vadakku karaseri	7.6	0.43	0.88	360	19	412	1.72	3.02	2.18	07.13
15.	Meenakshipetti	7.4	0.29	1.18	380	20	522	2.07	1.74	2.33	07.53
	Range value	6.8-8.2	0.18-0.62	0.55-1.21	315-540	17-38	197-573	1.38-2.61	1.43-3.05	2.04-4.57	6.55-17.64
	Mean value	7.5	0.33	0.93	408	35	362	1.79	2.15	2.91	9.56

Table 3. Physical properties of tank silt of system tanks

Sl.No.	Tank / Village	Clay(%)	Silt (%)	Sand (%)	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Pore space (%)	Water holding capacity (%)	Volume expansion (%)
1.	Tholappanpannai	62.5	30.4	7.1	1.23	2.24	47	54.2	12.8
2.	Padmanapa mangalam	60.4	29.5	10.1	1.28	2.28	44	58.4	12.7
3.	Srivaikuntum	64.3	31.4	4.3	1.22	2.18	44	55.2	13.4
4.	Sivagalai	70.8	25.3	3.9	1.20	2.21	46	57.8	14.8
5.	Perur	71.2	26.7	2.1	1.24	2.38	48	59.2	15.5
6.	Perunkulam	67.8	29.3	2.9	1.27	2.32	45	56.5	14.5
7.	Vasavapappuram	60.4	33.5	6.1	1.19	2.38	50	63.5	11.8
8.	Nanalkadu	64.5	31.4	4.1	1.21	2.14	44	59.6	13.5
9.	Mangalakkuruchi	72.4	24.8	2.8	1.28	2.17	47	57.7	15.8
10.	Pudhukkudi	63.3	28.2	8.5	1.24	2.24	45	53.3	12.7
11.	Agaram	65.4	28.8	5.8	1.26	2.28	45	52.2	12.3
12.	Kongarayakkuruchi	64.7	29.4	5.9	1.27	2.31	45	56.1	12.6
13.	Thiruppuliankudi	65.2	31.3	3.5	1.18	2.34	50	60.4	12.6
14.	Maramangalam	67.4	29.2	3.4	1.28	2.37	46	55.4	15.2
15.	Aaram pannai	59.6	31.5	8.9	1.17	2.42	52	60.3	12.3
	Range value	59.6-72.4	24.8-33.5	2.1-10.1	1.17-1.28	2.14-2.42	44-52	52.2-63.5	11.8-15.8
	Mean value	65.3	29.4	5.3	1.23	2.29	46.5	57.3	13.5

Table 4. Chemical properties and available nutrient content in tank silt of system tanks

Sl.No.	Tank / Village	pH	EC (dSm^{-1})	Organic carbon	Available macro nutrients(mg kg^{-1})			Available micronutrients(mg kg^{-1})			
				(%)	N	P	K	Zn	Cu	Mn	Fe
1.	Tholappanpannai	6.7	0.27	0.89	585	43	252	4.33	2.45	13.14	20.52
2.	Padmanapa mangalam	6.9	0.35	0.76	562	45	288	4.08	2.83	12.86	22.23
3.	Srivaikuntum	7.4	0.48	1.16	627	39	302	5.53	3.56	16.43	19.58
4.	Sivagalai	7.6	0.31	1.23	672	48	281	4.06	2.36	12.04	22.23
5.	Perur	7.3	0.28	0.95	534	31	342	3.20	4.38	15.56	24.73
6.	Perunkulam	7.5	0.25	1.75	848	32	315	3.14	4.05	14.25	23.88
7.	Vasavapappuram	6.7	0.18	1.02	623	43	366	2.96	2.24	13.37	20.61
8.	Nanalkadu	7.6	0.31	0.94	645	31	262	2.76	2.86	12.59	16.53
9.	Mangalakkuruchi	7.2	0.58	1.68	756	37	388	3.24	5.64	15.55	17.50
10.	Pudhukkudi	7.4	0.32	0.83	543	30	295	2.01	2.55	14.86	18.42
11.	Agaram	7.8	0.73	1.24	663	33	282	3.05	3.64	13.74	16.33
12.	Kongarayakkuruchi	6.8	0.20	0.88	555	36	343	4.88	2.16	12.08	21.24
13.	Thiruppuliankudi	7.2	0.23	1.33	686	47	365	4.86	3.05	15.62	22.83
14.	Maramangalam	7.6	0.42	1.51	742	39	312	5.08	5.04	14.23	16.28
15.	Aaram pannai	6.7	0.22	0.74	491	37	284	2.81	3.33	12.22	18.73
	Range value	6.7-7.8	0.18-0.73	0.74-1.75	491-848	30-48	252-388	2.01-5.53	2.16-5.64	12.04-16.43	16.28-24.73
	Mean value	7.23	0.34	1.13	635	38	312	3.74	3.34	13.90	20.11

Table 5. Relationship between available nutrients and relevant soil properties of non-system tank silts

	pH	EC	Organic carbon	Clay	Silt	Sand
Avail. N	0.603	0.024	0.461*	0.480	0.217	-0.657
Avail. P	-0.667	-0.589	-0.124	-0.343	0.215	0.290
Avail. K	0.754	0.062	0.268*	0.417	0.065	-0.498
Avail. Zn	0.265	-0.378	0.361*	0.139	0.269	-0.313
Avail. Cu	0.297	-0.109	0.071	0.052	0.125	-0.132
Avail. Mn	0.277	0.001	0.149	0.145	0.293	-0.334

Table 6. Relationship between available nutrients and relevant soil properties of system tank silts

	pH	EC	Organic carbon	Clay	Silt	Sand
Avail. N	0.526	0.302	0.951*	0.528	-0.213	-0.646
Avail. P	-0.347	-0.202	-0.002	-0.157	0.121	0.136
Avail. K	-0.186	-0.065	0.419*	0.351	-0.135	-0.435
Avail. Zn	-0.065	0.011	0.169	0.065	0.113	-0.216
Avail. Cu	0.377	0.534	0.670*	0.606	-0.439	-0.549
Avail. Mn	0.295	0.341	0.436*	0.370	-0.133	-0.469
Avail. Fe	-0.278	-0.575	-0.044	0.137	-0.083	-0.140

organisms and other sources of organic residues in the tank. Similar findings were observed earlier by Osman Mohammed *et al.,* (2009).

The correlation study of available nutrients with relevant tank silt properties are presented in table 5 and 6. Available nitrogen, potassium and zinc were found to be significantly and positively correlated with organic carbon in non-system tank silt (r=0.461, 0.365 and 0.265) and system tank silt (r= 0.951, 0.419 and 0.670) at 1% level significance. Nitrogen, potassium and zinc being integral part of organic matter, the amount of organic carbon determines available N,K and Zn status. Phosphorus was negatively correlated with organic carbon. However, pH was negatively correlated with these available nutrients in system tank silts. These findings are in conformity with those of Chandan Kumar Jha *et al.,* (2015).

CONCLUSION

Among the two regions tanks, The physico-chemical properties *viz.,* bulk density, particle density, pore space, and water holding capacity

are significant and favorable in system tanks. Also the available macro and micronutrients are higher in system tank silts. In non-system tank silts, physic-chemical properties are not favorable with low nutrient content due to climatic factors *viz.,* erratic rainfall, minimum duration of water stagnation with minimum storage of rain water that led to lower deposition of eroded residue and surface soil from the surrounding areas. Whereas, in system tanks, the physico-chemical properties and the available macro and micronutrients are higher and therefore advisable to apply to agricultural fields.

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ASSESSMENT OF LEAF CHLOROPHYLL CONTENT IN PARTS OF THE THAR DESERT USING REMOTE SENSING TECHNIQUES

SURAJ KUMAR SINGH, JAGPAL SINGH TOMAR, AGNI KUNDU, SUDHANSHU and SRUTI KANGA*

Centre for Sustainable Development, Suresh GyanVihar University, Jaipur - 302025

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ABSTRACT

Recent advances in remote sensing led to an improved approach for monitoring vegetation properties depending on chlorophyll content. The study brings out the importance of indices as valuable approach to measure the chlorophyll content in Luni Upper Basin (Rajasthan and Gujarat). Chlorophyll content was measured using four different vegetation indices, *i.e.,* modified chlorophyll absorption ratio index, chlorophyll index green model, chlorophyll index red-edge model, and normalized differential vegetation index. In addition, the Landsat-8, Operational Land Imager (OLI) for 2015 with spatial resolution of 30 m, and Sentinel-2 multispectral imagery of 2020 with a spatial resolution of 10 m was used for all the three seasons *Rabi*, *Kharif*, and *Zaid* (2015-2020) to estimate the vegetation cover and chlorophyll content in plant leaves. The results showed 25% area was with good vegetation and high chlorophyll content, and 35% area was under unhealthy vegetation with low chlorophyll content in *the Kharif* season. In the *case of Rabi* season, 15% area was under good vegetation and 40% area was under vegetation with low chlorophyll content was recorded. In the *Zaid* season, 10% area with good vegetation, and 30% area with low vegetation chlorophyll content was estimated. The results indicated that in the arid zone, where primarily low and moderate vegetation cover were recorded contains low and medium chlorophyll content in the plant.

Keywords: Chlorophyll, NDVI, Vegetation Index, Remote Sensing

INTRODUCTION

Chlorophyll, a primary natural pigment for green plants, is a vital variable in assessing physiological status. The content of chlorophyll (Chl) serves as the key indicator for the photosynthetic process that transforms light energy into chemical energy for growth and survival. It has a distinct role in green plants' physiology, production, and economy (Broge and Mortensen, 2002). The photosynthesis rate of a plant depends on the amount of chlorophyll per unit area. The quantity of chlorophyll in leaf tissue depends on the availability of nutrients and environmental stress such as drought, salinity, andextreme temperature (Le Maire *et al*., 2004). Many researchers used spectral

*Corresponding Author E-mail i.d: shruti.kanga@mygyanvihar.com

means of calculating plant leaf chemistry (Gitelson *et al*., 2002). As a vegetative parameter, the leaf chlorophyll (Chl) content provides valuable knowledge on the physiological situation and the phenotypic patterns of plants. Therefore, reliable, efficient, and viable methodologies are required to estimate non-destructive remote determination of the chlorophyll content of the leaves to calculate the variance in chlorophyll (Chl) over conventional methods, which are time-consuming and expensive measurements. Extensive research has been done to identify the spectral sensitivity of 'chl' and its sensitive areas from a vegetation spectrum andquantification using waveband combinations and concluded that vegetation indices (Vis) are helpful in large-scale biomass phenotyping, studies on the green, nitrogen content, pigment composition, and photosynthetic conditions (Croft *et al*., 2014). Various studies have shown that the adjacent Chl (700 nm) and green band (550 nm) maximum absorption wavelengths are most susceptible to an extensive array of Chl contents. Several researchers have also developed a leaf structure algorithm insensitive to variations in the calibration (Cui and Zhou, 2017).

The Normalized Difference Vegetation Index (NDVI) is one of the most commonly used and implemented indices calculated from multispectral information (Xue and Su, 2017; Natalie *et al*., 2016). Many researchers have compared NDVI with LAI, which is defined as the total area of single-sided leaves per total soil area. Remote sensing imagery gives information on plant and tree leaf and canopy spectral properties (Croft *et al*., 2020; Lu *et al*., 2015). One of the most popular validation processes is indirect or direct correlations between measurements taken in situ, such as LAI, biomass, growth, vigor, and the vegetation parameters of interest, such as plant cover. NDVI is somewhat affected by various factors, including soil brightness, soil colour, atmosphere, cloud, cloud shadow, and leaf canopy shadow (Hunt Jr *et al*., 2013; Mancino *et al*., 2020). The MCARI represents the amount of chlorophyll absorbed and the responsiveness to changes in chlorophyll concentrations and Leaf Area Index (LAI). The MCARI measures do not respond to differences in light conditions, such as soil or other non-photosynthetic materials' reflected. To compute the Red-Edge Index, is essential (Zhou *et al*., 2020; Cui *et al*., 2019) which is sensitive to chlorophyll concentration, with medium to high amounts having a noticeable effect. In this case, red-edge indicates crop health since the chlorophyll concentration is higher at the middle and late stages of the crop's development. In contrast to the red band absorbed by the chlorophyll in the first few layers, the red-edge band can be piercing the leaf surface better than the red band.

MATERIAL AND METHODS

Region of research is the area of Luni's High Basin and the Southern portion of Rajasthan, and the northern portion of Gujarat, beside India-Pakistan (24°23'50.5" to 27°21'35.36" N and 70°44'29.58" to 75°05'07.09" E). The Luni Upper Basin research area covers 70174 sq. km, including Rajasthan and Gujarat. It occupies one-third of Rajasthan and two districts of northern Gujarat.

The improved image quality, compared to the previous Landsat-7, the introduction of new spectral channels, and the availability of constant

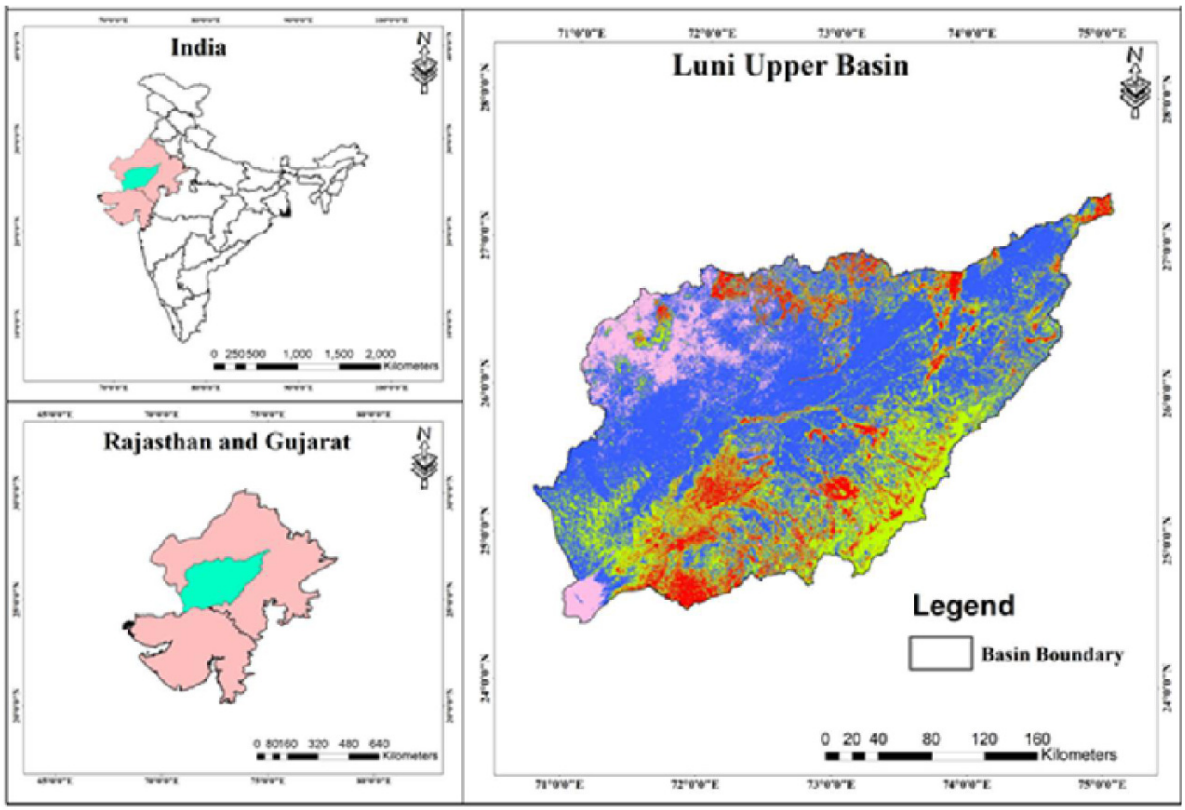

Fig.1. Location Map of Luni Upper Basin

acquisitions makes Landsat-8 a valuable tool for monitoring and analyzing the territory. There are two primary sensors of Landsat 8: the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS).The Operational Land Imager (OLI) consists of nine spectral bands with 15 m, 30 m, and 60 m spatial resolution. The Thermal Infrared Sensor (TIRS) contains two thermal bands with a spatial resolution of 100 m.

Sentinel-2 is one of the superior satellites, which provides freely available data for long-term high-frequency remote sensing applications. Sentinel-2A and Sentinel-2B decorated with Multispectral Instrument (MSI) able of acquiring 13 bands information at different spatial resolution (10 m, 20 m, and 60 m). Sentinel-2A is more popular due to its excellent features, including more bands, short revisit time and higher spatial resolution. The Sentinel-2 gives more details using the NIR band and the SWIR band, which are helpful for agriculture, forest monitoring, and natural disaster management applications. All Sentinel-2A satellite images could be freely downloaded from Sentinel Hub, developed by ESA and USGS Earth Explorer.

In this analysis, four different types of vegetation indices were used to estimate Chl from natural vegetation for the estimation of the coverage area of vegetation (2015-2020). NDVI values range from –1 to +1. Second, Chlorophyll Modified Chlorophyll absorption index 2 is a critical vegetation index that calculates chlorophyll depth in plants. The other two are the Green Chlorophyll ModelS and Red-edge Chlorophyll (Table 1).

Table 1.The formula used for vegetation index

Name of the Vegetation index	Formula
Normalized Different Vegetation Index	$NDVI = {}_{NIR-R/NIR+R}$
Modified Chlorophyll Absorption Ratio Index 2	$MCARI2= 1.5[2.5(R_{800}-R_{670})-1.3(R_{800}-R_{550})] / SqRoot[(2R_{800}+1)^2-\{6R_{800}-5SqRoot(R_{670})\}-0.5]$
Chlorophyll Green Model	$CI_{Green} = (R_{800} / R_{550}) -1$
Chlorophyll Red-edge Model	$CI_{Red-edge} = (R_{800} / R_{705}) -1$

An elementary form of image segmentation is called image thresholding. It is a method to convert a grayscale or full-color image into a binary image. Typically, this is done to aid in image processing by segregating object or foreground pixels from background pixels. We use thresholding to convert images from color or grayscale to binary images, which means the images have to be either completely black or completely white. In practice, it is common to employ thresholding to isolate regions of interest in a snap while disregarding sections not to be included. This satellite image was thresholded based on various indices to map the changes and see which areas had increased or decreased in cholorphyll content. Finally, density was sliced into three groups to examine chlorophyll changes: low, medium, and high values.

RESULTS AND DISCUSSION

NDVI

Normalized Difference Vegetation Index is one of the most commonly used algorithms (NDVI). It is notably beneficial for large-scale vegetation monitoring due to its ability to counteract surface slope, illumination, and viewing angle approach was used to identify this plant cover. These readings for barren rock or sand areas are normally low (for example, 0.1 or less). When shrubs and grasslands or crops are sparse, NDVI values are likely to be moderate (approximately 0.2 to 0.5). Dense vegetation such as temperate and tropical forests or crops at their peak development stage yields NDVI values of roughly 0.6 to 0.9. NDVI map were reclassified values ranging from non-vegetation, low vegetation (0.2 to 0.5), and high vegetation (0.5 to 1.0). Normalized difference vegetation index in *Kharif* (rainy/s-w monsoon) season shows that during 2015-19, about 2% area is the non-vegetate area with no chlorophyll contents, 36% area under poor vegetation cover, and unhealthy vegetation with low chlorophyll contents whereas 42% area under moderate vegetation with medium chlorophyll pigments. In this season, the precipitation rate is usually high compared to other seasons. Due to rainfall, vegetation growth increases, leading to good vegetation cover, decreasing the non-greenery area with 20% area under good vegetative cover with healthy vegetation. The period that extends from March to June is known as the *Zaid* season with high temperatures. In this season, the earth's surface becomes dehydrated because the sun's rays directly fall on the surface. In this arid region, the temperature becomes more as well as the

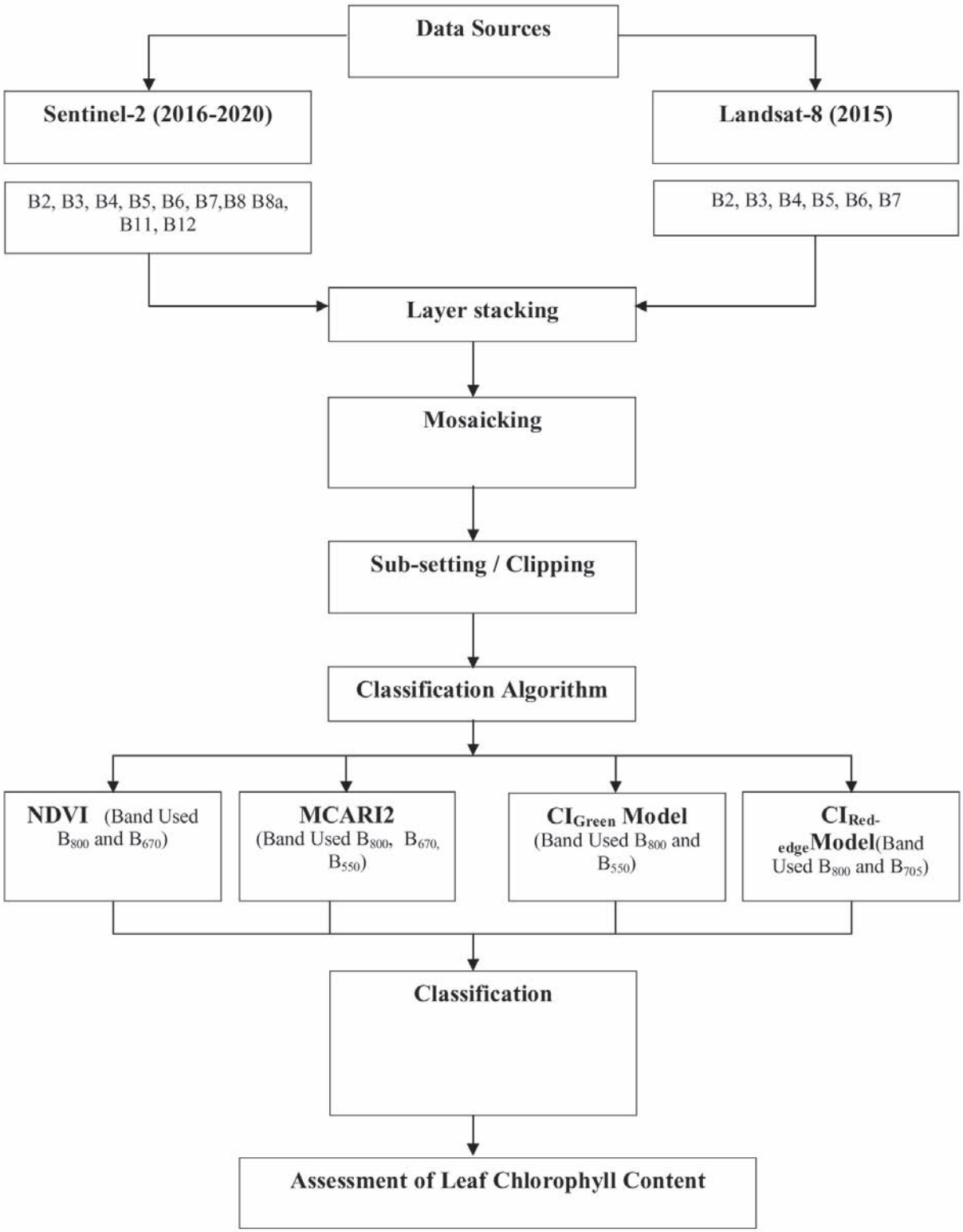

Fig. 2. Flowchart of Methodology

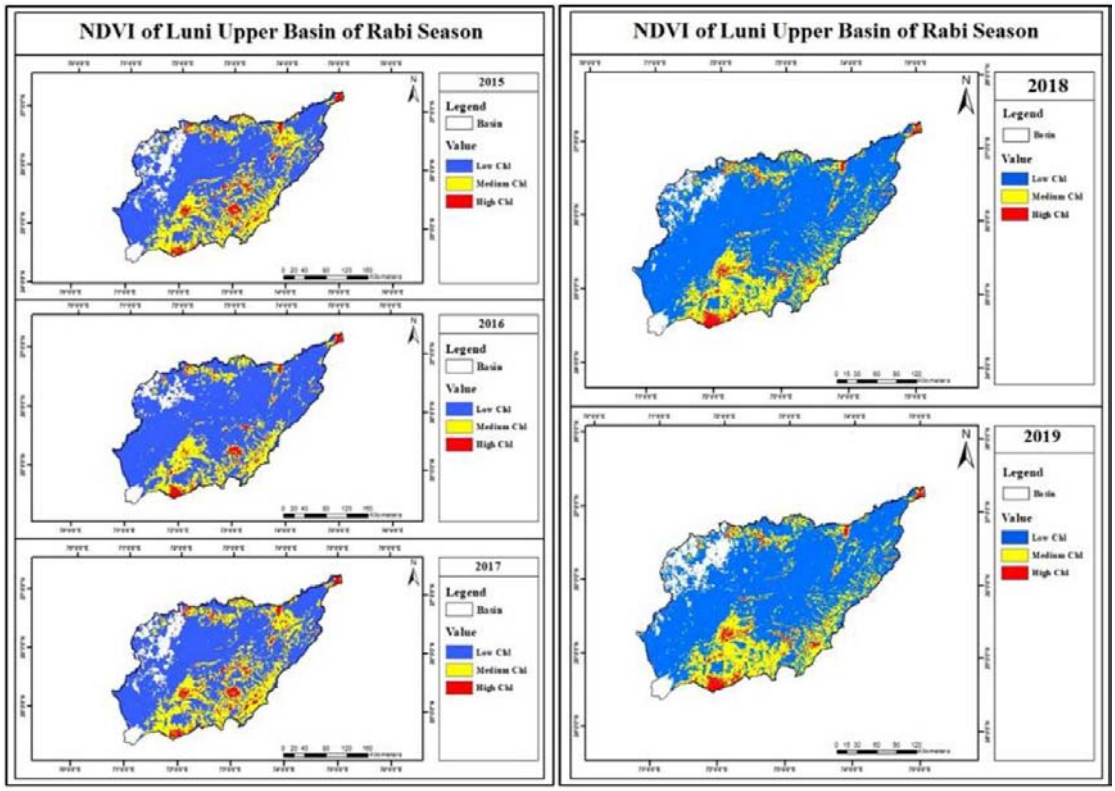

Fig.3. NDVI of Luni Upper basin (*Rabi* season)

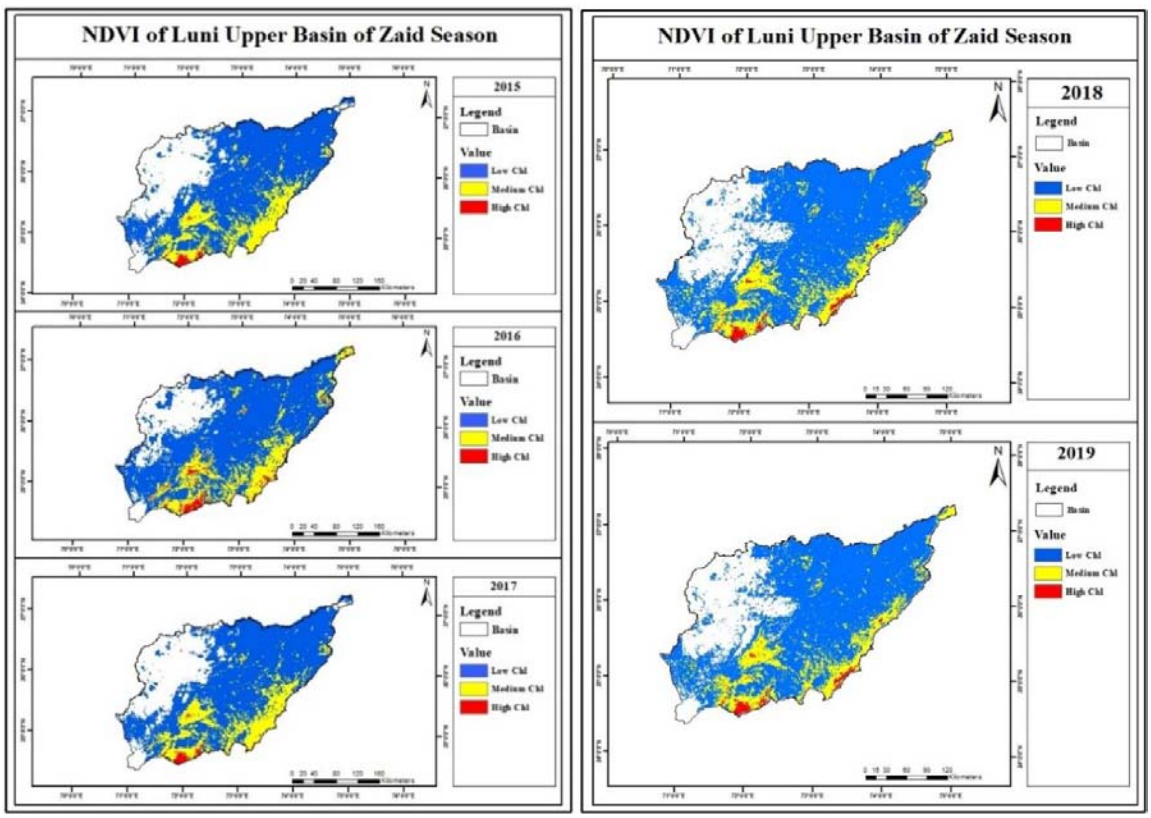

Fig.4. NDVI of Luni Upper basin (*Zaid* season)

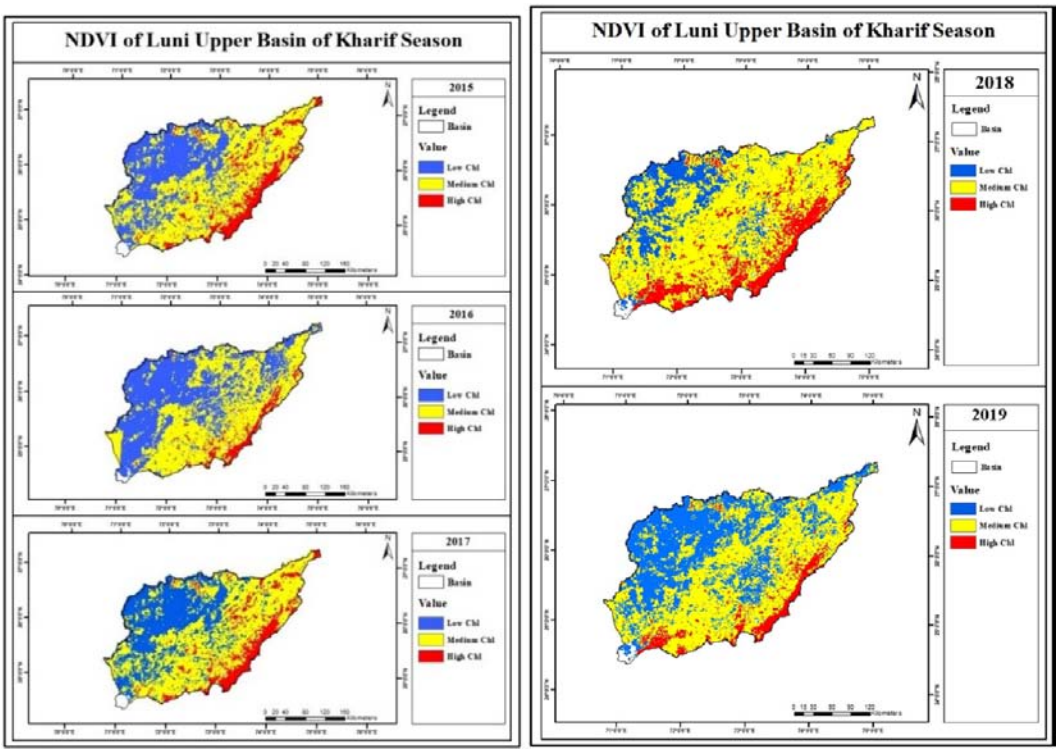

Fig.5. NDVI of Luni Upper basin (*Kharif* season)

dryness. The precipitation rate in this season is very low for that, the vegetation growth becomes very low and found unhealthy vegetation. The results revealed that in this season, the non-vegetated area with no chlorophyll contents was 30% of the area; low vegetation comprises 55%, medium 13%, and good vegetation with 2% cover area (Fig. 3-6).

MCARI2

Modified Chlorophyll Absorption Ratio Index 2 (MCARI2) is the same as MCARI, but it is deliberated as a better indicator of leaf area index (LAI). It includes soil adjustment factors while conserving sensitivity to leaf area index. In vegetation cover, plant growth is directly related to water supply and plant water status. The strongest predictors of the green leaf area index (LAI) was a modified chlorophyll absorption ratio index (MCARI2). Xueand Su (2017) created the Chlorophyll Absorption Ratio Index (CARI), which uses 670 nm as the reference for measuring the depth of chlorophyll absorption and 550 nm as the reference for green reflectance. To obtain the Modified Chlorophyll Absorption Ratio Index, the CARI was simplified by Daughtry *et al*. (2000). (MCARI), Daughtry *et al*. (2000) observed that the LAI, chlorophyll, and chlorophyll–LAI interaction, respectively, accounted for 60%, 27%, and 13% of the MCARI variance discovered in the first place. Therefore, because of this, the possibility that MCARI could yield accurate LAI predictions while no near-infrared band (or wavelength) was utilized in its formulation (Fig. 7-10).

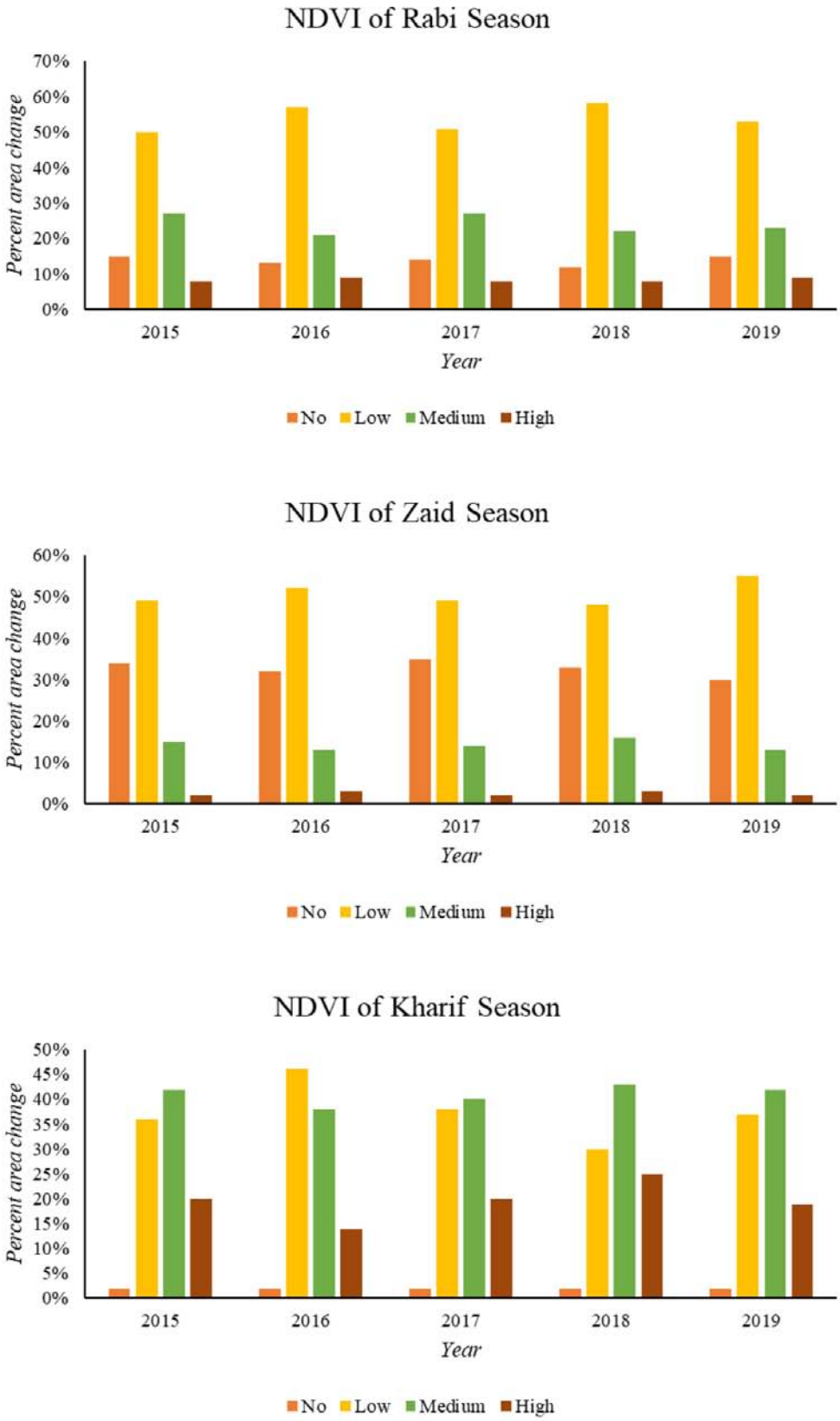

Fig.6. Area statistics of NDVI during three seasons

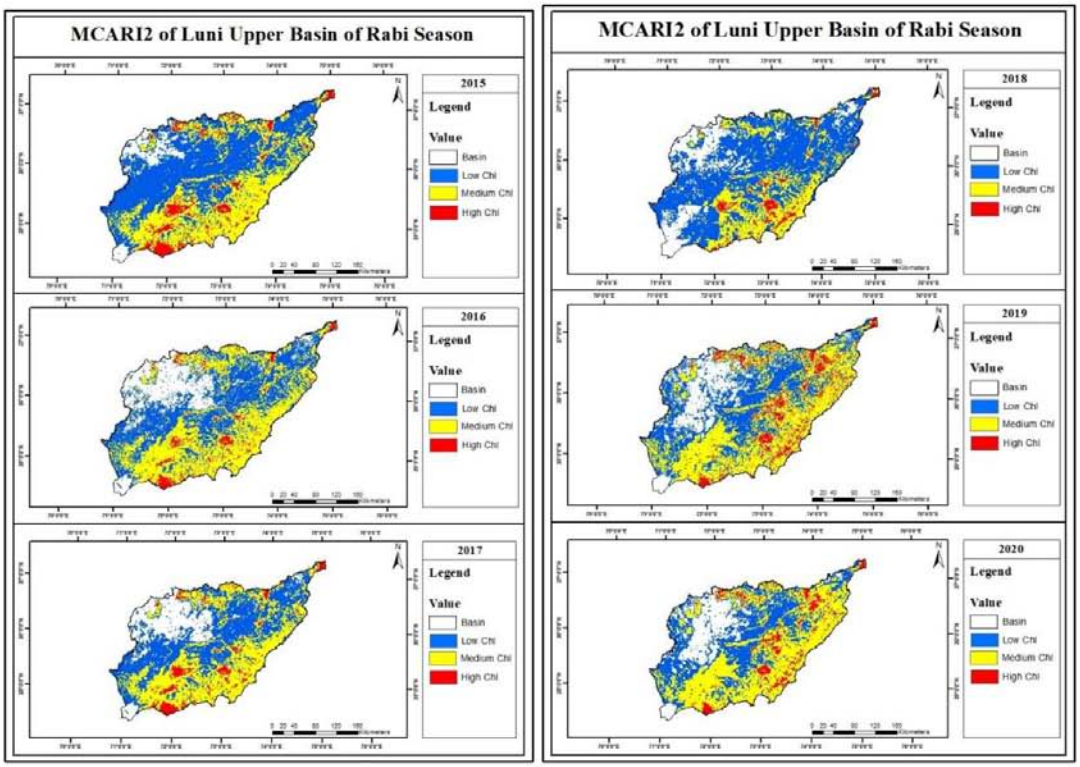

Fig. 7. MCARI2 of Luni Upper basin (*Rabi* season)

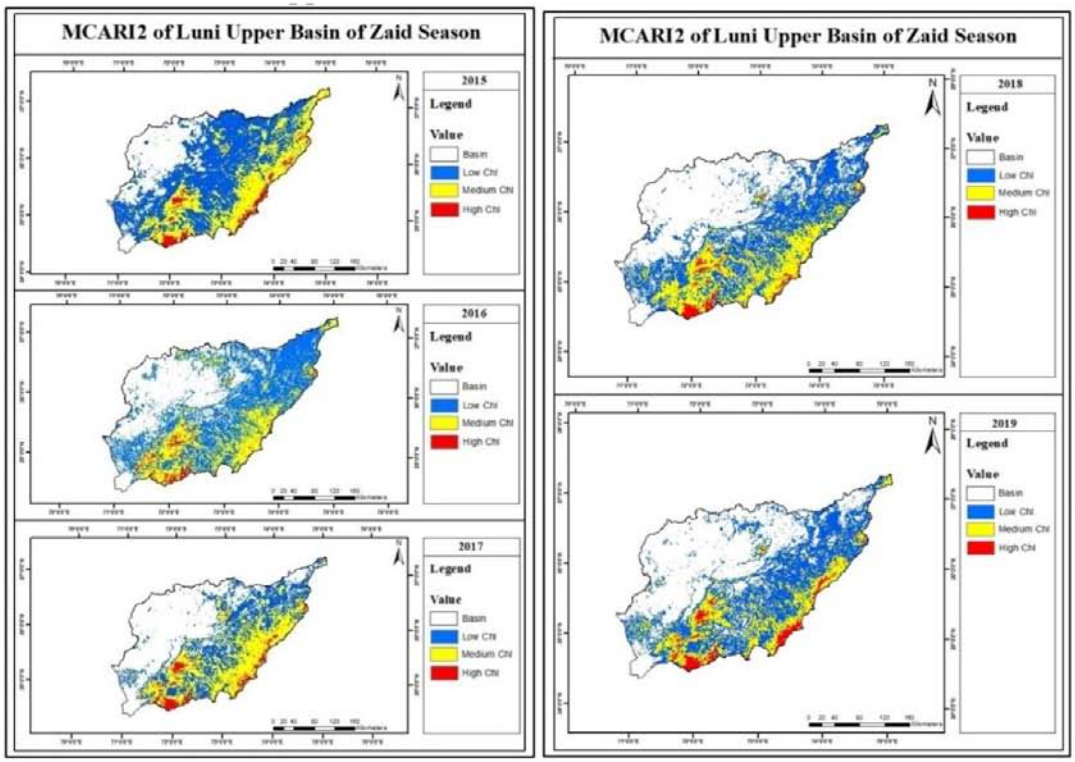

Fig.8. MCARI2 of Luni Upper basin (*Zaid* season)

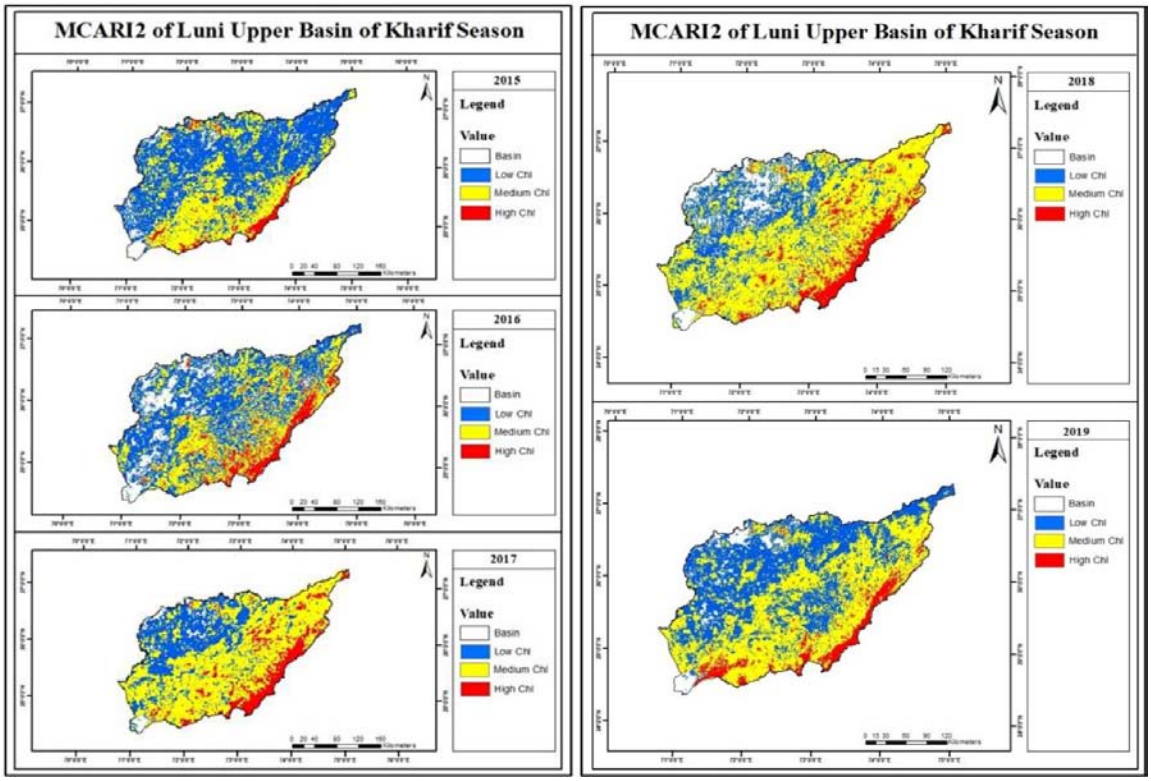

Fig. 9. MCARI2 of Luni Upper basin (*Kharif* season)

Chlorophyll Index Green Model

The Green Chlorophyll Index is used in remote sensing to estimate leaf chlorophyll in diverse plant species. The chlorophyll content of vegetation reflects its physiological state; it decreases in stressed plants and can thus be used to measure plant health (Viña *et al*., 2011). Better chlorophyll amount prediction with the GCI vegetation index can be achieved using satellite sensors with broad NIR and green wavelengths. The Green Chlorophyll Index is used to track how seasonality, environmental challenges, and pesticide use affect plant health. It was also observed that the chosen canopy greenness metric (green chlorophyll index) outperforms other classic vegetation indices like NDVI. Green reflectance (used in the green chlorophyll index) is more responsive to leaf chlorophyll concentration fluctuations than red reflectance (used in the NDVI). Therefore it's likely that the Green Chlorophyll Index catches the variables in nutrient insufficiency that are linked to yield. It was found that vegetative indexes that incorporate canopy greenness outperform more standard red reflectance-based methods on a methodological level. The Green Chlorophyll Index suggests that 9% of the area with low greenery, 60% poor, 19% moderate, and 12% with a high rate of chlorophyll content during the *Kharif* season. GCI model in *Zaid* season shows that 32% area is covered by low vegetation, 34% poor, 31% moderate, and 3% with good vegetation cover. MCARI2 shows that 23% area was covered by good vegetation, 37% moderate, 27% poor, and 13% area with no chlorophyll content in *Kharif* season. In the *Zaid* season, 57% was low, 23% poor, 13% moderate and 7% high vegetation area (Fig.11-14).

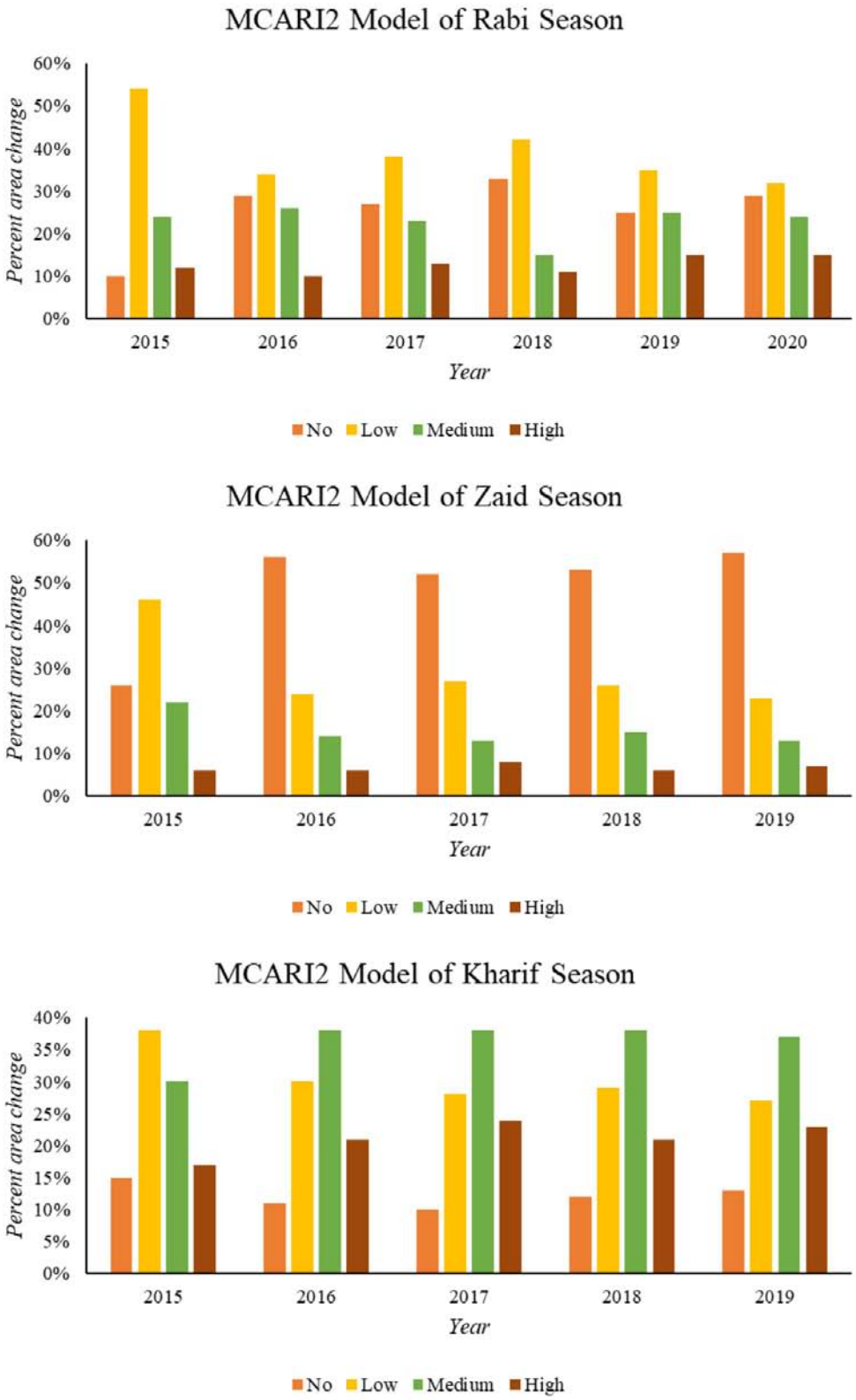

Fig. 10. Area statistics of MCARI2 for the three seasons

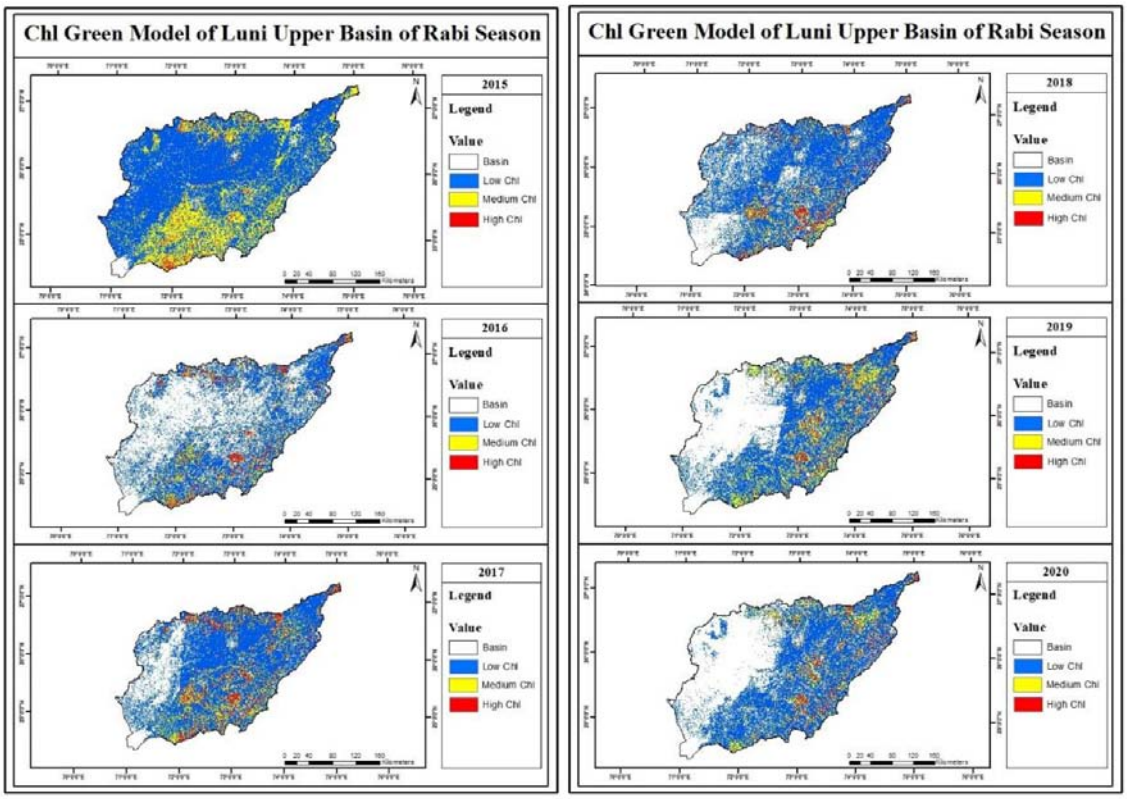

Fig.11. Chl green model of Luni Upper basin (*Rabi* season)

Chlorophyll Index Red-Edge Model

The red-edge area is defined as the spectral region between 680 nm and 750 nm, where the reflectance of vegetation suddenly changes. This is due to the transition from chlorophyll absorption in the cell transmitted red area in the NIR. Many chlorophyll-related VIs, particularly those based on red-edge reflectance, has lately been successfully employed to estimate leaf or canopy chlorophyll concentration. Miller et al. 2007 discovered that the two combinations aboveindices might evaluate canopy chlorophyll content when the red-edge reflectance replaces the red reflectance at 670 nm at 705 nm and the reflectance at 700 is replaced by the red reflectance red-edge reflectance at 750 nm as the red-edge reflectance is affected by both leaf chlorophyll concentration and LAI. The CIgreen and CIred-edge reflectances were found to significantly increase the accuracy of canopy chlorophyll content estimation, with the red-edge reflectance providing a robust canopy chlorophyll content estimation across various crops. The red-edge indices help estimate LAI or chlorophyll content across multiple crop varieties. This could be because the red-edge reflectance was more responsive to changes in LAI than the red reflectance. Sentinel-2's red-edge band, located at 740 nm, was farther away from the red band than Sentinel-1's red-edge band, centered at 705 nm. The findings of this study were consistent and found that using CIred-edge to estimate canopy chlorophyll content had a higher connection with canopy chlorophyll content. According to GI Red edge, it was observed that low vegetation comprises 19%, 43% poor, 23%

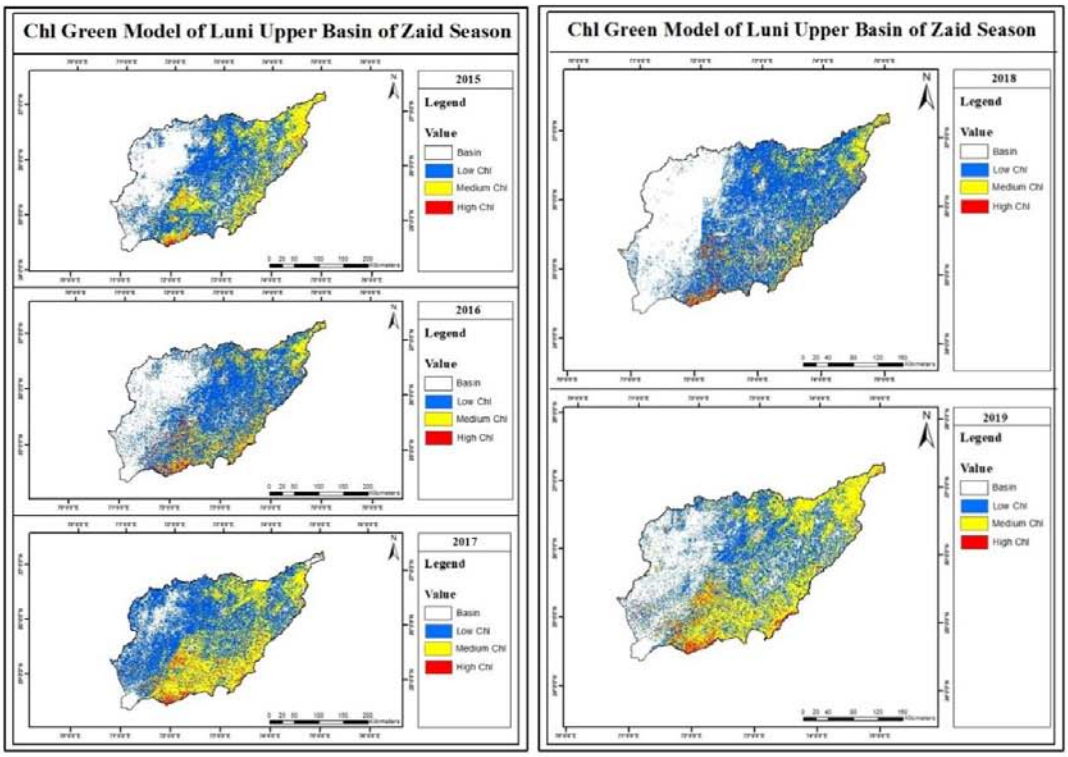

Fig.12. Chl green model of Luni Upper basin (*Zaid* season)

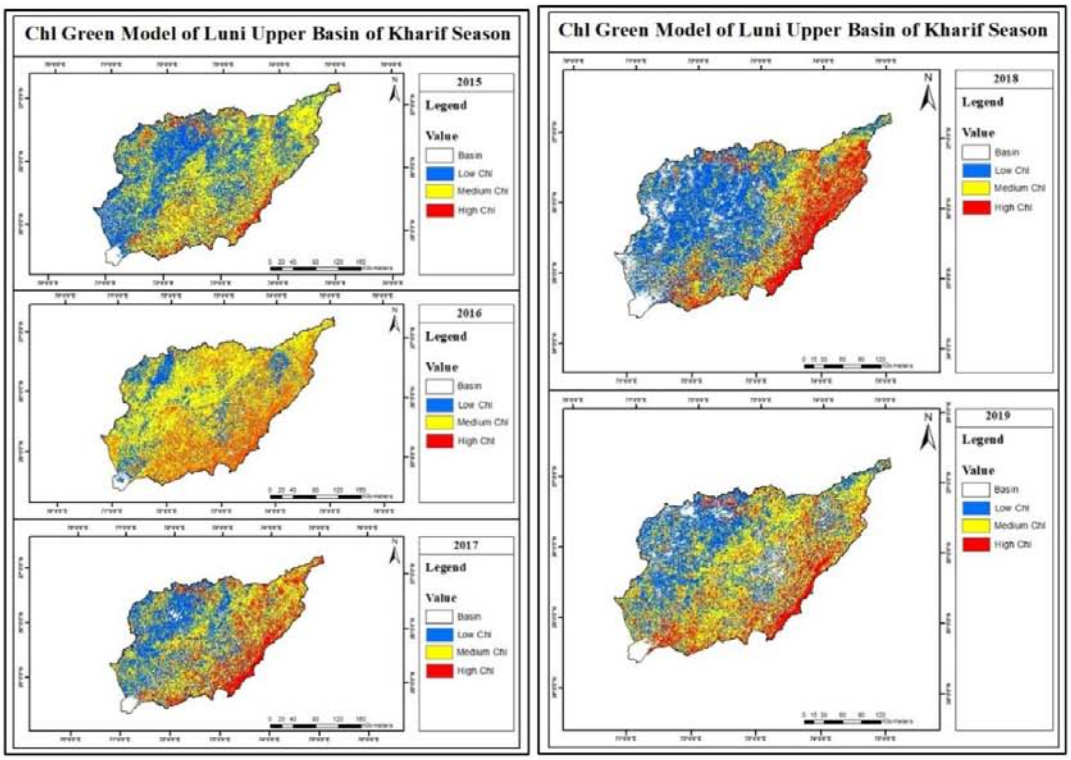

Fig. 13. Chl green model of Luni Upper basin (*Kharif* season)

Fig.14. Area statistics of Chl green model during the three seasons

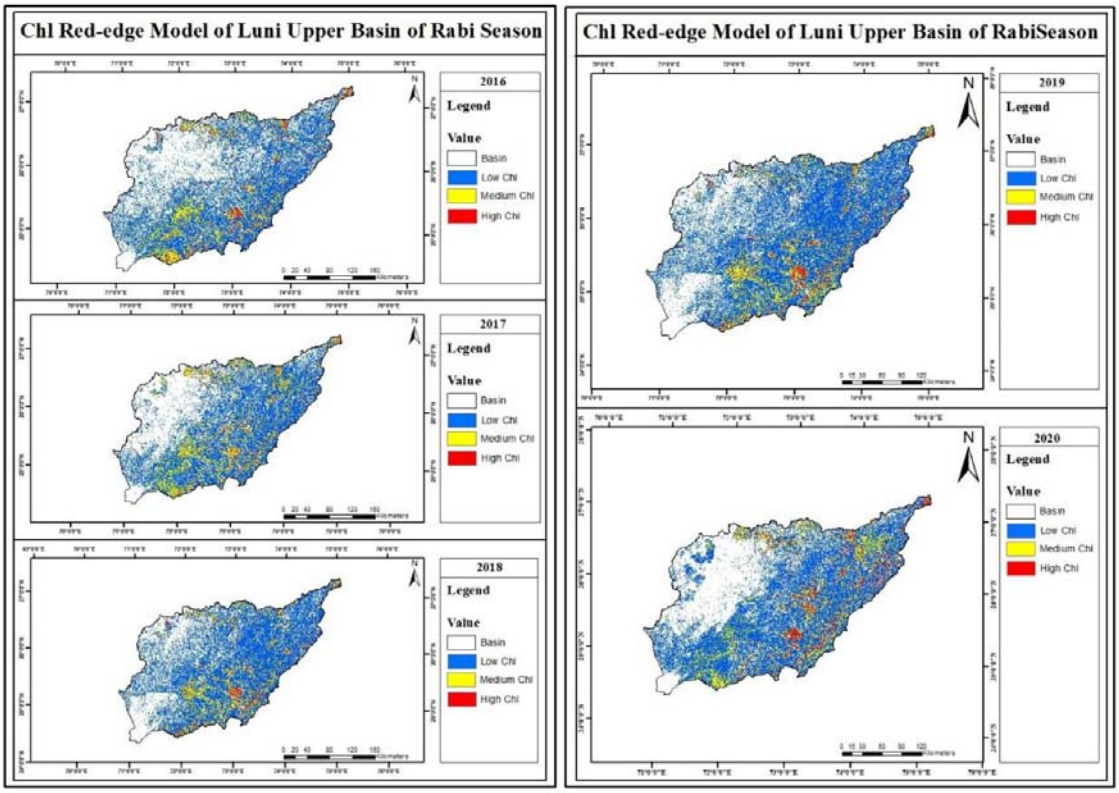

Fig.15. Chl Red-edge model of Luni Upper basin (*Rabi* season)

moderate, and 15% high vegetation cover during *Kharif* season. Whereas in *Zaid* season, only 2% area was covered with good vegetation and high chlorophyll pigments, 10% area with moderate vegetation, 50% area with low and 38% area with low vegetation cover.

CONCLUSION

Remotely estimating biophysical features of vegetation can be done by many ways that utilize various spectral bands, derivatives of reflectance spectra, and statistical modeling techniques. Visible and near-infrared reflectance bands are most commonly employed in tandem with mathematical calculations. Chlorophyll indices *(i.e.,* the CIGreen, the CIRed-edge, and the MCARI2), were closely and linearly related to the Green LAI and had higher sensitivity to moderate-to-high Green LAI than indices similar to NDVI. However, the indices were affected by varying leaf and canopy characteristics. Therefore, when employing these indices for mapping applications over varied canopies, utmost care should be taken to use them accurately. This study recorded that chlorophyll indices such as the CIGreen, the CIRed-edge, and the MCARI2 can serve as reliable surrogates of Green LAI. Although the Green LAI may be based on subjective measurements, these indices respond to both leaf area and foliar chlorophyll concentration and hence can be more accurate metrics. Using remote satellite sensor systems, the CIRed-edge is an appropriate, accurate, and economical method for determining Green LAI at many scales, from close range to regions and continents.

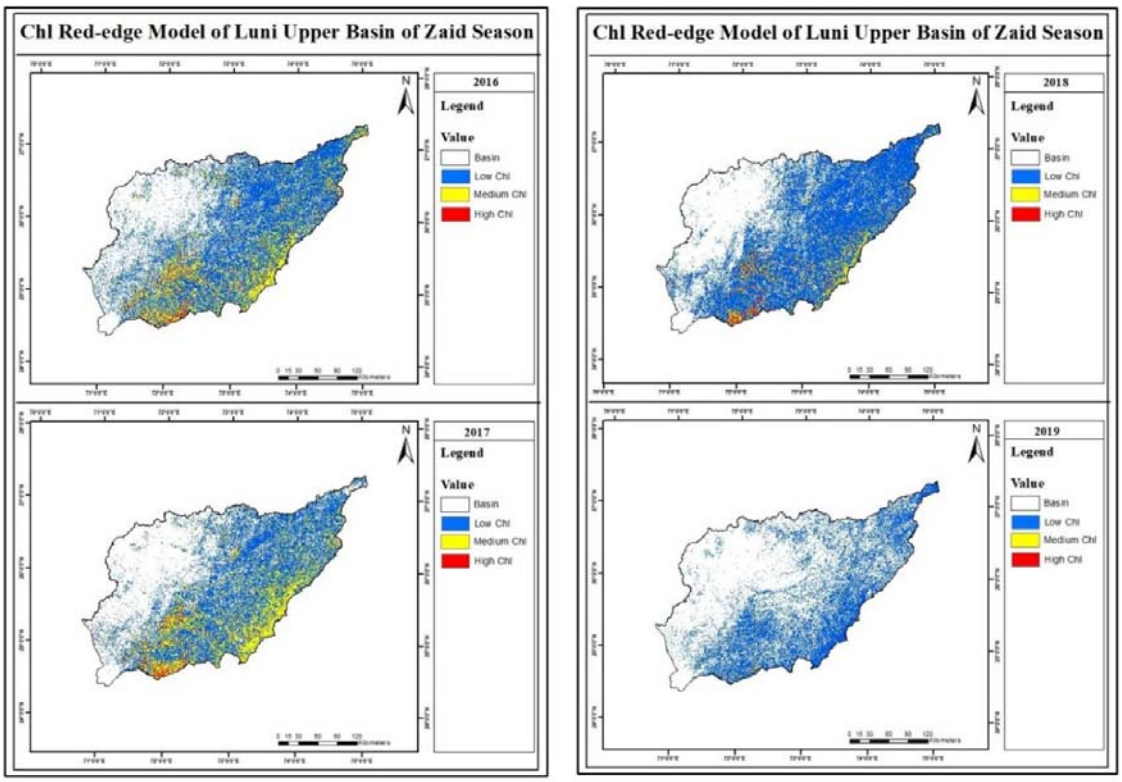

Fig.16. Chl Red-edge model of Luni Upper basin (*Zaid* season)

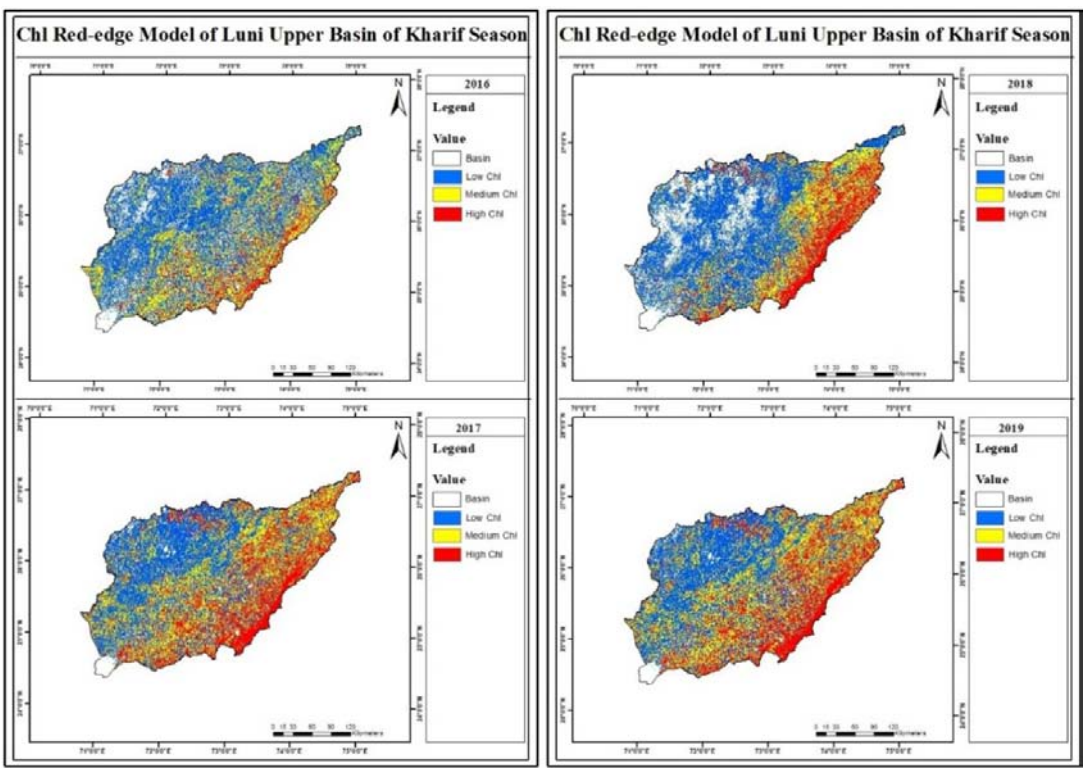

Fig.17. Chl Red-edge model of Luni Upper basin (*Kharif* season)

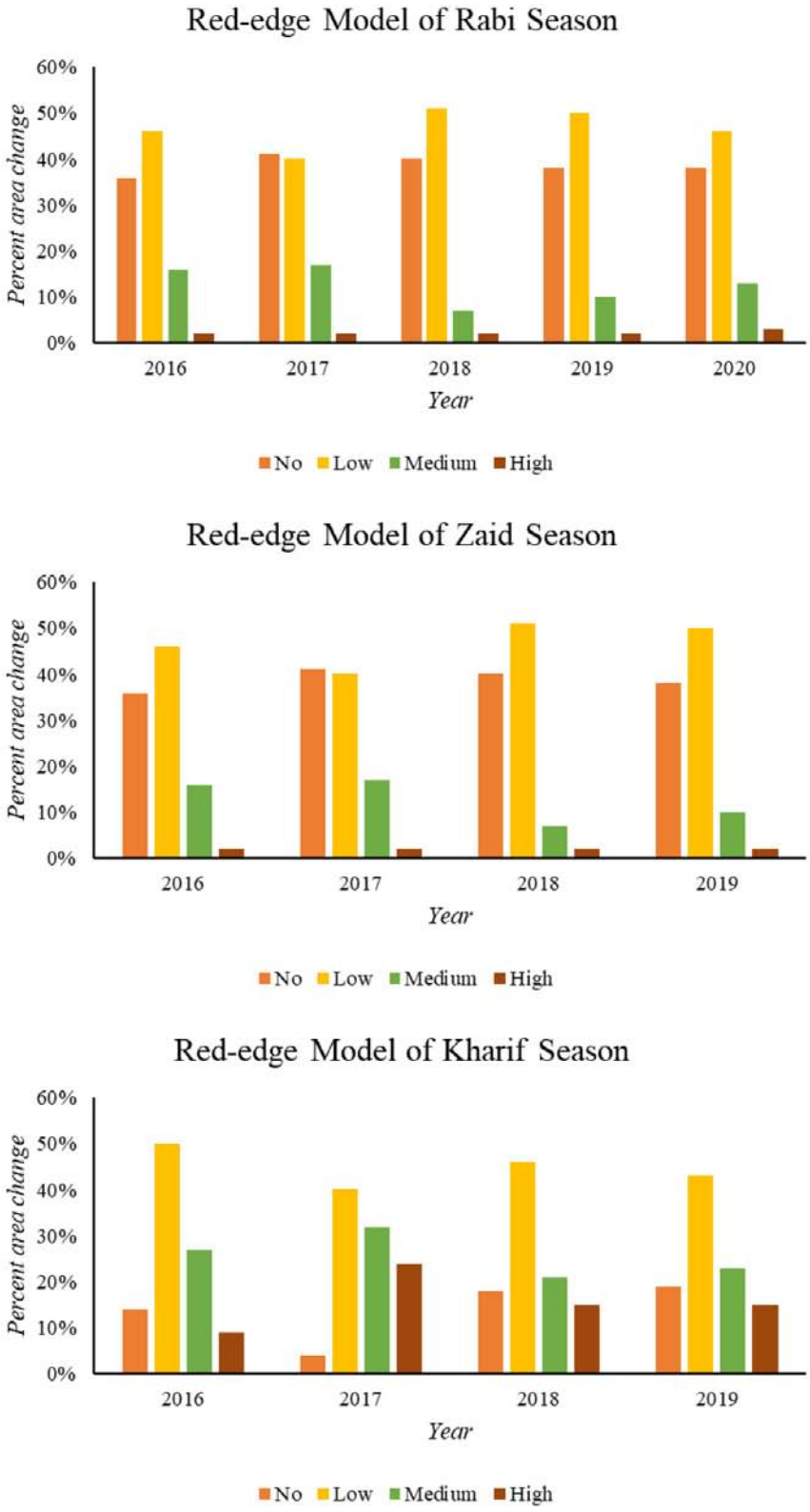

Fig.18. Area statistics of Chl Red-edge during the three seasons

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CONSUMPTION EXPENDITURE PATTERN AND INEQUALITY AMONG AGRICULTURAL HOUSEHOLDS IN SOUTH COASTAL REGION OF ANDHRA PRADESH STATE

M. AREEF*, Y. RADHA, V.S. RAO, P.V.S. GOPAL, K.S.R. PAUL, K. SUSEELA and S. RAJESWARI

Department of Agricultural Economics,
Agricultural College, Acharya N.G. Ranga Agricultural University, Bapatla - 522101

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ABSTRACT

The study is an attempt to analyse consumption pattern and inequality by distinguishing total consumption expenditure into food items and non-food items. Average propensity to consumption (APC) was formulated to know the proportion of income consumed. Engel ratio was estimated to know the difference in expenditure on each of food and non-food items separately by the agricultural households. Lorenz curve, Gini index, Atkinson's index and Theil index were employed to measure the consumption expenditure inequality for agricultural households across landholding categories. The results of Gini, Atkinson and Theil indices showed that within the landholding category except semi-medium farmers, the expenditure distribution was more unequal for non-food items than food items. The marginal farmer households reported with more unequal distribution of consumption expenditure (Gini=0.2221).

Keywords: Consumption inequality, Engel ratio, Gini index, Non-food items and Theil index

JEL codes- D13, E21 and R20

INTRODUCTION

Absolute income hypothesis explained that consumption was a function of current disposable income whether linear or non-linear. The changes in taste and living conditions of farmers showed significant influence on share of income allocated for food items and non-food items. Sendhil *et al*. (2012) emphasized that increased level of income, led to a major shift in the consumption pattern in India. Basole and Basu (2015) highlighted about "food budget squeeze" explaining that the expenditure on non-food essentials was increased so fast that it squeezed the food budget, leaving insufficient income to spend on food and resulted in decline in calorie, protein and fat intake. Poverty in general terms is a situation of low income and low consumption. Most of the research scholars pointed out that quantifying the decline in the level of consumption expenditure based

*Corresponding Author E-mail i.d: areefmulla009@gmail.com; Ph.D thesis submitted to Acharya N.G. Ranga Agricultural University, Guntur

measures of poverty might not give complete picture (Areef *et al*., 2021; Basole and Basu, 2015; Bhalla, 2003). There is a need to focus on consumption expenditure by separating food and non-food items from total household expenditure, to know welfare of farmer household (by observing share of expenditure on non-food items such as A.C, bike, T.V, mobile, *etc*.) and nutrition status of farmer household (by observing share of expenditure on food items such as fruits, vegetable, milk, *etc*.)

This study has been taken up with the objective of analysing the consumption expenditure pattern and consumption inequality by focusing on distinction between food and non-food items across landholding categories of agricultural households in South Coastal region of Andhra Pradesh state. The hypothesis formulated for testing was that the share of consumption expenditure on food items and consumption inequality were high for large farmer households.

MATERIAL AND METHODS

The primary data on agricultural households' income and consumption expenditure on various food and non-food items were collected through personal interview method using well-designed schedules with structured questionnaire for the agricultural year 2018-19. Guntur district was selected among six districts of South Coastal region, based on highest percentage of operational holdings (20.38 percent). Based on the highest number of operational holdings criteria, top two mandals (namely Bapatla and Sattenapalli) of Guntur district were selected (Govt. of A.P, 2016). A proportionate stratified random sampling procedure was used to select a total of 100 agricultural households with 51 from Bapatla mandal and 49 households from Sattenapalli mandal. Each stratum sample size is equalized to 50 agricultural households for ease of analysis,. For the monthly income estimation, agricultural households were further categorised into marginal, small, semi-medium, medium and large farmers based on landholding size (owned land). In each category, 10 agricultural households from each stratum (mandal), and, thus, finally 100 agricultural households at district level were selected. The analysis has been carried out in R software using ineq and glorenz packages.

To know the proportion of income consumed, the average propensity to consume (APC) was calculated as the ratio of consumption expenditure to level of disposable income.

APC = Consumption expenditure (C) / level of income (I)

Monthly Per Capita Income (MPCI) and Monthly Per Capita Expenditure (MPCE) were calculated by following the consumption unit. The consumption unit for an agricultural household was constructed by converting the no. of children into adult units on the basis of equivalent: Three children belonging to 1 to 8 years age group are equal to one adult unit and two children belonging to 8 to 15 years age group are equal to one adult unit.

Engel ratio was estimated to examine the differences in expenditure on each of food and non-food items separately across the landholding categories of agricultural households. Engel ratio was formulated as the

expenditure on a particular item expressed as a proportion of total expenditure.

Measures of consumption expenditure inequality

Lorenz curve, Gini index, Atkinson's index and Theil index were employed to measure consumption expenditure inequality for agricultural households across landholding categories.

Lorenz curve is one of the simplest graphical representations of the disparity aspect of dispersion of family consumption expenditure. The horizontal axis was the cumulative share of agricultural household and the vertical axis displays the cumulative share of consumption expenditure.

Gini index is most widely cited measure of inequality because of its certain desirable properties, such as anonymity, population replication or invariance, scale invariance or mean independence or relative income and Dalton's transfer as detailed in Singh *et al*. (2016). The Gini index is a summary statistic and is bound by zero and one. The higher is the value of Gini index, the higher is the inequality in distribution. The Gini coefficient (G), of consumption expenditure is calculated by

$$G = 2\,\mathrm{cov}[y, F(y)] / \bar{y}$$

Where, y = Consumption expenditure,

F(y) = Cumulative distribution and

$\bar{y}$ = Mean consumption expenditure of the household.

Atkinson's inequality index is the most popular welfare-based measure of inequality and ranges between zero and one. The value equal to zero represents state of equal distribution.

The index was computed as

$$A_e = 1 - \left[\frac{1}{N}\sum_{i=1}^{N}\left(\frac{y_i}{\bar{y}}\right)^{1-e}\right]^{\frac{1}{(1-e)}}, \quad e \neq 1$$

$$A_e = 1 - \frac{\prod_{i=1}^{N}(y_i^{1/N})}{\bar{y}}, \quad e = 1$$

Where, $\bar{y}$ is the mean consumption expenditure, i is number of households [i=1,2,…,N (N=20 for each landholding category or N=100 for overall households)] and e is a weighing parameter and it measures aversion to inequality.

Theil index measure was labelled to the family of generalised entropy (GE) inequality measure (Jenkins, 1991). The formula is written as:

$$GE(\alpha) = \frac{1}{\alpha(\alpha-1)}\left[\frac{1}{N}\sum_{i=1}^{N}\left(\frac{y_i}{\bar{y}}\right)^{\alpha} - 1\right]$$

Where, $\bar{y}$ is the mean consumption expenditure, i is number of households [i=1,2,…,N (N=20 for each landholding category or N=100 for overall households)] and the common values of á used were 0, 1 and 2.

GE(1) is Theil's T index, represented as

$$GE(1) = \frac{1}{N}\sum_{i=1}^{N}\frac{y_i}{\bar{y}}\ln\left(\frac{y_i}{\bar{y}}\right)$$

Where, $\bar{y}$ is the mean consumption expenditure, i is number of households [i=1,2,…,N (N=20 for each landholding category or N=100 for overall households)]. The values of Theil vary between zero and one, with zero representing an equal distribution and higher value representing a higher level of inequality.

RESULTS AND DISCUSSION

Agricultural household income and consumption expenditure pattern

Household referred as a group of people living together (temporary visitors were excluded) and taking food from a common kitchen. For present study, the monthly income and expenditure on food and non-food items were calculated across the landholding categories of agricultural households (Table 1). The results revealed that as landholding size increases, the monthly per capita income and monthly per capita expenditure of household also increased linearly. Marginal farmers observed with highest average propensity to consumption (76.27 per cent) and income spent on non-food (58.19 per cent) items was higher compared with food (41.81 per cent) items. The next level of average propensity of consumption (51.59 per cent) was reported by semi-medium farmers with the share of expenditure on food items as 41.74 per cent and share of expenditure on non-food items as 58.26 per cent. The comparison across the landholding categories revealed that level of income is rising from marginal farmers to large farmers, furthermore the share of expenditure on non-food items relatively rising compared with share of expenditure on food items. When the monthly income of agricultural households was allowed to increase, the expected pattern of consumption expenditure as share of expenditure on food items was decreased and expenditure on non-food items was increased. The results of the study concluded that the selected study area followed this expected pattern. Basole and Basu (2015) also reported results in India and observed that for the households with higher level of income, the share of expenditure on food items decreased and share of expenditure on non-food items increased. The consumption expenditure is considered as a one of proxy for household welfare, such increased expenditure on non-food

Table 1. Average inc\ome and consumption expenditure of agricultural households

(Rs./household/month)

Categories of Land holding	Average monthly income (Rs.)	Average monthly consumption expenditure (Rs.)			Average Propensity to Consume (APC)	Monthly Per Capita Income (Rs.) (MPCI)	Monthly Per Capita Consumption (Rs.) (MPCE)
		Food	Non-food	Total			
Marginal farmers (<1 ha)	12,420	3961	5512	9,473	0.7627	4,439	3,308
Small farmers(1 to 2 ha)	18,412	4702	8056	12,758	0.6929	6,730	4,615
Semi-medium farmers(2 to 4 ha)	34,166	7356	10269	17,625	0.5159	11,499	5,641
Medium farmers(4 to 10 ha)	43,175	10827	16201	27,029	0.6260	13,683	8,593
Large farmers(10 ha and above)	63,429	15634	22829	38,463	0.6064	23,069	13,886
All categories of farmers	34,321	8496	12573	21,069	0.6139	11,884	7,209

Table 2. Engel ratios and average consumption expenditure on food items

(Rs./household/month)

Items	Marginal farmers	Small farmers	Semi-Medium farmers	Medium farmers	Large farmers	All Categories of farmers
Cereals and cereal substitutes	985 (24.87)	934 (19.86)	1100 (14.96)	1302 (12.02)	719 1(10.99)	1208 (14.22)
Pulses and their products	89 (2.25)	93 (1.99)	111 (1.51)	315 (2.91)	549 (3.51)	231 (2.72)
Milk and milk products	760 (19.19)	831 (17.67)	1340 (18.22)	2267 (20.94)	3000 (19.19)	640 1(19.30)
Salt and sugar	56 (1.41)	59 (1.25)	84 (1.14)	118 (1.09)	180 (1.15)	99 (1.17)
Edible oils	172 (4.33)	143 (3.04)	224 (3.04)	374 (3.46)	556 (3.56)	294 (3.46)
Meat, Fish and eggs	498 (12.58)	791 (16.82)	1161 (15.17)	1702 (15.72)	2367 (15.14)	1295 (15.24)
Vegetables	736 (18.58)	778 (16.54)	1066 (14.49)	1340 (12.38)	2032 (13.00)	1190 (14.01)
Fruits (fresh and dry)	390 (9.85)	510 (10.85)	980 (13.32)	1654 (15.28)	2622 (16.77)	1231 (14.49)
Spices	98 (2.47)	121 (2.56)	152 (2.07)	234 (2.16)	348 (2.23)	191 (2.24)
Beverages, etc.	177 (4.47)	443 (9.41)	1183 (16.08)	1521 (14.05)	2261 (14.46)	1117 (13.15)
Total food expenditure	3961 (100.00)	4702 (100.00)	7356 (100.00)	10827 (100.00)	15634 (100.00)	8496 (100.00)

Note: Figures within the parentheses represents Engel ratio values

items like clothing, footwear, education, medical, durables and other goods/services could be interpreted as a welcoming development of agricultural households.

Data collected for expenditure on food items, pan, tobacco, intoxicants, fuel & light, medical (non-institutional) and miscellaneous goods and services was based on last 30 days reference

period. For non-food items such as education, medical (institutional), clothing, footwear and durable goods, last 365 days reference period was followed. To know the differences in expenditure on each of food and non-food items, expenditure on education, medical (institutional), clothing, footwear and durable goods converted into uniform reference period (URP) data. The Uniform Reference Period (URP) refers to consumption expenditure data collected using the 30-day reference period. Engel ratio and average consumption expenditure on each food and non-food items were calculated separately (Table 2 and Table 3).

Marginal farmers observed with more consumption of cereals and cereal substitutes (24.87 per cent) among food items. High value commodities like milk, vegetables, eggs, fish, meat and fruits combinedly constitute 60.20 per cent of consumption, the remaining 39.80 per

Table 3. Engel ratios and average consumption expenditure on non-food items

(Rs./household/month)

Items	Marginal farmers	Small farmers farmers	Semi-Medium	Medium farmers	Large farmers	All Categories of farmers
Pan, tobacco & intoxicants	173 (3.13)	670 (8.32)	1005 (9.79)	1305 (8.05)	1265 (5.54)	883 (7.03)
Fuel & light	336 (6.10)	568 (7.04)	703 (6.85)	950 (5.86)	1492 (6.53)	810 (6.44)
Medical (institutional & Non-institutional)	2315 (42.00)	2725 (33.83)	3295 (32.09)	4890 (30.18)	6495 (28.45)	3944 (31.37)
Entertainment	155 (2.81)	425 (5.28)	535 (5.21)	1355 (8.36)	3110 (13.62)	1116 (8.88)
Clothing & footwear	596 (10.81)	871 (10.81)	1117 (10.88)	1329 (8.20)	1391 (6.09)	1061 (8.44)
Education	225 (4.08)	554 (6.88)	675 (6.57)	2063 (12.73)	1000 (4.38)	903 (7.18)
Durable goods	1590 (28.85)	2025 (25.14)	2075 (20.21)	2405 (14.84)	4155 (18.20)	2450 (19.49)
Miscellaneous goods & services	123 (2.22)	219 (2.71)	864 (8.41)	1905 (11.76)	3922 (17.18)	1406 (11.18)
Total non-food expenditure	5512 (100.00)	8056 (100.00)	10269 (100.00)	16201 (100.00)	22829 (100.00)	12573 (100.00)

Note: **Figures within the parentheses represents Engel ratio values**

cent consumption got distributed among cereals, pulses, salt & sugar, edible oil, spices and beverages *etc*. Among non-food items, 42.00 per cent income was spent on healthcare, 28.85 per cent on durables, 10.81 per cent on clothing & footwear and 4.08 per cent income spent on education.

Small farmer reported with very low consumption of pulses & their products (1.99 per cent only). Also, marginal farmers and small farmer households also spent highest income on cereals and cereal substitutes compared with other landholding categories. Milk, vegetables, eggs, fish, meat and fruits combinedly constitute 61.88 per cent of consumption among food items. Healthcare contributed the highest share of expenditure with 33.83 per cent among non-food items.

Except marginal and small farmer households, remaining categories of farmer households spent highest income on milk and milk related products (up to 21 percent) and further observed that the consumption of pulses and their products was very low (about 1.5 per cent). However, the share of consumption on milk, vegetables, eggs, fish, meat and fruits combinedly constitute nearly 64.50 per cent among food items for semi-medium, medium and large farmers, inferring that the shift in the dietary diversity was attributed to consumption of high value commodities like milk, vegetables, fruits and meat replacing the consumption of cereals and pulses (Kumar *et al*., 2007; Nasurudeen *et al*., 2006). Also, The results of this study highlighted that all the categories of agricultural households diversified from consumption of cereals and pulses to consumption of high value commodities like milk, vegetables, eggs, fish, meat and fruits.

The highest percentage share of expenditure on healthcare and durable goods was reported among non-food items for semi-medium, medium and large farmer households. The inadequate sanitation measures and significant role of private individual in medical sector is one of the reasons for increased expenditure on healthcare. Durable goods refer to expenditure incurred on repairs and purchase & construction of durables (expected lifetime one year or more than one year) used for domestic purpose. Maintain residential building with well infrastructure and motor vehicle with good condition farmer households spent more share of income on durable goods among non-food items in the study area.

Inequality in consumption expenditure

The inequality indices were used to identify the degree of skewness in the level of well-being across the landholding categories of agricultural households. Lorenz curve used to depict the graphical inequality in expenditure on food items, non-food items and total monthly expenditure for agricultural households. The results were depicted in Figures 1 to 5 for marginal, small, semi-medium, medium and large farmer households, respectively. Fig.6 shows the Lorenz curve for consumption expenditure of overall agricultural households.

Except semi-medium farmer households, all other categories showed slightly higher level of inequality for expenditure on non-food items compared with food items. Expenditure on non-food items was more unequal compared with expenditure distribution on food items (Table 4). At the aggregate level, inequality indices were low and within non-food items inequality indices were high. For example, marginal farmer

Table 4. Inequality indices for consumption expenditure in agricultural households

Indices	Items	Marginal farmers	Small farmers farmers	Semi-Medium	Medium farmers	Large farmers	All Categories of farmers
Gini	Food	0.2060	0.1280	0.1466	0.1365	0.0692	0.3104
	Non-food	0.2525	0.1428	0.1226	0.1687	0.0822	0.3096
	Total	**0.2221**	**0.1278**	**0.1168**	**0.1504**	**0.0678**	**0.3055**
Atkinson	Food	0.0351	0.0131	0.0181	0.0162	0.0039	0.0763
	Non-food	0.0556	0.0159	0.0123	0.0223	0.0058	0.0778
	Total	**0.0417**	**0.0128**	**0.0114**	**0.0182**	**0.0035**	**0.0746**
Theil	Food	0.0678	0.0259	0.0353	0.0312	0.0078	0.1508
	Non-food	0.1047	0.0316	0.0248	0.0443	0.0115	0.1524
	Total	**0.0797**	**0.0253**	**0.0227**	**0.0357**	**0.0070**	**0.1469**

households reported with more inequality index for non-food items (Gini=0.2525) than the total household expenditure inequality index (Gini=0.2221). This pattern of expenditure inequality was reported not only in the Gini index but also in Atkinson and Theil index of inequality.

The level of income across the landholding category showed increasing rate from marginal farmers (Rs.12,420 per month) to large farmers (Rs.63,429 per month). However total expenditure inequality indices showed decreasing rate from marginal farmers (Gini=0.2221) to large farmers (Gini=0.0678). The results clearly indicated that within the landholding category, inequality indices were more for non-food items than food items but semi-medium farmers showed more inequality for consumption of food items. When inequality indices were observed across the landholding categories, the share of consumption expenditure distribution for marginal farmer households was more unequal (Gini=0.2221) compared to other categories. Hence the hypothesis was rejected and concluded that semi-medium farmer households were have more consumption expenditure on food items whereas marginal farmer households have highest consumption inequality at aggregate level among agricultural households.

CONCLUSION

The monthly per capita income and monthly per capita expenditure of households across the landholding categories increased linearly. The level of monthly income was increased from marginal farmers (Rs.12,420) to large farmers (Rs.63,429). The share of expenditure on non-food items was relatively more compared to food items, except in semi-medium farmer households, who spent little more income on food items (like milk products and beverages) than on non-food items. Due to high retail prices of pulses, the share of consumption expenditure on pulses and their products was very low (1.51 percent to 3.51

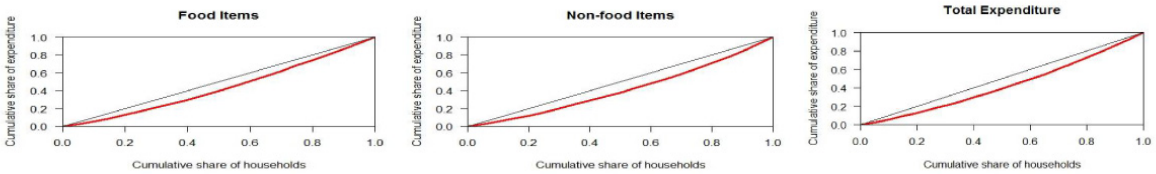

Fig. 1. Lorenz curves for consumption expenditure of marginal farmers (¹ /household /month)

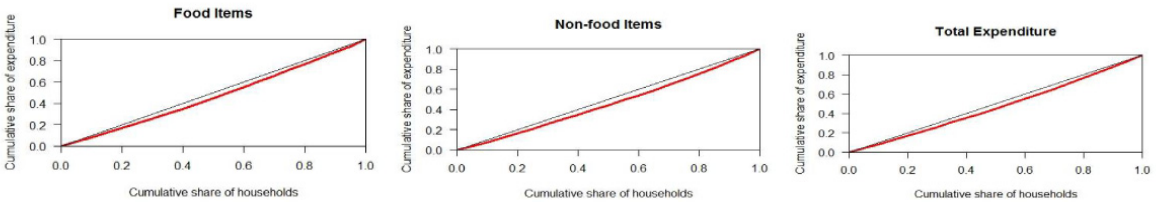

Fig. 2. Lorenz curves for consumption expenditure of small farmers (Rs. /household /month)

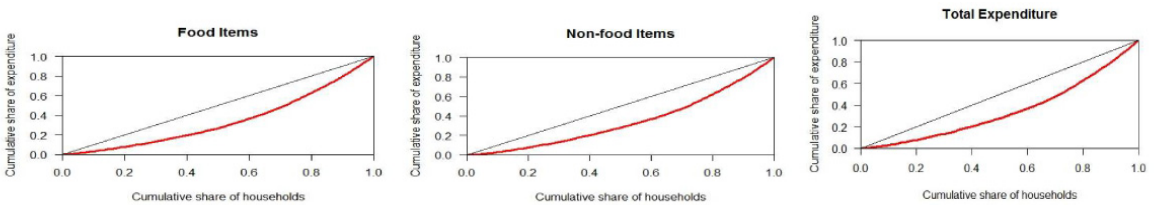

Fig. 3. Lorenz Curves for consumption expenditure of semi-medium farmers (Rs. /household / month)

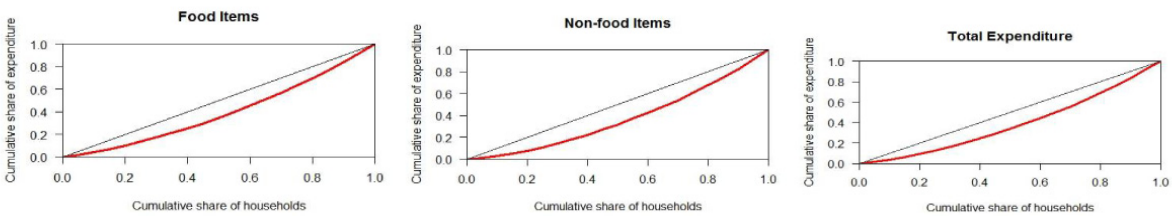

Fig. 4. Lorenz Curves for consumption expenditure of medium farmers (Rs. /household /month)

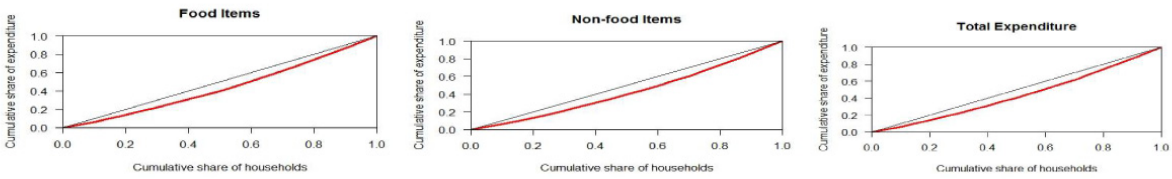

Fig.5. Lorenz Curves for consumption expenditure of large farmers (Rs. /household /month)

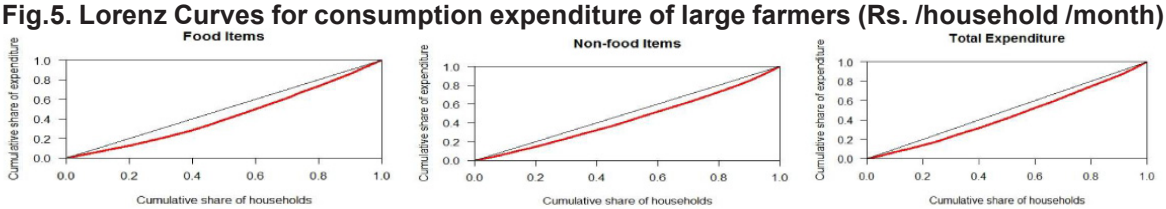

Fig. 6. Lorenz Curves for consumption expenditure of agricultural households (Rs. /month)

per cent) for agricultural households. The results of this study highlighted that all categories of agricultural households diversified from consumption of cereals and pulses to consumption of high value commodities like milk, vegetables, eggs, fish, meat and fruits.

The results indicated that within the landholding categories except semi-medium farmers, share of expenditure distribution was more unequal for non-food items than food items and inequality indices were observed across the landholding categories.

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ESTIMATION OF CLIMATE CHANGE IMPACT ON CROP PROFITABILITY IN KARNATAKA

SRINIVASA SASDHAR PONNALURU* and ARPITA PANDEY

Department of Economics, Vijayanagara Sri Krishnadevaraya University,
Bellary - 583 105

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ABSTRACT

Climate change can significantly impact crop profitability andsocio-economicstatus of farmers. Quantification of these climatic impacts is of vital importance for agrarian states such as Karnataka. This study estimates the function for crop profits with climatic variables as explanatory variables using Arellano Bond Dynamic Panel Estimator under the Generalized Method of Moments framework. The data set utilized in the study is the district level panel spanning over 29 years from 1990 to 2018.The results indicated a decrease in profits due to an increase in average annual temperature. Impacts of past periods'profits on the current periodare positive and decreasing over time, indicating a convergent time path. Climate change impacts are heterogeneous across the space and are more pronounced in the northern districts compared to southern districts of the Karnataka State.

Key Words: Climate Change, Crop Profitability, Arellano Bond Estimator, Spatial Impacts, Dynamic Panel Regression.

INTRODUCTION

Climate change can significantly impact crop profitability for the farmers. The agriculture in India is predominantly monsoon fed and the dependence of farming on climatic factors is extremely high. In the purview of changing climate, it becomes necessary to assess its impact on farmers' socio-economic conditions. This study proposes the dynamic evaluation of climate change impact on crop profitability. Climatic impacts are dynamic in nature, as, the changes that occur in the profits realized during the current period could affect the profits realized in the future periods. Profit depends on revenues generated and costs incurred from the farming activity. Changes in temperature, cloud cover, and rainfall could impactthese revenues and costs. Climatic changes affect crop profitability directly by affecting plant productivity, and indirectly by affecting the incidence of crop pests and diseases, interactions of plant and microbes which are vital for crop plant physiology. These changes could translate into changes in quantity, and quality of produce, affecting the output prices, generating monetary impacts on farmer. These impacts could result in significant social

*Corresponding Author E-mail i.d: sasdhar@vskub.ac.in

and economic changes in the lives of farmers. Quantification of these climatic impacts on crop profitability is vital for understanding and solving the agrarian crisis. The study models farming as a dynamic process where next period's capital is generated out of the profits realized from the current crop. Hence, the shock resulting from a climate change event will affect not only the profits realized from current crop but also from subsequent crops over time.

The previous studies in the domain of agriculture economics and climate change by Bantilan *et al*. (2013), Rao *et al*. (2013) and Acharya *et al*. (2011) assessed the impact of temperature change on crops' revenues. Objective of the study is to quantify the impact of change in climatic variables such as temperature, rainfall, wet day frequency, drought incidence and cloud cover on profits after controlling for confounding unobserved effects such as pest, disease incidence. This study utilized Arellano Bond dynamic panel estimator under Generalized Method of Moments estimation method to quantify the impacts of climatic variables on profits at district level in Karnataka.

Karnataka is an agrarian state with large area under rain fed farming. Climatic conditions vary across the state with drier regions in the northern part of the state compared to the southern part. The eastern part of state faces dry spell during monsoon season due to its position in leeward side of Western Ghats. As per Kumar *et al.* (2004), the crop productivity depends on the annual rainfall quantum along with its distribution over the space and time.The climatic variables incorporated in study aretemperature, rainfall, wet day frequency, cloud cover andprecipitation levels. The study has limitation of unavailability of data for four districts *viz..,* Dakshina Kannada, Udupi, Uttara Kannada and Vijayapura.

MATERIALS AND METHODS

Agronomic Data used in this study was obtained from ICRISAT's District Level Dataset (DLD)and the Directorate of Economics and Statistics (DES). The data set utilized in the study is a district level panel covering 26 districts of Karnataka, spanning over 29 years from 1990 to 2018. ICRISAT DLD provides coverage on agronomic and weather variables fromthe year 1990 to 2015 and DES covers the rest of period. The data on costs of cultivation was obtained from Directorate of Economics and Statistics, Government of India, New Delhi. Indian Meteorological Department (IMD) provided climate data spanning over 100 years from 1900 to 2002. Data from all these sources is collated and organized into a SAS database in the year 2019-2020. SAS SQL, SAS IML,and Base SAS routines were utilized for analysis.

Given the dynamic nature of the model, Arellano Bond GMM estimator was utilized for calculating the parameter estimates. Dependant variable in the model is profit earned from growing the crops in a year. It is calculated as net revenue after deduction of costs of growing the crop. Revenue from a crop is calculated as a product of quantity produced in tons and the market price received in rupees. Cost of cultivation is in rupees and A2 component of cost is considered as per the CACP (2020). Paddy, wheat, maize, sunflower, groundnut, and cotton were considered in this study given their predominance in the State.

Climate data is constructed using weather data on each district. Climate normal for variables such as temperature, rainfall, and cloud cover are calculated as moving average of thirty years. For example, normal temperature for the year 2016 is an average of temperatures recorded for years 1986 through 2015. Similarly, normal temperature for the year 2017 is an average for the years 1987 through 2016. Period of thirty years is used for calculating climate normal from weather data as per the convention in the literature. Trend analysis of climate variables showsthat in last 29 years annual average temperature is gradually increasing, and rainfall is highly inconsistent causing frequent droughts conditions.Cloud cover percentage has also increased, a phenomenon which is meteorologically consistent with a temperature rise. According to Nelson *et al*. (2009), the climate change (temperature increase, rainfall decrease, in all season shifts) makes agriculture more vulnerable.Temperature and rainfall are specified as quadratic functions to capture the nonlinearity in the relation between profits realized and climate. Annual average temperature is considered in this study.The atmospheric mean-maximum temperature ranges between 23°C to 43°C during summer and between 9°C to 27°C during winter. Distribution of annual temperatures across the districts of the state is provided in Fig. 1.

Northern districts of Karnataka record higher normal temperature compared to the southern districts. Hyderabad Karnataka Region comprising of Bidar, Gulbarga (Kalaburgi), Raichur, Koppal, Yadgir and Bellary shows higher temperature compared to most of the other districts. It is hypothesized that the parameter estimate on temperature is negative, as the study region is in the South India, which falls under Torrid Zone closer to Tropic of Cancer. Cloud cover could affect photosynthesis directly. Whitcraft *et al*. (2015) commented that the cloud cover affects the early and mid-agricultural cropping season which are important period for crop yield forecasting. Higher cloud covers could indicate increased wetness of soil, affecting crop growth, along with pest and disease incidence. Garcia-Carreras *et al*. (2017) observed that increase in cloud cover likely leads to vegetation growth. Cloud cover is measured in Okta units. With measurement ranging on a scale of 0 to 8, with 0 denoting clear skies and an 8 denoting completely overcast. However, Indian Meteorological Department reported this data as a percentage. Given the positive and negative impacts on crop growth, parameter estimate on cloud cover could be either positive or negative. Distribution of cloud cover across the districts is shown in Fig.1.

Karnataka receives 80% of annual rainfall from the South-West monsoon, during themonths of June, July, and August. North-East Monsoon contributes about 20% to the annual rainfall.Western Ghats region of coastal and southern Karnataka receive most of the rainfall whereas the HK region receives lesser due to its position in leeward side and least occurs in Raichur District. Normal annual rainfall is considered in this study. As the region is in dryagro-economic zone and agriculture is predominantly rainfed, increase in rainfall could increase agricultural production, and the profits realized. Parameter estimate on rainfall is hypothesized to be positive. The differences in

rainfall pattern and its impact over farmers income was studied by Pablo and Antonio (2015). Wet day frequency is measured in HPA (Heavy Precipitation Amount) units. IMD defines a day as rainy (wet day) when rainfall is e”2.5mm. Increase in wet day frequency could increase crop growth but in a nonlinear manner. Parameter estimate on WDF could either be positive or negative. Distribution of rainfall across the districts is shown in Fig.1.

Standardized Precipitation Index (SPI) was calculated using monthly precipitation data. SPI captures the impacts of both quantum and spread of the rainfall during the crop growing season. Negative deviations in SPI indicate drought spells and positive deviations indicate periods of high rainfall. Standardized Precipitation Index measures the meteorological drought. SPI values range between -3.0 to 3.0, values represent deviation of rainfall in standard deviation units. Extremely dry condition is indicated by -3.0 and extremely wet value is indicated by 3.0. Mishra and Nagaranjan (2012) studied the change in crop’s irrigation demand with the change in SPI valuesin different time scales. The study included the SPI in 12-month scale. Average of SPI values in the state for 28 yearsranged from 0 to 0.52 as shown in Fig. 1. Parameter estimate on SPI is hypothesized to be negative.

Profit function has been estimated under dynamic framework. Arellano Bond dynamic estimator under Generalized Method of Moments estimation is utilized in this study. Dynamically lagged dependent variable has been included in the panel data model of profit. This lagged dependent variable accounts for the autocorrelation arising from the effects of unobserved effects of biotic factors such as crop pest and disease incidence. Arellano Bond Estimator uses lagged values of the dependent variable as instruments to control for the endogeneity from the included lagged dependent variable. Suitability of these lags as instruments was verified by Sargan test. Results from this test (Degrees of freedom:18, Teststatistic value:19.65 with a p value(Prob >Chi-square): 0.3529) indicate the adequacy of instruments being used. *PROC PANEL* procedure of *SAS* was utilised for estimating the model.

RESULTS AND DISCUSSION

Parameter estimate on lagged dependent variable is positive and statistically significant, indicating that profit earned in the current period is influenced positively by the profits in the past period. Magnitude of the estimate indicates that the lagged effect dies down eventually. Parameter estimate on rainfall is not statistically significant. Parameter estimate on temperature is negative (-2.1E+08) indicating that profits decrease with increase in temperature. The decrease in profits is at a decreasing rate as indicated by the quadratic term (-3062362) on temperature. Parameter estimator on cloud cover is significant and positive. It indicates that more cloud cover percentage helps in generating more profit (Table 1).

Table 1. Parameter estimates from the Dynamic panel model with Arellano Bond GMM estimator

Variable	Parameter Estimates	Pr > |t|
Profit lag1	0.038079	0.0508
Rainfall	-538264	0.8830
Rainfall squared	-277.7	0.7260
Temperature	-2.1E+08	0.0099
Temperature Squared	-3062362	0.0557
Cloud Cover	1.22E+08	<.0001
Wet Day Frequency	-7.2E+08	0.0028
Standardized Precipitation Index	-2.2E+07	0.0013
Dependent Variable: Profit		

Parameter estimate for wet day frequency is statistically significant and negative indicating that with the higher amount of daily rainfall, the profit margin declines. It is contradictory to the assumption that wet day frequency could support crop growth. Parameter estimate on SPI is statistically significant and negative. It implies that the frequent drought incidence has negative impact on crop profitability.

Impact of change in temperature on profit is calculated as marginal effects from partial differentiation. Impact of change in temperature (1degree C increase) is calculated when the effect of rainfall and all other variables is held constant (at the mean). This marginal impact of change in annual temperatures is shown in Fig. 2. Districts of Bidar, Raichur and Gulburga are most affected by changes in temperature. Southern districts exhibit lesser impacts from temperature change compared to the northern districts. However, district of Chickmaglur in southern region is most affected by changes in temperature.

Interaction between cloud cover, temperature and profits is shown in Fig. 3. A quadratic relationship in terms of temperature and a linear relationship in cloud cover could be observed in the graph. Fig. 3 shows the impact of change in temperature on the profit is negative, higher temperature leads to lesser profit over the period and decline in profit is at decreasing rate. Whereas, the increase in cloud cover helps in earning higher profits over the period. Fig. 3 shows that in case of interaction of two variables the profit is changing its direction after a certain point. The optimum profit level occurs somewhere in middle region of the response surface manifold.

CONCLUSION

Impact of climate change on profitability of farming is estimated in a dynamic panel framework using Arellano Bond GMM Estimator for all the districts in Karnataka state from 1990 to 2018. Results from the model indicated that profits decreased with increase in maximum temperatures (of June month) and the decrease in these profits is observed at a decreasing rate. The impact of cloud cover is positive which shows that in dry regions it supports plant growth and helps in higher revenue generation. The drought incidence measured through SPI shows negative impact on profit. The close observation of SPI-12 shows the inconsistency in drought incidence over the period making farming more vulnerable. Profits realized in the past periods have a statistically significant positive impact on the

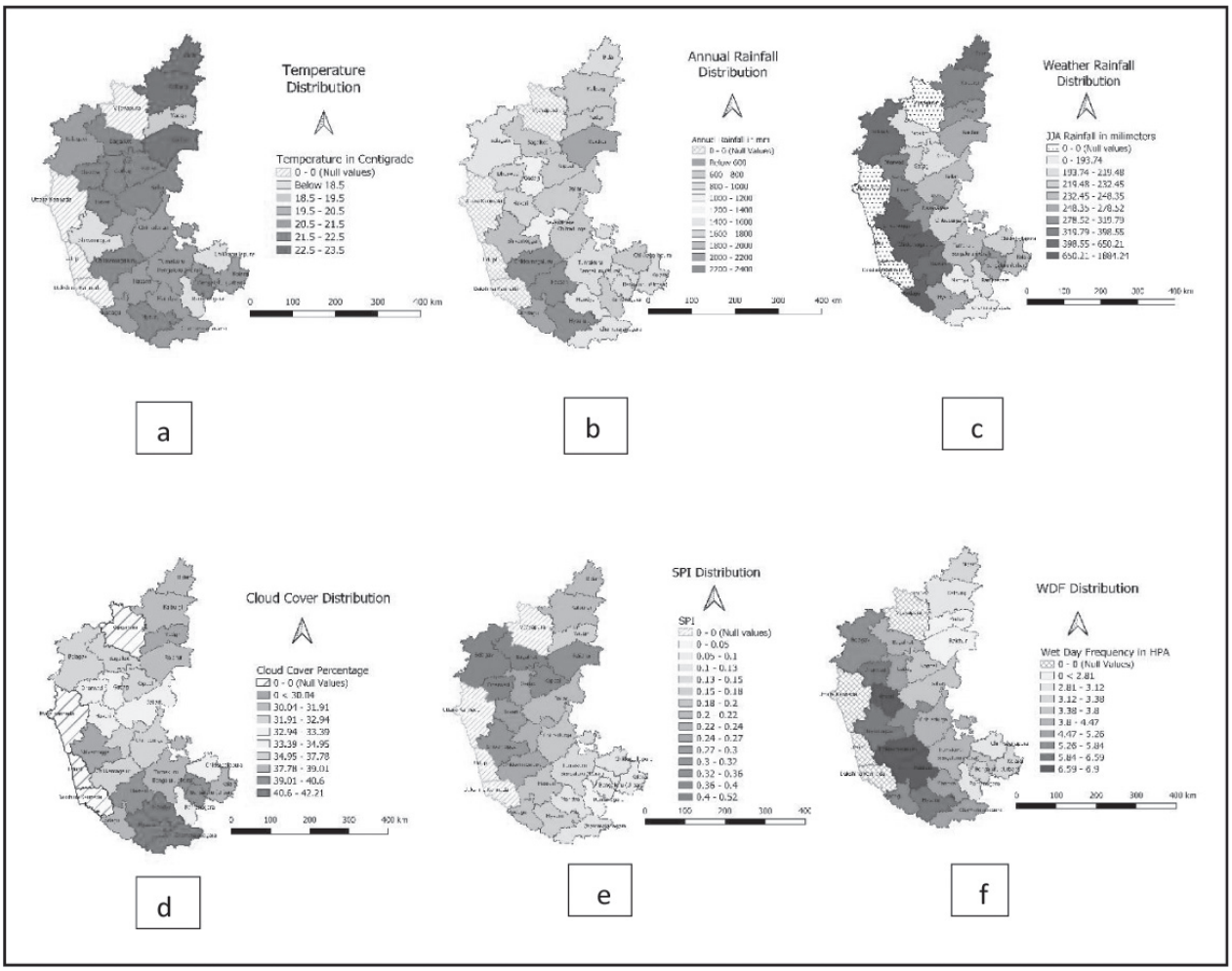

Fig.1. Distribution of Climatic variables across the districts in Karnataka state

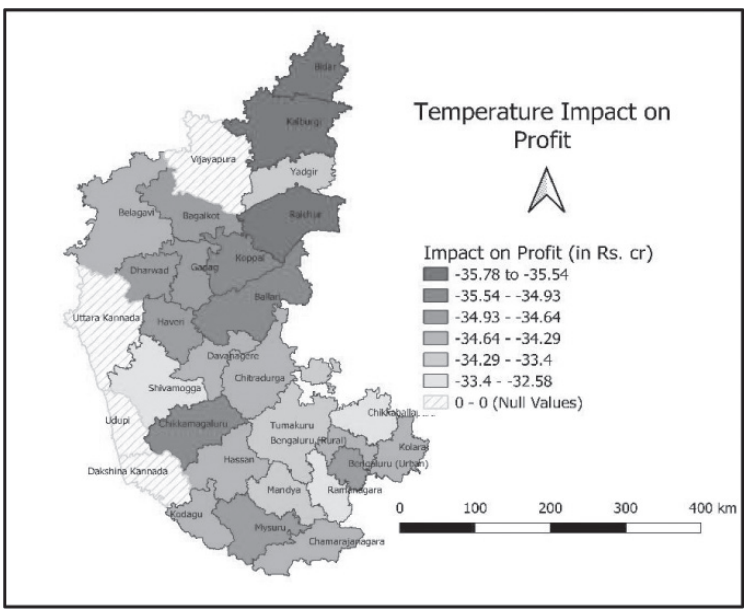

Fig. 2. Impact of temperature change on profit of the districts in Karnataka state

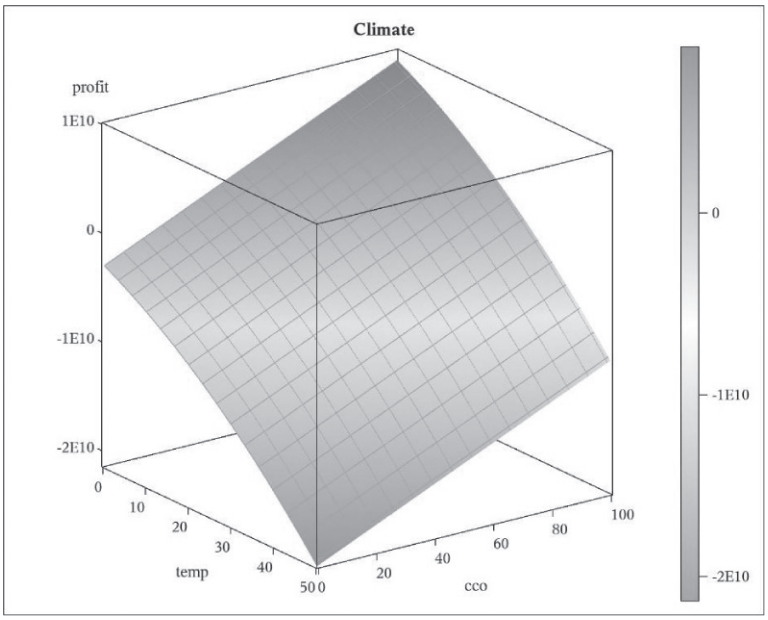

Fig.3. Impact of cloud cover and temperature changes on profit of the districts in Karnataka

current period profits. Due to the presence of these dynamic effects, shocks in any single period could have a long-lasting impact. The study observed that the northern districts with temperature higher than normal and lower annual rainfall than normal are severely affected in terms of crop profitability. Results from the estimated model could be useful to the farmers in making informed choices of consumption and re-investment into next crop from the income generated. Also, the results could improve the understanding of changes of climate on realised income in terms of Rupees. Crop choice could also be made using these results. Crop scientists could design appropriate cultivars, package of practices, given the differential response across different regions of the state. The Government and administrators could also consider these results in designing relief packages that reflect differences across regions to mitigate the adverse impacts arising out of climate change.

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INTEGRATION AND CAUSALITY OF MAJOR GARLIC MARKETS IN UTTAR PRADESH STATE

SUNIL JHADE * and ABHISHEK SINGH

Department of Agricultural Engineering, Institute of Agricultural Sciences,
Banaras Hindu University, Varanasi - 221 005

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ABSTRACT

Garlic prices showed volatility over the past few years, exposing the growers to more risk and consumers paying more.The lack of market intelligence about the potential markets and their pattern of arrivals and prices are the main causes for distress sale of the garlic. The study was aimed to assess the extent and integration among garlic major markets and to study the price movement of garlic major markets in Uttar Pradesh. Different tests *viz.*,Augmented Dickey-Fuller test, Johansen co-integration test, Granger causality test were used for analysis,Monthly wholesale prices from January 2010 to December 2019 of garlic were collected from major garlic markets in Uttar Pradesh. The study recorded that all major markets were well-integrated and at least two co-integrating equations were confirmed by the Johansen test. The Granger causality test indicated that there was bi-directional causality observed in garlic prices between Etah and Luckow markets. The remaining all market pairs exhibited unidirectional causality and affects.

Key Words: Augmented Dickey-Fuller, Co-integration, Granger causality test**,** Market integration, Stationarity

INTRODUCTION

Garlic (*Allium sativum*) is one of the important bulb crops belonging to the family Alliaceous,grown and used as a spice or condiment throughout India. It is also an important foreign exchange earner for India.During the year 2018-2019, Uttar Pradesh is the third largest garlic producer with 0.23 million tonnes, witha cultivated area and producing of 34,310 hectares and 6.62 tonnes per hectare, respectively(Gayathri *et al*., 2018a).

Garlic prices showed volatility in the past few years, exposing the growers to more risk. Moreover, due to its short longevity nature, garlic crop require immediate marketing to ensure quality produce to the consumer and remunerative prices to the growers. The lack of market intelligence about the potential markets and the pattern of arrivals and prices further add to the distresses of the garlic growers (Gayathri *et al*., 2018b).

*Corresponding Author E-mail i.d: suniljhade13@gmail.com

Therefore, the need for proper market efficiency helps the farmer to decide where or in which market to sell their produce to earn more profit. The market integration concept explains the inter-relationship between price movements in the two markets that are spatially separated. The high degree of integration among the markets indicates of efficient functioning of the markets, provides remunerative prices for producers and sellers. The study was undertaken to research extent of integration in major markets of garlic in Uttar Pradesh.

MATERIAL AND METHODS

This study was conducetd during 2020 based on time series data on prices for the period of January 2010 to December 2019 of four selected major garlic markets of Uttar Pradesh *viz.,* Varanasi, Lucknow, Faizabad, and Etah; based on the maximum quantity of arrivals (Agmarknet, 2020).

Analysis of market integration

The market integration concept explains the inter-relationship between price movements in the two markets that are spatially separated. When the markets are integrated, it implies that the markets in the system operate as a single market system. The markets that are not integrated may convey inaccurate price information that might distort market decisions and contribute to inefficient product movement. Johansen's multivariate co-integration test was used to measure the market integration. To check stationarity, the Augmented Dickey-Fuller test was employed. The number of lags was selected by using the Akaike Information Criterion (AIC), Sequential modified LR test statistic (LR),Granger causality test was used to know the direction of causation between the selected markets. Analysis was conducted by EViews software version 10.0.

Co-integration

The concept of co-integration (Engel and Granger, 1987) provides a framework for estimating and testing the long-run equilibrium relationships between the non-stationary integrated variables. If p_{1t} and p_{2t} are the prices in two spatially separated markets (or different levels of the supply chain), if they possess the stochastic trends and are integrated of the same order, say I (*d*), the prices are said to be co-integrated. It can be expressed as follows:

$p_{1t} = \hat{a}_0 + \beta_1 p_{2t} + \varepsilon_t$ ..... (1) where $\mathring{a}_t$ I(0).

Where â is the co-integrating coefficient and the equation (1) is referred to be as the co-integrating regression model. The above relationship can be estimated by using either the Ordinary Least Squares OLS (Engel and Granger, 1987) or a Full Information Maximum Likelihood method developed by Johansen. (Gujarati, 2003)

Augmented Dickey-Fuller test

The stationarity of time series data on garlic prices was tested by applying the Augmented Dickey-Fuller test (ADF). If the series is found to be non-stationary, the first differences of the series are tested for stationary. The number of times (d) a series is differenced to make it stationary is referred to as the order of integration, I(d)**.** Cointegration is investigated for a set of integrated series, however if all of the series are stationary therefore type I (0) the co integration does not exist by definition in this case, its exit series are at stationary I (1). The hypothesis is: H_0: ä = 0 (unit root)

H_1: ä # 0

If t* > ADF critical value then accept the Null hypothesis, i.e., unit root exists, and if t* < ADF critical value then reject the null hypothesis, i.e., unit root does not exist (Sekhar, 2012).

Lag length selection criteria

The number of lags was selected by using different lag length selection criteria viz., Akaike information criterion (AIC), Schwarz information (SC), Hanna n-Quinn information criterion (HQ), Sequentially modified LR test statistic (LR) and Final prediction error (FPE). (Wani *et al.,* 2015)

Co-integration Methods

1) Traditional method: The long-run equilibrium between the markets was examined by using the correlation coefficient between the markets. 2) Modern method: The cointegration between the markets was examined by using modern methods *viz.*, Engel and Grangertwo step method, Johansen's Multiple Co-integration Test, for the present study was used Johansen's Multiple Co-integration test.

Johansen's Multiple Co-integration test

Johansen (1988) has developed a multivariate system of equations approach, which allows for simultaneous adjustment of both or even more than two variables. It relies onthe Maximum Likelihood method and is based on the relationship between the rank of a matrix and its characteristics roots. This cointegration test is based on two test statistics viz., trace statistic, and maximum eigenvalue estimated to test the null hypothesis of 'r' cointegrating vectors against the alternative hypothesis of 'r+1' cointegrating vectors. (Reddy *et al.*, 2012)

Granger Causality test

The Granger causality test was applied to study the price integration and to know the direction of causation between the selected markets. It is named after the first causality tests performed by Clive Granger (1969). Granger causality between prices of two markets P_{1t} And P_{2t} is specified as:

$$P_{1t} = \alpha_0 + \sum_{i=1}^{m} \alpha_i P_{1t-i} + \sum_{j=1}^{m} \beta_j P_{2t-j} + \varepsilon_{1t}$$

$$P_{2t} = \alpha_0 + \sum_{i=1}^{m} \gamma_i P_{2t-i} + \sum_{j=1}^{m} \theta_j P_{1t-j} + \varepsilon_{2t}$$

in which,

P_{1t} And P_{2t} are price series of two markets at period t

á, â, ã, and è are parameters to be estimated m is the maximum number of lagged prices included in the model.

However, between P_{1t} and P_{2t}, if P_{1t} Granger causes P_{1t} and P_{2t}, Granger cause P_{1t} and P_{2t},, it is called as bi-directional causality. If only one exists, then it is the case of uni-directional causality. If both do not exist, then the price series are independent of each other, it means no causal relationship exists (Rita, 2018).

RESULTS AND DISCUSSION

Correlation coefficient for prices of garlic at selected markets in Uttar Pradesh state

The bivariate correlation coefficients were calculated using price series for garlic in major markets of Uttar Pradesh state, and correlation coefficients ranges between 0.903 to 0.958 (Table 1).The strong associations were observed for three market pairs namely Varanasi–

Table 1. Correlation coefficient of prices for selected garlic markets in Uttar Pradesh state

Markets	Varanasi	Lucknow	Faizabad	Etah
Varanasi	1	0.9586**	0.9501**	0.9219**
Lucknow	0.9586**	1	0.9388**	0.9036*
Faizabad	0.9501**	0.9388**	1	0.9261**
Etah	0.9219**	0.9036*	0.9261**	1

* Significant at 5% level; ** Significant at 1% level

Table 2. ADF test results of garlic prices for selected markets

Variables	level		First difference	
	t-statistics	p-value	t-statistics	p-value
Varanasi	-2.203335	0.2064	-7.798205	0.0001
Lucknow	-2.425185	0.1371	-8.786603	0.0001
Faizabad	-1.640149	0.4589	-7.885665	0.0001
Etah	-2.471125	0.1251	-11.76008	0.0001

Table 3. VAR lag order selection criteria results

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-3740.518	NA	1.29E+24	66.86639	66.96348	66.90579
1	-3560.354	344.2413	6.87E+22	63.9349	64.42035*	64.13186*
2	-3539.107	39.08008*	6.26e+22*	63.84120*	64.715	64.19573
3	-3531.652	13.17991	7.31E+22	63.99378	65.25594	64.50588
4	-3521.866	16.60012	8.21E+22	64.10476	65.75527	64.77442
5	-3506.963	24.21755	8.45E+22	64.12434	66.16322	64.95158
6	-3496.307	16.55502	9.41E+22	64.21977	66.647	65.20458
7	-3483.83	18.493	1.02E+23	64.28268	67.09827	65.42505
8	-3474.321	13.41396	1.17E+23	64.3986	67.60254	65.69854

*** indicates lag order selected by the criterion**

Table 4. Johansen's co-integration test results

	Eigen Value	Trace Statistics	Critical Value	Probability	Max Eigen Stats	Critical Value	Probability
None *	0.316366	73.10534**	40.17493	0.0001	44.49885**	24.15921	0.001
At most 1 *	0.158746	28.6065*	24.27596	0.0134	20.22476*	17.7973	0.0211
At most 2	0.068632	8.381736	12.3209	0.2086	8.318843	11.2248	0.1551

* Significant at 5% level; ** Significant at 1% level

Table 5. Testing for pair-wise Granger causality

Null Hypothesis	No. of observations	F-Statistic	Prob.	Direction
LUCKNOW does not Granger Cause VARANASI VARANASI does not Granger Cause LUCKNOW	117	1.0624 413.6485**	0.3491 5.00E-06	Uni
FAIZABAD does not Granger Cause VARANASI VARANASI does not Granger Cause FAIZABAD	117	5.72746** 0.38878	0.0043 0.6788	Uni
ETAH does not Granger Cause VARANASI VARANASI does not Granger Cause ETAH	117	2.52707 14.4384**	0.084 43.00E-06	Uni
FAIZABAD does not Granger Cause LUCKNOW LUCKNOW does not Granger Cause FAIZABAD	117	16.7685** 0.192	4.00E-07 0.8256	Uni
ETAH does not Granger Cause LUCKNOW LUCKNOW does not Granger Cause ETAH	117	9.27666** 9.54818**	0.0002 0.0001	Bi
ETAH does not Granger Cause FAIZABAD FAIZABAD does not Granger Cause ETAH	117	0.32523 22.1134**	0.723 8.00E-09	Uni

* Significant at 5% level; ** Significant at 1% level

Lucknow, Varanasi – Faizabad and Faizabad – Lucknow. A weak association composed with other pairs was observed for the market pairs Etah - Lucknow. There is a high and positive significant relation between Varanasi, Lucknow, Faizabad, and Etah markets (Table 1).

Testing stationary in price series

The Augmented Dickey-Fuller (ADF) based unit root test was carried out to check the stationary of the time series price data from four representative garlic markets. From Table 2, it is observed that at level with lag one, the ADF

values of Varanasi (-2.20), Lucknow (-2.42), Faizabad (-1.64), and Etah (-2.47) were more than the critical value at one per cent level of significance indicating the non-existence of unit root which implies that the price series of four markets were non-stationary. After taking the first difference with lag one, the Augmented Dickey-Fuller (ADF) values of Varanasi (-7.79), Lucknow (-8.78), Faizabad (-7.88), and Etah (-11.76) are lower than that of the critical value at one per cent level. This implied that the prices series become stationary at first difference level and are free from the consequence of unit root.

Lag length selection criteria

Vector autoregressive (VAR) lag order of five selection criterion was employed to the cointegration and calculated optimum numbers of lags of endogenous variables (Table 3). The table shows that outof five criteria, two *i.e.,* SC and HQ are showingthe use of one lag for model. AIC and FPI suggests the lag of three for the study. Optimum Lag of one was selected for the analysis to avoid complexities.

Co integration among the prices of the commodity in different markets

To test whether the selected garlic markets are integrated or not, Johansen's Multiple Co-integration test was employed (Table 4). The results of the co-integration test showed that at least two co-integration equations are at 5% level of significance indicating that the selected garlic markets are having a long-run equilibrium relationship and there exists co-integration between them.

Causality among prices

Granger Causality Test (Granger, 1969) can be used to analyse the direction of two variables, if co-integration relationship is present. Theoretically, a variable is said to Granger-cause another variable, if the current value is conditional on the past value. Table 5 shows that there was unidirectional causality affected on garlic prices of Varanasi – Lucknow, Faizabad –Varanasi, Etah – Varanasi, Faizabad – Lucknow, and Faizabad – Etah, which means that a price change in the former market in each pair Granger cause the price formation in the latter market, whereas, the price change in the latter market is not fed back by the price change in the former market. There is bidirectional causality affected on garlic prices of Etah-Lucknow, indicating that Etah and Lucknow prices were dependent upon each other.

CONCLUSION

The study analysed market integration and causality of major garlic markets in Uttar Pradesh state. The selected garlic markets showed cointegration among them as indicated by the results of Johansen's Multiple Co-integration Test. There was a bi-directional causality between Etah and Lucknow markets. The remaining all market pairs exhibited unidirectional causality and effects. It is recommended that the long-term procurement policy should be adopted to maintain price stability throughout the year.

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IMPACT OF FARM MECHANIZATION ON INCOME AND EMPLOYMENT AND CONSTRAINTS IN MECHANISATION OF RICE CULTIVATION IN WEST GODAVARI DISTRICT

SK. GOUSIYA and K. SUSEELA*

Department of Agricultural Economics, Agricultural College,
Acharya N.G. Ranga Agricultural University, Bapatla- 522 101

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ABSTRACT

Impact of mechanised rice cultivation on income and employment in West Godavari district was estimated using multiple linear regression analysis. The results revealed that the coefficient of machine cost and fertilizer cost was found to be significant,in fully mechanised farmswhich indicates increase in machine and fertilizer cost by one unit would result in 2.31 units and 0.25 units increase in the net income, respectively. In partially mechanised farms, the coefficient of machine cost and manures cost was found to be significant. This means an increase in machine cost and manures cost by one unit would result in an increase of 13.21 and 0.20 units in the net income, respectively. Impact of farm mechanisation on employment of labour revealed that the coefficient of input costs and machine time were negative and significant which indicates that, one unit increase in the input costs and machine use time, would decrease the labour requirement by 0.06 and 4.34 units respectively. Major constraints identified in fully mechanised farms were insufficient number of machinery and high cost of machines. Whereas, in partially mechanised farms, lack of awareness on government subsidyfor machines and low amount of subsidy were the major constraints.

Keywords: Rice, income, employment, mechanised farms, Andhra Pradesh

INTRODUCTION

Agricultural labour has become the most important resource in Indian agriculture and the cost of human labour constituted almost half of the total cost of cultivation of major crops. Even though India has the second largest man-power in the world, all the sectors of the economy have been affected by the scarcity of labourers, but the impact being felt more in the agricultural sector. Labour are migrating to different parts of the country for higher income and growth opportunities in other sectors, when compared to agricultural sector. The agricultural labour to total workforce ratio is expected to decrease from 55 per cent in 2011 to 41 percent by 2020, with a further decline to 26 percent by 2030 (FICCI, 2017). This trend of declining agricultural labour to total work force can become a serious threat

*Corresponding Author E-mail i.d: ; M.Sc thesis submitted to Acharya N.G. Ranga Agricultural University, Guntur

to the overall sector's productivity, income level and standard of living of Indian farmers. Technology and machines will be key solutions to the problem of growing shortage of labour as they save time and money besides resulting in higher yield. In Andhra Pradesh, the area under rice is 23.79 L ha with a production of 92.27 MT and productivity of 3941 kg ha^{-1} (TE 2015-16). Rice is the principal crop grown in West Godavari district. However, the district is facing the problem of labour shortage due to high economic growth, fast infrastructure development, higher wages in other jobs available locally, shifting to regular/ permanent job from agricultural job, agriculture labour being presumed to be a low esteemed job, migration to nearby city for higher wages, migration due to improvement in educational status etc. This labour shortage necessisates promotion of the mechanisation which provides much needed support to farmers troubled by shortage of labour. Hence, the study was undertaken to assess the impact of farm mechanisation on income and employment of labour in fully and partially mechanised rice farms and constraints in adoption of mechanisation in rice farms.

MATERIALS AND METHODS

West Godavari district was purposively selected for the study as it is the highest rice producing district in Andhra Pradesh with an area of 3.99 lakh ha and with a production of 2.54 lakh tonnes for the year 2017-18. Four mandals and two villages from each mandal were selected purposively based on the extent of adoption of mechanisation in rice. The desired sample size was determined by using the Cochran's formula and from each village the sample was selected randomly in proportion to the sample size thus, making a total sample of 122 rice farmers. The selected respondents were interviewed personally with the help of well-structured interview schedule and the information collected was analysed using multiple linear regression and Garrett's ranking technique.

Multiple Linear Regression model

The following multiple linear regression analysis was used to study the impact of mechanisation on income in rice production for the sample farmers.

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6$$

In the above equation:

Y = Net income (Rs. ha^{-1})

X_1 = Human labour cost (Rs. ha^{-1})

X_2 = Machine power cost (Rs. ha^{-1})

X_3 = Seed cost (Rs. ha^{-1})

X_4 = Manures cost (Rs. ha^{-1})

X_5 = Fertilizers cost (Rs. ha^{-1})

X_6 = Plant protection chemicals cost (Rs. ha^{-1})

b_1, b_2, b_3, b_4, b_5 and b_6 are regression co-efficients and 'a' denotes intercept

Multiple Linear Regression model with dummy variable

The multiple linear regression with dummy variable analysis was used to study the impact of mechanisation on employment of human labour in rice production for the sample farmers.

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4$$

In the above equation:

Y = Human labour (hrs. ha^{-1})

X_1 = Machine labour (hrs. ha^{-1})

X_2 = Gross returns (Rs. ha^{-1})

X_3 = Cost of cultivation (Rs. ha^{-1})

X_4 = Dummy (1 for fully mechanized, zero for partially mechanised)

X_1, X_2, X_3 and X_4 are all parameters affecting the level of Y

b_1, b_2, $b_3$and $b_4$are regression co-efficients and 'a' denotes intercept

Garett Ranking Technique

The constraints were ranked by the farmers and these ranks were converted into scores by using Garett table. The ranks were converted into percentage positions by using the Garrett's formula.

Percentage position = $\frac{100\ (R_{ij} - 0.5)}{N_j}$

Where,

R_{ij} = Rank given for i^{th} item by the j^{th}individual

N_j = Number of items ranked by the j^{th} individual

The percentage position of each rank thus obtained was converted into scores and the scores of the individual respondents were added and divided by the total number of respondents. Thus, the mean score for all the constraints were arranged in descending order and then ranks were assigned to individual constraints.

RESULTS AND DISCUSSION

Impact of farm mechanisation on income

Impact of farm mechanisation on income was estimated by using multiple linear regression (Table 1).The coefficient of multiple determination R^2 for fully mechanised farms was 0.83 which indicated that83 per cent of variation in dependent variable would be explained by independent variables. The coefficient of machine cost and fertiliser cost was found to be significant. This means an increase in machine cost and fertiliser cost by one unit would result in an increase of 2.31 and 0.25 units in the net income, respectively. The estimated coefficient of human labour cost and plant protection cost were found to be negatively significant indicating that every one unit increase in human labour cost and plant protection cost would reduce the net income by 1.00 and 0.55 units respectively, indicating excessive use of plant protection chemicals and human labour.

In partially mechanised farms, the coefficient of multiple determination R^2 was 0.79 which indicated that 79 per cent of variation in dependent variable will be explained by the independent variables. The coefficient of machine labour cost and manures cost was found to be significant. This means an increase in machine labour cost and manures cost by one unit would result in an increase of 13.21 and 0.20 units in the net income, respectively. The coefficient of human labour cost and plant protection cost was found to be negatively significant indicating that every one unit increase in human labour cost and plant protection chemical cost would reduce the net income by 5.06 and 2.32 units, respectively indicating excessive use of human labour and plant protection chemicals.

Impact of farm mechanisation on employment of human labour

Impact of farm mechanisation on employment of human labour was estimated by using multiple linear regression and the results (Table 2). The results revealed that the coefficient of multiple determination R^2 was 0.82

Table 1. Estimation of Multiple regression analysis of fully and partially mechanised rice farms

S.No.	Variables	Fully mechanised farms		Partially mechanised farms	
		Coefficient	Standard error	Coefficient	Standard error
1	Intercept	893.56	439.38	524.21	138.26
2	Machine labour cost	2.31***	0.14	13.21***	2.35
3	Human labour cost	-1.00**	0.60	-5.06**	0.065
4	Seed cost	1.87	5.06	-2.1	3.89
5	Manures cost	-0.006	0.52	0.20***	0.97
6	Fertilizers cost	0.25**	0.40	0.01	0.19
7	Plant protection chemical cost	-0.55**	0.92	-2.32**	0.42
	R^2	0.83	0.79		

Note: ***significant at one per cent level; **significant atfive per cent level

Fully mechanized = $Y= 893.56 + 2.31X_1 - 1.00X_2 + 1.87X_3 - 0.006X_4 + 0.25X_5 - 0.55X_6$

Partially mechanized = $Y = 524.21 + 13.21X_1 - 5.06X_2 - 2.1X_3 + 0.20X_4 + 0.01X_5 - 2.32X_6$

Table 2. Estimated regression coefficients of labour employment

S.No.	Notation	Variables	Co-efficient	Standard error	t-value	F-value	R^2 value
1	Y	Human labour use time (hrs)	252.30	18.86	13.37***	37.95	0.82
2	X_1	Machine labour use time (hrs)	-4.34	0.76	5.69***		
3	X_2	Output (Rs)	0.002	0.007	3.32		
4	X_3	Input (Rs)	-0.06	0.003	3.61***		
5	D	Dummy variable	-112.6	2.50	5.03***		

Number of observations = 122; **Note:** *** significant at one per cent level

Model = $Y= 252.30 - 4.34X_1 + 0.002X_2 - 0.06X_3 - 112.6D$;

Where, dummy variable ‘one’ represents fully mechanised farms and ‘zero’ represents partially mechanised farms

Table 3. Constraints in adopting mechanisation by fully and partially mechanised farms

S. No.	Constraints	Fully mechanised farms		Partially mechanised farms	
		Mean score	Rank	Mean score	Rank
1	Insufficient number of machineries	81.57	I	48.37	IX
2	Higher cost of machineries	76.15	II	72.03	III
3	Poor scope for custom hiring	24.90	XIV	43.67	X
4	Land quality	47.14	IX	50.16	VIII
5	Lack of knowledge to operate and maintenance of farm machineries	50.34	VIII	64.06	IV
6	Fuel cost and spare parts of machines	60.38	V	52.96	VII
7	Lack of awareness on subsidy for purchase of machines	40.12	XI	83.72	I
8	Education	43.61	X	39.45	XI
9	Timely availability of skilled labour at cheaper rate to operate the machines	70.36	III	61.59	V
10	Use of by product for livestock maintenance	53.19	VII	37.37	XII
11	Manufacturing defects	32.17	XIII	27.20	XIV
12	Weather/ climate	35.73	XII	18.18	XV
13	Size of the farm	18.52	XV	63.18	VI
14	Service of implements	57.12	VI	32.54	XIII
15	Inadequate amount of Govt. subsidy	66.92	IV	77.47	II

which indicates that 82 per cent of variation in labour requirement would be explained by the independent variables. The negative and significant coefficient of input costs and machine time indicated that one unit increase in the input costs and machine labour time, would decrease the labour requirement by 0.06 and 4.34 units, respectively. The results are in line with Rahman *et al.* (2011) and Aurangzeb (2007) who also stated that a unit increase in machine labour would decrease the human labour requirement.

Constraints in adopting farm mechanisation in rice cultivation

The constraints in mechanisation of rice cultivation were studied using Garett's ranking technique (Table 3). The results revealed that in case of fully mechanised farms, insufficient number of machineries with a mean score of 81.57 followed by high cost of machinery (with a mean score of 76.15) , timely availability of skilled labour at cheaper rate to operate the

machines (with a mean score of 70.36) , low amount of govt. subsidy (with a mean score of 66.92) , fuel cost and spare parts of machines (with a mean score of 60.38), service of implements (with a mean score of 57.12), use of by-product for livestock maintenance with a mean score of 53.19 were the major constraints.

In partially mechanised rice farms, lack of awareness on subsidy for purchase of machines (with a mean score of 83.72), low amount of government subsidy (with a mean score of 77.47), higher cost of machinery with a mean score of 72.03, lack of knowledge to operate and maintain farm machineries (with a mean score of 64.06), timely availability of skilled labour at cheaper rate to operate the machines (with a mean score of 61.59), size of the farm (with a mean score of 63.18), fuel cost and cost of spare parts of machines (with a mean score of 52.96) were the major constraints.

CONCLUSION

Impact of farm mechanisation on income and employment in rice cultivation revealed that in the case of fully mechanised farms, one unit increase in machine cost and fertilizer cost would increase the net income by 2.31 and 0.25 units, respectively. In the case of partially mechanised rice farms, one unit increase in machine cost and manures cost would increase the net income by 13.21 and 0.20 units, respectively. Impact of farm mechanisation on employment revealed that one unit increase in input costs and machine time would decrease the labour requirement by 0.06 and 4.34 units, respectively. The major constraints in fully mechanised farms were insufficient number of machinery and high cost of machines. Whereas, in partially mechanised farms, lack of awareness on subsidy for the purchase of machines and inadequate amount of government subsidy were the major constraints. Hence, the government should provide subsidy on the machinery for partially mechanized farms to increase the rice productivity.

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ASSESSMENT OF SUPPLY CHAINS IN DAIRY SECTOR OF TELANGANA STATE: RISK, RETURNS AND PERFORMANCE ANALYSIS

MOHD ABDUL MUQEET MAAZ* AND RAIS AHMAD

Department of Agricultural Economics and Business Management,
Aligarh Muslim University, Aligarh- 202 002

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ABSTRACT

The objective of this study is to examine risks, returns and performance of farmer-producers in the dairy supply chain and to empirically test the relationship between risk, returns and performance of farmers-producers for Telangana state. This study is based on primary data consists of 213 farmers from the state of Telangana. The results revealed that organized (institution) selling had lower risks and lower returns when compared to unorganized (personal) selling. Farmers prefer cooperatives societies, though they offer lesser price compared to other channels, owing to overall benefits which are mostly intangible. Risk had positive impact on returns and negative impact on performance, whereas, returns had positive impact on performance.

Keywords: Risk, Returns, Dairy farmers, Dairy supply chain, Supply chain performance

INTRODUCTION

Dairy industry is one of the largest industries providing employment to masses. Production of milk offers monetary as well as health benefits; therefore, milk production is spread across length and breadth of India (Khamkar, 2014). India is highest producer of milk in the world with a record of 187.7 million tons in 2018-19 with a growth rate of 6.5% (Economic Survey, 2019), (Basic Animal Husbandry Statistics, 2019). There are several channels of milk marketing in India and more than half of milk is marketed by unorganized sector (Rajendran and Mohanty, 2004), (Maaz *et al*., 2020). These channels of marketing form dairy supply chain through which milk ultimately reach the consumer. A farmer-producer may exclusively sell product through one channel or a combination of channels based on risk and returns involved in each channel. The risks for a farmer-producer in a dairy supply chain include fluctuations in price/production, health of the cattle, spoilage and wastage, risks of changes in weather, quality of input etc. The extent of risk and return in each channel differs; therefore, a farmer tries to maximize his earnings through selection of best channel/channels in a supply chain.

*Corresponding Author E-mail i.d: mamaaz@myamu.ac.in; PhD thesis submitted to Aligarh Muslim University, Aligarh

A dairy supply chain consists of farmer-producers, bulk milk coolers, processing units, wholesalers, retailers and consumers (Mishra and Shekhar, 2011). The framework proposed by Aramyan*et al*., 2006 measures agri-food supply chain performance through four indicators namely efficiency, reponsiveness, flexibility and quality. Efficiency is the input-output ratio; flexibility and responsivenss is the ability to change according to customer demands and fulfill them and quality include attributes such as tatse, shelf-life,etc.

Though dairy industry is one of the largest sectors of employment, yet its competitiveness in global market is low and its exports also do not match its production (Madhavan *et al*., 2020). Many researchers and practioners agree that improvement in supply chain will enhance global competitiveness. Since farmer-producers are the originators of dairy supply chain, improvements at this stage will lead to improvements in all other stages of supply chain. In this context, this study has been designed to examine how risks and returns in various channels of a dairy supply chain can impact performance at producer level. Keeping this in view, the study was conducted in 2020 with following objectives: To study risks and returns of farmer-producers from sale of milk through various channels in a dairy supply chain; To study the performance of supply chain at farmer-producer level in a dairy supply chain; To study the impact of risk on returns and To study the impact of risks and returns on performance of farmer-producers in a supply context.

Hypotheses

H1: Higher risks in production of milk brings higher returns; H2: Higher risks in production of milk enhances supply chain performance producer-level; and H3: Higher returns from production of milk enhances supply chain performance at producer-level.

MATERIAL AND METHODS

The sample of this study is dairy industry Telangana of state. The state of Telangana was chosen purposefully because it is hub to successful dairy cooperatives and reputed private brands.

The sample was selected in two stages; in the first stage, list of dairy cooperatives (Telagana State Dairy Development Cooperative Federation with its processing units in seven districts was taken as separate units (because of their separate production and marketing operations) and private dairy firms list was obtained and two from each category were randomly selected and their cooperative societies/procurement centers were traced. In the second stage, four villages from each firm were selected randomly and 15 farmers from each village were taken as the sample. The final sample consisted of 213 farmers . The survey was carried out from August 2020 to December 2020.

The selected farmers were interviewed personally. The questions on risk and prerformance was converted to a scale of 5 where 1 is lowest and 5 is highest. Data on returns was collected through costs and returns.

Analytical Tools: The profibility is calculated as difference between costs and revenue. The Return on Invetsment (ROI) is calculated as ratio of costs and profit. The assigned scores of performance are: 1= very low, 2= low, 3= modertae, 4= high, 5= very high.

The assigned scores scores of risks are:

- Probability: 1= very low; 2= low; 3= moderate; 4= high; 5= very high.
- Severity: 1= insignificant; 2= minor; 3= neutral; 4= serious; 5= catastrophic
- Impact: 5 = very weak; 6 to 10 = weak; 11 to 15 = moderate; 16 to 20 = strong; above 20 impact = very strong.

The variables under study were analysed in SPSS AMOS version 20 to derive the results.

RESULT AND DISCUSSION

Table 1. Sale of milk through different channels (n=213)

Institute type	Quantity (L/ day	Selling price /litre(Rs)
Cooperative societies	4.01	44
Private dairy industry	2.12	45
Local dairy units	2.98	49
Direct sale	4.14	54

Source: field survey

Table 1 shows quantity of milk sold through various channels and their selling price. Highest quantity of milk is sold directly to consumers that fetches highest price of Rs.54 per litre; followed by sale to cooperative societies at an average price of Rs.44; local dairy units at a price of Rs. 49 and least amount of milk is sold to private dairy firms at a cost of Rs.45 per liter. Personal selling offers higher price compared to institutionalized selling because of the fact that dairy cooperative and private dairy firms offer price based on fat content which brings fluctuations in price received averaging Rs.44 and Rs.45 per litre; whereas, personal selling does not involve any kind of tests; therefore, they sell at uniform price thus bringing average cost to Rs.49 and Rs.54 per litre.

Table 2. Cost of milk production per liter of milk (n=213)

Factors	Cost (rupees)
Feed and fodder	9.13
Medicines	5.17
Labor	3.07
Maintenance	0.89
Miscellaneous	0.20
Total	**18.46**

Source: Field survey

Table 2 shows factors and their costs in production of milk. Highest cost is incurred in procuring feed and fodder followed by medicines and labor. Maintenance and miscellaneous costs are very low and together form a rupee for one liter of milk. The total cost for production of one liter of milk is Rs.18.46.

Table 3 is a depiction of costs and returns of milk production. The discussions with farmers reveal they use one or two methods to minimize risks and maximize returns. For instance, a farmer selling milk to private dairy firms will sell a part of his produce directly to consumer.

All the values in the Table 3 are calculated for 1 liter of milk. The total costs are 18.46 rupees (from Table 2); cost of institutionalized selling is 0 because it does not require storage or transportation. Selling through local dairy units and directly to consumer costs 0.79 and 0.77 rupees per litre in the form of storage, transportation, etc. Total cost of selling milk is same as production cost for institutionalized selling while total costs for sale through local

Table 3. Costs and returns of milk production per litre in rupees (n=213)

Item	Cooperative societies (Rs.)	Private dairy firms	Local dairy units	Direct sale (Rs.)
Cost of milk production per litre	18.46			
Cost of selling milk per litre	0	0	0.79	0.77
Total costs of farmer-producer per litre of milk	18.46	18.46	19.25	19.23
Revenue	44	45	49	51
Profit	25.54	26.54	29.75	31.77
Return on investment (%)	37.81	43.77	54.54	65.21

Source: Researchers' calculation based on field survey

dairy units is Rs.19.25 and direct sale is Rs.19.23 rupees. The revenue is gross returns which are same as selling price. Profit is 25.54 rupees for farmers selling to dairy cooperatives; 26.54 rupees for farmers selling to private dairy firms; 29.75 rupees for farmers selling to local dairy units and 31.77 rupees for farmers selling directly to consumers. The profit from one liter of milk is high because only operational costs are deducted from the revenue; fixed costs such as purchase cost of cattle, cost of cattle shed etc. are not deducted from the revenue. The return of investment (ROI) for farmers selling to dairy cooperatives is 37.81%; ROI for farmers selling to private dairy firms is 43.77%; ROI for farmers selling to local dairy units is 54.54% and ROI for farmers selling directly to consumers is 65.21%.

The probability of the risks is low in institutionalized selling and moderate in personal selling. The difference in the risk probability scores is not very high across the four categories offarmers. However, the probability of risks is low in institutionalized selling because of fewerfluctuations in price in contrast to personal selling which is characterized by higher pricefluctuations since they are very sensitive to market conditions. The probability of health and low-quality input risk in also low in institutionalized selling; therefore, overall risk probability ofinstitutionalized is lower compared to personal selling. The severity of risks is serious for institutionalized sellers and catastrophic for personal sellers. The low probability and high risk severity indicates that risks are of low occurrence, but if they are to occur, the consequenceswould be serious. The risk impact is weak for institutional sellers and moderate for personalsellers.

The risk matrix shows that selling milk directly is riskiest proposition and selling milk through dairy cooperatives is least risky. In institutional selling, farmers do not have to worry about issues such as spoilage and wastage as they need not store milk; the milk is sold as soon as it is harvested. It not only saves cost but also

Table 4. Risk matrix of farmer-producers (n=213)

Risks	Probability				SeverityImpact				(probability* severity)			
	DC	PF	LD	DS	DC	PF	LD	DS	DC	PF	LD	DS
Fluctuations in production	2	2	2	2	3	3	3	4	6	6	6	8
Fluctuations in price	1	2	2	3	3	4	5	5	3	8	10	15
Spoilage and wastage of milk	3	3	3	3	2	2	5	5	6	6	15	15
Health risks and mortality	2	2	3	3	5	5	5	5	10	10	15	15
Risks of changing weather and climate	2	2	2	2	3	3	3	3	6	6	6	6
Low quality input	1	2	3	3	4	4	4	4	4	8	12	12
Consolidated risk scores	**1.83**	**2.16**	**2.5**	**2.83**	**3.83**	**4**	**4.66**	**5**	**7.0**	**8.6**	**11.6**	**14.1**

Source: Field survey; DC= Dairy cooperatives; PF= Private firms; LD= local dairy units; DS= Direct sale to consumer

transfers the risk to the cooperative society, unlike direct selling where milk has to be stored until it is supplied to the consumer.

Table 5. Performance indicators of farmer-producers in a dairy supply chain (n=213)

Indicator	Score
Efficiency	3.32
Flexibility	3.01
Responsiveness	3.19
Quality	3.78
Overall performance	**3.32**

Source: Field survey

Table 5 shows performance of producer-farmers in a supply chain context. The score of efficiency is 3.32 indicating the production system is moderately efficient; the score of flexibility is 3.01 indicating that performance of flexibility is moderate; the score or responsiveness is 3.19 which means moderate performance and score of quality is 3.78 which is moderate to high.

The Table 6 shows results of the research model. An increase of risk by 1.0 standard deviation will increase returns by 0.21 standard deviations; increase in risk by 1.0 standard deviation will bring a decrease of 0.03 standard deviations in supply chain performance of farmer-producers; increase of returns by 1.0 standard deviation will cause an increase of 0.43 standard deviation in the performance of supply chain. The p-value of H1 and H3 are less than 0.05, therefore, H1 and H3 are supported implying that there is positive relationship between supply chain risk and returns from the milk production; returns from the milk production and supply chain performance. The p-value of hypothesis H2 is greater than 0.05; therefore, H2 is not supported.

Table 6. Testing of hypothesis (n=213)

	Standardized coefficient	P value	Decision
Returns<— Risk	0.21	0.009**	H1: Supported
Performance<— Risk	-0.03	0.091	H2: not supported
Performance<— Returns	0.43	0.000**	H3 : Supported

Source: Researcher's calculations

Higher risks results in higher returns and lower performance, while, higher returns lead to higher performance. Risks at the level of farmers-producer in the dairy supply chain add to returns but reverse good performance.

CONCLUSION

Farmers continue to prefer dairy cooperatives for sale of their milk eventhough low average price per litre is obtained because of intangible benefits from the membership of the cooperatives. Organized Institutional selling/ buying is less risky and enhances overall supply chain performance; therefore, dairy cooperatives must play proactive role in milk procurement and expand their reach to include farmers from all corners of the country. The interactions between risk, returns and performance of farmer-producers in the dairy supply chain revealed that higher risks result in higher returns, but this proposition is not successful in the long-run. Higher risks cause negative performance of supply chain.

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AWARENESS OF FARMERS AND TRADERS TOWARDS BENEFITS OF ELECTRONIC NATIONAL AGRICULTURE MARKET (E-NAM)

NITISH KUMAR SINGH* and M. V. ALAGAWADI

Department of Business Studies, School of Business Studies,

Central University Karnataka (CUK), Kalaburagi - 585102

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ABSTRACT

The study aims to comprehend the scope of e-platforms in the agriculture sector viz., e-NAM (e-National Agriculture Market), launched by the Government of India in 2016 and to solve the inherent problems andstudy aimed to explore the awareness of farmers and traders towards the e-NAM benefitsin three selected *mandis* (markets) in Andhra Pradesh. The sample constituted for the studycomprised of 110 farmers and 90 traders across Andhra Pradesh mandis selected through quota sampling method.Garrett's ranking technique and the chi-square test areused to analyse data in SPSS software. The study revealed that educational qualification and age are essential factors in creating the awareness of e-NAM and surfaced thatthe benefits of the electronic platform would effectively reach the farmers and traders through strategies for sensitisation towards e-NAM.

Keywords: Agriculture Marketing,e-NAM, Farmers, Electronic platform, electronic-National AgricultureMarket, Sensitisation

INTRODUCTION

The agriculture sector is a significant part of the Indian economy, accounting for about 17% of GDP (Gross Domestic Product) and employing around 60% of the population (Aggarwal *et al*., 2016). Food grain demand increased from 51 million tonnes in 1950-51 to 297 million tonnes in 2019-20 (IBEF, 2021). The Government of India (GOI) has paid more attention for improving coverage of irrigated land and increasing the financial capabilities of farmers. However, there has been paid less attention for improving the post-harvest infrastructure of agricultural marketing (NABARD, 2018). Although India is among one of the top producers of agricultural commodities, the farmers face uncertain marketing facilities, lack of infrastructure, transportation problems, and interference of middlemen (Saxena *et al*., 2017).

The Government of India recognises the importance of effective agricultural produce marketing for the sector's growth to address the above-stated problems, including developing and upgrading the country's agricultural

*Corresponding Author E-mail i.d: nitishsingh@cuk.ac.in; PhD thesis submitted to Central University Karnataka (CUK), Kalaburagi - 585102

marketing mechanism. The most significant intervention has been developing controlled markets to ensure public scrutiny of the entire marketing system. The APMC bill was primarily based on a Model APMC Act (2003), to resolve problems with the traditional marketing system by creating processes for proper produce sale, weighing, assaying, grading, and standardisation, proportional to the services provided, timely payment without unjustified deductions, and so on.

The Union Government took the initiative to encourage farmers of other states and UTs' of India to market their agricultural produce through an electronic platform for agriculture marketing *i.e.*, e-NAM, which is the replica of Karnataka Model; ReMS (Rashtriya e-Marketing Services). E-NAM aims to recreate a similar model for trade in agricultural marketing to support farmers and traders.

Under the Digital India flagship program, Electronic National Agricultural Market (e-NAM) system was introduced in 2016 for farmers and traders to market their crops online across India (Chand, 2016). The e-NAM aims to improve current market conditions by increasing transparency, creating well-regulated markets, allowing farmer-to-consumer participation, and providing farmers with fair prices for their produce. Agricultural markets are community centres where buyers (consumers, vendors, etc.)and sellers can exchange agricultural goods.

The e-NAM system and platform are operationalised and maintained by Small Farmers' Agribusiness Consortium (SFAC) with Strategic Partner *viz*.., M/s Nagarjuna Fertilizer and Chemicals Limited. SFAC is a registered society of the Department of Agriculture, Cooperation & Farmers' Welfare (DAC&FW) under the Ministry of Agriculture and Farmers' Welfare (MoA&FW) (source: http://www.enam.gov.in). The e-NAM system was launched with the initial acceptance of 21 *Mandis* across eight states in 24 commodities on a pilot basis, and presently strengthened to 1000 mandis across the country (from 18 states and 3 UTs).

The performance of e-NAM varied across states in India. The farming community was found to be the most vulnerable segment in the agricultural marketing chain. The farmers and traders were unable to utilise the complete facilityof e-NAM emphasising the need for its sensitisation (Reddy, 2016). The study aims to assess the awareness of both farmers and traders towards e-NAM.

MATERIAL AND METHODS

The qualitative study aimed at assessing the awareness of farmers and traders who had continuously participated in the e-NAM process for the past three years.The exploratory research design was used to comprehend the stated research objective. The respondents of the study were chosen using the quota sampling technique. The sample comprised of 110 farmers and 90 traders following the Yamane formula n = N / (1 + Ne^2) Where, n= corrected sample size, N = population size, and e = Margin of error (MoE), e = 0.05 (Yamane, 1973),across Andhra Pradesh mandis, between the age groups of 21 to 70 years (mean = 37.5 and SD = 4.5). Three e-NAM mandis were selected based on the highest arrivals *i.e.*, Adoni, Kurnool, and Duggirala. From each mandi, 30 traders and 37 farmers were selected after their due consent.

The pre-tested questionnaire was prepared and responses were collected from the farmers and traders.

Data Analysis

The obtained data was analysed using Garrett's ranking technique and the chi-square test in SPSS version 25. The chi-square test was used to analyse the association between the different age groups and the educational qualifications of farmers and traders. Chi-square formula is ÷ 2 = ™ (O ™ E) 2 / E, O - observed frequency, E - expected frequency.Whereas Garrett's ranking technique wasused to rank the benefits of e-NAM ina numerical score by the respondents. After computing the mean score, benefits are positioned as per the following formulae (John, 2014):

$$\text{Percent position} = 100 * (R_{ij} - 0.5)/N_j$$

Where,

R_{ij}= rank given for i^{th}benefits of e-NAM by jthindividual;

N_j = number of benefits ranked by j^{th}individual.

RESULTS AND DISCUSSION

APMC markets are an integral part of the sellers (producers) and buyers (traders), since they exchange more than half of all marketable surplus and online auctions have become prevalent after the implementation of e-NAM. The e-NAM marketing systemwould be very helpful for the farmers and traders to transform agricultural marketing in India (Yadav and Sharma, 2017). Besides, the e-NAM platform is supportive for farmers and trading merchants, as transparency could certify the best price for growers and ensure the best crop quality for traders. To assess the awareness towards e-NAM benefits, educational qualification and age are two important demographics (Brizand Ward, 2009; Ishak and Zabil, 2012). Technological awareness comes when literacy is present (Okello *et al*., 2014). Farmers with a high level of education were receiving information from several sources for the adaption of technology (Supasub *et al.,* 2020).To achieve the proposed objective, two hypotheses were framed to analyse the association between the different age groups and the educational qualifications of farmers and traders:

Ho: There is no significant difference between the age groups of farmers and awareness regarding e-NAM.

The results of the chi-square test presented in Table 1 depicted that of the 110 farmers, 45 were aware of eNAM and they constituted majorly from the age groups of the youth (below 35 yrs) and the middle (35-50 yrs), which comprised 27 percent and 38 percent, respectively. The analysis revealed the fact that lack of awareness on e-NAM was predominant in the old age group (above 50) which constituted 38 per cent of the sample. However, P-value 0.000 showed thata significant difference between the age groups of farmers and awareness regarding e-NAM. Therefore, the null hypothesis is rejected.

Ho: There is no significant difference between the education qualification of farmers and awareness regarding e-NAM.

The farmers were grouped based on the criteria of their educational qualifications viz., 10th/ Diploma (45%), 12^{th} (26%), Under-

Table 1. Response of Farmers and Traders towards e-NAM Awareness (n=200)

	Aware	Partially Aware	Unaware	Freq-uency	%	Result of chi-square ($\div^2$)
Farmers	45	33	32	110	-	-
Traders	74	14	02	90	-	-
Age Group (Farmers)						
Young (below 35)	20	5	5	30	27%	$\div^2$ = 15.84
Middle (35-50)	18	18	6	42	38%	p = .000*
Old (above 50)	7	10	21	38	35%	
Total	45	33	32	110	100%	
Age Group (Traders)						
Young (below 35)	10	6	0	16	18%	$\div^2$ = 18.39
Middle (35-50)	35	6	1	42	47%	p = .000*
Old (above 50)	29	2	1	32	36%	
Total	74	14	2	90	100%	
Educational Qualification (Farmers)						
10th/ Diploma	9	13	28	50	45%	$\div^2$ = 19.63
12th	15	12	2	29	26%	p = .003*
Under-Graduation	20	6	2	28	25%	
Post-Graduation	1	2	0	3	3%	
Total	45	33	32	110	100%	
Educational Qualification (Traders)						
10th/ Diploma	30	4	0	34	38%	$\div^2$ = 19.63
12th	27	8	1	36	40%	p = .23
Under-Graduation	15	2	1	18	20%	
Post-Graduation	2	0	0	2	2%	
Total	74	14	2	90	100%	

*Significance level p<.05

Graduation (25%), and Post-Graduation(3%).The percentage of farmer respondents against each category are indicated in parenthesis. Awareness regarding e-NAM was noticed among the Under-Graduate group, while the lack of information on e-NAM was conspicuous among the found to be 10th /Diploma group. However, P-value .000 showed a significant difference between the education qualification of farmers and awareness regarding e-NAM. Therefore, the null hypothesis is rejected.

Ho: There is no significant difference between the age groups of traders and awareness regarding e-NAM.

The chi-square test resultsof about 90 traders are presented in Table 1. A total of 74 traders confirmed awareness regarding e-NAM, 14 traders reported partial awareness, while, two traders reported about their unawareness. The data segregated age group wise revealed that 47 percent of traders belonged to the middle age group (35-50 yrs), 36 per cent to old age (above 50 yrs) and 18 percent accounted to the young age group (below 35 yrs). The middle age group have maximum awareness followed by old age group and youth.

The findings of Kumar *et al*.(2018), on awareness of e-NAM opined about the requirement of considerable time to sensitise farmers and traders as most of them are illiterate. However, P-value 0.0 indiactes that there is a significant difference between the age groups of traders and awareness regarding e-NAM. Therefore, the null hypothesis is rejected.

Ho: There is no significant difference between the education qualification of traders and awareness regarding e-NAM.

The traders were grouped based on the criteria of their educational qualifications viz., 10th/ Diploma (38%), 12th(40%), Under-Graduation (20%), and Post-Graduation (2%). The percentage of traders against each category is indicated in parenthesis. The highest awareness on e-NAM was found in the 10th / Diploma group i.e., 30 traders. Total unawareness on e-NAM was reported by two traders, one with 12th class and another with under-graduation, respectively. However, a P-value of 0.23 indicated no significant difference between the education qualification of traders and awareness regarding e-NAM. Therefore, the null hypothesis is accepted.

Indian farmers' involvement in e-auctions and e-platforms isn't well known as compared to other countries' farmers. Chand (2017) and Rathore *et al*. (2017) stated that digital media platforms and business-related organisations cater tothe farmer's and trader's development.

Garrett's means score technique was used to rank the benefits of e-NAM for traders and farmers respectively (Table 2). The benefits of e-NAM gained by farmers and traders were ranked highest to lowest from I to VII respectively.As per the mean score of traders, first rank was earmarked for time-saving, second rank for online payment, third rank for better price with e-auction, fourth, fifth and sixth ranks for transparency in trade; quality assaying lab; real time price information on prices & trading respectively while the last rank *i.e.*, seventh was attributed for more markets to buy produce. The e-NAM benefits gained by farmers are described in the following order *viz.,* rank one for transparency in trade, rank two for time-saving third rank for better price with e-auction, fourth,

Table 2. Garrett Means Score of e-NAM benefits for traders and farmers

S.No	Benefits	Traders		Farmers	
		Garrett's Mean Score	Rank	Garrett's Mean score	Rank
1	Transparency in trade	71.09	IV	82.23	I
2	Quality assaying lab	66.25	V	60.01	V
3	Time-saving	88.95	I	76.55	II
4	Better price with e-auction	75.44	III	73.98	III
5	Online payment	85.25	II	51.78	VII
6	Real time price information on prices & trading	61.98	VI	71.45	IV
7	More markets to buy produce	58.36	VII	55.95	VI

Source:*PrimaryData*

fifth and sixth ranks for real time price information on prices & trading; quality assaying lab, more markets to buy produce respectively while the last and seventh rank was reported for online payment system.

As per the findings, transparency in trade, buy from other markets and quality assaying facility are still not achieved fromthe trader's viewpoint. Besides, that farmers are happy with time-saving, better price, and transparency in trade.The education and age factors are important in creating awareness regarding e-NAM. The finding of this research clearly shows that time and e-auction is the crucial factor in e-NAM for both farmers and traders as stated by Reddy (2018),Yadav and Sharma, (2017) and Rathore, *et al.* (2017). Pavithra *et al.* (2018) explained that e-NAM has the provision of online payment, which prevents unauthorised deductions by various market intermediaries. Rathore *et al.* (2017) and Reddy (2016) suggested that e-platforms in agricultural marketing will help farmers and traders due to transparency and online payment.

CONCLUSION

E-NAM is still in its infancy stage, however, future growth will be helpful for farmers. The establishment of e-NAM is a landmark initiative that will aid in strengthening the agricultural marketing sector and the increase of farmer income. Farmers will be able to use e-NAM once it is fully operational around the country, making online payment gateways easy to use and allowing for quicker transactions. At present, only around 11% of the country's wholesale mandis are covered by e-NAM.The most significant challenge would be that the Indian government has to incorporate every mandi in the country by building assaying labs in each mandi, providing logistics and other support structures for inter-mandi and inter-state trade, increasing market participants' capacity, developing infrastructure and institutional facilities, and persuading farmers to engage more in e-trading on e-NAM. The Garrett rank technique and chi-square results will assist the policymakers and

the authorities of e-NAM in formulating the essential measures to avail the opportunities for farmers and traders.

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MODEL BIOPHILIC SPACES FOR WASTE MANAGEMENT AT THE HOUSEHOLD LEVEL

M.S.S. MAHALAKSHMI* and S. VISALAKSHI RAJESWARI

Department of Resource Management, Avinashilingam Institute for Home Science and Higher Education for Women, (Deemed to be University), Coimbatore – 641 043

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ABSTRACT

Biodegradable organic waste that come from kitchen and retentate, the waste from reverse osmosis water purifier have become a significant concern to the environment pollution. In order to reclaim and recylce the wastes, the experimental study was carried out during the pandemic period from March 2020 to October 2020 in the peri-urban area of Coimbatore. The sampling method adopted was purposive. The women-centred environmental strategy of utilizing household wastes (through vermicompost and hydroponics) and converting them into eco-friendly, viable economic products were attempted. The experimental study infers that on an average 5.73 ± 0.62 kilograms of vermicompost was harvested in every batch in two months period.The ratio of decomposed wastes to vermicompost realized was 46:100. The experimental study conducted to upcycle the retentate adopting hydroponic technology showed a good result, and it promoted biophilic spaces in the micro-environment, consuming less space. This research showcased few model biophilic spaces tried and used to promote hydroponic technology and successfully display waste management approaches.

Keywords: Environment, Kitchen waste, Retentate, Biophilic spaces, Hydroponics

INTRODUCTION

In a society, the role of women is multifaceted. Women as caregivers are responsible for the well-being of family members as well as the society.The inborn nature and skill of managing resources by women is well known, perhaps because they are considered stewards of natural resources since their daily activities are interlinked with nature. The indigenous knowledge and pro-environmental consciousness in managing resources make them more aware of the surroundings and the resource availability. Nevertheless, they face problems in gratifying the basic requirements of family members in lieu of the increasing environmental problems. Changes in the environmental conditions do bring drastic changes in women and their livelihood. This is in relation to the unique microenvironment of the family. Bharucha (2005) stated that at macro

*Corresponding Author E-mail i.d: mahalakshmimss@gmail.com; PhD thesis submitted to Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore

level, the earth faces several environmental issues of which, increasing level of resource utilization and misuse of resources cause adverse effects to the environment. In particular, the local and fundamental renewable resources like water and air are facing limitations (more than non-renewable resources) which get manifested as modifications in their original characteristics.Now, people looking for possible alternatives to save natural resources.

The world needs effective resource managers to protect the limited available resources. The proactive volunteers who work from the grassroot level are the present need of the hour. According to Eaton and Lorentzen (2003) women are good at creating new practical and intellectual ecological paradigms; best equipped to address local environmental problems. As per the third claim of ecofeminism, women are "closer" to nature/earth than men and possess innate traits of caring, community building, nonviolence, and Earth sensitivity. Women, as sustainable saviors are qualified volunteers for society and the environment (meso and macro environment). According to Mehta and Leach (2015), women have been and can be central actors in pathways to sustainability and green transformation. Women consider taking pro-environmentally conscious decisions as of utmost significance while purchasing, using and reusing resources at the household level. Simple anthropogenic activities revolving around the domestic front many a time also emerge socially irresponsible.

For quality living, dependence on technology is on the increase. Certain domestic appropriate technologies have served their functions with some limitations. One such technology is the reverse osmosis water purification unit, which tends to discharge considerably high volumes of wastewater (retentate) for every liter of purified water (permeate) – a factor of wastewater generation. This is quite common in urban households. And as for organic wastes (solid waste), kitchen wastes are considered as common waste generated out every day. Evidently, a household consciously disposes both solid and liquid wastes into their personal environment (family subsystem). This is a common scenario familiar to every woman in their day-to-day life. It is up to them to decide how best they can make use of these wasted resources. The source segregation of organic wastes from the household wastes can be done perfunctorily as a waste reduction measure. Furthermore, converting these wastes into viable economic product using valorization process can contribute to family health and well-being of society. Feasible solutions to reduce wastewater directly can also be deliberated. Hence, the research focuses on women-centered ecofriendly strategies that can be utilized by households and also introduce a few user-friendly, model biophilic spaces in the family ecosystem for all to enjoy.

MATERIAL AND METHODS

The methodology of the study was streamlined in the following four phases: Home-level pilot study, Vermicomposting: Home-level resource recovery strategy, Model Biophilic spaces in family ecosystem adopting hydroponics and Awareness generation

Household-level pilot study

The study was conducted in a sample household located in a peri-urban area of Coimbatore in March 2020. Sampling was

purposive, considering mainly that they had installed a reverse osmosis water purification system from which the waste water was let out (retentate) regularly. They had made no attempt to use the retentate. This prompted quantification of the retentate. Using a calibrated container, the liquid waste was collected and measured, weekly thrice, for a month. Similarly, the domestic kitchen wastes arising every day was also collected and weighed for a period of eight months. It comprises organic wastes such as vegetable wastes, fruit wastes, eggshells, tea and coffee ground wastes.

A sample of one litre of retentate (RO waste water) was collected and given to a reputed water testing laboratory to analyze the presence of toxic substances and/or other essential elements.

Vermicomposting: Home- level resource recovery strategy

Fig. 1. Vermiculture bed

In order to recover the wasted resource generated from kitchen wastes, one of the eco – friendly waste management strategy, vermicomposting was attempted during the COVID-19 pandemic time from March to October, 2020. For vermicompost production process, only indigenous eco-friendly materials were utilized throughout. The kitchen wastes which includes fruit and vegetable wastes, eggshells, tea and coffee ground wastes were allowed to decompose for 30 days. Bamboo basket, shredded newspapers, pre-digested kitchen wastes, leaf litter, dried cow dung and coir pith (used) were used to produce vermicompost. Quality earthworms (*Eisenia foetida* spp.- 400g) were introduced into the vermicompost unit. Vermiculture bed or worm bed was made using a layer of coir pith, and shredded newspaper acted as an excellent bedding material for the earthworms (Fig.1). This layer was moistened every four days with retentate alone. Pre-digested organic kitchen wastes and dried cow dung were the food source for the worms.Sixty per cent moisture was maintained in the unit. The materials on complete decomposition would appear black and granular. At this stage, the watering was stopped. The worms were segregated from the compost using a manual process, and the vermicompost was harvested.

Model Biophilic spaces in family ecosystem adopting hydroponics

Five model biophilic spaces adopting hydroponics (soilless) technique was initiated in the selected sample's home environment. Retentate from RO unit and coir pith only were used to raise plants in the five models, for which only used up containers and other materials were used as plant holders. The growth stages of plants were monitored and recorded periodically.

Creating Awareness

The previous phases of the study showed good outputs. Thus, this final phase was conducted with goodwill to share the knowledge and also to reclaim the kitchen wastes and RO wastewater productively for the well-being of the

society. Five homemakers (RO water purifier users) were encouraged to initiate biophilic spaces in their premises, adopting hydroponic techniques. During the early phases of the study, rapport was created with the selected respondents, followed by knowledge sharing. Materials such as grow bags, seeds, plants and substrate (coir pith) were provided to the homemakers for the conduct of the experiment. Only resource they had to put in was retentate from their home RO Units. This encouraged the homemakers to raise plants within their premises. Periodical visits for monitoring plant growth stages were done by the researcher.

RESULTS AND DISCUSSION

Details on retentate (liquid) and kitchen wastes (solid) generated

Details on retentate generated from the RO unit

Table 1 furnishes details on retentate (liquid wastes) discharged from the RO unit. Wastewater was collected thrice a week for one whole month (4 weeks). Waste water let out till the concerned RO tank was filled with purified water was the endpoint every day. For all the day's collected, care was taken to see the tank was emptied and filled up daily. The trial experiment proved that for every liter of permeate obtained, waste water to the tune of 3.2 ± 0.81 L was let out as discharge.

Table 1. Details on Retentate generated from the RO unit

Duration (in weeks)	Retentate* collected per liter of permeate ** (in L/Day)	Mean ± S.D	Retentate collected (Mean ± S. D per L of permeate) for 12 days	Permeate consumed (L per day/ household)	Cumulative permeate consum-ption (for 30 days)	Cumulative retentate generated (for 30 days)
I	3.5	2.97	3.2 ± 0.818	20	600 (20 L /day x 30)	600 x (3.2 ± 0.818)
	2.45	±				
	3.2	0.742				
II	4.2	3.5				
	2.3	±				
	4	1.044				
III	3.5	3				
	2.2	±				
	3.3	0.7				
IV	4.25	3.41				
	2	±				
	4	1.23				

*Retentate – is waste water let out ; **Permeate – is purified water collected in the tank

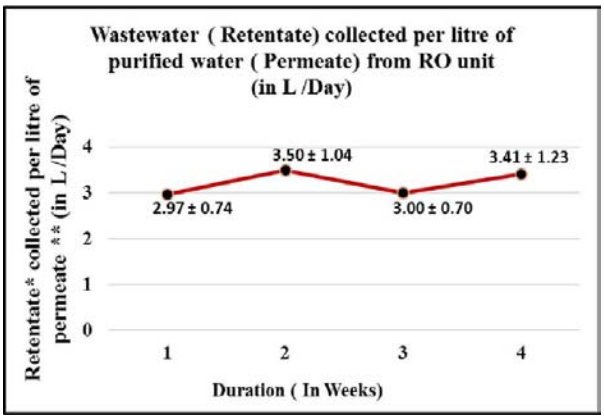


Fig. 2. Wastewater generation from RO unit

On a cumulative basis, selected sample housewhich consists of four members was consuming 20 L of water per day using RO water purification unit. Fig.2 represents the wastewater generated from the RO unit in consecutive weeks. On extrapolation for a month's time (30 days), the quantum of water wasted or received as retentate amounts to a range between 1429 L to 2410 L from the selected RO unit. Surreptitiously, a nation is losing a highly precious resource (though renewable, but not easily renewed) from every household unit and the loss is comparably high. Thus, it was evident from the study that managing this waste water and diverting it for productive use is need of the hour.The waste water analysis report of retentate indicated the absence of heavy metals (only BDL: Below Detection Limit) and was found to be safe for irrigation. Further test findings listed presence of essential mineral elements such as Calcium, Magnesium, Manganese, Zinc, Boron, and adding to its nutrient value. Hence, it was proved that though it was let out as retentate it is quite harmless and can be safely used for other purposes, if not for drinking.

Details on organic waste generated

The wastes generated was collected and quantified for a period of eight months (Table 2).

Table 2. Details on organic waste generated

Duration (in months)	Organic waste collected (kg/month)				Wastes generated (kg/month)
	Vegetable wastes	Fruit wastes	Eggshells	Tea/ Coffee ground	
1	2.933	2.174	0.24	0.848	6.195
2	3.01	0.9	0.222	1.043	5.175
3	3.102	5.223	0.235	1.012	9.572
4	3.299	1.356	0.342	0.923	5.92
5	3.809	1.706	0.282	0.854	6.651
6	2.67	2.016	0.291	1.082	6.059
7	2.493	2.114	0.481	1.275	6.363
8	3.076	0.186	0.151	0.102	4.433
Total	24.392	15.675	2.244	8.057	50.368
Mean± S. D	3.05 ± 0.40	1.96 ± 1.48	0.28 ± 0.10	0.89 ± 0.35	6.30 ± 1.50

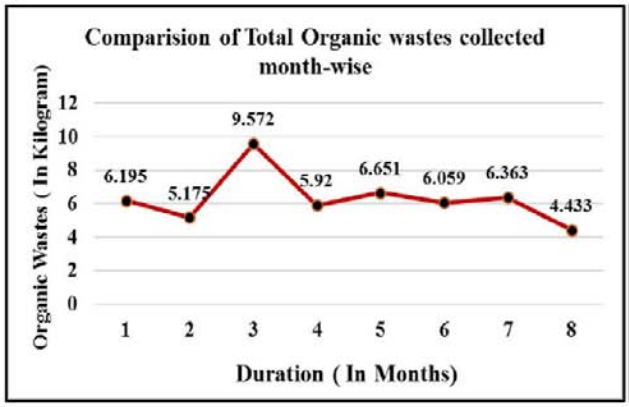


Fig. 3. Total Organic Waste (kitchen) collected (month-wise)

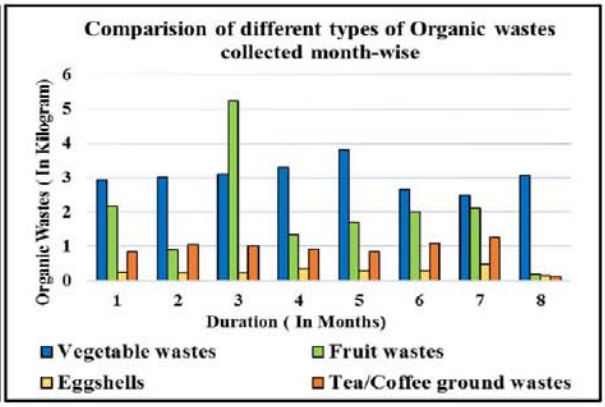


Fig. 4.Types of Organic Waste (kitchen) collected (month-wise)

An average of 6.30 ± 1.50 kilogram of organic waste was generated per month. The total organic wastes and their types collected per month are presented in Fig.3 and Fig.4. The vegetable waste was comparatively higher than the other wastes such as fruit, eggshells, tea, and coffee ground wastes. Seeds, rind, skin peels and pomace are the main compositions of vegetable and fruit wastes (Joseph, 2019). They are a good source of potentially valuable bioactive compounds, such as polyphenols, carotenoids, dietary fibers, vitamins, enzymes, and oils. Instead of dumping this valuable organic waste into the bin, one can productively utilize and transform them into organic fertilizer by vermicomposting. Vermicompost is the potential option to upcycling kitchen waste. It involves joint actions of both earthworms and microorganisms by degrading of organic matter, which can enrich soil fertility state (Dominguez, 2004).

Production of Vermicompost: From the vermicompost unit, every 60 days a batch (in kilograms)of vermicompost was harvested. The predigested wastes decompose quickly during the vermicompost production.Table 3 presents the details on quantum of vermicompost harvested within a span of eight month

On an average 5.73 ± 0.62 kilograms of vermicompost was harvested every batch comprising two months. Table 3 shows the productive output of recovering the kitchen wastes and liquid wastes using appropriate valorization technology - vermicompost. On an average, the conversion rate of organic waste to vermicompost was 46 percent. The study proves that even a fraction of household waste can be converted into productive eco–friendly by-products or end products. Above all, a viable waste management strategy that contributes to the environment and the society can be envisaged. Beyond these benefits, this can create an entrepreneurial avenue to the homemakers who can practice this technology at home and wish to generate income from it. The ratio of decomposed to vermicompost waste realized is presented in Fig.6. The laboratory analysis reporton homemade vermicompost indicated the presence of essential elements such as nitrogen, phosphorous, Potassium, Organic carbon, Calcium, Magnesium, Zinc, etc at adequate levels.

Table3. Production of Vermicompost

Waste Generated/ Month(in kg)	Organic waste (sumof consecutive months)(in kg)	Quantum of vermicompost harvested (batch -wise) (in kg)		Rate of Conversion [C/B] (in percentage)	Ratio of decomposed to vermicompost realized (Cx100/B)
6.195	11.37	I	5.86	51	51:100
5.175					
9.572	15.49	II	5.28	34	34:100
5.92					
6.651	12.71	III	6.56	51	51:100
6.059					
6.363	10.8	IV	5.22	48	48:100
4.433					
Total	50.37	Mean ± S.D	5.73 ± 0.62	46	46:100

Fig. 5. Ratio of decomposed to vermicompost waste realized

Fig. 6. Harvested Vermicompost

Model Biophilic Spaces designed

Next aspect considered was designing model biophilic spaces (Fig.7). The model biophilic spaces was initiated with an aim to reclaim the retentate (waste water) to the maximum in a productive way. These models can serve both as functional and aesthetic units. The biophilic spaces were initiated using plants which show visible growth within a short duration of nine to fourteen days. According to Kellert (2008), the inherent human affiliation with natural systems and processes is known as biophilia. This tendency enhances the human physical, emotional, and intellectual fitness. People's dependence for contact with nature reflects the

reality of having evolved in a largely natural, not artificial or constructed world. Plants are the sources of food, fiber, fodder, and other aspects of sustenance and security. In addition, their presence into the built environment can enhance comfort, satisfaction, well-being, and performance. The biophilic spaces included:

Tray units: Fodder is significant in a rural / peri-urban household where they rear cattle. With this in view, fodder crops using maize (*Zea mays*.L) and jowar (*Sorghum vulgare*. L) seeds were raised. The hydroponic fodder tray unit (used up trays with storage shelves) showed decent growth within the short duration of only nine days.

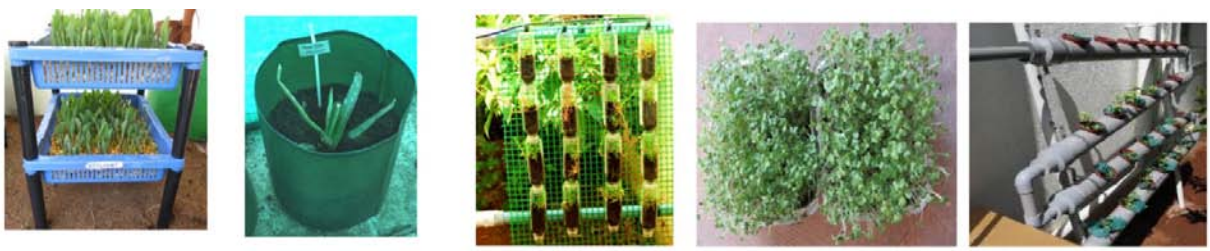
Hydroponic microgreens - Edible, short duration crops were also successfully raised using retentate in used clear rectangular food packaging containers (capacity-1000ml). Different microgreens varieties such as mustard (*Brassica juncea* L), fennel (*Foeniculum vulgare* Mill), fenugreek (*Trigonellafoenum graecum* L.) and Coriander (*Coriandrum sativum* L.) were raised. Coir pith was used as substrate to raise fodder and microgreens.They showed commendable growth.

Portulaca unit: This standalone unit was designed using waste plastic bottles and wire mesh. Using drip irrigation technique, watering was completed. A used - up bubbletop container was used as a reservoir for retentate. Portulaca (*Portulaca grandiflora* Hook.) plant cuttings started flowering at stipulated time. At flowering stage, it created appreciable aesthetic look.

Grow bags: Air purifying plants were grown in grow bags those which were torn and thrown away). Except Areca Palm (*Dypsis lutescens* H.Wenl) all other plants such as snake plant (*Dracaena trifasciata* Prain Mabb), aloe vera (*Aloe barbadensis* M.), Devils Ivy (*Epipremnum pinnatum* cv. *Aureum)* and Spider plant (*Chlorophytum comosum*Thunb.) showed good growth.

NFT: In case of NFT (mimicked Nutrient Film Technique), retentate was recycled through the plant units.Except tomato (*Solanum lycopersicum* L.) (which was slightly stunted) in this technique, all other plants such as fenugreek (*T foenum-graecum)*, mint (*Mentha spicata* L.) and coriander (*C sativum)* showed decent growth. The device was fabricated using waste PVC tubes and an old stand. Expenditure incurred is minimum (only for the paper cups in which the plants were grown).

These models being flexible, cost effective units occupied minimum space in the micro environments (balcony, patio, living area,



Fodder crop | **Grow bag** | **Portulaca Unit** | **Microgreens** | **Vegetable plants in Mimicked NFT**

Fig. 7. Model Biophilic Spaces developed

terrace/roof top).One can easily dismantle and reconstruct the units. The added advantage of being light in weight and of good water holding capacity (becasuse of coir pith) facilitated any one to raise plants in them easily and create a beautiful, aesthetic and healthy biophilic environment. All the model biophilic spaces designed occupied vantage spots in the family ecosystem, mainly in balconies, kitchen window sills, verandah corners, compound wall spaces, etc. They were not only functional, but creative and aesthetic, attracting attention of passer-by.

Outcome of the awareness generation

The selected home makers showed interest in raising microgreens as they considered the microgreens as good, inexpensive nutritive supplements. They were provided with grow trays, substrate and seeds to raise microgreens (Fig. 8). They were eager to monitor the day-wise growth of the planted microgreens. They shared their experiences and liked the mini version or sizes of plants especially clover like shaped leaves of mustard microgreens (Fig. 9). Furthermore, guidance to harvest and store them enabled use of microgreens in preparation of novel dishes. Some samples were dried and stocked for future use.

Fig. 8. Harvesting microgreens

Fig. 9. Mustard microgreens

CONCLUSION

The results proved that vermicompost and hydroponics are viable, appropriate technologies to recycle the wastes.

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RELATION ANALYSIS OF HAPPINESS AND EMPATHY AMONG ADOLESCENTS

MANISHA DHAMI* and NEHA JOSHI

Human Development & Family Studies, College of Community Science
Punjab Agricultural University, Ludhiana- 141 001

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ABSTRACT

The study investigates the profile and relationship of happiness and empathy among adolescents. For this purpose, a sample of 120 senior secondary students, 60 girls and 60 boys, residing in the Ludhiana district of Punjab was taken. Research tools used were Happiness Scale by Rastogi and Moorjani (2016) and Empathy Scale developed by Dubey and Tandon (2014). To find out the gender difference across different variables, descriptive statistics (frequency and percentage) and t-test were used. To identify the relationship between empathy and happiness the Pearson Correlation Coefficient was applied. Results showed gender differences exist in happiness and empathy with girls having a higher level of happiness and empathy with better mean scores as compared to their counterparts. The correlation analysis showed a significantly positive relationship between happiness and empathy of adolescents.

Keywords: Adolescents, empathy, happiness, gender, relationship

INTRODUCTION

With rapid urbanization and industrialization, the three main explosions of the present era include population explosion, knowledge explosion, and aspiration explosion. Hence, it creates difficultly in leading a peaceful life. Adolescents particularly are very much affected due to these rapid changes, which ultimately results in higher levels of stress among them. Adolescence is a transitional phase from childhood to adulthood with intense physiological, psychological, and socio-emotional transition, with significant changes in the past decades (Sawyer *et al.,* 2018).

The 19.6% percent of the Indian population comprised of adolescents (UNFPA, 2014). Adolescence is considered as the phase rather than a fixed time period in an individual's life. Thus, the storm-and-stress view has given way to a more balanced view of adolescence (Susman and Rogol, 2004). Adolescence is well known to have its own unique set of problems with an elevated stress level that is marked as emotional tensions, non-conformity, suicide,

*Corresponding Author E-mail i.d: manisha-hd@pau.edu

destructiveness and rebelliousness (Mishra and Vashist, 2014). The study of adolescents' happiness becomes vital, because of diverse transitions at this phase influencing their development and well-being (González *et al.,* 2007).

Happiness is a state of psychological or emotional well-being that could be defined as positive and pleasant emotions that ranges from contentment to intense joy. It is the indicator of people's overall degree of emotional intelligence and emotional functioning. Happiness is a key factor for psychological health and was introduced as a main component of health by the World Health Organization (Cohn *et al.,* 2009). As per authentic happiness theory, happiness is the main component of positive psychology having three subjective features: positive emotion, meaning and engagement (Seligman, 2011). The psychological well-being model of happiness states that a person's happiness is a combination of various positive psychological parameters, like personal growth, autonomy and environmental mastery (Ryff, 2013). It is a sign of mental integrity. Heizomi *et al.* (2015) reported a significant relationship of happiness with better academic achievement and a higher level of success in life. Research also revealed that happy people showed greater extraversion, openness and conscientiousness as compared to less happy persons (Sahoo *et al.,* 2005). Individual involved in various kinds of pro-social behaviour has numerous benefits with significant influence on ones' happiness and well-being in various aspects (Liu *et al.,* 2020).

Empathy is defined as the ability to share and understand the emotional states of others (Batson *et al.,* 1987). It facilitates everyday social interactions and literature indicates its link to prosocial behavior. Substantial shreds of evidence have been found that indicate the positive relationship of experiencing empathy with prosocial behavior (Telle and Pfister, 2016). This trait is linked to various dimensions of happiness/well-being also (Choi *et al.,* 2016). Empathy is an essential trait for promoting positive behaviors toward others and expediting social interactions (McDonald and Messinger, 2011). Literature supported empathy is malleable in every stage of life span and adolescence is a significant developmental period that seems to be critical for the development of empathy. The expansion of adolescents' social world and the forthcoming transition to adulthood perhaps create a fundamental need for youths to develop and apply their capacity to make contributions to others. The social reorientation of adolescence creates concerns regarding peer acceptance and social status paramount (Brown and Larson, 2009; Nelson *et al.,* 2004). Besides this, empathy may stimulate a sense of generativity among adolescents. Lawford *et al.* (2005) also reported that adolescents with a greater sense of generativity exhibit better psychological functioning in later years.

In a nutshell, the development of empathy is a vital building block for emotional regulation among adolescents and is so valuable in being able to adapt and succeed in an ever-changing world that ultimately results in a higher level of overall happiness. About the importance of happiness in all aspects of life, this research aims to assess the happiness and empathy among adolescents as well as to study the relationship of empathetic behavior to their happiness. The objectives of the study are: To identify and

compare the empathy and happiness of adolescents of both gender groups; To explore the correlation between empathy and happiness of adolescents.

MATERIAL AND METHODS

The study was conducted in Government Senior Secondary schools of Ludhiana city. Municipal Corporation Ludhiana has divided the city into four zones i.e. Zone A, Zone B, Zone C and Zone D. Out of four zones, Zone D was purposely selected for this study. The total sample of the study comprised 120 adolescents in the age range of 16-18 years drawn randomly. Care was taken to distribute the total sample equally across two genders [boys (n1=60) and girls (n2=60)]. To assess the happiness level of respondents, the Happiness Scale was developed by Rastogi and Moorjani (2016). This scale consists of 62 items. The maximum score was 350 and the minimum was zero. Higher score indicated a better level of wellbeing and happiness. Norms for interpretation of the level of happiness is given below:

S.No.	Levels of Happiness	Range of Scores
1	High	254 -350
2	Medium	140-253
3	Low	0-139

Similarly, the Empathy Situational Test developed by Dubey and Tandon (2014) was used to measure the level of situational empathy in adolescents across various levels i.e., low, medium and high. The scale consisted of 15 items. The maximum score was 90 and the minimum was zero. The score values of the responses were assigned according to the responses showing the level of empathy as given below in the table:

S.No.	Levels of Empathy	Range of Scores
1	High	61 and above
2	Medium	30-60
3	Low	29 and less

RESULTS AND DISCUSSION

Table 1. Gender wise differences in distribution of respondents across various levels of empathy

Levels of empathy	Male n1= 60		Female n2= 60		Overall n= 120	
	f	%	f	%	f	%
Low	20	33.33	10	16.66	30	25.00
Average	35	58.33	32	53.33	67	55.83
High	5	8.33	18	30.00	23	19.16

Table 1 aims to provide gender-wise differences of respondents across various levels of empathy. It brings to light that more than half of respondents (55.83%) were at the average level of empathy followed by low (25%) and high level (23%) of empathy.

A look into the gender distribution of respondents across various levels of empathy revealed that more than half of male and female respondents (Male: 58.33% and Female: 53.33%) were clustered at the average level of empathy, whereas, females show more empathy (30%) than males (8.33%). A contrasting result was found at a low level, females were found proportionately less (33.33%) than males (16.66%).

Empathy is an ability to understand others, to relate to others, and to treat others as one would like to be treated would enable a person to forgive others. In line with this finding, a study by Loffler and Greitemeyer (2021) concluded that women rated themselves significantly higher in empathetic capacity. Biologically also females showed stronger neural activation across all empathy tasks in emotion-related areas, including the amygdala (Derntl et al., 2010).

Table 2. Gender-wise distribution of respondents across various levels of happiness

Levels of empathy	Male n1= 60		Female n2= 60		Overall n= 120	
	f	%	f	%	f	%
Low	18	30.00	13	21.66	31	25.83
Average	34	56.66	27	45.00	61	50.83
High	8	13.33	20	33.33	28	23.33

The data presented in table 2 elucidate gender-wise differences in the distribution of respondents across various levels of happiness. From the overall population, half of the respondents were accumulated at an average level (50.83%) followed by low level (25.83%) and high level (23.33%) Finding of the study indicated that at a high level of happiness, females were reported to have more happiness (33.33%) than males (13.33%). On the other hand, males were found more at high (13.33%) and average level (56.66%). Similar evidence was found by Zweig (2015), Women were either happier than men or that there is no significant difference between women and men in nearly all of the 73 countries examined. Also, when men and women with the same life circumstances were compared, women were happier than men in nearly a quarter of the countries.

Table 3. Gender–wise differences in the mean scores (± S.D.) of empathy

Empathy				
Male n1= 60		Female n2= 60		t value
Mean	SD ±	Mean	SD±	
40.87	15.66	51.73	21.27	3.19**

**p=0.05

Data presented in Table 3 evinced the gender differences in the mean scores of respondents. Results illustrated a significant difference between male and female respondents. Mean scores of females were found high (51.73±21.27) as compared to males (40.87± 15.66). Thus, it could be concluded that females had more empathy than males. In line with distribution findings, a similar result was found in mean scores also where females exhibited more empathy than males. Research by Mestre et al. (2009) also contributes information on women's greater empathic disposition in comparison with men by means of a longitudinal design in an adolescent population.

Table 4. Gender differences in the mean scores (± S.D.) of happiness

Happiness				
Male n1= 60		Female n2= 60		t value
Mean	SD ±	Mean	SD±	
177.86	66.63	211.58	74.34	2.62**

**p=0.05

Data furnished in table 4 depicted gender differences in mean scores of happiness. Females (211.58± 74.34) outnumbered males (177.86±66.63) in terms of mean scores and depicted more happiness than males with a significant difference (t value- 2.62; p=0.01). A study by Kashdan et al. (2009) found that women express more pro-social emotions such as gratitude which act as a catalyst to have more happiness.

Table 5. Relationship between empathy and happiness

	Happiness		
	Male	Female	Total
Empathy	n1= 60	n2= 60	n= 120
	0.614*	0.561*	0.606*

*Correlation is significant at the 0.01 level (2-tailed).

Table 5 highlights the correlation between happiness and empathy. Both the gender group indicated a significant (p=0.01) level of positive correlation (male r= 0.614, female r= 0.561) between happiness and empathy. Happiness is one of the most fundamental positive feelings having a pertinent role in creating empathy in both the individual and the society. Fostering empathy among children can lead them to develop better emotional intelligence. In the line of this study, Meyzari Ali and Dasht Bozorgi (2016) reported a significant and positive relationship between empathy and happiness thus suggested that empathy act as a predictor of happiness. People's beliefs about happiness are flexible, controllable, and internally influenced by their empathetic attitude.

Table 6. Correlation of socio-personal variables with empathy and happiness among adolescents

Variable	Happiness	Empathy
Father's education	0.49	0.38
Mother's education	0.44	0.26
Family size	0.29*	0.35**
Birth order	0.31	0.42**

*Correlation is significant at the 0.01 level (2-tailed)

** Correlation is significant at the 0.05 level (2-tailed)

The data in Table 6 portrays the correlation of socio-personal variables of adolescents with empathy and happiness. As per the data observed in the table, happiness among adolescents was found to be significantly and positively correlated with family size (r=0.29). Similarly, a significantly positive relation of empathy was found with family size (r=0.35) and birth order (r= 0.42). In line with this study, the family environment and ordinal position has potential influence in shaping the sensitivity of the young individuals towards the needs of others in a similar degree. Empirical research findings also revealed that family structure plays a substantial role in the personal growth of happiness and empathetic behavior of adolescents (Park & Peterson 2006; Silke *et al.,* 2019). Adolescents from large size families were found to more empathetic with other people than their counterparts.

CONCLUSION

The study recorded that significant gender difference exists between male and female's happiness levels and empathy. A significant and positive relationship exists between empathy and the happiness of adolescents. Thus, the educational curriculum should focus on teaching the art of being empathetic towards one another. Extracurricular activities need to be designed based on empathy to develop mutual understanding among adolescents for the community.

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Research Note

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QUALITY CHANGES IN OSMO DRIED BANANA SLICES AS INFLUENCED BY SUGAR SYRUP CONCENTRATIONS

T. UMA MAHESWARI*, N.SUGANTH AND M.R. NARENDRAKUMAR

Department of Horticulture, Faculty of Agriculture, Annamalai University
Annamalainagar-608 002

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Banana is nutritive fruit which is consumed as fresh or cooked (both as ripe and raw fruit). Banana is a rich source of carbohydrate, and vitamin B. It is also rich in potassium, phosphorus, calcium and magnesium. It reduces the risk of heart diseases when consumed regularly and is given for patients suffering from high blood pressure, arthritis, ulcer, gastroenteritis and kidney disorders. Value added products, such as chips, banana puree, jam, jelly, juice, wine and halwa can be made from the fruit. Banana powder is used as the first baby food. Osmotic dehydration found wide application in the preservation of food-materials since it lowers the water activity of fruits and vegetables.Since there is a tremendous scope for enhancing its processing and value addition, this study was conducted to develop osmo dried slices from banana and for extending the storage life.

This experiment was conducted in Completely Randomized Design with four formulations and five replications during 2019. The influence of preservation on the nutritional quality and organoleptic quality of the osmo dried slices was studied. The shelf life and economics of the products were calculated in this study. The organoleptic evaluation was carried out at monthly basis for three months during storage. Osmo dried slices were prepared with four formulations *viz.,* 60 %(T_1), 80% (T_2), 100 %, (T_3) and 120% (T_4) concentrations of sugar. The ripe bananas were peeled manually for the preparation of osmo dried banana slices. After peeling, bananas were cut into slices of uniform thickness by using a stainless steel knife. Banana slices were soaked in sugar syrup of country sugar for 3 hours. Then the slices were dehydrated at a temperature of about 50°C. After dehydration the slices were packed in polythene bags and then they were stored in a cool place.

The organoleptic qualities of the processed banana products were evaluated by the panellists for sensory attributes such as colour, taste, flavour, and overall acceptability. As explained by Wichchukit and Mahony (2014) a nine-point hedonic scale was used ranging from like extremely (9) to dislike extremely (1). All samples were presented before the panellists at ambient temperature under normal lighting conditions. Nutritional quality such as pH, titratable acidity (%), vitamin C (mg/100g) and total sugars(%) were determined. Total sugars

*Corresponding Author E-mail i.d: umahorti2003@gmail.com

(%) and Vitamin C was analysed by the method of AOAC (1990). Titratable acidity (citric acid mg/ 100g) was determined according to the method of Farooq *et al.* (2016). pH was determined through pH meter.

The lowest value for pH in osmo dried banana slices was recorded in treatment T_1 (4.51), followed by T_2 (4.64) and T_3 (4.76). The highest value for pH was recorded in T_4 (4.85).The lowest value for titratable acidity was recorded in treatment T_4 (0.35 %), followed by T_3 (0.38 %) and T_2 (0.41 %). The highest value for acidity was recorded in T_1 (0.45 %). The highest value for vitamin C was recorded in treatment T_1 (9.89 mg/100g), followed by T_2 (9.12 mg/100g) and T_3 (8.41 mg/100g). The lowest value for vitamin C was recorded in T_4 (7.54 mg/100g). The highest value for total sugar was recorded in treatment T_4 (52.89 %), followed by T_3 (50.25 %) and T_2 (47.57 %). The lowest was recorded in T_1 (44.33 %).

Titratable acidity in dried slices was affected by different osmotic pretreatments and increase in concentration of syrup reduced the acidity content. The acidity of sugar syrup also have a significant role in maintaining acidity of final products as reported by Thippanna and Tiwary (2013). Among the formulations, treatment with 120% sugar concentration recorded the lowest value for titratable acidity. The 60% sugar solution recorded the highest value for titratable acidity.

Vitamin C content in osmotically dehydrated banana is comparatively reduced when compared to the fresh fruits. The reduction in ascorbic acid during dehydration could be attributed to heat destruction and leaching of acid in hypertonic solution as reported by Kumar and Sagar (2009). The highest vitamin C content was found in 60% sugar syrup solution. The lowest content was found in 120% sugar syrup solution.

The increase in total sugar content in the dehydrated samples could be attributed to the effect of sugar used as an osmotic agent as confirmed by Kayamak-Ertekin and Sultangulu (2000). The higher sugar content might be due to infusion of sucrose during immersion in different solution as reported by Mohumud *et al.* (2015). This phenomenon of uptake of solutes and an increase in sugar content in fruit slices during osmotic dehydration might be occurred. The highest value for total sugar content was recorded in treatment with 120% sugar and the lowest value for sugar content was recorded in 60% sugar concentration, due to the percent availability of sugar content.

Osmo dried banana slices prepared with variation in sugar concentration were subjected to sensory evaluation at monthly interval for a period of three months. The average score for taste (7.5), colour (7.3), flavor (6.9) and overall acceptability (7.3) were highest in the treatment T_3 in the first month of sensory evaluation(Table 1, 2 & 3). The treatment T_4 recorded the second best score for sensory characters *viz.,* taste (7.1), colour (7.1), flavor (6.7) and overall acceptability (7.0). The same trend was followed in all the three months of sensory evaluation.The lowest sensory scores were given for the treatment T_1 regarding in taste (6.4), colour (6.0), flavor (5.7) and overall acceptability (6.2) during first month of sensory analysis. The sensory scores for the osmo dried slices gradually decreased in the consecutive months of sensory analysis in all the treatments. The organoleptic attributes of osmo dried banana slices gradually

Table 1. Sensory scoring for osmo dried banana slices at 1st month of evaluation (October, 2019)

Taste panel (TP)	T_1 (60% sugar syrup)				T_2 (80% sugar syrup)				T_3 (100% sugar syrup)				T_4 (120% sugar syrup)			
	Taste	Colour	Flavour	Overall acceptancy	Taste	Colour	Flavour	Overall acceptancy	Taste	Colour	Flavour	Overall acceptancy	Taste	Colour	Flavour	Overall acceptancy
TP1	6	7	7	7	6	5	5	5	8	8	8	8	8	7	8	8
TP2	7	5	5	6	6	6	6	6	6	7	6	6	7	8	7	7
TP3	8	7	6	7	7	6	6	6	7	8	7	7	6	6	6	6
TP4	5	7	6	7	6	7	6	7	8	7	8	8	7	8	6	7
TP5	6	4	4	5	7	7	7	7	7	5	7	6	8	7	7	7
TP6	8	6	5	6	8	6	8	8	8	8	6	8	6	6	6	6
TP7	6	6	7	6	8	7	7	7	8	7	6	7	7	6	7	7
TP8	6	5	4	5	7	7	6	7	7	8	7	7	7	8	7	7
TP9	5	7	6	6	7	6	7	7	8	7	8	8	7	7	6	7
TP10	7	6	7	7	8	8	6	8	8	8	8	8	8	8	7	8
Grand Total	64	60	57	62	70	65	64	68	75	73	69	73	71	71	67	70
Average	6.4	6.0	5.7	6.2	7.0	6.5	6.4	6.8	7.5	7.3	6.9	7.3	7.1	7.1	6.7	7.0

Table 2. Sensory scoring for osmo dried banana slices at 2nd month of evaluation (November, 2019)

Taste panel (TP) S	T_1 (60%sugar syrup)				T_2 (80% sugar syrup)				T_3 (100% sugar syrup)				T_4 (120% sugar syrup)			
	Taste	Colour	Flavour	Overall acceptancy	Taste	Colour	Flavour	Overall acceptancy	Taste	Colour	Flavour	Overall acceptancy	Taste	Colour	Flavour	Overall acceptancy
TP1	5	6	7	6	6	5	5	5	8	7	8	8	7	6	8	6
TP2	7	5	5	6	5	5	6	5	7	6	6	6	6	8	6	6
TP3	8	7	5	7	7	6	5	6	8	7	7	7	8	7	6	7
TP4	5	6	4	5	5	7	6	6	6	6	6	6	7	8	7	7
TP5	6	4	4	5	7	7	7	7	8	6	7	7	7	6	7	7
TP6	7	6	5	6	8	6	8	8	8	8	6	8	6	7	5	6
TP7	6	6	6	6	6	5	7	6	8	6	6	6	6	5	6	6
TP8	6	5	6	6	7	7	6	7	7	7	7	7	8	6	6	6
TP9	5	7	6	6	7	6	5	6	8	7	5	7	7	7	6	7
TP10	7	7	5	7	5	7	6	6	9	8	8	8	8	8	7	8
Grand Total	62	59	53	60	63	61	61	62	77	68	66	71	70	68	64	66
Average	6.2	5.9	5.3	6.0	6.3	6.1	6.1	6.2	7.7	6.8	6.6	7.1	7.0	6.8	6.4	6.6

Table 3. Sensory scoring for osmo dried banana slices at 3rd month of evaluation (December, 2019)

Taste panel (TP) S	T_1 (60% sugar syrup)				T_2 (80% sugar syrup)				T_3 (100% sugar syrup)				T_4 (120% sugar syrup)			
	Taste	Colour	Flavour	Overall acceptancy	Taste	Colour	Flavour	Overall acceptancy	Taste	Colour	Flavour	Overall acceptancy	Taste	Colour	Flavour	Overall acceptancy
TP1	5	6	7	6	6	5	5	5	6	7	8	7	7	6	7	7
TP2	7	5	5	6	5	4	6	5	7	6	6	6	6	5	6	6
TP3	6	7	5	6	7	6	5	6	8	7	5	7	7	7	6	7
TP4	5	5	4	5	5	6	5	5	6	5	6	6	6	8	7	7
TP5	6	4	4	5	6	5	6	6	6	6	7	6	7	5	6	6
TP6	6	6	5	6	8	6	8	8	7	6	5	6	5	7	5	6
TP7	5	6	6	6	6	5	7	6	8	7	6	7	6	5	6	6
TP8	6	5	6	6	6	7	6	6	7	6	7	7	7	7	6	7
TP9	5	6	6	6	7	5	5	5	6	7	5	6	7	5	5	6
TP10	7	7	5	7	5	7	6	6	7	5	8	7	6	6	7	6
Grand Total	58	57	53	59	61	56	59	58	68	62	63	65	64	61	61	64
Average	5.8	5.7	5.3	5.9	6.1	5.6	5.9	5.8	6.8	6.2	6.3	6.5	6.4	6.1	6.1	6.4

reduced during storage. Among the various treatments, osmo dried banana slices treated with sugar solution of 100% concentration obtained highest scores with regard to taste, colour, flavor and overall acceptability. This is in agreement with the results of Thippanna and Tiwary (2013). The lowest scores were given for the treatment with 60% sugar concentration. Though the treatment with 120% recorded the best scores for total sugar, the treatment with 100% sugar was found more acceptable for consumption.

Among the various treatments of the osmo dried slices, the treatment with 100% and 120% recorded the highest shelf life upto 5 months. The product was prepared without the addition of any preservatives. The greater shelf life might be due to the higher sugar content of the treatments. Sugar (glucose, sucrose, lactose, dextrose) acts as a preservative when used at a higher concentration. The lower shelf life was recorded in 60% and 80% sugar concentration. Benefit cost obtained through development of osmo dried banana slices was found to be 1.89. Processing of banana into osmo dried banana slices can be used for commercial exploitation.

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Research Note

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FOOD CONSUMPTION PATTERN OF THE RURAL HOUSEHOLDS IN THE ADOPTED VILLAGE OF MANAGE INSTITUTE

G. SRIHARSHA, VEENITA KUMARI*, M. S. CHAITANYA KUMARI and J. SHIRISHA

Centre for Gender Studies, National Institute of Agricultural Extension Management, Hyderabad - 500 030

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India's rural population is spending about 54% of its income on food alone. However, share of non-food consumption has increased proportionately when compared to food consumption expenditure over the years as observed by the researchers. Also, it can be noticed that different components of the food basket such as cereals like rice and wheat, has declined steadily, as a share of food consumption (Basole and Basu, 2015). Rice and wheat are the primary grains consumed, accounting for 90% of cereals consumption (Kumar and Kalita, 2017). Food consumption is one of the determining factors for health and nutritional status of the population. Poor dietary intake is the major risk factor, in addition to alcohol, tobacco and lack of physical activity for the non-communicable diseases (NCDs) (Ezzati and Riboli, 2013). Cooking plays significant role by incorporating changes in chemical composition and influencing the concentration and bioavailability of bioactive compounds, For Ex: vegetables. Food consumption surveys, sometimes referred to as food intake surveys or dietary surveys monitor the food consumption at national, household and individual level. Household food consumption has been defined as the total quantity of food available for consumption in the household, generally excluding the food taken outside unless prepared at home (Fogel, 1993). It serves as a direct indicator of food security as well as an indirect measure for poverty (Webb *et al*., 2006). Hence, this study focused on cooking methods, food consumption pattern and seasonal food intake by the rural households with the following objectives: to find out the cooking methods practiced by the respondents; to assess food consumption pattern of the rural households. The study was conducted in the adopted village of MANAGE, Hyderabad namely Sriramnagar, Moinabad Mandal, Ranga Reddy District of Telangana state with 100 rural women as the respondents. Data was collected through structured questionnaire in the year 2019.

A list of different cooking methods (12) was mentioned and the respondents were asked to indicate the response as 'yes' or 'no' for the given method that they were used on a daily basis. The sum of all the methods practiced by the respondents was obtained and then categorized

*Corresponding Author E-mail i.d: veenita.k@manage.gov.in

into different groups based on the number of cooking methods practiced by them. Food consumption pattern of the respondents was collected by using an exhaustive list of probable food items which were listed under the respective food groups. The respondents were asked to indicate food consumption of different food items at the household level. For the ease of computation and comparision, the data was converted to monthly basis. A summated quantity of a particular food item per month for all the 100 household was obtained. This was further reduced to food consumed by 100 households per day by dividing the total amount of a particular food item by 30 (days). This data was again divided by 100 to obtain per day consumption of a particular food item by an individual. It has to be noted that the data was taken on average consumption of the different food items which denotes that the same foods may not be consumed on a daily basis. Hence, the values indicates an average consumption calculated over a period of one month. Food pattern was also studied to know the variations in food preference over the different seasons of the year.

Cooking methods adopted will influence the quality of the nutrients, hence, efforts were made to study different cooking methods used by the respondents. An exhaustive list of cooking methods was prepared. As per the findings, out of the 12 cooking methods, four cooking methods *i.e.* steaming, poaching, blanching and deep frying was used by cent percent of the respondents. Next commonly used cooking method is 'stir frying' and 'roasting' with 94% and 89%, respectively. Steaming might be used for idli making and cooking rice, a common breakfast meal of the respondents, poaching method for eggs, deep frying for puri and vada making, blanching for vegetables, stir frying for curries making and roasting for making chutney from pea nuts, channa dal, etc. Moist heat methods of steaming, poaching, blanching and dry heat method of deep frying was adopted by the respondents which will have advantages of conserving nutritive value, colour, flavor and palatability. This cooking processes also helps in easy digestion (Greeley, 2009).

Food habits of the respondents were assessed by collecting food consumption pattern at the family level. These highlights the food consumption pattern of the respondent's under different food category. It is evident that rice is the staple diet of the respondents *i.e*. 849.7g per day/ household, while there is very less consumption on wheat *i.e.* 93.8 g/day/household. They consumed chapatis mainly made from wheat flour occasionally, and, hence, the average consumption of wheat per day is very low. The average per day consumption of millets and its products is 249.8 g/day/household. Sorghum forms the next important food source next to rice consumption. The millets commonly consumed were sorghum and ragi, whereas, other millets were not noticed. Millets are rich source of protein, fibre, minerals, and Vitamin B complex. Finger millet (ragi) has a high calcium content. Millets are also a rich source of phytochemicals, which act as antioxidants and detoxifying agents (Devi *et al*., 2014). Hence, the respondents should be encouraged to start consumption of different millets to meet the dietary requirements and to ensure the nutritional security. The commonly consumed pulses and legumes were black gram dhal (42.17

g/day/household), red gram dhal (35.33 g /day/household), cluster beans (28.50 g/day/household) and beans (26.33 g/day/household). An individual family consumed about 115.71 g/day from the different types of pulses and legumes group. The most widely consumed roots and tubers were potato (144.3 g/day/household), carrot (72.7 g/day/household) and onion (68.3 g/day/household).The findings indicated that frequent consumption of roots and tubers, because of their easy availability and lower price. The respondents commonly consumed the following green leafy vegetables such as spinach, Chinese spinach, amaranthus, and sorrel. The consumption of individual green leafy vegetables range was 162.7g to 66.0g per day. Vegetables occupied an important part of the respondent's food habits. They consumed different types of available vegetables such as brinjal (65.0g per day), tomato (75.7g per day), ladies finger (71.3g per day), gherkins (72.0g per day).The data showed that a good amount of vegetables consumption by the respondents which are good source of micronutrients, vitamins and minerals. The yellow fruits such as papaya and mango are known as the rich sources of vitamin A. Vitamin A is good for eye sight and immune system. However, the data denotes poor consumption of vitamin A rich fruits by the respondents. The data pertaining to consumption of other fruits is also low. The data depicts that average daily consumption of milk per family is 480 ml only. Most of this milk is used for preparing tea. There is no consumption of other milk products like curd, butter milk, ghee etc. The frequency of consumption of eggs, fish and other meat products is also noticed to be very low. Since the frequency of consumption is very low, the corresponding values were also significantly low. The food item of this group is rich source of protein, but it was compensated by the adequate consumption of pulse and legumes from the respondent's diet. The respondents can also be trained in poultry farming especially backyard farming so that they can afford to eat eggs in adequate quantities and on a regular basis. It can have a significant impact on their food habits and nutritional status.

The percentage adequacy for food groups consumed was calculated. For the food groups cereals, vegetable-A and vegetable-B consumption was on par with the suggested consumption by National Institute of Nutrition (NIN) with 110%, 123% and 108%, respectively. Whereas, consumption was very low for the food groups of pulses and legumes, fruits, milk and milk products, and meat & meat products (48%, 18%, 45% and 18%, respectively). The respondents have to increase the consumption of fruits as they are good sources of micronutrients which protects from many degenerative diseases. Also, consumption of pulses & legumes, meat & meat products, milk & milk products which are good source of protein, iron and calcium.

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