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Preface

We would like to present, with great pleasure, the inaugural volume-8, Issue-8, August 2022, of a scholarly journal, *International Journal of Environmental & Agriculture Research*. This journal is part of the AD Publications series *in the field of Environmental & Agriculture Research Development*, and is devoted to the gamut of Environmental & Agriculture issues, from theoretical aspects to application-dependent studies and the validation of emerging technologies.

This journal was envisioned and founded to represent the growing needs of Environmental & Agriculture as an emerging and increasingly vital field, now widely recognized as an integral part of scientific and technical investigations. Its mission is to become a voice of the Environmental & Agriculture community, addressing researchers and practitioners in below areas.

Environmental Research:

Environmental science and regulation, Ecotoxicology, Environmental health issues, Atmosphere and climate, Terrestric ecosystems, Aquatic ecosystems, Energy and environment, Marine research, Biodiversity, Pharmaceuticals in the environment, Genetically modified organisms, Biotechnology, Risk assessment, Environment society, Agricultural engineering, Animal science, Agronomy, including plant science, theoretical production ecology, horticulture, plant, breeding, plant fertilization, soil science and all field related to Environmental Research.

Agriculture Research:

Agriculture, Biological engineering, including genetic engineering, microbiology, Environmental impacts of agriculture, forestry, Food science, Husbandry, Irrigation and water management, Land use, Waste management and all fields related to Agriculture.

Each article in this issue provides an example of a concrete industrial application or a case study of the presented methodology to amplify the impact of the contribution. We are very thankful to everybody within that community who supported the idea of creating a new Research with *IJOEAR*. We are certain that this issue will be followed by many others, reporting new developments in the Environment and Agriculture Research Science field. This issue would not have been possible without the great support of the Reviewer, Editorial Board members and also with our Advisory Board Members, and we would like to express our sincere thanks to all of them. We would also like to express our gratitude to the editorial staff of AD Publications, who supported us at every stage of the project. It is our hope that this fine collection of articles will be a valuable resource for *IJOEAR* readers and will stimulate further research into the vibrant area of Environmental & Agriculture Research.

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Soil Science	Plant Science
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Sustainable Natural Resource Utilisation	Management of the Environment
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Dynamic Changes of Vitamin C in Actinidia deliciosa 'Xuxiang' During Fruit Development

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Abstract— *Vitamin C is an important component in plants and humans. Kiwifruit was a valuable fruit with characteristic taste and flavor and high vitamin C contents. To date no studies have investigated the formation and accumulation mechanism on vitamin C in 'Xuxiang' kiwifruit. To elucidate the mechanism by which vitamin C accumulated of 'Xuxiang', we systematically investigated the gene expression profiles of the L-galactose pathway as well as the ascorbate–glutathione cycle. Our results showed that the content of vitamin C was high in ''Xuxiang' early fruit development, and then it decreased 50% during fruit division. The content of vitamin C kept about 80 mg/ 100 g when fruit developed completely. L-galactose pathway was an important route for vitamin C accumulation, which PGI1, PMM1, GMP1, GME1, GGP1, GDH1 and GalLDH1 were all important genes consist with vitamin C content*.

Keywords— Xuxiang, Vitamin C, Transcript regulation, L-galactose pathway.

I. INTRODUCTION

Vitamin C was one of water-soluble vitamins. It could be obtained from most fruits and vegetables [1]. Unlike animals, human could not synthesis vitamin C in liver [2]. As we all known, vitamin C was a way to prevent scurvy. More recent studies showed that Vitamin C can be used in additional health benefits and the prevention other diseases such as hyperuricemia [3], melanoma [4]. Thus, vitamin C was a vital component of human diet and it was responsible for several body actions such as aiding in the reaction of key enzymes and redox reactions [5]. In most plants, vitamin C was known as a cofactor for enzymes and also plays a role in the regulation of genes involved in defense mechanism and signaling in hormone pathways.

Vitamin C biosynthesis in plants occurred through various routes but activation of each pathway was dependent upon species and developmental stages of the plant [6]. Vitamin C biosynthesis most used D-Glucose as main precursor in mitochondrion. The first route was promoted is L-galactose pathway in strawberry [6]. Later on, several studies have promoted other vitamin C biosynthesis routes, which was L-gulose, the *myoinositol* and D-galacturonic acid pathways as well as ascorbate–glutathione cycle [7]. Additionally, L-galactose pathway was considered to be one of significant pathways, although other routes were also existed [8].

Kiwifruit (*Actinidia* spp.), an economically important crop, was cultivated worldwide. Kiwifruit was native to China, which included *A. chinensis*, *A. deliciosa* and a small amount of *A. arguta.* Kiwifruit was a valuable fruit with characteristic taste and flavor and high vitamin C contents. Before, fruit producers mainly paid attention on fruit yield, appearance, size and quality. In recent years, consumers have been more and more increasing concerned about the nutritional value such as Vitamin C.

To date no studies have investigated formation and accumulation mechanism on vitamin C of 'Xuxiang' kiwifruit. The main objective was to analysis the correlation with Vitamin C contents and genes involved in L-galactose pathway and ascorbate–glutathione cycle. Via the correlation analysis, the key genes possibly close related to vitamin C accumulation would be discovered. Other objectives of this study were to discover the fruit traits change rules in terms of fresh weight, TSS, titratable acid, total sugar, Vitamin C and organic acid content.

II. MATERIALS AND METHODS

2.1 Plant material

Fruit samples were collected from five-year-old 'Xuxiang' kiwifruit vines in an experiment orchard of Jiangsu Province. From May 6, 2016 (3 days after anthesis, DAA), once a week, more than 20 fruits were randomly sampled and peeled. In order to avoid interaction of seeds and flesh components, the seeds and inner cortex were subsequently removed. Meanwhile, the remaining flesh were cut in slice, frozen by liquid nitrogen and preserved in -70^{o}C refrigerator. 'Xuxiang' kiwifruit were harvest on September 27, 2016 (i.e. 148 DAA).

2.2 Fresh Weight, Dry Weight, Diameter, Firmness and TSS

Following sampling, fresh fruits were weighed. Single fruit was cut in slice and weighed. Then slices were dried at 65°C for enough time unto constant weight to determine the percentage fruit dry matter. Vertical, transverse and side diameters of individual fruits were measured by Vernier caliper. Fruit firmness was determined using a sclerometer with a probe d=0.1 following removal of a 1-mm thick slice of epicarpium [9]. TSS was determined for juice taken from fruit using the portable refractometer.

2.3 Titratable acid, Total sugar and Vitamin C content

After taking 10 g pulp from samples in -70℃ refrigerator and grinding in the mortar, titratable acid contents was measured in accordance with Akusu [10], total sugar contents were determined in accordance with Yilmaz [11] and vitamin C contents were assessed in accordance with Xu [12] These operations were all three repeats for determination.

2.4 Organic Acid content

5.0g pulps were selected from 5 stages (45, 73, 113, 148, 151 DAA). After grinding and transferred into 25 ml volumetric flasks, liquid chromatography (HPLC) was used to ascertained the components and contents of organic acids [13]. This was three repeats for determination. The standard components of various organic acids needed to be determined by HPLC.

2.5 RNA isolation and real-time PCR

The first-strand cDNA was synthesized using oligo (DT) following RNA was extracted from samples preserved in -70℃ refrigerator and assessed the quality by measuring the absorbance at 260 nm [14]. The synthesized cDNA was diluted 10-fold for the following quantitative RT-PCR analysis. Quantitative RT-PCR was performed using SYBR according to Ren [15]. The genes and primers used in this study were listed in Table 1. The quantitative RT-PCR primers were designed according to plant sequences from available databases (i.e. the Kiwifruit Genome Database) using Primer Premier 5 software. The kiwifruit *Actin* gene was used to normalize expression differences in each sample. Every sample was conducted three repeats respectively.

TABLE 1
SEQUENCES OF SPECIFIC PRIMERS USED FOR QUANTITATIVE REAL-TIME PCR

Gene	Kiwifruit ID	Forward primer 5'-3'	Reverse primer 5'-3'	Fragment length
PGI1	Achn087691	AACCTGTTGAACCATTGACACTTG	TTGATGCTACGAGGCGAACC	151
PGI2	Achn197361	CTCTTATCTGTGACACGGAGCAATG	GTGAGTAATCCAATAGCATCCCATCG	147
PMI1	Achn330131	TTCACCGAACTCATGTCTGCTAG	CTTATCCGTCAACTGCCTCACC	105
PMM1	Achn302501	TCACAGGCAGGTCCAGTCTC	AAGTGTAGGCAGCAGCAATCTC	178
GMP1	Achn055281	GGTGGATGAGACCGCAACAATC	GGTTGAGTGCCAGCCGATAATG	175
GME1	Achn030021	TGGAAAGGTGGAAGGGAGAAAGC	ATGAAGGTGAAAGATCGGGTTTGC	113
GGP1	Achn155031	GAGGGTGAAAGAGGTTGTTGGTG	CGCAAGCAGTGACATCGTAGC	146
GGP2	Achn339231	AACAGAGCAACGATAGCAAATCCC	GAGGCAAGCAGTCAAGAACACG	147
GPP1	Achn262331	CTCAGAGTTCCTCGCCATTGC	GCCCTTATGCTCCACATGCTTG	97
GPP2	Achn341581	ACTGAACCTTTGTGGGATTGC	CGCTGATGTCAAATTCTTTACCG	152
GDH1	Achn334011	GCTTTGATTTCAGTGCCGAGAGAG	GGGAGTCCTGTAATACCAATAAACC	199
GalLDH1	Achn136491	TTAGGCTGGAGTGATGAGATTCTGG	TCATACTGGGCTTTGTTAAGGTTCC	100
AO1	Achn228031	ACGACTTCTGGGTGTTGGGATAC	AGGCTCTATGTGGCAGTGGAATG	179
AO2	Achn230561	AATGCCAACACAATGAATCCCAAC	CTCATAGCAGTCCAGCCGTAGG	188
APX1	Achn059971	GTGGGAAGCGGCAAGACATTG	CCTCACTCACAGTCGGGTAGC	178
APX2	Achn315041	GAACTTCTGAATGAGTCGGAGGAG	ACAAGAGGACGATGGAGTGAACC	188
APX3	Achn289741	GCTCTCATCTCCCCAGAATGC	TGACCTCAACTGCCACACC	250
APX4	Achn207061	GAACTTCTGAATGAGTCGGAGGAG	ACAAGAGGACGATGGAGTGAACC	183
DHAR1	Achn224231	ACCTTTGGTAACACCGCCTGAG	ATGCTTGCTCTGTTCCATTGCTG	107
MDHAR1	Achn005611	GTGGTTGGTGGTGGTTACATTGG	TCGGCGAGGGAAGGAGTAAAC	125
MDHAR2	Achn132811	AGTGGTGGTGGTTGGTGGTG	GGCGAGGGAAGGAGTAAACAATC	130
MDHAR3	Achn075231	GGAGGAGGATACATCGGTCTTGAG	GCGTTAAACCCAACAGCCACAG	191
MDHAR4	Achn297231	AGTCAGGAACCAGAACCAGAACC	CCGATGCTGCCACAATAACACC	127
Actin		TGCATGAGCGATCAAGTTTCAAG	TGTCCCATGTCTGGTTGATGACT	

2.6 Statistical analysis

Statistical analysis was performed by ANOVA and Spearman Rank Order Correlation in SPSS software. Quantitative RT-PCR data was analyzed using the $2^{-\triangle\triangle CT}$ Method. In all figures, error bars donated the standard deviation of the mean. Statistical analyses were conducted at least thrice (n=3).

III. RESULTS

3.1 The changes of fruit development

The development trend of fresh weight of 'Xuxiang' kiwifruit looked like the shape of '2S' and it can be divided into four stages: 'rapid-slow-fast-slow' (Fig. 1(a)). The rapid development stage is 3~66 DAA, lasting for 62 days in which fresh weight reaching 74.73% of final fresh weight and increasing 0.96g per day on average. The fast development stage is 94~113 DAA, in which fresh fruit respectively increasing 19.39% of final fresh weight and equal to increasing 0.36g per day. Thus, rapid and fast stages were two critical periods for the change of fresh weight.

During 3~31 DAA, vertical, transverse and side diameter grew fast and the growth rate of vertical diameter was higher than transverse and side diameter. During 31~156 DAA, the growth rate of these diameters became slower and slower gradually (Fig. 1(b)). Therefore, from 3 to 31 DAA was the critical period for the fruit of rapid expansion.

Similar to the change trend of fresh weight, the development of dry weight could be also divided into four stages: 'fast (3~80 DAA) – slow (80~101 DAA) – fast (101~128 DAA) – slow (128~156 DAA)' (Fig.1(c)). It was not exactly consisting with the change of fresh weight. 3~80 and 101~128 DAA are important periods for the rapid accumulation of dry matter. During 31~156 DAA, the change trend of dry weight and dry matter were consisted. But during 17~31 DAA, when the dry weight increased, the dry matter decreased, which was a possible that moisture content was high and continued increasing in the early fruit development.

Before harvest, total soluble solids of 'Xuxiang' kiwifruit were between 4% and 7% (Fig. 1(d)). In general, TSS showed upward trend except for 3~31 DAA. After harvest (148~156 DAA), the TSS rose sharply and more than 14%. During 73~135 DAA, the firmness of kiwifruit was higher than 10 kg/cm^2 (Fig. 1(d)). After harvest (148~156 DAA), the firmness decreased sharply (Fig. 1(d)). The changes of TSS and firmness were small before harvest, in the contrary, TSS and firmness all showed a sharp change after harvest, which indicated that the fruit softening and the TSS increasing were caused by storing at room temperature after harvest.

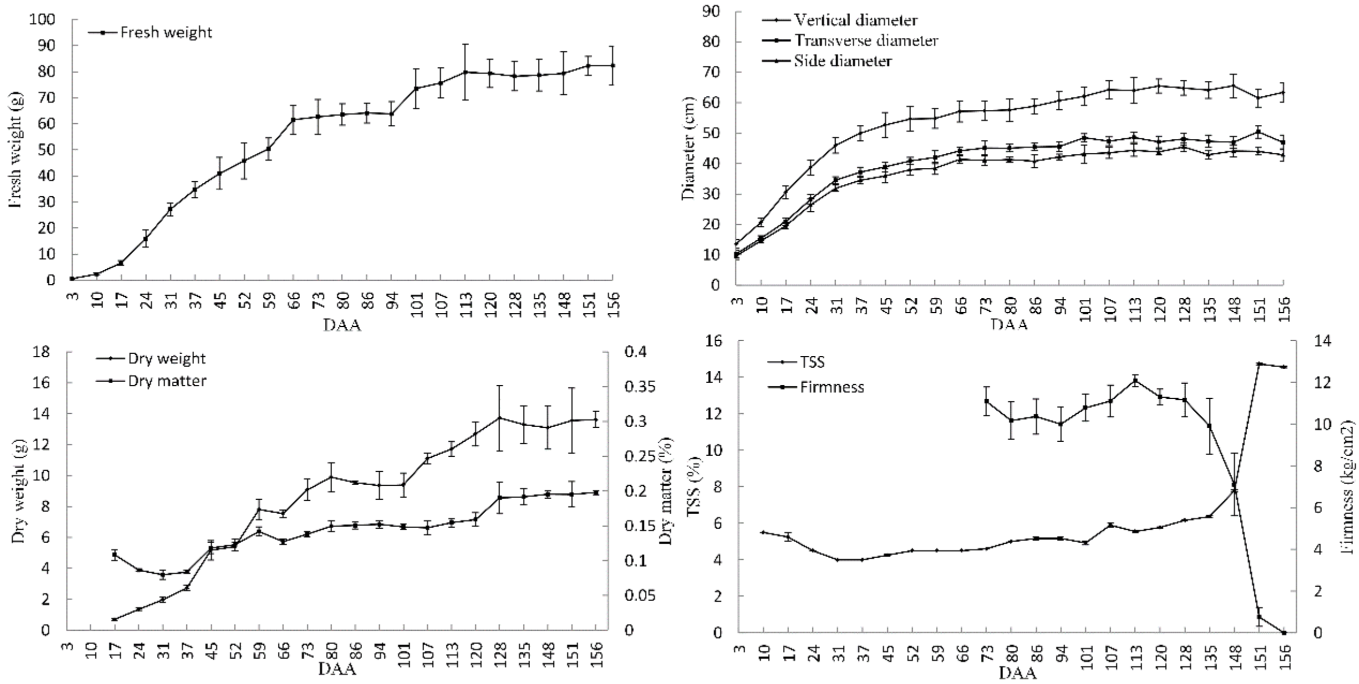

FIGURE 1: Changes in Fresh Weight, Dry Weight, Diameter, Firmness and TSS of 'Xuxiang' kiwifruit during the development period. Fresh weight and Diameter values were presented as means ± SE (n = 10); other weight values were present as means ± SE (n=3)

3.2 Titratable acid, Total sugar

During 17~73 DAA, the change trend of titratable acid kept upward. After up to peak content 21.62 g/100 g, it ranged between 17.57 g/100 g and 20.74 g/100 g (Fig.2). It can be inferred that 17~73 DAA is a mainly stage of titratable acid synthesis. Like-wise, during 31~86 and 101~156 DAA, the change trend of total sugar also kept upward (Fig.2). The reported total sugar concentrations in kiwifruits in highly variable and most exceed 6 g/100g [16], so the content of total sugar in 'Xuxiang' kiwifruit is relatively low, after harvest, it ranges only between 3 g/100 g and 5 g/100 g.

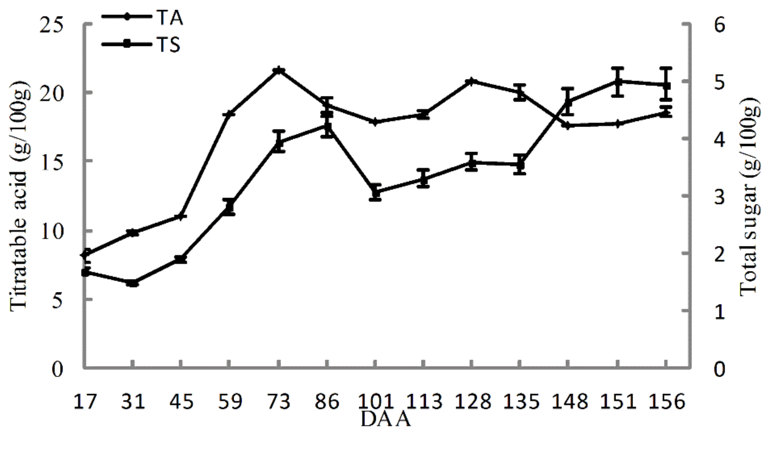

FIGURE 2: Changes in titratable acid and total sugar contents of 'Xuxiang' kiwifruit during the development period. Each value was presented as means ± SE (n = 3)

3.3 Organic Acid content

'Xuxiang' kiwifruit contain a range of organic acid, including malic acid, quinic acid and citric acid as well as trace amount of oxalic acid, shikimic acid, lactic acid and fumaric acid (Tab. 2). In 45 DAA, malic acid content is the highest, followed by quinine acid, and finally citric acid. After 113 DAA, the gap of malic acid, quinic acid and citric acid content became smaller gradually. Through the development period, the content of citric acid was always the lowest which different from the content of malic acid in 'Hort16A' was always lowest (Richardson et al., 2011). The former research reported that fruit of *Actinidia* species had a relatively high total acid content (1~3 % w/w fresh weight) [17]. 'Xuxiang' also had a relatively high total acid content (more than 2.4%). On 156 DAA, there was 37.7% quinic acid, 32.8% malic acid and 29.5% citric acid in the fruit of 'Xuxiang'. The content of acids was a dynamic progress, with citrate accumulating throughout fruit development, but quinic acid primarily accumulating in young fruit, which is same as the research of Marsh [17].

TABLE 2
DETERMINATION OF ORGANIC ACIDS COMPOSITION AND CONTENT IN 'XUXIANG' DURING 5 DEVELOPMENT PERIODS

DAA	oxalic acid (mg/g)	tartaric acid (mg/g)	quinic acid (mg/g)	malic acid (mg/g)	shikimic acid (mg/g)	lactic acid (mg/g)	acetic acid (mg/g)	citric acid (mg/g)	fumaric acid (mg/g)	butanedioic acid (mg/g)
45	0.000	-	13.317	21.191	0.053	0.178	0.051	0.946	0.000	-
73	-	-	18.599	19.148	0.041	0.116	0.007	5.720	0.000	-
113	-	-	12.754	14.779	0.026	0.114	0.009	8.964	0.001	-
148	-	-	8.847	7.798	0.017	0.111	-	7.817	0.001	-
151	-	-	11.136	9.682	0.020	0.175	0.008	8.727	0.001	-

3.4 Vitamin C

On 31 DAA, the content of VC reached its peak 180 mg/100 g, hereafter it decreased (Fig.3). After 101 DAA, the content of VC ranged between 76 and 87 mg/100 g which was consisted with the report that the content of VC in green kiwifruit ranged between 65 and 90 mg/100 g [18].

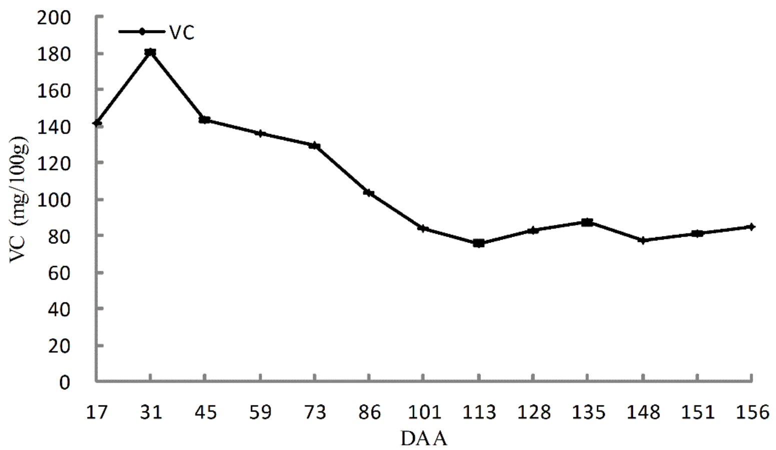

FIGURE 3: Changes in vitamin C contents of 'Xuxiang' during the development period. The value was presented as means ± SE (n = 3)

3.5 Genes expression

Reported VC synthesis pathway included L-galactose, L-gulose, the *myoinositol* and D-galacturonic acid pathways. L-galactose pathway was considered the central VC synthesis pathway [11]. In L-galactose pathway, enzymes such as PGI, PMI, PMM, GMP, GME, GGP, GPP, GDH and GalLDH were involved with VC synthesis. Experiment showed that gene *PGI2, PMM1, GMP1, GME1, GGP1, GDH1* and *GalLDH1* were positively correlated with VC content (Tab. 3). The change trends which expression levels of gene *PMM1, GMP1, GME1, GGP1* and *GDH1* were consistent (Fig 4). In addition, expression level of gene *PMM1, GMP1* and *GME1* were significant positively correlated (Tab. 3). It could be conferred that gene *PGI2, PMM1, GMP1, GME1, GGP1, GDH1* and *GalLDH1* were important genes involved in VC synthesis.

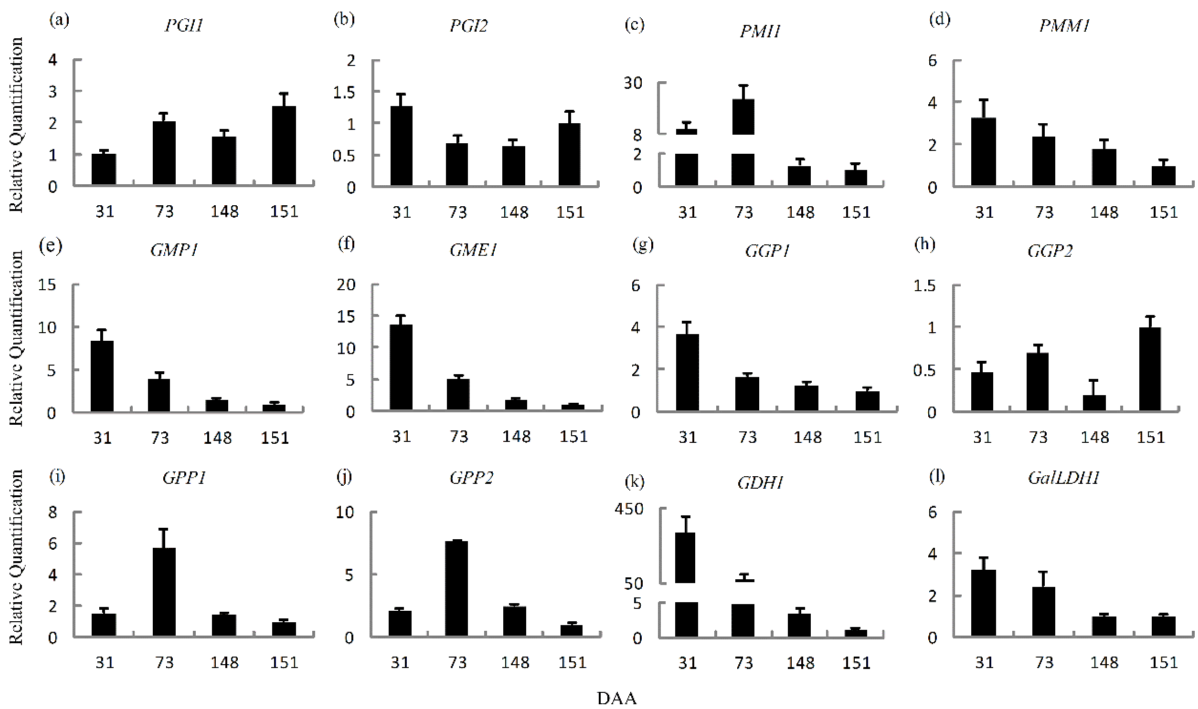

FIGURE 4: Expression profiles of genes involved in L-galactose pathway in fruits of 'Xuxiang' identified by RNA-Seq analysis using quantitative real-time PCR. The expression of each gene was normalized against *ACTIN*. Error bars represent SE for three replicate reactions. (a, b) *PGI*, (c) *PMI*, (d) *PMM*, (e) *GMP*, (f) *GME*, (g, h) *GGP*, (i, j) *GPP*, (k) *GDH*, (l) *GalLDH*.

TABLE 3
CORRELATION MATRIX OF GENES INVOLVED IN L-GALACTOSE PATHWAY.

	PGI1	*PGI2*	*PMI1*	*PMM1*	*GMP1*	*GME1*	*GGP1*	*GGP2*	*GPP1*	*GPP2*	*GDH1*	*GalLDH1*
PGI2	-0.2											
PMI1	-0.4	0.0										
PMM1	-0.8	0.4	0.8									
GMP1	-0.8	0.4	0.8	1.0**								
GME1	-0.8	0.4	0.8	1.0**	1.0**							
GGP1	-0.8	0.4	0.8	1.0**	1.0**	1.0**						
GGP2	0.8	0.4	-0.2	-0.4	-0.4	-0.4	-0.4					
GPP1	-0.4	0.0	1.0**	0.8	0.8	0.8	0.8	-0.2				
GPP2	-0.2	-0.6	0.8	0.4	0.4	0.4	0.4	-0.4	0.8			
GDH1	-0.8	0.4	0.8	1.0**	1.0**	1.0**	1.0**	-0.4	0.8	0.4		
GalLDH1	-0.4	0.8	0.6	0.8	0.8	0.8	0.8	0.2	0.6	0.0	0.8	
VC	-0.4	0.8	0.6	0.8	0.8	0.8	0.8	0.2	0.6	0.0	0.8	1.0**

Note: ** indicated correlation coefficients significantly negative or positive at P＜0.01 as based on Spearman Rank Correlation (two tails).

In ascorbate–glutathione cycle, AO and APX were enzymes involved in VC degradation, which was consist with expression of gene *AO1* and *APX2* were significantly positive correlated with VC content (Tab. 4). On the contrary, DHAR was enzyme involved in VC recycle, which was consist with *DHAR1* was significantly negative correlated with VC content (Tab. 4). In addition, two types gene *APX* that *APX1* and *APX2* were positively correlated with a correlation coefficient of 0.8 and two types of gene *MDHAR* that *MDHAR3* and *MDHAR4* were negatively correlated with a correlation coefficient of -0.8 (Fig. 5,

Tab. 4). It could be inferred that gene *APX1* and *APX2* were with similar function in ascorbate–glutathione cycle, but gene *MDHAR3* and *MDHAR4* were with contrary function.

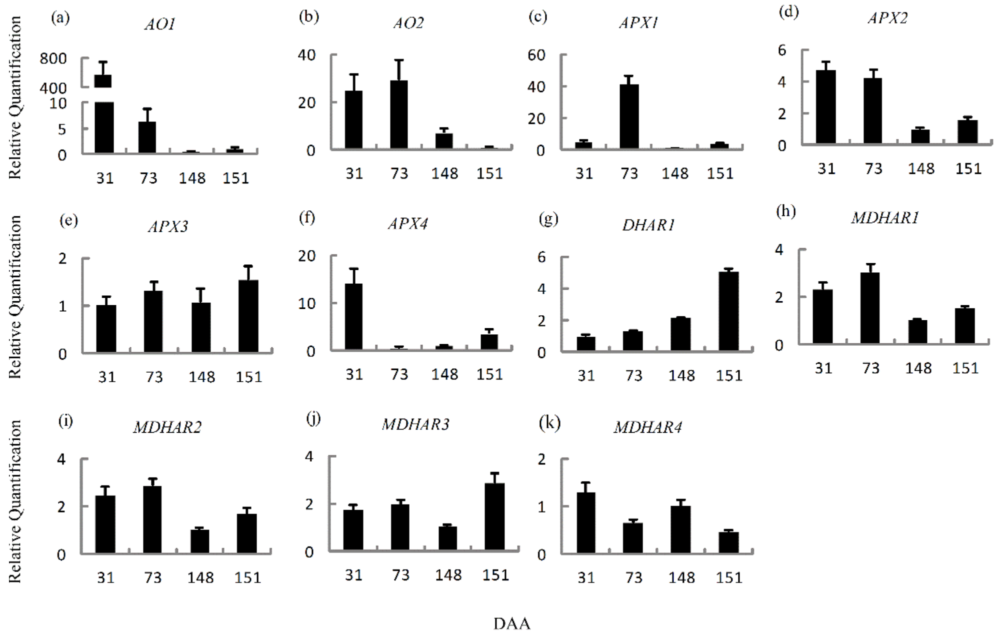

FIGURE 5: Expression profiles of genes involved in ascorbic acid—glutathione pathway in fruits of 'Xuxiang' identified by RNA-Seq analysis using quantitative real-time PCR. The expression of each gene was normalized against *ACTIN*. Error bars represented SE for three replicate reactions. (a, b) *AO*, (c, d, e, f) *APX*, (g) *DHAR*, (h, i, j, k) *MDHAR*.

TABLE 4
CORRELATION MATRIX OF GENES INVOLVED IN ASCORBIC ACID—GLUTATHIONE PATHWAY.

	AO1	*AO2*	*APX1*	*APX2*	*APX3*	*APX4*	*DHAR1*	*MDHAR1*	*MDHAR2*	*MDHAR3*	*MDHAR4*
AO2	0.6										
APX1	0.8	0.8									
APX2	1.0**	0.6	0.8								
APX3	-0.4	-0.4	0.0	-0.4							
APX4	0.4	-0.4	-0.2	0.4	-0.4						
DHAR1	-0.8	-0.8	-0.6	-0.8	0.8	-0.2					
MDHAR1	0.8	0.8	1.0**	0.8	0.0	-0.2	-0.6				
MDHAR2	0.8	0.8	1.0**	0.8	0.0	-0.2	-0.6	1.0**			
MDHAR3	0.2	-0.2	0.4	0.2	0.8	0.0	0.4	0.4	0.4		
MDHAR4	0.4	0.4	0.0	0.4	-1.0**	0.4	-0.8	0.0	0.0	-0.8	
VC	1.0**	0.6	0.8	1.0**	-0.4	0.4	-0.8	0.8	0.8	0.2	0.4

Note: ** indicated correlation coefficients significantly negative or positive at P＜0.01 as based on Spearman Rank Correlation (two tails).

IV. DISCUSSION

During 3 and 31 DAA, i.e. early fruit development, pulp cells split and expanded rapidly, and the content of vitamin C was high, which may due to vitamin C were involved in cell expansion. During 31 and 113 DAA, the content of vitamin C declined gradually, which may due to vitamin C dilution caused by fruit expansion or the rate of vitamin C degradation was higher than synthesis. From 113 DAA to fruit softening, the changes of fresh weight, size and vitamin C content were little, which may due to vitamin C degradation was in the mass balanced with synthesis.

The expression change trend of *AO1* was consisted with gene *PMM1*, *GMP1*, *GME1*, *GGP1*, *GDH1* and *GalLDH1* (Fig. 5, Fig. 6), which may due to *PMM1*, *GMP1*, *GME1*, *GGP1*, *GDH1* and *GalLDH1* high expression levels contributed to high vitamin C content. At the same time, *AO1* high expression level contributed to the decrease of vitamin C content. The content of vitamin C was high in the early fruit development (Fig. 3), which was a possible that the rate of vitamin C in L-galactose pathway was higher than in ascorbate–glutathione cycle. On the contrary, the gene *GDH1* expression level was diametrically opposed to the gene *PMM1*, *GMP1*, *GME1*, *GGP1*, *GDH1*, *GalLDH1* and *AO1* (Fig. 4, Fig. 5), which was a possible that only low vitamin C content allured gene *GDH1* high expression to promote vitamin C accumulation. Different studies have showed that overexpression of *DHAR* in range of plants i.e. tobacco has a little change of vitamin C content [19], which provided an evidence that *DHAR* was not key gene and L-galactose pathway played a more important route than ascorbate–glutathione cycle in vitamin C accumulation of kiwifruit.

Former research showed that the vitamin C content in leaves was higher than petioles and roots [15], which was a possible that vitamin C synthesis in leaves and then transport in other organs such as roots and fruits. This needed further study. Additionally, in ascorbate–glutathione cycle, part of vitamin C was decomposed into oxalic acid and tartaric acid, and the content of oxalic acid was high [19]. But in our studies, it was special the content of oxalic acid and tartaric acid were very low even unable to detect.

V. CONCLUSION

The content of vitamin C was high in 'Xuxiang' early fruit development, and then it decreased 50% during fruit division. The content of vitamin C kept about 80 mg/100 g when fruit developed completely. L-galactose pathway was an important route for vitamin C accumulation, which *PG1*, *PMM1*, *GMP1*, *GME1*, *GGP1*, *GDH1* and *GalLDH1* were all important genes consist with vitamin C content.

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REFERENCES

[1] Iqbal, K., Khan, A., & Khattak, M. M. (2017). Biological significance of ascorbic acid (vitamin C) in human health -- a review. *Pakistan Journal of Nutrition, 3*(1).5-14

[2] Horio, F. (2015). Regulatory mechanisms of vitamin C biosynthesis and physiological functions of vitamin C relating to disease prevention. *Vitamins, 89*(11):528-536

[3] Azzeh, F. S., Al-Hebshi, A. H., Al-Essimii, H. D., & Alarjah, M. A. (2017). Vitamin C supplementation and serum uric acid: A reaction to hyperuricemia and gout disease. *PharmaNutrition, 5*(2), 47-51.

[4] Fischer, A. P., & Miles, S. L. (2017). Ascorbic acid, but not dehydroascorbic acid increases intracellular vitamin C content to decrease Hypoxia Inducible Factor -1 alpha activity and reduce malignant potential in human melanoma. *Biomedicine & pharmacotherapy = Biomedecine & pharmacotherapie, 86*, 502.

[5] Da, S. T., Aguiaroliveira, E., Mazalli, M. R., Kamimura, E. S., & Maldonado, R. R. (2017). Comparison between titrimetric and spectrophotometric methods for quantification of vitamin C. *Food Chemistry, 224*, 92-96.

[6] Kumar, A., Kumar, S., Bains, S., Vaidya, V., Singh, B., Kaur, R., Singh, K. (2016). De novo Transcriptome Analysis Revealed Genes Involved in Flavonoid and Vitamin C Biosynthesis in Phyllanthus emblica (L.). *7*, 1610.

[7] Magwaza, L. S., Mditshwa, A., Tesfay, S. Z., & Opara, U. L. (2017). An overview of preharvest factors affecting vitamin C content of citrus fruit. *Scientia Horticulturae, 216*, 12-21.

[8] Laing, W. A., Wright, M. A., Cooney, J., & Bulley, S. M. (2007). The missing step of the L-galactose pathway of ascorbate biosynthesis in plants, an L-galactose guanyltransferase, increases leaf ascorbate content. *Proceedings of the National Academy of Sciences of the United States of America, 104*(22), 9534-9539.

[9] Richardson, A. C., Boldingh, H. L., Mcatee, P. A., Gunaseelan, K., Luo, Z., Atkinson, R. G., . . . Schaffer, R. J. (2011). Fruit development of the diploid kiwifruit, Actinidia chinensis 'Hort16A'. *BMC Plant Biology, 11*(1), 182-195.

[10] Akusu, O. M. (2016). Quality Characteristics of Orange/Pineapple Fruit Juice Blends. *Rev.bras.anestesiol, 59*(4), 481-486.

[11] Yilmaz, K. U., Ercisli, S., Cam, M., Uzun, A., Yilmaztekin, M., Kafkas, E., & Pinar, H. (2015). Fruit Weight, Total Phenolics, Acidity and Sugar Content of Edible Wild Pear (Pyrus elaeagnifolia Pall.) Fruits. *Erwerbs-Obstbau, 57*(4), 1-6.

[12] Xu, Y., Zhu, X., Chen, Y., Gong, Y., & Liu, L. (2013). Expression profiling of genes involved in ascorbate biosynthesis and recycling during fleshy root development in radish. *Plant physiology and biochemistry, 70*, 269-277.

[13] Cheng, C. H., Seal, A. G., Boldingh, H. L., Marsh, K. B., Macrae, E. A., Murphy, S. J., & Ferguson, A. R. (2004). Inheritance of taste characters and fruit size and number in a diploid Actinidia chinensis (kiwifruit) population. *Euphytica, 138*(2), 185-195.

[14] Sun, Y., Mu, C., Chen, Y., Kong, X., Xu, Y., Zheng, H., Li, Z. (2016). Comparative transcript profiling of maize inbreds in response to long-term phosphorus deficiency stres. *Plant Physiology & Biochemistry Ppb*, *109*, 467-481.

[15] Ren, J., Chen, Z., Duan, W., Song, X., Liu, T., Wang, J., .. Li, Y. (2013). Comparison of ascorbic acid biosynthesis in different tissues of three non-heading Chinese cabbage cultivars. *Plant physiology and biochemistry, 73*, 229-236.

[16] Henare, S. J. (2016). The Nutritional Composition of Kiwifruit (Actinidia spp.). *Nutritional Composition of Fruit Cultivars*, 337-370.

[17] Marsh, K. B., & Harker, F. R. (2016). Acid Metabolism in Kiwifruit. In R. Testolin, H.-W. Huang & A. R. Ferguson (Eds.), *The Kiwifruit Genome* (pp. 179-188). Cham: Springer International Publishing.

[18] Vissers, M. C., Carr, A. C., Pullar, J. M., & Bozonet, S. M. (2013). The bioavailability of vitamin C from kiwifruit. *Advances in Food & Nutrition Research, 68*, 125-147.

[19] Bulley, S. M. (2016). *Ascorbic Acid-Related Genes*: Springer International Publishing.

The Effect of Arbuscular Mycorrhyza Inoculation and SP 36 Fertilizer on the Growth of Palm Oil (*Elaeis Guineensis* Jacq.) Seedling DxP PPKS 540 Variety Grown in Pre Nursery Phase

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Abstract—*The aims of the study were to determine the effect of arbuscular mycorrhizal inoculation and SP-36 fertilizer and their interaction on the growth and yield of oil palm seedlings of the DxP PPKS 540 variety and to obtain the appropriate dose of mycorrhizal biofertilizer and SP-36 fertilizer for the growth of oil palm seedlings at the pre-nursery stage.The research was carried out from April 2020 to August 2020.The place of research was held on Jl. Rapak Indah, Karang Asam Ilir urban Village, Sungai Kunjang sub District, Samarinda City, East Kalimantan Province.The materials used in this study were DxP PPKS 540, Fungi Mycorrhizal, SP 36 Fertilizer, Dithane M-45, polybag size 22x14 cm and paranet.The tools used in this study were arco carts, soil pH measuring instruments, hoes, soil loosening tools, writing instruments, analytics, and gembor.The study used a completely randomized design (CRD) in a 5x4 factorial experiment, with two treatment factors and repeated 4 times.Mycorrhizal dose factor (M) which consists of 5 levels, namely: no mycorrhizal application or control (m_0); 2.5 g polybag^{-1} (m_1); 5.0 g polybag^{-1} (m_2); 7.5 g polybag-1 (m_3) and 10.0 g polybag^{-1} (m_4) Dosage factor SP 36 (P) consisting of 4 levels, namely: no SP 36 fertilizer application of control (p_0); 1.0 g polybag^{-1} (p_1); 1.5 g polybag^{-1} (p_2); and 2.0 g polybag^{-1} (p_3).Research activities, namely: preparation of planting media, treatment of microzia, preparation of sprouts, planting of seedling, treatment of SP-36 fertilizer, maintenance of seedlings (watering, weeding, and loosening of planting media), and data collection.Data collection is analysis of soil chemical properties in the laboratory, seedling height, stem diameter, number of leaves at aged 1, 2, 3 months after planting and root length at 4 months after planting.Data analysis was carried out by analysis of variance, if the results of variance were significantly different (F-count > F-table 5%) or very significantly different (F-count > F-table 1%), then a further test was carried out with the Least Significant Difference test at 5% level.The results showed that (1) Arbuscular mycorrhizal application had no significant effect on the growth in height, stem diameter, number of seedling leaves at the age of 1, 2, and 3 months after planting, and root length of seedlings at 4 months after planting;(2) application of SP-36 fertilizer had a significant to very significant effect on the height growth at 1, 2, and 3 months after planting, seedling diameter at 1 month after planting, number of leaves at 1 and 3 months after planting, and root length. seedlings at the age of 4 months after planting.Application of SP-36 fertilizer at a dose of 1.5 – 2.0 g plant^{-1} tends to inhibit the growth of oil palm seedlings in the pre-nursery phase;and (3) there was no interaction between mycorrhizal treatment and SP-36 fertilizer treatment on the growth of oil palm seedlings in the pre-nursery phase.*

Keywords— Arbuscular mycorrhizae, SP-36 Fertilizer, Pre Nursery, Oil Palm Seedling.

I. INTRODUCTION

Palm oil is a strategic commodity that is very important as a source of foreign exchange, a source of community livelihood and a profitable commodity for businessmen and smallholders. Palm oil is a very sensitive commodity, palm oil is the most efficient oil-producing crop today. Palm oil production can reach 4 tons ha^{-1} $year^{-1}$, much larger than soybean oil which only produces 0.6 tons ha^{-1} $year^{-1}$ [1].

The success of CPO production is largely determined by the use of certified superior seedlings, as well as the quality (type of seedling and growth rate) and quantity of oil palm seedling.Seedling quality also determines whether oil palm plants can be harvested starting at the age of 30 months in the field.It is influenced, among others by: (1) varieties and sources of seedling or genetic potential; (2) the process of nursery or technical culture in planting and maintaining seedlings; (3) seed selection; and (4) seedling age at the time of planting in the field [2]

Nurseries are a crucial first step for the success of oil palm plantations.Nurseries aim to provide good and healthy seeds in sufficient quantities.In oil palm cultivation, there are two nursery systems, namely single-stage nurseries and two-stage nurseries.What is meant by "double stage" nursery is that the seedlings are carried out in small polybags or in the pre-nursery stage until the seedlings are 3 months old.After the seedlings are 3 months old, the seedlings are transferred to large polybags or the main nursery stage until the seedlings are ready to be planted in the field when they are 12 months old [3].

Success in pre-nursery is strongly influenced by fertile soil conditions and maintenance. Efforts to improve the level of soil fertility is the provision of fertilizers.There are two types of fertilizers that are currently widely used, namely inorganic fertilizers (chemical) and organic fertilizers.Chemical fertilizers can increase soil productivity in a very short time but cause damage to soil structure [4].Organic fertilizers have the advantage of releasing nutrients slowly so that they have a residual effect in the soil and are beneficial for plants [5].One of the organic fertilizers is biological fertilizer.Biological fertilizers, in this case mycorrhizae, are fungi that live in symbiosis with plant roots.Some of the benefits of mycorrhizae are: increasing the absorption of N, P, K, Ca some micro nutrients; increase plant resistance to drought, control root pathogen infection, produce growth-stimulating compounds, stimulate the activity of several beneficial organisms (Rhizobium, Frankia and phosphorus-fixing bacteria); improve soil structure and aggregation; and helps the mineral cycle [6].Arbuscular mycorrhizal fungi are a form of mutualism symbiosis that occurs between plant roots and fungi.Currently, it is known that almost 80% of plants are symbiotic with arbuscular mycorrhizal fungi [7].

In addition to the use of mycorrhizae, to stimulate seedling growth, SP-36 fertilizer can also be applied.This fertilizer contains high levels of phosphorus (P) and dissolves faster than DSP and TSP fertilizers.

II. RESEARCH METHODS

2.1 Time and place

The research was conducted from April 2020 to August 2020.The research site is on Jl. Rapak Indah, Karang Asam Ilir urban Village, Sungai Kunjang sub District, Samarinda City, East Kalimantan Province.

2.2 Materials and tools

The materials used in this study were DxP PPKS 540, Fungi Mycorrhizal, SP 36 Fertilizer, Dithane M-45, polybag size 22x14 cm and paranet.The tools used in this study were arco carts, soil pH measuring instruments, hoes, soil loosening tools, writing instruments, analytical balances, and water sprayer.

2.3 Research design

The study used a completely randomized design (CRD) in a 5x4 factorial experiment, repeated 4 times.The first factor is the mycorrhizal dose (M), which consists of 5 levels, namely: without mycorrhizae (m_0);2,5 g $polybag^{-1}$ (m_1);5,0 g $polybag^{-1}$ (m_2); 7,5 g $polybag^{-1}$ (m_3); and 10,0 g $polybag^{-1}$ (m_4).Dosage factor of SP 36 (P) yang terdiri atas 4 taraf yaitu :tanpa pupuk

SP 36 which consists of 4 levels, namely: without SP fertilizer (p_0);1,0 g polybag $^{-1}$ (p_1); 1,5 g polybag $^{-1}$ (p_2); and 2,0 g polybag $^{-1}$ (p_3).

2.4 Research activities

The stages of research activities are: (1) preparation of planting media; (2) giving mycorrhizal treatment; (3) preparation of sprouts; (4) planting; (5) application of SP-36 fertilizer; (6) maintenance: watering, loosening the soil; and weed control; and (7) data collection and analysis.

2.5 Data retrieval

The data collected were: (1) analysis of the chemical properties of planting media before treatment, (2) height of seedlings aged 1, 2, and 3 months after planting; (3) stem diameter at 1, 2, and 3 months after planting; (4) number of leaves at 1, 2, and 3 months after planting; and (5 lengths of roots aged 4 months after planting.

2.6 Data analysis

Analysis of data from observations of seedling growth with variance and followed by a 5% BNT test if (F Count > F Table 5% and 1%).

III. RESULTS AND DISCUSSION

3.1 Chemical Properties of Planting Media Before Giving Treatment

The results of the analysis of growing media in the laboratory are presented in Table 1.

TABLE 1
RESULTS OF ANALYSIS OF CHEMICAL PROPERTIES OF PLANTING MEDIA BEFORE TREATMENT

Sample Code	pH	C Organic (%)	N Total (%)	C/N	P Bray (ppm)	K Morgan (ppm)	Al	H
1	7,78	1,25	0,16	7,70	1,71	42,31	0,00	0.00
2	8,11	1,01	0,14	7,24	1,46	69,23	0,00	0.00
3	8,05	1,33	0.11	11,89	1,95	51,54	0,00	0.00
4	8,15	2,09	0,15	13,79	1,46	52,31	0,00	0.00
5	8,08	1,16	0,13	9,02	3,17	43,85	0,00	0.00
Status	Alkalis	R - S	R	R - S	SR	T	SR	SR

Source: Soil Laboratory, Faculty of Agriculture, Unmul Samarinda (2019)
Description: SR = very low; R = low; S = moderate; and T = height.

Based on Table 1 shows that the pH of the growing media ranged from 7.78 - 8.15 (classified as alkaline), C-organic content was between 1.01 - 2.09% (classified as low to moderate), N-total content was between 0.11 - 0.16% (classified low), C/N ratio between 7.24 – 13.79 (classified low to moderate), P available between 1.46 – 3.17 ppm (classified very low), K available between 42 .31 – 69.23 ppm (classified high), the content of Al and H cations is 0 me/100 g of soil (classified very low).In general, the fertility status of the growing media is low.

3.2 Effect of Arbusquar Mycorrhizae and SP-36 Fertilizer and their Interaction

The results of the effect of Arbuskuar Mycorrhizae and SP-36 fertilizer and their interaction on the growth of oil palm seedlings in the pre-nursery phase are presented in Table 2 and 3.

TABLE 2
SEEDLING STEM HEIGHT AND DIAMETER GROWTH.

Factors Treatment	Height (cm) at ages			Diameter (cm) at ages		
	I BST	2 BST	3 BST	I BST	2 BST	3 BST
Mycorrhizal Treatment (M)	**tn**	**tn**	**tn**	**tn**	**tn**	**tn**
NoMycorrhizae (m_0)	5,20	14,53	19,58	1,23	1,73	2,03
2,5 g polibag^{-1} (m_1)	3,68	15,25	21,55	1,35	1,70	1,93
5,0 g polibag^{-1} (m_2)	5,08	13,23	19,15	1,25	1,65	1,95
7,5 g polibag^{-1} (m_3)	6,10	14,43	20,39	1,25	1,78	2,05
10,0 g polibag^{-1} (m_4)	4,58	13,80	19,67	1,25	1,70	2,03
SP-36 Treatment (P)	**	*	**	**	**tn**	**tn**
Tanpa SP-36 (p_0)	7,20 a	15,92 a	22,54 a	1,42 a	1,78	2,10
1,0 g polibag^{-1} (p_1)	6,02 b	15,28 a	22,16 a	1,36 a	1,82	2,06
1,5 g polibag^{-1} (p_2)	4,24 c	12,70 b	18,26 b	1,14 b	1,62	1,92
2,0 g polibag^{-1} (p_3)	3,64 c	11,09 b	17,31 b	1,14 b	1,64	1,90
Interacation (Mx P)	**tn**	**tn**	**tn**	**tn**	**tn**	**tn**
m0p0 m0p1 m0p2 m0p3	7,10 5,90 4,30 3,50	17,10 15,50 12,30 13,23	23,10 23,50 14,90 16,83	1,40 1,40 1,10 1,00	1,90 1,90 1,60 1,50	2,00 2,30 1,80 2,00
m1p0 m1p1 m1p2 m1p3	7,60 5,80 3,80 4,50	18,00 13,40 14,30 15,30	24,90 21,00 19,40 20,90	1,50 1,40 1,10 1,40	1,80 1,60 1,50 1,90	2,00 1,80 1,90 2,00
m2p0 m2p1 m2p2 m2p3	7,30 6,60 3,80 2,60	15,60 16,50 10,80 10,00	22,30 22,30 18,00 14,00	1,50 1,40 1,10 1,00	1,80 1,80 1,50 1,50	2,30 2,10 1,80 1,60
m3p0 m3p1 m3p2 m3p3	8,60 7,00 4,30 4,50	16,60 15,90 11,60 13,60	21,60 23,50 18,10 18,30	1,40 1.50 1,10 1,00	1,80 1,90 1,60 1,80	2,10 2,00 2,00 2,10
m4p0 m4p1 m4p2 m4p3	5,40 4,80 5,00 3,10	12,30 15,10 14,50 13,30	20,80 20,50 20,90 16,50	1,30 1,10 1,30 1,30	1,60 1,80 1,90 1,50	2,10 2,10 2,10 1,80

Note: the average number followed by the letter which is not significantly different based on the results of the 5% BNT test. tn = not significant effect; * = significant effect; ** = very significant effect; and BST = month after planting

TABLE 3
GROWTH OF LEAF NUMBER AND ROOT LENGTH

Factors Treatment	Number of Leaves (Strands) at Age			Root Length at Age 4 BST (cm)
	1 BST	2 BST	3 BST	
Mycorrhizal Treatment (M)	**tn**	**tn**	**tn**	**tn**
NoMycorrhizae (m_0)	1,23	2,57	2,85	21,80
2,5 g polibag^{-1} (m_1)	1,35	2,48	2,90	24,00
5,0 g polibag^{-1} (m_2)	1,25	2,20	2,70	21,93
7,5 g polibag^{-1} (m_3)	1,38	2,45	3,00	21,58
10,0 g polibag^{-1} (m_4)	1,25	2,10	2,98	23,77
SP-36 Treatment (P)	**	**tn**	**	**
Tanpa SP-36 (p_0)	1,42 a	2,46	3,36 a	25,58 a
1,0 g polibag^{-1} (p_1)	1,36 a	2,49	3,06 a	26,40 a
1,5 g polibag^{-1} (p_2)	1,18 b	2,42	2,66 b	21,00 ab
2,0 g polibag^{-1} (p_3)	1,20b	2,36	2,47 b	17,40 b
Interaction(Mx P)	**tn**	**tn**	**tn**	**tn**
m0p0	1,40	3,00	3,50	28,30
m0p1	1,40	2,30	3,40	27,30
m0p2	1,10	2,50	2,40	26,30
m0p3	1,00	2,50	2,13	15,30
m1p0	1,50	2,30	3,50	25,30
m1p1	1,40	2,30	2,50	30,00
m1p2	1,10	2,80	2,80	21,70
m1p3	1,40	2,50	2,80	19,00
m2p0	1,50	2,50	3,30	29,30
m2p1	1,40	2,30	2,90	30,00
m2p2	1,10	2,00	2,30	10,70
m2p3	1,00	2,00	2,30	17,70
m3p0	1,40	2,50	3,00	27,30
m3p1	1,50	2,30	3,50	20,70
m3p2	1,30	2,50	2,50	21,00
m3p3	1,30	2,50	3,00	17,30
m4p0	1,30	2,00	3,50	27,70
m4p1	1,10	2,30	3,00	24,00
m4p2	1,30	2,30	3,30	25,70
m4p3	1,30	1,80	2,10	17,40

Note: the average number followed by the letter which is not significantly different based on the results of the 5% BNT test. tn = not significant effect; ** = very significant effect; and BST = month after planting

3.2.1 Effect of Arbuscular Mycorrhizae

The results of variance showed that arbuscular mycorrhizal inoculation had no significant effect on seedling height, stem diameter, number of leaves at 1, 2, and 3 months after planting, and root length at 4 months after planting.The results presented in Table 2 show that the mycorrhizal inoculation treatment (m1, m2, m3, and m4) resulted in seedling height at the age of 1 month after planting which ranged from 3.68 to 6.10 cm, while in the treatment without mycorrhizae (m0) which is 5.20 cm; seedling height at the age of 2 months after planting ranged from 13.23 to 15.25 cm, while in the treatment without mycorrhizae (m0) it was 14.53 cm; and seedling height at the age of 3 months after planting ranged from 19.15 to 21.55 cm, while in the treatment without mycorrhizae (m0) it was 19.58 cm.Mycorrhizal inoculation treatments (m1, m2, m3, and m4) produced seedling diameters at the age of 1 month after planting which ranged from 1.25 to 1.35 cm, while the treatment without mycorrhizae (m0) was 1.25 cm; seedling diameter at the age of 2 months after planting ranged from 1.65 to 1.78 cm, while in the treatment without mycorrhizae (m0) it was 1.73 cm; and the diameter of the seedlings at the age of 3 months after planting ranged from 1.93 to 2.05 cm, while in the treatment without mycorrhizae (m0) it was 2.03 cm.

The results presented in Table 3 show that the mycorrhizal inoculation treatment (m1, m2, m3, and m4) resulted in the number of seedling leaves at the age of 1 month after planting which ranged from 1.25 to 1.38 strands, while in the treatment without mycorrhizae (m0) ie 1.23 strands; the number of seedling leaves at the age of 2 months after planting ranged from 2.10 to 2.48 strands, while in the treatment without mycorrhizae (m0) it was 2.57 strands; and the number of seedling leaves at the age of 3 months after planting ranged from 2.70 to 3.00 leaves, while in the treatment without mycorrhizae (m0) it was 2.85 strands.Mycorrhizal inoculation treatments (m1, m2, m3, and m4) resulted in seedling root length at the age of 4 months after planting ranging from 21.58 to 24.00 cm, while the treatment without mycorrhizae (m0) was 21.80 cm.

In general, the results showed that the various doses of arbuscular mycorrhizal inoculation (m1, m2, m3, and m4) resulted in seedling height, stem diameter, number of leaves, and root length of oil palm seedlings in the pre-nursery phase which were not significantly different compared to the treatment without arbuscular mycorrhizal inoculation (m0).This situation can be caused by internal factors of the seeds themselves, namely oil palm seedlings in the pre-nursery phase, which are still in early growth, so they have few roots.This condition causes the infection of mycorrhizal inoculum with the roots of oil palm seedlings has not/did not work as expected.Mycorrhizal inoculation process requires time and a process that is not short. Mycorrhizal inoculation requires good media so that it is able to maintain mycorrhizal conditions according to their natural characteristics.

In addition to these factors, the condition factor of the chemical properties of the growing media which is classified as infertile, with the following characteristics, namely having a pH (7.78-8.15) is classified as alkaline, the content of organic matter (1.01-2.09%) is classified as alkaline. low to moderate, the total N content (0.11 – 0.16%) is low, the P content (1.46 – 1.95 ppm) is very low and the K content (42.31 – 69.23 ppm) is classified as low. high, and very low Al and H content (Table 1).With these chemical conditions, oil palm seedlings cannot grow optimally, seedling roots are underdeveloped, so that it affects mycorrhizal infections to oil palm seedling roots.As stated by [8] that in each plant the percentage of infection is different, this may be due to differences in several factors that affect mycorrhizal infection in plants, including: dependence of plants on mycorrhizae, effectiveness of isolates, and condition of elements. nutrients / nutrients. Furthermore, it was stated [9] that the development of arbuscular mycorrhizae was influenced by the sensitivity of the host plant to infection, light intensity, temperature, soil moisture content, soil pH, organic matter, root residues, availability of nutrients, heavy metals and fungicides.

3.2.2 Effect of SP-36 Pupuk Fertilizer

The results of variance showed that the SP-36 fertilizer treatment had a significant to very significant effect on seedling height at 1, 2, and 3 months after planting.The results presented in Table 2 show that the treatment with various doses of SP-36 fertilizer (p1, p2, and p3) resulted in seedling height at the age of 1 month after planting which ranged from 3.64 to 6.02 cm without SP-36 fertilizer (p0) which is 7.20 cm; seedling height at the age of 2 months after planting ranged from 11.09 to 15.28 cm, while the treatment without SP-36 fertilizer (p0) was 15.92 cm; and seedling height at the age of 3 months after planting ranged from 17.31 to 22.16 cm, while the treatment without SP-3a (p0) was 22.54 cm.

The results of variance showed that the SP-36 fertilizer treatment had a very significant effect on seedling diameter at 1 month after planting, but had no significant effect on seedling diameter at 2 and 3 months after planting.The results presented in Table 2 show that the treatment with SP-36 fertilizer (p1, p2, and p3) resulted in seedling diameter at the age of 1 month after planting which ranged from 1.14 to 1.36 cm, while in the treatment without fertilizer SP-36 (p0) is 1.42 cm; seedling diameter at the age of 2 months after planting ranged from 1.62 to 1.82 cm, while in the treatment without SP-36 fertilizer (p0) it was 1.78 cm; and the diameter of the seedlings at the age of 3 months after planting ranged from 1.90 to 2.05 cm, while the treatment without SP-3a (p0) fertilizer was 2.10 cm.

The results of variance showed that the SP-36 fertilizer treatment had a very significant effect on the number of seedling leaves at the age of 1 and 3 months after planting, but had no significant effect on the number of seed leaves at the age of 2 months after planting.The results presented in Table 3 show that the treatment with SP-36 fertilizer (p1, p2, and p3) resulted in the number of leaves of seedlings at the age of 1 month after planting which ranged from 1.20 to 1.36 strands, while in the treatment without fertilizer SP-36 (p0) which is 1.42 strands; the number of seedling leaves at the age of 2 months after planting ranged from 2.36 to 2.49 strands, while in the treatment without SP-36 fertilizer (p0) it was 2.46 strands; and the number of seedling leaves at the age of 3 months after planting ranged from 2.47 to 3.06 strands, while in the treatment without SP-3a fertilizer (p0) it was 3.36 strands.

The results of variance showed that the SP-36 fertilizer treatment had a very significant effect on the root length of the seedlings at 4 months after planting.The results presented in Table 12 (recapitulation) show that the treatment with SP-36 fertilizer (p1, p2, and p3) resulted in seedling root length at the age of 4 months after planting which ranged from 17.40 to 26.40 cm, while the treatment without SP-36 fertilizer (p0) was 25.58 cm.

In general, the results showed that the application of SP-36 fertilizer, especially at a dose of 1.5 g polybag-1 (p2) and 2.0 g polybag-1 (p3) tended to reduce growth in height, stem diameter, number of leaves at the age of 1, 2, and 3 months after planting and root length of oil palm seedlings at 4 months after planting.This situation is due to the fact that oil palm seedlings in the pre-nursery phase are still in the early stages of growth, so they do not need nutrients like mature plants, with nutrient content in the planting medium (based on the results of laboratory analysis of organic matter content of 1.01 - 2 ,09% (low – moderate), N-total content of 0.11 – 0.16% (low), P content of 1.46 – 1.95 ppm (very low) and K content of 42, 31 – 69.23 ppm (high enough) has met the nutrient/nutrient needs of the seeds, and the addition of SP-36 fertilizer tends to inhibit the growth of oil palm seedlings.As stated by [10] that plant growth is influenced by the availability of nutrients in the soil.Growth is an increase in the number and dimensions of plants, both diameter and height in a plant.Plant growth will increase if plant nutrients are met or vice versa. Added by [11] that the needs of plants for various fertilizers/nutrients during growth and development are not the same, require different times/times and are not the same in number.Furthermore, it is stated by [12] that plants will thrive and give good results if the nutrients they need are available in sufficient and balanced quantities.

3.2.3 Effect of Interaction between Arbuscular Mycorrhizal Inoculation and SP-36 Fertilizer

The results of variance showed that the interaction between arbuscular mycorrhizal inculation factors and SP-36 fertilizer had no significant effect on seedling height at 1, 2 and 3 months after planting, seedling stem diameter at 1, 2 and 3 months after planting, number of seedling leaves. at 1, 2 and 3 months after planting and root length of seedlings at 4 months after planting.This situation indicates that the arbuscular mycorrhizal inoculation factor and the SP-36 fertilizer factor did not simultaneously affect the growth of oil palm seedlings in the pre-nursery phase.As stated by [13] that if the effect of the different interactions is not significant, it can be concluded that the treatment factors act independently of each other.

In general, the results presented in Tables 2 and 3 show that the combination treatment between various doses of arbuscular mycorrhizal inoculation and various doses of SP-36 fertilizer tended to result in lower seedling height growth, smaller stem diameter, fewer number of leaves, and lower growth rates.The root length of oil palm seedlings in the pre-nursery phase was shorter than the combination without arbuscular mycorrhizae and without SP-36 fertilizer and with arbuscular mycorrhizae and without SP-36 fertilizer.There was no interaction or independent effect of giving mycorrhizae on the growth of oil palm seedlings.It was assumed that the available P content in the soil was sufficient so that the application of mycorrhizae and SP-36 fertilizer did not have a significant effect on the vegetative growth of seedlings.According to [14] that the condition of the nutrients in the soil is sufficient and adequate if given fertilizer containing nutrients it will show a slight increase in yield or less response to fertilization.Besides that, it is suspected that phosphate is not needed much in the early growth process of oil palm seedlings.

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

Conclusion Based on the results of research and discussion, conclusions can be drawn, as follows:

1. Provision of arbuscular mycorrhizae had no significant effect on growth height, stem diameter, number of leaves of seedlings at 1, 2, and 3 months after planting, and root length of seedlings at 1 month after planting.
2. Application of SP-36 fertilizer had a significant to very significant effect on height growth at 1, 2, and 3 months after planting, seedling diameter at 1 month after planting, number of leaves at 1 and 3 months after planting, and root length of seedlings. at 4 months after planting. The application of SP-36 fertilizer at a dose of 1.5 – 2.0 g plant-1 tends to inhibit the growth of oil palm seedlings in the pre-nursery phase.
3. There is no interaction between mycorrhizal treatment and SP-36 fertilizer treatment on the growth of oil palm seedlings in the pre-nursery phase.

4.2 Suggestion

Based on the results of the study, several suggestions can be put forward, namely as follows:

1. In the pre-nursery phase of oil palm nurseries, mycorrhizal inoculation and application of SP-36 fertilizer are not necessary.
2. Further research is needed regarding the application of mycorrhizae and SP-36 fertilizer as well as nitrogen fertilizer in oil palm seedlings in the main nursery phase.
3. In further research, a longer research time is considered until the seedlings are ready to be transferred to the field.

REFERENCES

[1] https://sawitindonesia.com/main-nursery-kelapa-sawit/diakses diakses 20 January 2021.

[2] https://spks.or.id/file/publikasi/4__SOP_PEMBIBITAN_Fixed-edit1.pdf/diakses 20 January 2021

[3] Darmosarkoro, W.Akiyat, Sugiyono, and Edy Sigit Sutarta, 2008. Oil Palm Nurseries, How to Get Jagur Seeds. Palm Oil Research Center, Medan.

[4] Sutanto, R. 2002. Organic Farming: Towards Alternative and Sustainable Agriculture. Kanisius, Yogyakarta.

[5] Suprapto and I. B. Ariba. 2002. Effect of Residues of Several Types of Organic Fertilizers on Growth and Yield of Shallots in Dry Land. Online (http:www.bptp.jatim deptan.go.id/templates/16 suprapto, p).

[6] Dela Cruz, R.E., H.T. Bartolome and N.S. Anggangan.1988. Pilot Testing of Mycorrhizal Tablets for Pines and Eucalyptus in the Philippines. Publ. by UPLB. The Philippine.

[7] Humphreys, C. P., Franks, P. J., Rees, M., Bidartondo, M. I., Leake, J. R., & Beerling, D. J. (2010). Mutualistic Mycorrhiza-like Symbiosis in the Most Ancient Group of Land Plants. Nature Communications, 1, 103

[8] Setiadi Y. 1995. The Practical Application of Arbuscular Mycorrizhae Fungi for Reforestation in Indonesia [Thesis]. Kent: Research School of Biosciences, University of Kent.

[9] Indriani, N.P., Mansyur, Susilawati, I. and Islami, R.Z.2011. Improving the Productivity of Feed Plants Through Arbuscular Mycorrhizal Fungi (FMA).Pastura 1(1) : 27 -30

[10] Wulandari, A.S. and Susanti, S. 2012. Application of Organic Leaf Fertilizer to Increase Jabon Seed Growth (*Anthocephalus cadamba* Roxb. Miq.). Journal of Tropical Silviculture. 3(2): 137 -142.

[11] Mulyani Sutejo, M. and A.G. Kartasapoetara. 2002. Fertilizer and Fertilization Method. Bina Aksara, Jakarta.

[12] Dwidjoseputro, D. 1998 . Introduction to Plant Physiology. Gramedia, Jakarta

[13] Steel, R.G.D and J. H. Torrie. 1991. Statistical Principles and Procedures of a Biometric Approach. Gramedia Pustaka Utama, Jakarta.

[14] Rosmarkam, A. and N. W, Yuwono 2002. Soil Fertility Science.Kanisius, Yogyakarta

Adopting a Beneficial Carbon Farming in the Cropping Pattern Using an Optimization Technique: A Case Study

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Abstract— *Plants can capture CO_2 from the air and sequester it in the leaves through photosynthesis. Even additional carbon sequestration could be achieved by allowing higher cropping intensity on the same piece of land in a single cropping season. There is a growing demand that agricultural developers and practitioners consider carbon farming in the design of cropping patterns in order to intensify carbon sequestration and trade it as a carbon credit for extra financial benefits. However, adopting a sustainable carbon farming while respecting the farmer's needed income and food security may seem a difficult task. Nevertheless, this fundamental challenge can be addressed using an optimization technique such as simplex linear programming (SLP). The Microsoft Excel program includes a SLP solver tool, which can easily be accessed from the Excel program Data menu after activating the Add-Ins part of the Excel Options. In this study, seven scenarios were developed to be analyzed by the SLP to investigate the various options of adopting carbon farming into the cropping pattern while maximizing either the individual or the combined benefits of farmer's income and farmer's food security for the Mekabo irrigation scheme in Ethiopia. The result shows that the optimized cropping pattern in scenario seven best satisfies the farmer's food security and farmer's income while still stimulating extra financial benefits from carbon farming. Alley cropping, multi-species-cover cropping, and no-till planting in scenario seven could encourage the highest rate of additional carbon sequestration so it could better contribute to the alleviation of global warming. This paper will discuss how the SLP is developed and applied leading to the attainment of an optimized cropping pattern while the financial benefit is maximized.*

Keywords— carbon farming, optimization technique, simplex linear programing, cropping pattern.

I. INTRODUCTION

With the growing threat of global warming, it is expected the industries that can not halt releasing Carbon Dioxide (CO_2) into the atmosphere, at least try to offset their emissions through partnering with carbon mitigators who can remove CO_2 from the air on their behalf. This process has triggered the birth of carbon credit exchange (CCX) in the global market and is still rising. Crops cultivated in the agricultural lands are known to be a consistent driver for capturing CO_2 from the air and sequestering it into different forms of carbon through photosynthesis. Even additional carbon sequestration could be achieved by allowing higher cropping intensity on the same piece of land in a single cropping season. Crops cultivated in the millions of ha of agricultural lands in any given country can significantly contribute to the massive carbon sequestration in the plants and soils. Accordingly, there is a growing demand that agricultural developers and practitioners accommodate carbon farming in the cropping pattern as an integrated part of their agricultural practices for both its positive environmental impact and financial benefits from selling the carbon credit in the CCX market.

The land-based carbon sequestration is measured in metric tons per hectare and one metric ton earns one carbon credit. In California – the only state in the US with a full-fledged cap-and-trade program – the current value of a carbon credit is around $12 to $13. Alberta, which has the most robust carbon market in Canada rewards several agricultural practices with carbon credits of up to $30 per credit [1]. According to the global pricing of various types of carbon credits, the current carbon credit produced from plantation ranges from $US 2.2 to 20$^+$ depending on the project type, size, location, and other determining factors [2].

Adopting carbon farming in the cropping pattern while several agronomic and environmental constraints should also be considered may seem a challenging task. However, an optimization technique such as the Simplex Linear Programming (SLP) can assist to tackle this complex issue. The SLP quantifies an optimal way of integrating the constraints to optimize crop production, financial profits, and carbon farming. Favorably, the Microsoft Excel includes a Linear Programming Solver, which could be applied to solve this optimization problem. The principal objective of this paper is to use the SLP as a case study example to investigate different carbon sequestration scenarios to define the best beneficial option.

II. MATERIALS AND METHODS

2.1 The Mekabo Irrigation Scheme

The selected case for this study is the Mekabo small-scale irrigation scheme, which is located about 50 km north of the city of Mekelle (center of the Tigray state). It features a weir constructed across the Augla river to divert irrigation water to the command area. Fig. 1 shows a view of the weir and the irrigation command area, which was financially supported and constructed by the REST NGO in March 2016.

FIGURE 1. The weir and irrigation command area for Mekabo small- scale irrigation scheme

The 60-ha irrigation land accommodates 144 smallholder farmers and receives gravity water from a 1.3 km stone paved conveyance canal diverted from the weir. The input parameters for this study were collected from the field survey during the implementation of SMIS Project (A small-scale irrigation support project funded by the governments of Canada and the Netherlands during 2014-2019). Some other inputs were produced by visiting the area and assessing the field parameters. The types of crops cultivated in the Mekabo irrigation scheme are almost according to the results of agro-ecological suitability and socio-economic studies performed during the feasibility study conducted by REST NGO. Given the necessity of satisfying the farmers' nutritious diet, the types of crops for the Mekabo irrigation scheme include vegetables (potato, tomato, and cabbage), cereals (corn and barley), pulses (beans, peas, and lentils), fruits (mango, and papaya), and fallow.

2.2 Scenarios

To ensure the study is inclusive of the farmer's food security demand, farmer's income, and additional carbon farming benefits, seven cropping pattern scenarios were developed and presented in table 1. These initial cropping patterns would be optimized by the SLP while utilizing the constraints to maximize either the individual or the combined benefits of farmer's income, farmer's food security demand, and additional carbon farming. To gain the benefits of additional carbon farming, no specific crop was added to the cropping pattern; instead, the cropping intensity was raised and suitable crops were paired on the same piece of land sharing the same growing season.

TABLE 1
THE SEVEN SCENARIOS FOR OPTIMIZATION

Scenario	Subject of Optimization
Scenario 1	Farm income
Scenario 2	Farmer's food security
Scenario 3	Additional carbon farming
Scenario 4	Combined benefits of additional carbon farming and farm income
Scenario 5	Combined benefits of additional carbon farming and farmer's food security
Scenario 6	Combined benefits of farmer's food security and farm income
Scenario 7	Combined benefits of farm income, farmer's food security, and additional carbon farming

The Carbon Cycle Institute (CCI) has identified a collection of eighteen (18) different agricultural practices depicted in fig. 2 that introduce various choices of increasing the amount of carbon sequestering [3], [4], [5]. Among the various carbon sequestration practices introduced by CCI, the alley-cropping (number 2), multi-species-cover cropping (number 11), and the no-till planting (number 18) are considered low input and simple technique practices that could easily be adopted in the Mekabo small-scale irrigation scheme and will be discussed below.

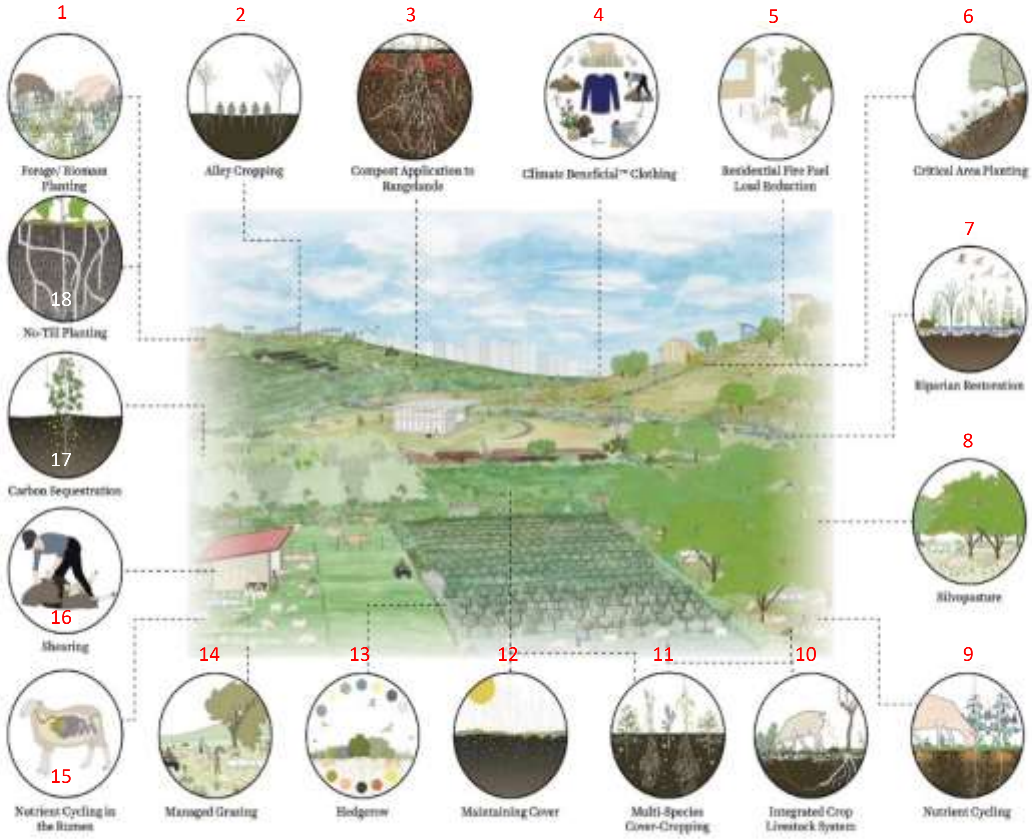

FIGURE 2: Various carbon sequestration options (adopted from [3])

2.2.1 Alley cropping

Alley cropping includes planting of trees or shrubs that are generally implanted in a single or multiple-row with traditional crops like small grain in between [6]. In the Mekabo irrigation scheme all vegetable crops, cereals, and pulses could be cultivated under the mango and papaya fruit trees, which in turn can add to the rate of carbon sequestration. There is no solid research information in the literature for carbon sequestration by agricultural crops in Ethiopia [7], [8]. Nair et.al. [9] reports the rate of crop carbon sequestration in Mali and the West African Sahel at about 1.09 tons/ha/year. In the absence of similar information for Ethiopia, the average rate of 1.0 ton/ha/year carbon sequestration has been used for estimation in the Mekabo irrigation scheme. Also, there is no confirmed CCX price for Ethiopia in the literature [10]; therefore, an equivalent value of $US 10 has been extracted [2] and has been used as an average CCX price for calculating additional benefits in the Mekabo irrigation scheme.

2.2.2 Multi-species cover cropping

Multi-species cover cropping involves the cultivation of two or more species on the same piece of land where the growth cycles of different species overlap at least for part of their growing duration [11], [12]. In the case of the Mekabo irrigation scheme, it may take the form of inter-cropping where mango and papaya trees are inter-planted with annual species such as beans, peas, and lentils. The previous studies in water-limited environments estimated the carbon sequestration for cover crops between

2.37 ± 2.3 tons/ha/year [13]. In the absence of a valid information for Ethiopia, an average rate of 2.0 tons/ha/year has been adopted for carbon sequestration and an equivalent of $US 10 per carbon credit is used for the calculation of economic benefits of multi-species cover cropping in this study [2].

2.2.3 No-till Farming

No-till farming is the process of growing crops without disturbing the soil through tillage [14]. No-till farming increases both water absorption and organic matter retention by recycling nutrients back into the soil. According to the existing information in the literature, farmers who convert to no-till practices and start using cover crops may achieve a net carbon gain of one or two tons per hectare each year [1]. In the absence of adequate information for Ethiopia, an average value of 1.0 ton/ha carbon sequestration has been assumed for no-till plantation in the Mekabo irrigation scheme. For estimating the economic benefits [15], an average CCX price of $US 10 has been extracted from Opanda [2] and was used in this paper.

2.3 Using the Simplex Linear Programming (SLP)

The standard form of SLP has the following components [16], which will be discussed as follows:

- Decision variables to be optimized;
- Objective functions that must be maximized and will be subjected to constrains;
- Constraints.

2.3.1 Decision variables

Decision Variables are the combination of mathematical expressions in the objective functions to be optimized by the SLP. The goal is that SLP finds optimized values for the coefficient of decision variables to provide the best rate of the objective functions [16]. For the Mekabo irrigation scheme, the types of selected crops are the decision variables that the percentage of which is to be optimized. The types of crops for the Mekabo irrigation scheme include vegetables (potato, tomato, and cabbage), cereals (corn and barley), pulses (beans, peas, and lentils), fruits (mango, and papaya), and fallow. Accordingly, table 2 shows the list of twelve decision variables X_1, X_2, X_3, $X4$…...... X_{12}, and their coefficients C_1, C_2, C_3, C_4......... C_{12}, for the Mekabo irrigation scheme to be utilized in the SLP.

2.3.2 Objective function

The Objective Function is a mathematical expression that combines the decision variables and their coefficients to maximize farm benefits as follows [16]:

$$Z\ f(C_1X_1, C_2X_2, C_3X_3, C_4X_4 \cdots\cdots\cdots C_nX_n) \quad (1)$$

The maximum farm benefits for the Mekabo irrigation scheme means the combination of secure food produce, adequate farming income, and the highest carbon farming benefits subjected to the agronomic and environmental constraints. The general form of an objective function (Z) could mathematically be expressed as follows [17], [18]:

$$Max\ Z\ \approx\ \sum_{j=1}^{n} C_j\, X_j\ \ where{:}\ j = 1\ to\ n \quad (2)$$

Given the twelve decision variables (n=12), in case of the Mekabo scheme, then the objective function could be developed as follows:

$$Max\ Z\ \approx C_1X_1 + C_2X_2 + C_3X_3 + C_4X_4 + \cdots\cdots\cdots\cdots\cdots C_{12}X_{12} \quad (3)$$

Where Z is the farm gross benefits resulting from growing 11 crops (plus a fallow). The C_1, C_2, C_3, C_4 ....C_{12} are the coefficients of decision variables in the objective function related to Z (the objective function value). Table 2 shows the elements in the objective function.

TABLE 2
THE DECISION VARIABLES AND THE ELEMENTS IN THE OBJECTIVE FUNCTION

Crops	Decision variable	Coefficient	Element in the objective function	
Vegetables	Potato	X_1	C_1	$C_1 * X_1$
	Tomato	X_2	C_2	$C_2 * X_2$
	Cabbage	X_3	C_3	$C_3 * X_3$
Cereals	Corn	X_4	C_4	$C_4 * X_4$
	Barley	X_5	C_5	$C_5 * X_5$
Pulses	Beans	X_6	C_6	$C_6 * X_6$
	Peas	X_7	C_7	$C_7 * X_7$
	Lentils	X_8	C_8	$C_8 * X_8$
Cash crops	Watermelon	X_9	C_9	$C_9 * X_9$
Fruits	Mango	X_{10}	C_{10}	$C_{10} * X_{10}$
	Papaya	X_{11}	C_{11}	$C_{11} * X_{11}$
Fallow	No crop	X_{12}	C_{12}	$C_{12} * X_{12}$

2.3.3 Constraints

Constraints are the mathematical expressions to represent limits in the linear program related to agronomic, environmental, and carbon farming. The model assesses and identifies possible solutions that respect those limits in order to achieve the optimum objective function [16]. The general form of constraints is expressed as follows:

$$\sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij}\, x_j \leq b_i \tag{4}$$

or

$$\sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij}\, x_j \geq b_i \;\; where: j = 1 \; to \; n \; and \; i = 1 \; to \; m \tag{5}$$

Where a_{ij} and b_i are the coefficients and the values for constraints, respectively. Expansion of the above expression for “n” (the number of decision variables or crops) and for “m” (the number of constraints) are presented as follows:

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 + \cdots\cdots\cdots\cdots\cdots\cdots + a_{1n}x_n \leq b_1$$

$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + a_{24}x_4 + \cdots\cdots\cdots\cdots\cdots\cdots + a_{2n}x_n \leq b_2$$

$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + a_{34}x_4 + \cdots\cdots\cdots\cdots\cdots\cdots + a_{3n}x_n \leq b_3$$

$$a_{41}x_1 + a_{42}x_2 + a_{43}x_3 + a_{44}x_4 + \cdots\cdots\cdots\cdots\cdots\cdots + a_{4n}x_n \leq b_4$$

$$\vdots \vdots \vdots \vdots \vdots \vdots \vdots$$

$$a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + a_{m4}x_4 + \cdots\cdots\cdots\cdots\cdots\cdots + a_{mn}x_n \leq b_m \tag{6}$$

Since there are 22 constraints and 12 decision variables in this study; therefore, m=22 and n=12 will be substituted in the above expressions and the mathematical expression would be expanded as follows:

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 + \cdots\cdots\cdots\cdots\cdots\cdots + a_{112}x_{12} \leq b_1$$

$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + a_{24}x_4 + \cdots\cdots\cdots\cdots\cdots\cdots + a_{212}x_{12} \leq b_2$$

$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + a_{34}x_4 + \cdots\cdots\cdots\cdots\cdots\cdots + a_{312}x_{12} \leq b_3$$

$$a_{41}x_1 + a_{42}x_2 + a_{43}x_3 + a_{44}x_4 + \cdots\cdots\cdots\cdots\cdots\cdots + a_{412}x_{12} \leq b_4$$

$$\vdots\vdots\vdots\vdots\vdots\vdots\vdots$$

$$a_{221}x_1 + a_{222}x_2 + a_{223}x_3 + a_{224}x_4 + \cdots\cdots\cdots\cdots\cdots\cdots + a_{2212}x_{12} \leq b_{22} \qquad (7)$$

In order to prevent accidental negative values for the decision variables, the following assumption should also be added to constraints:

$$X_j \geq 0 \qquad (8)$$

Therefore, the above-mentioned equation develops to:

$$X_1 \geq 0;\ X_2 \geq 0;\ X_3 \geq 0;\ X_4 \geq 0; \cdots\cdots\cdots\cdots\cdots X_{12} \geq 0 \qquad (9)$$

However, in Mekabo scheme due to the allocation of zero or minimum percentage of crops in the cropping pattern, there is no need to include the non-negativity constrains in the model.

2.3.4 Setting the constraints limits

Twenty-two constraints are defined in the design of the cropping pattern for the Mekabo irrigation scheme. The constraints 1 to 9 reflect the cropping pattern's agro-ecological conditions that include crop water consumption, nutrition values, disease resistance, pest resistance, market demand, fertilizer input, labor requirement, capital expenses, and post-harvest processing demand. The constraint number 10 constitutes the total desired cropping intensity in each scenario. The significance of constraints 1 to 9 is ranked according to the crop performance ranking index (CPR) and is presented in table 3 [17].

TABLE 3
THE CPR INDEX FOR THE MEKABO IRRIGATION SCHEME

Step	CPR index	Definition	Description
1	1-10	Very low/Weak	Lowest condition possible
2	11-20	Poor	Needs fundamental improvement
3	21-30	In adequate	Needs moderate improvement
4	31-40	Low	Needs some improvement
5	41-50	Satisfactory	Needs slight improvement
6	51-60	Acceptable	Fulfils the needs
7	61-70	Good	Average conditions
8	71-80	Favorable	Above average conditions
9	81-90	Very good	Meets perfectly all the requirements
10	91-100	Very high/Excellent	Highest condition possible

The constraints 11 to 22 would only include the minimum desired cropping area for each scenario, which is presented in table 4. For water consumption, fertilizer input, labor requirement, capital expenses, and post-harvesting demand (constraints 1, 6, and 7 to 9), the "≤" sign was used as a desired condition for analysis in the SLP. However, to maximize the advantage of nutritious crops, disease resistance, pest resistance, and market demand (constraints 2 to 5) the "≥" sign was adopted.

TABLE 4
THE INITIALLY DEFINED CROPPING AREAS FOR EACH SCENARIO

Crops		Constraints	Condition	Scenarios (ha) 1	2	3	4	5	6	7	Rationale
Vegetables	Potato	Constraint 11	≥	0.00	0.02	0.00	0.00	0.00	0.05	0.05	To improve nutrition level in the farmer's diet, to generate some income, and to allow carbon farming
	Tomato	Constraint 12	≥	0.00	0.01	0.00	0.00	0.00	0.02	0.05	
	Cabbage	Constraint 13	≥	0.00	0.01	0.00	0.00	0.00	0.00	0.02	
Cereals	Corn	Constraint 14	≥	0.00	0.15	0.00	0.00	0.10	0.10	0.10	To improve fiber level in the farmer's diet and to produce forage for livestock
	Barley	Constraint 15	≥	0.00	0.10	0.00	0.00	015	0.20	0.10	
Pulses	Beans	Constraint 16	≥	0.00	0.05	0.20	0.20	0.05	0/05	0.07	To improve nourishment in the farmer's diet and to allow carbon farming
	Peas	Constraint 17	≥	0.00	0.05	0.00	0.00	0.01	0/00	0.00	
	Lentils	Constraint 18	≥	0.00	0.05	0.15	0.15	0.15	0/15	0.10	
Cash crops	W/rmelon	Constraint 19	≥	0.00	0.01	0.00	0.00	0.00	0/00	0.00	To improve farmer's income
Fruits	Mango	Constraint 20	≥	0.00	0.10	0.20	0.15	0.10	0/10	0.10	To improve nutrition in the farmer's diet, to generate income, to allow carbon farming
	Papaya	Constraint 21	≥	0.00	0.10	0.00	0.20	0.10	0/10	0.10	
Fallow	No crop	Constraint 22	=	0.10	0.10	0.10	0.10	0.10	0.10	0.10	To improve soil health
Total initially defined cropping area (ha)			=	0.10	0.75	0.65	0.80	0.76	0.87	0.79	-

Table 5 shows the matrix of all twenty-two constraints, the sum of the product of each constraint with cropping pattern area, analysis condition, and the minimum or maximum limit for each constraint to be used by SLP.

TABLE 5
THE CONSTRAINTS USED FOR THE ANALYSIS BY THE SLP

CONSTRAINTS	Potato	Tomato	Cabbage	Corn	Barley	Beans	Peas	Lentils	W/melon	Mango	Papaya	Fallow	Sum of product of constraint and cropping pattern area	Condition	Required Limit
	a_{i1} x_1 +	a_{i2} x_2 +	a_{i3} x_3 +	a_{i4} x_4 +	a_{i5} x_5 +	a_{i6} x_6 +	a_{i7} x_7 +	a_{i8} x_8 +	a_{i9} x_9 +	a_{i10} x_{10} +	a_{i11} x_{11} +	a_{i12} x_{12}			
Constraint 1	65 x_1 +	70 x_2 +	60 x_3 +	50 x_4 +	40 x_5 +	40 x_6 +	45 x_7 +	40 x_8 +	80 x_9 +	30 x_{10} +	30 x_{11} +	0 x_{12}	Sum of product of constraint 1 and cropping area	≤	50
Constraint 2	60 x_1 +	70 x_2 +	70 x_3 +	80 x_4 +	80 x_5 +	70 x_6 +	70 x_7 +	85 x_8 +	60 x_9 +	75 x_{10} +	70 x_{11} +	0 x_{12}	'Sum of product of constraint 2 and cropping area	≥	70
Constraint 3	60 x_1 +	50 x_2 +	70 x_3 +	50 x_4 +	70 x_5 +	60 x_6 +	65 x_7 +	70 x_8 +	70 x_9 +	80 x_{10} +	80 x_{11} +	0 x_{12}	'Sum of product of constraint 3 and cropping area	≥	60
Constraint 4	80 x_1 +	80 x_2 +	85 x_3 +	40 x_4 +	80 x_5 +	70 x_6 +	80 x_7 +	85 x_8 +	80 x_9 +	80 x_{10} +	80 x_{11} +	0 x_{12}	'Sum of product of constraint 4 and cropping area	≥	60
Constraint 5	100 x_1 +	95 x_2 +	70 x_3 +	90 x_4 +	70 x_5 +	65 x_6 +	50 x_7 +	40 x_8 +	90 x_9 +	95 x_{10} +	95 x_{11} +	0 x_{12}	'Sum of product of constraint 5 and cropping area	≥	50
Constraint 6	80 x_1 +	80 x_2 +	70 x_3 +	85 x_4 +	60 x_5 +	60 x_6 +	55 x_7 +	50 x_8 +	85 x_9 +	40 x_{10} +	40 x_{11} +	0 x_{12}	'Sum of product of constraint 6 and cropping area	≤	70
Constraint 7	100 x_1 +	100 x_2 +	80 x_3 +	50 x_4 +	40 x_5 +	65 x_6 +	65 x_7 +	60 x_8 +	90 x_9 +	20 x_{10} +	20 x_{11} +	0 x_{12}	'Sum of product of constraint 7 and cropping area	≤	50
Constraint 8	90 x_1 +	90 x_2 +	70 x_3 +	50 x_4 +	40 x_5 +	50 x_6 +	50 x_7 +	50 x_8 +	90 x_9 +	30 x_{10} +	30 x_{11} +	0 x_{12}	'Sum of product of constraint 8 and cropping area	≤	50
Constraint 9	60 x_1 +	70 x_2 +	60 x_3 +	30 x_4 +	20 x_5 +	30 x_6 +	40 x_7 +	30 x_8 +	80 x_9 +	90 x_{10} +	90 x_{11} +	0 x_{12}	'Sum of product of constraint 9 and cropping area	≤	50
Constraint 10	a_{101} x_1 +	a_{102} x_2 +	a_{103} x_3 +	a_{104} x_4 +	a_{105} x_5 +	a_{106} x_6 +	a_{107} x_7 +	a_{108} x_8 +	a_{109} x_9 +	a_{1010} x_{10} +	a_{1011} x_{11} +	a_{1012} x_{12}	Sum of cropping area (ha)	=	1.0 or 1.2 or 1.35 ha
Constraint 11	a_{111} x_1												Area for potato (ha)	≥	according to scenario (ha)
Constraint 12		a_{122} x_2											Area for tomato (ha)	≥	according to scenario (ha)
Constraint 13			a_{133} x_3										Area for cabbage (ha)	≥	according to scenario (ha)
Constraint 14				a_{144} x_4									Area for corn (ha)	≥	according to scenario (ha)
Constraint 15					a_{155} x_5								Area for barly (ha)	≥	according to scenario (ha)
Constraint 16						a_{166} x_6							Area for beans (ha)	≥	according to scenario (ha)
Constraint 17							a_{177} x_7						Area for peas (ha)	≥	according to scenario (ha)
Constraint 18								a_{188} x_8					Area for lentils (ha)	≥	according to scenario (ha)
Constraint 19									a_{199} x_9				Area for watermelon (ha)	≥	according to scenario (ha)
Constraint 20										a_{2010} x_{10}			Area for mango tree (ha)	≥	according to scenario (ha)
Constraint 21											a_{2111} x_{11}		Area for papaya tree (ha)	≥	according to scenario (ha)
Constraint 22												a_{2212} x_{12}	Area for fallow (ha)	=	according to scenario (ha)

2.4 Application of the SLP

The "Add-Ins" choice in the Microsoft "Excel Options" [19], [20], [21] was activated and the "Solver" tool from the "Data" menu was utilized. The "Solver" tool needed inputs from the average crop production rates as well as the farm-gate prices for eleven selected crops, which was adopted by Jebelli et al., [17] with some adjustment in the prices (table 6). To run the "Solver", the crop production rates and the farm-gate prices were administered in two separate adjacent row cells in the Excel sheet. The "Solver" also required a third-row cells be allocated for the twelve optimized cropping areas calculated by the "Solver" (changing variable cells). For the "Solver" to inscribe the calculated maximum value (Max Z in ETBirr/ha), a single cell had also been allocated in the Excel sheet adjacent to the other three rows. The argument embedded in this single Excel cell would calculate the "SUMPRODUCT" of the three previously described sets of rows and then would pick the maximum value to inscribe it in the single cell.

When the "Solver" button in the Excel menu was clicked, it prompted a screen titled "Solver Parameters" as demonstrated in fig 3. The address of a single Excel cell for maximizing benefits (Max Z) was entered in the empty space for "Set Objective". The addresses of the row cells to receive the twelve optimized cropping areas were entered for "By Changing Variable Cells" and the addresses of the row cells containing the sum of products and the conditions of the twenty-two constraints were added one by one in the “Subject to the Constraints” sub-window [21]. After entering all the required data, the "Max" button on the Solver screen was checked. The process of optimization started when the “Solve” button was activated.

TABLE 6
THE MAXIMIZED BENEFITS AND THE OPTIMIZED CROPPING PATTERN FOR EACH SCENARIO

Crops		Crop production (kg/ha)	Farm-gate price (ETB/kg)	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7	
				Cropping area (ha)	Max Z (ETB/ha)	Cropping area (ha)	Max Z (ETB/ha)	Cropping area (ha)	Max Z (ETB/ha)	Cropping area (ha)	Max Z (ETB/ha)	Cropping area (ha)	Max Z (ETB/ha)	Cropping area (ha)	Max Z (ETB/ha)	Cropping area (ha)	Max Z (ETB/ha)
Vegetables	Potato	9,500	18	0.00	347,300	0.02	176,974	0.00	229,552	0.00	250,976	0.00	244,884	0.05	177,411	0.05	244,228
	Tomato	12,000	28	0.00		0.01		0.00		0.00		0.00		0.02		0.05	
	Cabbage	20,000	12	0.00		0.01		0.00		0.00		0.00		0.00		0.02	
Cereals	Corn	5,000	12	0.00		0.15		0.00		0.00		0.10		0.10		0.10	
	Barley	2,000	18	0.10		0.10		0.40		0.40		0.63		0.20		0.42	
Pulses	Beans	2,100	39	0.00		0.05		0.20		0.20		0.05		0/05		0.07	
	Peas	1,400	41	0.00		0.05		0.00		0.00		0.01		0/00		0.00	
	Lentils	1,000	83	0.40		0.29		0.15		0.15		0.15		0/27		0.10	
Cash crops	W/melon	10,000	21	0.00		0.01		0.00		0.00		0.00		0/00		0.00	
Fruits	Mango	12,600	28	0.00		0.10		0.20		0.15		0.10		0/10		0.10	
	Papaya	22,500	35	0.40		0.11		0.15		0.20		0.21		0/11		0.19	
Fallow	No crop	0	0	0.10		0.10		0.10		0.10		0.10		0.10		0.10	
Total desired cropping intensity (Input for constraint 10 in SLP)				1.00	-	1.00	-	1.20	-	1.20	-	1.35	-	1.00	-	1.20	-

Accordingly, the Solver estimated the optimized percentage for the twelve proposed crops as well as calculated the Max benefit (Z) and displayed it in the previously allocated single cells in the Excel sheet.

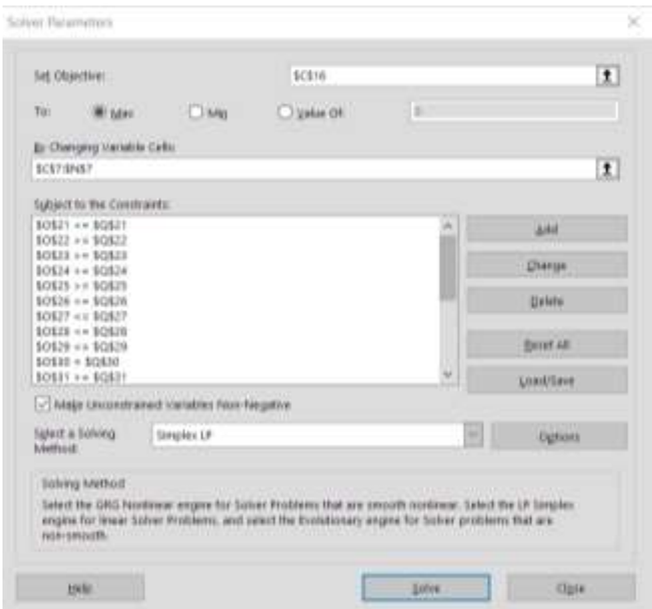

FIGURE 3. The snapshot of the “Solver Parameters” screen

III. RESULTS AND DISCUSSION

Accounting for all twenty-two constraints, the SLP has maximized the benefits while in the meantime optimizing the percentage of crops in the cropping pattern for each scenario. In each successful run, a message reading "Solver found a solution" followed by "All constraints and optimality conditions are satisfied" demonstrated the successful end of the optimization process. Table 7 shows the results of maximized benefits and the optimized percentages of cropping pattern for all scenarios. As demonstrated in table 7, the introduced Carbon farming would generate some extra financial benefits from selling the carbon credit in the CCX trade market. The total financial benefits of CCX and the selling crops are presented in table 8. The rate of additional carbon sequestered in each scenario as a result of additional carbon farming is also presented in table 8. Fig 4 compares the Max Benefits (Z) and the optimized cropping areas for all scenarios. The SLP has maximized the farmer's income in scenario one without considering the farmer's food security demand and carbon farming. In this case, the farmer can earn 347,300 ETBirr/ha/year if all its farm products are sold at the market.

TABLE 7
THE SUM OF TOTAL FINANCIAL BENEFITS IN EACH SCENARIO

Scenario	Optimized Cropping Intensity (ha)	Alley Cropping			Multi-species-cover Cropping			No-till Planting			Maximized Benefits by SLP (ETBirr/ha/year)	Sum of Total Benefits (ETBirr/ha/year)
		Match for Alley Cropping (ha)	(1)Unit CCX ($US)	(2)Total Price (ETBirr/ha)	Multi-species Cropping (ha)	(3)Unit CCX ($US)	Total Price (ETBirr/ha)	No-till Cropping (ha)	(4)Unit CCX ($US)	Total Price (ETBirr/ha)		
1	1.0	0	-	0	0	-	0	0	-	0	347,300	347,300
2	1.0	0	-	0	0	-	0	0	-	0	176,974	176,974
3	1.20 (0.2 ha extra allowed for carbon farming)	0.35 (beans under mango and lentils under papaya tree)	10	179	0	-	0	0.65 (no-till cropping for all available fields)	10	332	229,552	230,062
4	1.20 (0.2 ha extra allowed for carbon farming)	0.35 (beans under papaya and lentils under mango tree)	10	179	0	-	0	0.65 (no-till cropping for all available fields)	10	332	250,976	251,486
5	1.35 (0.35 ha extra allowed for carbon farming)	0.31 (beans+peas+ lentils under papaya and corn under mango)	10	158	0	-	0	0.69 (no-till cropping for all available fields)	10	352	244,884	245,394
6	1.0	0	-	0	0	-	0	0	-	0	177,411	177,411
7	1.20 (0.2 ha extra allowed for carbon farming)	0.29 (potato+tomato+cabbage+ beans under papaya & lentils under mango tree)	10	148	0.10 (corn and barley)	10	51	0.71 (no-till cropping for all available fields)	10	362	244,228	244,789

(1) The unit CCX price for alley cropping is estimated to be $US 10 [2].
(2) The $US conversion rate assumed to be 1$US= 51 ETBirr.
(3) The unit CCX price for multi-species-cover cropping is estimated to be $US 10 [2].
(4) The unit CCX price for no-till cropping is estimated to be $US 10 [2].

The lowest financial benefits are produced in scenario two because the SLP has maximized the farmer's food security benefits; therefore, the farm income and the carbon farming benefits are compromised.

TABLE 8
THE SUM OF ADDITIONAL CARBON SEQUESTRATION IN EACH SCENARIO

Scenario	Optimized Cropping Intensity (ha)	Alley Cropping			Multi-species-cover Cropping			No-till Planting			Sum of Total Carbon Sequestration (Ton/ha/year)
		Match for Alley Cropping (ha)	(1)Carbon Sequestration (Ton/ha/year)	Total Sequestration (Ton/ha/year)	Multi-species Cropping (ha)	(2)Carbon Sequestration (Ton/ha/year)	Total Sequestration (Ton/ha/year)	No-till Cropping (ha)	(3)Carbon Sequestration (Ton/ha/year)	Total Sequestration (Ton/ha/year)	
1	1.0	0	-	0	0	-	0	0	-	0	0
2	1.0	0	-	0	0	-	0	0	-	0	0
3	1.20 (0.2 ha extra allowed for carbon farming)	0.35 (beans under mango and lentils under papaya tree)	1.0	0.35	0	-	0	0.65 (no-till cropping for all available fields)	1.0	0.65	1.0
4	1.20 (0.2 ha extra allowed for carbon farming)	0.35 (beans under papaya and lentils under mango tree)	1.0	0.35	0	-	0	0.65 (no-till cropping for all available fields)	1.0	0.65	1.0
5	1.35 (0.35 ha extra allowed for carbon farming)	0.31 (beans+peas+ lentils under papaya and corn under mango)	1.0	0.31	0	-	0	0.69 (no-till cropping for all available fields)	1.0	0.69	1.0
6	1.0	0	-	0	0	-	0	0	-	0	0
7	1.20 (0.2 ha extra allowed for carbon farming)	0.29 (potato+tomato+cabbage+ beans under papaya & lentils under mango tree)	1.0	0.29	0.10 (corn and barley)	2.0	0.20	0.71 (no-till cropping for all available fields)	1.0	0.71	1.20

(1) The carbon sequestration for alley cropping is taken from Nair et.al., [9].
(2) The carbon sequestration for multi-species-cover cropping has been taken from Blanco-Canqui, et al., [13].
(3) The carbon sequestration for no-till cropping has been taken from Barth [1].

Scenario three considers the additional carbon farming as a top priority and the other two profits have less importance. Maximizing the combined benefits of additional carbon farming and farmer's income is reflected in scenario four. In scenario five, the combined benefits of additional carbon farming and farmer's food security is considered a high priority and the farmer's income gets lower importance. There is no carbon farming benefit in scenario six; thus, the combined benefits of farmer's food security and farm income play an important role in the process. The SLP has maximized the combined benefits of farm income, farmer's food security, and additional carbon farming in scenario seven. Figure 4 compares both the financial benefits and the cropping areas for all scenarios.

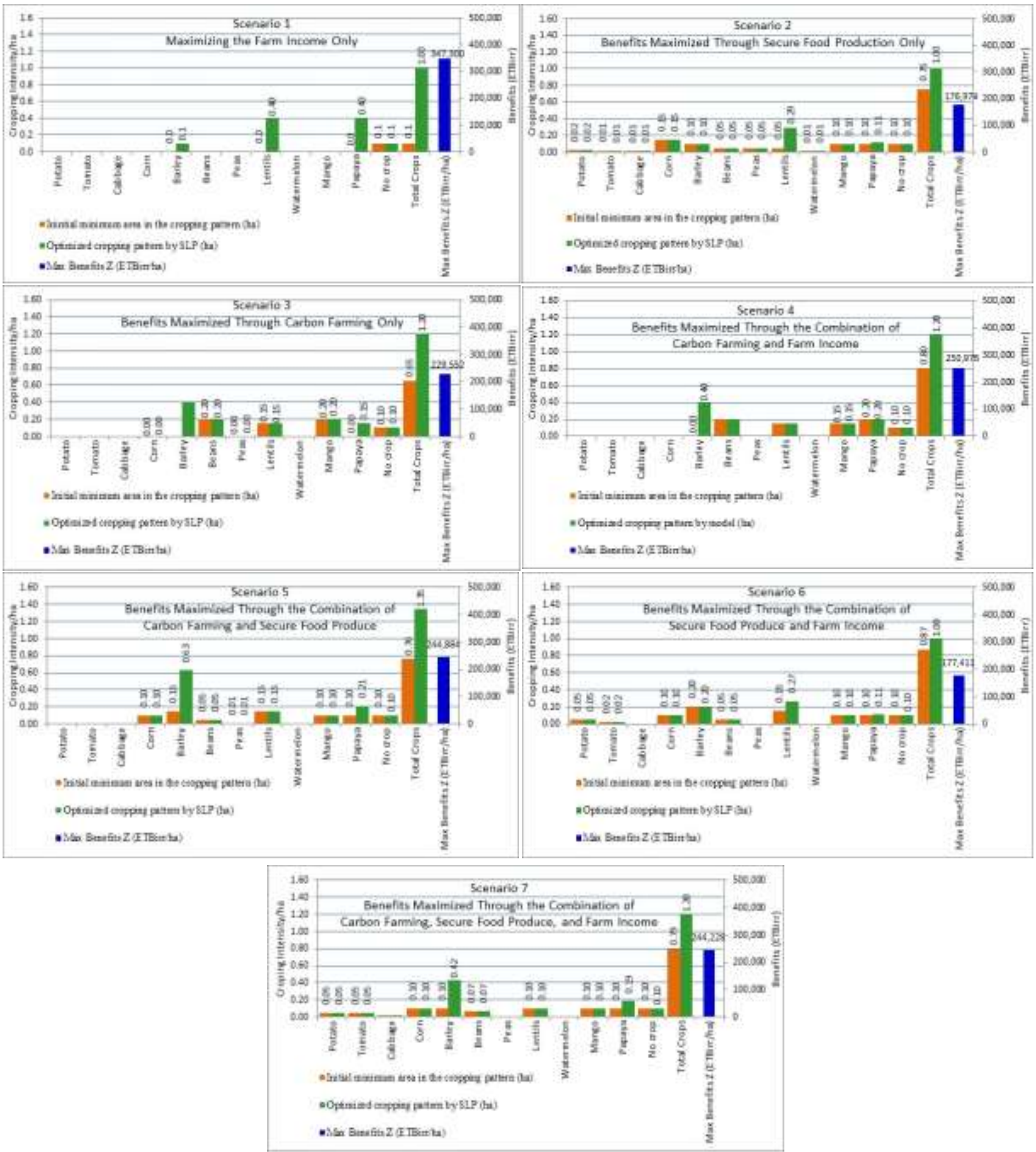

FIGURE 4. Comparing the financial benefits and the percentage of optimized cropping areas

IV. SUMMARY AND CONCLUSIONS

Seven scenarios were developed, and a simplex linear programming (SLP) was utilized to study various options of adopting carbon farming into the cropping pattern while maximizing either the individual or the combined benefits of farm income, farmer's food security, and additional carbon sequestration in the Mekabo irrigation scheme. The Solver tool from Microsoft Excel program was used to run the SLP. The results show that additional carbon farming increased the amount of carbon sequestration and created the potential for extra financial benefits from selling carbon credits. Figure 5 compares the total financial benefits and the rate of additional carbon sequestered in all scenarios. Among the scenarios, there is no additional carbon sequestration in scenarios 1, 2, and 6. However, among the remaining scenarios, scenario 7 has the highest rate of additional carbon sequestration (1.2 ton/ha/year). Because there are no meaningful financial benefit differences among scenarios 3, 4, 5, and 7; therefore, it could be concluded that scenario 7 is the most beneficial scenario because it has the highest rate of additional carbon sequestration while satisfies the benefit of farmer's food security and still generates relatively a good farming income. Alley cropping, multi-species-cover cropping, and no-till planting in scenario 7 could encourage the highest rate of additional carbon sequestration so it could have a better role in the alleviation of global warming.

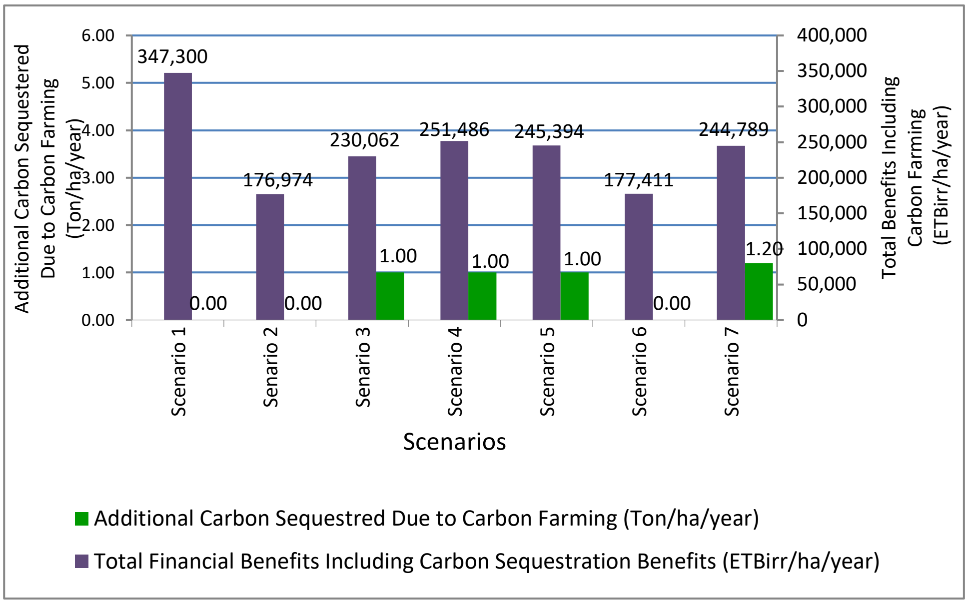

FIGURE 5. Comparison of total financial benefits and the additional carbon sequestration

REFERENCES

[1] B. Barth, "Farmers are Capitalizing on Carbon Sequestration: How Much is Your Carbon-Rich Soil Worth?" *Modern Farming* April 6, 2016. [Online]. Available: https://modernfarmer.com/2016/04/carbon-sequestration/

[2] S. Opanda, "Carbon Credit Pricing Chart: Updated 2022" *Billion Trees.com*, April 14, 2022 [Online]. Available: https://8billiontrees.com/carbon-offsets-credits/new-buyers-market-guide/carbon-credit-pricing/

[3] "What is Carbon Farming?" *Carbon Cycle Institute (CCI), 245 Kentucky Street, Petaluma, CA 94952.* Accessed June 27, 2022. [Online]. Available: https://www.carboncycle.org/

[4] V. Agaliotis, "Carbon Sequestration Technology and Methods" *ClimateOrb*. July 8, 2020. [Online]. Available: medium.com/climateorb/carbon-sequestration-technology-

[5] D. Sanchez, "Carbon Farming Has Potential" *Arid African Areas.* August 26, 2013. [Online]. Available: https://moguldom.com/18609/carbon-farming-has-potential-in-africa/

[6] "Alley Cropping", *Natural Resources Conservation Service (NRCS). Conservation Practice Job Sheet 311.* April 1997. [Online]. Available: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_013890.pdf

[7] "Carbon Africa" *Advisory services.* [Online]. Accessed June 21, 2022: www.carbonafrica.co.ke

[8] "Ecosur Afrique" *First intra-african transaction of carbon credits in West Africa.* [Online]. Accessed June 21, 2022: https://www.naijadopest.com/2015/06/first-intra-african-transaction-of.html

[9] Pk R. Nair, V. Nair, B. M. Kumar, and J. M. Showalter' "Carbon Sequestration in Agroforestry Systems" October 2010. [Online]. Available: www.researchgate.net/publication/223342889_Carbon...

[10] W. Sharpe "West African Carbon Credit Registry & Exchange Platform – A Collaboration of Natural Eco Capital & GEM Group Companies" October 24, 2018. [Online]. Available: https://ctxglobal.com/west-african-carbon-credit-registry-exchange-platform-a-collaboration-of-natural-eco-capital-gem-group-companies/

[11] J. McDowell, and Sabrina Ruis, "Cover Crops and Carbon Sequestration: Benefits to the Producer and the Planet" March 11, 2019. *Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln.* [Online]. Available: https://cropwatch.unl.edu/2019/cover-crops-and-carbon-sequestration-benefits-producer-and-planet

[12] C.A. Francis, P. Porter, "Multicropping" *Encyclopedia of Applied Plant Sciences (Second Edition)*. Volume 3, 2017, Pages 29-33 [Online]. Available: https://www.sciencedirect.com/science/article/pii/B9780123948076000241

[13] H. Blanco-Canqui, S.J. Ruis, J. D. Holman, C.F. Creech, and A. K., Obour, "Can cover crops improve soil ecosystem services in water-limited environments?" *Soil Science Society of America Journal. November 14, 2021: 86: 1-18.* [Online]. Available: https://acsess.onlinelibrary.wiley.com/doi/full/10.1002/saj2.20335

[14] S. Spears, "What is No-Till Farming?" *Regeneration International*. June 24, 2018. [Online]. Available: https://regenerationinternational.org/2018/06/24/no-till-farming/

[15] S. Winsor, "Get Paid for Carbon Credits" Farm Progress. February 15, 2007. [Online]. Available: www.farmprogress.com/get-paid-carbon-credits

[16] J. W. Chinneck, "Practical Optimization: A gentle introduction (chapter 2)" February 14, 2022. [Online]. Available: https://www.optimization101.org/

[17] J. Jebelli, B. Paterson, and A. Abdelwahab, "A linear program model to optimize cropping pattern in small-scale irrigation schemes: an application to Mekabo Scheme in Tigray Ethiopia" *International Journal of Environmental & Agriculture Research (IJOEAR). Vol-2, Issue-8, August 2016.* [Online]. Available: ijoear.com/Paper-August-2016/IJOEAR-AUG-2016-8.pdf

[18] M.A. Schulze, "Linear Programming for Optimization" *Perceptive Scientific Instruments, Inc.* 1998. [Online]. Available: https://1library.net/document/yj7l4156-linear-programming-optimization-mark-schulze-perceptive-scientific-instruments.html

[19] "How to activate the Solver add-in" Accessed June 2022. Available: https://support.microsoft.com/en-us/office/load-the-solver-add-in-in-excel-612926fc-d53b-46b4-872c-e24772f078ca

[20] "Define and solve a problem by using Solver" 2022. Accessed June 2022. Available: https://support.microsoft.com/en-us/office/define-and-solve-a-problem-by-using-solver-5d1a388f-079d-43ac-a7eb-f63e45925040?ns=excel&version=19&syslcid=1033&uilcid=1033&appver=zxl190&helpid=xladdin.chm1830&ui=en-us&rs=en-us&ad=us

[21] "Optimization Methods in Management Science" *MITOpenCourseWare*. Accessed June 2022. Available: https://ocw.mit.edu/courses/sloan-school-of-management/15-053-optimization-methods-in-management-science-spring-2013/tutorials/

Effect of Organic and Inorganic Source of Nutrients on Yield of Cotton (*Gossypium hirsutum L.*) under Teak (*Tectona grandis*) Based Agroforestry System

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Abstract— *The current investigation was conducted in the Forest Nursery, SHUATS, Prayagraj, U.P., between 2021 and 2022. Based on a field experiment conducted on the effect of Organic and Inorganic Nutrient Sources on Growth and Yield of Cotton (Gossypium hirsutum L.) Under Teak (Tectona Grandis) Based Agroforestry System, it was concluded that the treatment T7 (NPK 100 percent) was found superior among that treatment under teak based Agroforestry system. It was also observed that maximum Cotton Yield (i.e., 24.16t/ha) In terms of economic feasibility performance, treatment T7 (NPK 100 percent) demonstrated the highest benefit-cost ratio (i.e., 1.67).*

Keywords— Cotton, Teak, Growth, Yield, Organic, Inorganic, Agroforestry.

I. INTRODUCTION

Cultivating agricultural crops and trees in tandem is an ancient practise all over the world. Agroforestry refers to long-term land use systems that combine trees with arable crops or animals on the same plot of land in some kind of spatial arrangement or temporal sequence. Agroforestry is recognised as one of the most effective strategies for achieving optimal multiple benefits through an interactive and intentional land use system and technologies in which trees are purposefully planted with agricultural crops or animals. It is a traditional practise in India and has received increased attention in recent years as a high-potential sustainable land use option. The various components of an agroforestry system interact in both ecological and economic ways (**Lundgren and Raintree, 1982**). Agroforestry systems are designed to meet the economic, social, and cultural needs of the local population while maintaining ecological balance. Multipurpose tree species (MPTS) have been introduced into agroforestry systems to increase the economic importance of the tree component. Multipurpose trees and shrubs are those that have more than one preferred use, product, and/or service.

Teak (Tectona grandis) is the most important high-value furniture wood grown in plantations all over the world. Teak is a relatively easy plantation species to establish, and due to the ongoing global demand for teak wood products, it has good economic prospects as a plantation species for fine woods**. Ladrach, William (2009).**

More than 70 nations in tropical and subtropical regions cultivate cotton, a significant fibre crop on a global scale. With a productivity of 493 kg lint/ha in 2011–12, India had the biggest area (121 lakh ha) and the second-highest production (353 lakh bales), only behind China (Anonymous, 2012). In terms of creating direct and indirect jobs in the agricultural and industrial sectors, cotton is significant to the national economy (Shivamurthy D 2012). Cotton exports make up 65% of all textile exports and are responsible for 33% of all foreign exchange earnings for our nation (17 billion dollars). The production of cotton in Indian agriculture has seen a substantial transformation as a result of the introduction of Bt cotton, which is renowned for its resistance to bollworms, into the nation over the past ten years. Since the introduction of Bt cotton, the circumstances for growing cotton have improved in Karnataka. In 2012, 5.54 lakh hectares of cotton were used to produce 15.0 lakh bales of seed cotton at a productivity of 460 kg lint/ha. More than 90% of India's cotton land is now planted with bt cotton. However, when small pests like mealy bugs, shoot weevils, midges, mirid bugs, cotton leaf curl virus, and physiological problems like leaf reddening, squire dropping, squire drying, and so on become a serious danger, productivity is reducing year after year. As stated by **Hosmath (**2012). Red leaf index (1.82) was substantially higher in Bt cotton genotypes than in non-Bt cotton genotypes (1.63). Lack of nitrogen and magnesium, which results in the synthesis of anthocyanin, is the primary cause of reddening. In this regard, the planning and execution of the present inquiry took place throughout the kharif seasons of 2020 and 2021.

II. MATERIALS AND METHODS

The Present Investigation was Entitled with "Effect of Organic and Inorganic Source of Nutrients on Growth and Yield of Cotton (*Gossypium hirsutum* L.) under Teak (*Tectona grandis*) Based Agroforestry System"in Bhadradri Kothagudem District at Telangana, During *Kharif* Season 2021-22. MATERIALS: Location: The field experimental study was conducted at the Gollagudem Road, Gopathanda village, Sarvaram, Sujathanagar, Bhadradri Kothagudem District at Telangana. Experimental site: The experiment was carried out during *Kharif season* of 2021Sarvaram (Gopatanda) is situated at having the latitude 17.522337^0, longitude 80.585286^0. In direction of East- west and North -West direction. Climate and Weather condition

The temperature in Kothagudem is $26^{°c}$ maximum temperature would hover at $32^{°c}$, while minimum temperature is predicted to be $26^{°c}$.This region has a sub-tropical climate, and having Rainfall of Normal annual rainfall 824.1 mm Annual rainfall 1430.4mmmostly during the monsoon autumn i.e. July- Nov with a few occasional showers during winter months. The major Soils are Red sandy soils sandy loam soils black soils. The major soil types suitable for cotton cultivation are alluvial, clayey and red sandy loam. Cotton is grown both under irrigated and rain fed conditions.

III. RESULTS AND DISCUSSION

The findings of the present experiment entitled, **"Effect of Organic and Inorganic Source of Nutrients on Growth and Yield of Cotton (*Gossypium hirsutum* L.) Under Teak (*Tectona grandis*) Based Agroforestry System",** are being presented and discussed in the following pages under appropriate headings. Data on pre-harvest (pertaining to growth attributes) and post-harvest (relating to yield attributes and economic parameters) observations were statistically analyzed in the light of scientific reasoning and relevant review of literature has been stated.

Plant Height (cm) 30DAS Data presented in table 1 indicated that highest the plant height (cm) at 30 DAS was observed in treatment T_9 15.50cm (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 13.93cm (NPK 75% + FYM 25%), $T_6$12.40cm (NC 50% + FYM 25% + NPK 25%) and T_3 11.20cm (FYM 50% + NC 25% + NPK 25%). The lowest value for the plant height was observed in treatment T_1 6.20 cm FYM 100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study.

Plant Height (cm) at 60 DAS Data presented in table 1 indicated that highest the plant height (cm) at 60 DAS was observed in treatment T_9 79.33cm (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 75.03cm (NPK 75% + FYM 25%), T_6 75.03cm (NC 75% +FYM 25%) and T_3 67.40cm (FYM 50% + NC 25% + NPK 25%). The lowest value for the plant height was observed in treatment T_1 31.96 cm FYM 100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study.

Plant Height (cm) at 90 DAS: Data presented in table 1 indicated that highest the plant height (cm) at 90 DAS was observed in treatment T_9 106.53 cm (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 98.93 cm (NPK 75% + FYM 25%), T_6 91.83cm (NC 75% +FYM 25%) and T_3 86.73cm (FYM 50% + NC 25% + NPK 25%). The lowest value for the plant height was observed in treatment T_1 75.86 cm FYM 100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study.

Plant Height (cm) at 120 DAS: Data presented in table 1 indicated that highest the plant height (cm) at 120 DAS was observed in treatment T_9 123.33cm (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 121.33cm (NPK 75% + FYM 25%), T_6 115.33cm (NC 75% +FYM 25%) and T_3 113.66cm (FYM 50% + NC 25% + NPK 25%). The lowest value for the plant height was observed in treatment T_1 97.66 cm FYM100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study.

Leaf index at 30 DAS: Data presented in table 1 indicated that highest the Leaf index at 30 DAS was observed in treatment T_9 0.21 (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 0.19 (NPK 75% + FYM 25%), T_6 0.17(NC 50% + FYM 25% + NPK 25%) and T_3 0.16 (FYM 50% + NC 25% + NPK 25%). The lowest value for the Leaf index was observed in treatment T_1 0.10 FYM 100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study.

Leaf index at 60 DAS: Data presented in table 1 indicated that highest the Leaf index at 60 DAS was observed in treatment T_9 0.34 (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 0.33 (NPK 75% + FYM 25%), T_6 0.32 (NC 50% + FYM 25% + NPK 25%) and T_3 0.31 (FYM 50% + NC 25% + NPK 25%). The lowest value for the Leaf index was observed in treatment T_1 0.25 FYM 100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study.

Leaf index at 90 DAS : Data presented in table 1 indicated that highest Leaf index at 90 DAS was observed in treatment T_9 0.89 (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 0.88 (NPK 75% + FYM 25%), $T_{6\ 0.86}$ (NC 50% + FYM 25% + NPK 25%) and T_3 0.83 (FYM 50% + NC 25% + NPK 25%). The lowest value for the Leaf index was observed in treatment T_1 0.73 FYM 100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study.

Leaf index at 120 DAS: Data presented in table 1 indicated that highest the Leaf index at 120 DAS was observed in treatment T_9 1.21 (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 1.20 (NPK 75% + FYM 25%), T_6 1.17 (NC 50% + FYM 25% + NPK 25%) and T_3 1.16 (FYM 50% + NC 25% + NPK 25%) The lowest value for the Leaf index was observed in treatment T_1 0.10 FYM 100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study.

TABLE 1
EFFECT OF ORGANIC AND INORGANIC SOURCE OF NUTRIENTS ON GROWTH OF COTTON (*GOSSYPIUM HIRSUTUM* L.) UNDER TEAK (*TECTONA GRANDIS*), BASED AGROFORESTRY SYSTEM 30, 60, 90 & 120 DAS ON PLANT HEIGHT OF COTTON

	Treatment Combinations	Plant Height (cm)				Leaf area index			
		30DAS	60DAS	90DAS	120DAS	30DAS	60DAS	90DAS	120DAS
T_1	FYM 100%	6.20	31.96	75.86	97.66	0.10	0.25	0.73	0.10
T_2	FYM 75% + NC 25%	7.06	41.53	78.50	103.00	0.13	0.26	0.73	1.10
T_3	FYM 50% + NC 25% + NPK 25%	11.20	67.40	86.73	113.66	0.16	0.31	0.83	1.16
T_4	NC 100%	9.20	52.76	81.06	107.00	0.13	0.27	0.75	1.13
T_5	Neem Cake 75% + FYM 25%	8.13	47.83	80.20	105.00	0.11	0.26	0.74	1.11
T_6	NC 50% + FYM 25% + NPK 25%	12.40	70.66	91.83	115.33	0.17	0.32	0.86	1.17
T_7	NPK 100%	10.13	58.83	84.13	110.00	0.13	0.29	0.77	1.14
T_8	NPK 75 % + FYM 25%	13.93	75.03	98.93	121.33	0.19	0.33	0.88	1.20
T_9	NPK 50 % + FYM 25% + 25 NC %	**15.50**	**79.33**	**106.53**	**123.33**	**0.21**	**0.34**	**0.89**	**1.21**
	F test	S	S	S	S	**S**	**S**	**S**	**S**
	C.D. (0.05%)	0.357	2.087	3.114	5.228	0.02	0.01	0.009	0.003
	SE(m)	0.118	0.690	1.030	1.729	0.009	0.003	0.003	0.001
	SE(d)	0.167	0.976	1.457	2.445	0.013	0.005	0.004	0.001
	C.V.	1.966	2.048	2.048	2.705	10.52	1.94	0.63	0.17

***FYM: Farm** Yard Manure, NC**:** Neemcake, **NPK:** Recommended dose of nitrogen (120-60-60)*

TABLE 2
EFFECT OF ORGANIC AND INORGANIC SOURCE OF NUTRIENTS ON GROWTH OF COTTON (*GOSSYPIUM HIRSUTUM* L.) UNDER TEAK (*TECTONA GRANDIS*), BASED AGROFORESTRY SYSTEM30, 60, 90 & 120 DAS ON PLANT HEIGHT OF COTTON.

Treatment No.	Treatment Combinations	Primary fruiting branch plant	Secondary fruiting branch plant	Number of Sympodial branches (no)	Days of first flowering
T_1	FYM 100%	12.86	4.06	14.46	61.66
T_2	FYM 75% + NC 25%	12.66	5.06	14.60	64.00
T_3	FYM 50% + NC 25% + NPK 25%	13.10	5.43	15.66	65.00
T_4	NC 100%	12.76	5.33	14.90	63.33
T_5	Neem Cake 75% + FYM 25%	12.60	5.26	14.66	63.66
T_6	NC 50% + FYM 25% + NPK 25%	13.14	5.50	15.73	69.86
T_7	NPK 100%	12.96	5.46	15.36	64.66
T_8	NPK 75 % + FYM 25%	13.40	5.73	15.93	**70.33**
T_9	NPK 50 % + FYM 25% + 25 NC %	**14.10**	**5.93**	**16.06**	**70.66**
	F test	S	S	**S**	NS
	C.D. (0.05%)	0.732	0.33	0.62	-
	SE(m)	0.242	0.10	0.20	2.53
	SE(d)	0.342	0.154	0.29	3.58
	C.V.	3.209	3.557	2.32	70.66

3.1 Primary fruiting branch plant

Data presented in table 2 indicated that Primary fruiting branch plant was observed in treatment T_9 14.10 (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 13.40 (NC 75% + FYM 25%), T_6 13.14 (NPK 50% + FYM 25% + NPK 25%) and T_3 13.10 (FYM 50% + NC 25% + NPK 25%). The lowest value for the Primary fruiting branch plant was observed in treatment T_1 12.86 FYM 100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study.

3.2 Secondary fruiting branch plant

Data presented in table 2 indicated that Secondary fruiting branch plant was observed in treatment T_9 5.93 (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 5.733 (NPK 75% + FYM 25%), T_6 5.50 (NC 50% + FYM 25% + NPK 25%) and T_3 5.43 (FYM 50% + NC 25% + NPK 25%). The lowest value for the Secondary fruiting branch plant was observed in treatment T_1 4.06 NPK 100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study.

3.3 Number of Sympodial branches (no)

Data presented in table 3 indicated that Number of Sympodial branches (no) was observed in treatment T_9 16.06 (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 15.93 (NPK 75% + FYM 25%), T_6 15.73 (NC 50% + FYM 25% + NPK 25%) and T_3 15.66 (FYM 50% + NC 25% + NPK 25%). The lowest value for the Number of Sympodial branches (no) was observed in treatment T_1 14.46 FYM 100%. Under teak based Agroforestry system respectively. The result obtained was found Significant throughout the study.

3.4 Day of first flowering per days (no)

Data presented in table 2 indicated that Day of first flowering per days (no)was observed in treatment T_9 63.33(NPK 50 % + FYM 25% + 25 NC %) followed by T_8 61.66 (NPK 75% + FYM 25%), T_6 64.66 (NC 50% + FYM 25% + NPK 25%) and T_3

64.00 (FYM 50% + NC 25% + NPK 25%). The lowest value for the Day of first flowering per days (no) was observed in treatment T_1 70.66 FYM100%. Under teak based Agroforestry system respectively. The result obtained was found Significant throughout the study.

3.5 Number of bolls plant (no)

Data presented in table no 3 indicated that highest number of bolls plant (no) was observed in treatment T_9 90.66(NPK 50 % + FYM 25% + 25 NC %) followed by T_8 90.00 (NPK 75% + FYM 25%), T_6 86.66 (NC 50% + FYM 25% + NPK 25%) and T_3 84.33 (FYM 50% + NC 25% + NPK 25%) The lowest value for the Number of bolls plant was observed in treatment T_1 77.66 FYM 100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study. **Bolls per m^{-2}** Data presented in table 3 indicated that highest Bolls per m-2 was observed in treatment $T_9$148.66 (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 126.00 (NPK 75% + FYM 25%), T_6 112.53 (NC 50% + FYM 25% + NPK 25%) and $T_3$103.33 (FYM 50% + NC 25% + NPK 25%). The lowest value for Bolls per m-2was observed in treatment T_1 70.66 FYM 100%. Under teak based Agroforestry system respectively. The result obtained was found Significant throughout the study.

TABLE 3
EFFECT OF ORGANIC AND INORGANIC SOURCE OF NUTRIENTS ON GROWTH AND YIELD OF COTTON (GOSSYPIUM HIRSUTUM L.) UNDER TEAK (TECTONA GRANDIS) BASED AGROFORESTRY SYSTEM NUMBER OF BOLLS PLANT AND BOLLS PER M-2 OF COTTON.

	Treatment Combinations	Number of bolls plant	Bolls per m^{-2}	Single boll weight(g)	Cotton yield quintal / ha
T_1	FYM 100%	**77.66**	**70.66**	**4.03**	**17.00**
T_2	FYM 75% + NC 25%	71.00	80.13	4.06	17.04
T_3	FYM 50% + NC 25% + NPK 25%	84.33	103.33	5.26	23.48
T_4	NC 100%	76.66	88.93	4.53	21.01
T_5	Neem Cake 75% + FYM 25%	76.33	85.06	4.27	17.35
T_6	NC 50% + FYM 25% + NPK 25%	86.66	112.53	5.53	23.49
T_7	NPK 100%	80.66	96.40	5.00	23.04
T_8	NPK 75 % + FYM 25%	**90.00**	**126.00**	**5.78**	**23.74**
T_9	NPK 50 % + FYM 25% + 25 NC %	**90.66**	**148.66**	**5.90**	**24.16**
	F test	S	S	S	S
	C.D. (0.05%)	7.28	3.79	0.79	2.17
	SE(m)	2.40	1.25	0.26	0.71
	SE(d)	3.40	1.77	0.37	1.01
	C.V.	5.11	2.14	9.18	5.88

3.6 Single boll weight (g)

Data presented in table 3 indicated that highest Single boll weight (g) was observed in treatment T_9 5.90 (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 5.78 (NPK 75% + FYM 25%), T_6 5.53 (NC 50% + FYM 25% + NPK 25%) and T_3 5.26 (FYM 50% + NC 25% + NPK 25%). The lowest value for Single boll weight (g) was observed in treatment T_1 4.03 FYM 100%. Under teak based Agroforestry system respectively. The result obtained was found Significant throughout the study. **Cotton yield quintal/ ha:** Data presented in table 3 indicated that highest Cotton yield quintal/ ha was observed in treatment T_9 24.16 (NPK 50 % + FYM 25% + 25 NC %) followed by T_8 23.74 (NPK 75% + FYM 25%), T_6 23.49 (NC 50% + FYM 25% + NPK 25%) and T_3 23.48 (FYM 50% + NC 25% + NPK 25%). The lowest value for Cotton yield quintal / ha was observed in treatment T_1 17.00 FYM 100%. Under teak-based Agroforestry system respectively. The result obtained was found Significant throughout the study.

IV. DISCUSSION

M Jayakumar 2017 also reported a comparable outcome. The cotton plant height under the teak-based agroforestry model was 138.01 cm, which is significantly higher than the plant height 123.33 at 120DAS. **M Jayakumar 2014** also noted a comparable outcome. When compared to the largest number of sympodial branches, which was 16.06 at the time of growth, cotton grown under a teak-based agroforestry model had 18.08 fewer sympodial branches. **Islamm.K 2014**. also reported a similar outcome. Primary fruiting branches 14.04 are much fewer than primary fruiting branches 14.10, which were the highest at the time of growth in cotton under the teak-based agroforestry model. **Islamm.K 2014**. also reported a similar outcome. When compared to the highest Days of First Flowering per Day of 14.10 during the period of growth, Cotton under a teak-based agroforestry model has significantly fewer Days of First Flowering per Day of 14.04 than those. **Islamm.K 2014**. also reported a similar outcome. When compared to bolls fruiting branches, which were at their maximum at the period of growth (63.33), the number of fruiting per branch bolls for cotton under the teak-based agroforestry model was 68.10. **Das Anup 2010** also reported a comparable outcome. LAI 3.83 is much lower than LAI 1.210, which was the greatest during the period of growth for cotton under the teak-based agroforestry model. A similar result was also reported by **M Jayakumar 2014.** No of Bolls per plant 73.44. no as compere to No of Bolls per plant 90.66 highest at growth time, Cotton under teak-based agroforestry model that No of Bolls per plant significantly. **M Jayakumar 2014** also noted a comparable outcome. When compared to the highest single boll weight (g) of 5.90 g during growth time, cotton under a teak-based agroforestry model slightly outweighed single bolls at 4.94 g. **Manchalas.k. 2017** also reported a comparable outcome. Cotton under teak-based agroforestry model that single Cotton yield q/ h considerably, cotton yield 19.00 q/ h no as compare to single cotton yield 24.16 q/ h highest at growing time.

V. CONCLUSION

On the basis of field experiment conducted on "Effect of Organic and Inorganic Source of Nutrients on Growth and Yield of Cotton (*Gossypium hirsutum L.*) Under Teak (*Tectona grandis*) Based Agroforestry System" concluded that the treatment T_9 (NPK 100%) was found superior among that treatment under teak-based Agroforestry system it was also observed that maximum Cotton Yield (**24.16t ha-^{1}**)

REFERENCES

[1] Das Anup and Y. S. Shivay and M. Prasad (2010) Effects of prilled urea, farmyard manure and Azotobater on the cotton– wheat cropping system for realizing higher yield potential on Ustochrepts of Indo-Gangetic plain. *Trop Agric. (Trinidad)*, 87(3), 108-117.

[2] Elkins H. D'Ann (2017) Cotton, (*Gossypium Hirsutum L.*,) Cultivars Differential Response to Salinity. Provided by Texas A & M university, 17, 1-90.

[3] HosamaniVinayak, A.S. Halepyati, B. K. Desai, B. G. Koppalkar and M. V. Ravi (2013) Effect of macro nutrients and liquid fertilizers on the growth and yield of irrigated Bt cotton (*Gossypium hirsutum L.). Karnataka Journal of Agriculture Sciences,* 26 (2), 200-204.

[4] Islam M. K, Khalequzzaman, M. K. Hassan, M. Kaikobad (2014) Effect of Organic and Inorganic source of N on Cotton Yield. *Cotton Development Board*, 20(14), 131-142.

[5] Jayakumara.M, U. Surendran (2017) Intercropping and balanced nutrient management for sustainable cotton production. *Journal of Plant Nutrition,* 40(5), 632–644.

[6] Jayakumara.M, U. Surendranb, P. Manickasundaramc (2014) Drip fertigation effects on yield, nutrient uptake and soil fertility of Bt Cotton in semi-arid tropics. *International Journal of Plant Production.* 8 (3), 375-390.

[7] Manchala S. K S. M. Bhoyar, P. W. Deshmukh, E. Sathyanarayana and Leena DajuraoKarangami (2017) Yield and Quality of Rainfed Cotton in Response to Organic Manures Under Vertisol. *Plant Archives*, 17, 412-416.

[8] William Ladrach President Zobel Forestry Associates, (2009) Management of Teak Plantations for Solid Wood Products. *Bethesda, Maryland*, 16, (10), 16-20

Study of Agroforestry System and Socio Economic Status of Farmer in Leparada dist of Arunachal Pradesh

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Abstract*—*The present study was conducted in different villages of block Basar, Leparada district, Arunachal Pradesh. A total of 120 respondents were selected randomly. The data were collected by the researcher using pre-structured interview. The finding shows that the majority of respondent were practicing Agrisilviculture system and Agrosilvopastoral System (Home garden).

Keywords*— *Agrisilviculture system, Agro silvopastoral System, Home Garden.

I. INTRODUCTION

Agroforestry has a long tradition in Arunachal Pradesh, where trees are integrated in the crops and livestock production systems according to agro- climatic and other prevailing conditions. These systems are managed indigenously, with practices having been evolved by the farmers through trial and error over long periods of time Rai S N & Proctor J, (1986). Farmers usually plant trees in their traditional agroforestry systems in pursuit of their livelihood goals of income generation, risk management, household food security and optimal use of available land, labour and capital Arnold JEM & Dewees PAA, (1999). A great number of different traditional grain crops, rhizomatous crops, pineapple and vegetables are being grown with a number of fruits and other trees in their traditional systems, which are valuable for the farmers' everyday life.

Traditional cropping patterns also vary among the communities, since they have evolved in response to prevailing soil and climatic conditions and social and ethological preferences Ruthenberg H, (1976). The age, gender and socio- cultural status are the most frequently used proxies for household preferences Pattanayak SK, Mercer DE, Sills E & Yang J, (2003). The farmers of Arunachal Pradesh are not ready to adopt modern agroforestry as it is considerably more complex than traditional agriculture Arunachalam A, Khan ML & Arunachalam K, (2002). The tribesmen have also their own ways of identifying, classification and judicious uses of traditional ethnobotanical plants. Ethnobotanical uses of plants in Arunachal Pradesh have been reported Tewari KC, Majumdar R & Bhatiacharjee S, (1978) and Sabat BC, (2003). Arunachal Pradesh harbours ca. 500 plant species of medicinal and pharmacological significance. A detail study of community wise survey is required as this may provide a meaningful way for the promotion of the traditional knowledge. The medicinal plants used by Nyishi community of Arunachal Pradesh has also been reported but the ethnobotanical plants in traditional agroforests and their indigenous uses has not yet been explored and categorized for any community of Arunachal Pradesh Tag H, Das AK & Loyi H, (2007) and Murtem G & Das AK, (2005).

Large number of studies on wild edible plants and related topic of various states of North eastern India had been carried out by many researchers (Arora, 1981; Singh and Singh, 1985; Singh et al., 1988; Maikhuri and Gangwar, 1993; Borthakur, 1996; Sundriyal et al., 1998; Sundriyal and Sundriyal, 2003; Kumar, 2003; Samati, 2004; Sundriyal et al., 2004; Kayang, 2007; Tiwari et al., 2010) however, such study on various tribes of Arunachal Pradesh in general (Haridasan et al., 1990; Murtem, 2000; Kohli, 2001; Kar, 2004, 2005; Angami et al., 2006) is meager and on Adi tribe is lacking. Due to various physical barriers they have been leading practically a life of seclusion thereby preserving their traditional knowledge intact. So, documentation of their traditional knowledge on cultivated crops, semi-domesticated and wild vegetable plants become a prerequisite. Keeping the gap in consideration, present study was carried out which provide valuable information on cultivated crops, semi-domesticated and wild plants of East Siang district, Arunachal Pradesh, Northeast India.

II. MATERIALS AND METHODS

The present study was purposively undertaken in Basar Block which is located at the Leparada district of Arunachal Pradesh which is about 258.2 km away from the Itanagar city. It lies between 27o59'N longitude and 94o40'E latitude at an elevation of 680 m above the mean sea. Total area covers 1650 sq.km. The regions in the lower belts of the state experience hot and humid climates, with a maximum temperature in the foothills reaching up to 40°C (during the summer). The average temperature in this region in winter ranges from 15°C to 21°C while that during the monsoon season remains between 22°C and 30°C. The state receives an average rainfall of 300 cm. 120 respondent were selected randomly as a sample of study.

III. RESULTS AND DISCUSSION

3.1 Different agroforestry systems used by the native villagers

3.1.1 Agrisilvicultural System (crops and trees including shrubs/vines and trees)

This system involves the conscious and deliberate use of land for the concurrent production of agricultural crops including tree crops and forest crops.

This system was mainly comprised of agriculture crops along with forest trees (mainly on the bunds of the agriculture fields). The location of the trees was mostly on the bunds, but occasionally the trees were also found in-between and middle of the agricultural fields. They were mainly used for fodder, fuel and timber purpose. The major tree based agrisilviculture systems included the tree species like cajanus cajan, mesua ferrea, bambusa spp, Gmelina arborea, Along with agricultural crops.

3.1.2 Species found in a study area under Agrisilviculture system

Total 13 woody species viz. Michelia obtusifolia, Pinus kesia, Terminalia myriocarpa, Anthocephalus cadamba, Gmelina arborea, Cuppressus torulosa, Bauhinia varigeta, Acacia mangium, Lyonia ovalifolia, Aesculus indica, Ficus semicordata, Quercus serrata and Prunus cerasoides was recorded. Among which Michelia obtusifolia, Ficus roxburghi, Ficus palmate,

Gmelina arborea, Cuppressus torulosa were common to all villages. Whereas Castonopsis indica, Acacia mangium, Lyonia ovalifolia, Aesculus indica, Pinus kesia and Quercus serrata were found in Gori respectively. Bark and stem of Michelia obtusifolia were also used to make baskets. Pinus kesia was used for making agricultural implements. Herbaceous food crops species were documented in two prominent cropping seasons which were common to all villages. In kharif season cereals, pulses, oil crop, oilseed crop are cultivated. Among all the cultivated kharif season crops, Eleusine coracana, Echinochloa frumentacea, Oryza sativa, Dolichos uniflorus, Glycine max, Glysine soja and Sesamum indicum were main food crops which is cultivated in all the villages. In rabi season Triticum aestivum, Hordeum vulgare and Lens culinaris and Brassica campestris were prominent food crops observed. Total 5 shrub species viz. Rhus parviflora, Zanthoxylum alatum, Desmodium elegans, Rubus elipticus, Barberis eristata and 5 herb species, Cyndon dactylon, Euphorbia hirta, Oxalis acetosella, Eupitorium adenophorum and Solanum nigrum were documented in agrisliviculture system.

Bijalwan et al. (2009) also supported the present study; their study indicated a total of 19 tree species in northern and southern aspects in agrisilvicultural system in mid-hill situation of Garhwal Himalaya between 1000 m to 2000 m a.s.l. The most dominant tree species were Michelia obtusifolia, Gmelina arborea and Melia azedarach and successively grown under traditional agrisilviculture system. The dominant agricultural crops Eleusine coracana in summer cereals, Phaseolus vulgaris in summer pulses-oilseeds and Triticum aestivum in the winter season.

Kala (2010) documented a total of 26 herbaceous food crop species and 21 woody species that were raised by farmers in the selected villages of Uttarakhand. A total of 37 plant species available in the agro-forestry system and used for curing various ailments by traditional healers were also documented during the survey. The major cereals produced by farmers were Oryza sativa, Echinochloa frumentoacea, Eleusine coracana and Triticum aestivum. The indigenous system of cropping was locally called as Baranaja that revolved around the production of > 12 varieties of crops. Besides food, the species grown in the agro-forestry system were used for multiple purposes

3.1.3 Agrosilvopastoral System (trees + crops + pasture/animals)

3.1.3.1 Home Gardens:

This is one of the oldest agroforestry practices, found extensively in high rainfall areas in tropical south and south-east Asia.Many species of trees, bushes, vegetables and other herbaceous plants are grown in dense and apparently random arrangements, although some rational control over choice plants and their spatial and temporal arrangement may be exercised. Most home gardens also support a variety of animals (cow, buffalo, bullock, goat, sheep) and birds (chicken, duck). In some places pigs are also raised. Fodder and legumes are widely grown to meet the daily fodder requirements of cattle. The waste materials from crops and homes are used as fodder/feed for animals/birds and barn wastes are used as manure for crops.

3.1.3.2 Species grown in homegarden

A homestead garden is stratified into different strata like under story, middle story and top story. In under story, all annuals like weed grass and vegetables are grown. Maximum species are common in all the villages' viz. tomato, lady finger, bitter gourd, pumpkin, cabbage, arabi, coriander, turmeric, potato, radish, garlic and onion etc. In middle story all the shrubs and trees were raised, mainly fruits plants were dominant. In home garden 11 species of temperate and sub-tropical fruits are identified i.e Prunus persica, Mesua ferrea, Citrus sinensis, Mangifera indica, Pyrus communis, Mesua ferrea etc. Only one shrub species Tinospora cordifola was grown by the farmers of only one village Gori.

Similarly in two districts of Uttarakhand viz. Rudraprayag and Uttarkashi Rana et al., (2016) identified 35 species of trees (forest trees+ fruit trees), 18 species of agriculture crops, 13 species of vegetable crops, 9 species of grasses and 13 species of shrub.

Conformably to present study Sahoo (2009) documented a total of 231 species with 105 trees, 50 shrubs and 76 herbs species from 45 indigenous agroforestry homegardens. These tree, shrub and herb species were distributed in 84 and 49; 31 and 22 and 59 and 39 genera and families respectively. Overall, there were 88 families, out of which 24 tree species (23%) were common

3.1.4 Some important trees found in the study area

Top storeycomprisesof Hollock *(Terminaliamyriocrpa), Jutuli (Altinga excels), Hingori(Castanopsi sindica) , Bonsum (Phoebe goalprensis) , Sopa (Magnolia Spp), Dhuna (Canarium resinformis), Poma (Cedrela toona), Mekahi (Phoebe cooperiana), Khokon (Duabanga graaaandflora),*

Middle storey with Haldisopa *(Adina olgocephala), Jamuk(Syzgium cumini) , Pichola(Kydia calycina),*

Lower storey with*Gahori Sopa (Magnolia griffitti) , Bon Am (Mangfera sylvatic) , Ground Flora with Hati bhekuri (solanum subtracatum), Kolgoch (Musa Spp),*

Bamboo types like Kako bans *(Dendrocalamus hamiltonii) , Bojal bans (Pseudostachyumpolymorphum)* cane varieties Lejai bet- *(Calamus floribundus), Raidang bet (Calamus flagellum)* Palm species *like Toko palm (Livistonia jenkensii), Jeng (Calamus erectus) aanad* Climber species like *Ghila lata (Bauhinia Vahlii) , Pani lata (Vitis planicaulis) , Kuchai (Accia pinnata) , Gowlia lata (vitis latifolia) , Dimmorulata (Ficus Scandens), Hegumi lata (Tinospora coordifolia), Mermeri lata (Gnetum scandens)* etc. are found in the district.

3.2 Phyto-sociological aspects of selected tree species in agroforestry systems in Arunachal Pradesh.

TABLE 1
SPECIES IN STUDY AREA UNDER IN BAM VILLAGE TREE COMMUNITIES FOUND.

SL.NO	SPECIES	TOI	TNI	D	BA	F%	RF	RD	RDO	IVI
1	*Albizzia stipulata*	4	11	1.1	0.03	40	17.39	21.15	6.38	44.93
2	*Callistemom sp.*	1	2	0.2	0.03	10	4.35	3.85	6.38	14.58
3	*Caryota urens*	2	5	0.5	0.016	20	8.70	9.62	3.40	21.72
4	*Cedrela toona*	2	6	0.6	0.034	20	8.70	11.54	7.23	27.47
5	*Citrus maxima*	1	2	0.2	0.009	10	4.35	3.85	1.91	10.11
6	*Delonix regia*	2	4	0.4	0.042	20	8.70	7.69	8.94	25.32
7	*Engenia praecox*	1	2	0.2	0.04	10	4.35	3.85	8.51	16.70
8	*Erythrina suberosa*	1	2	0.2	0.007	10	4.35	3.85	1.49	9.68
9	*Euclyptus sp.*	6	12	1.2	0.035	60	26.09	23.08	7.45	56.61
10	*Ficus benghalensis*	3	6	0.6	0.228	30	13.04	11.54	48.51	73.09
	Total	23	52	5.2	0.47	230	100.00	100.00	100.21	300.21

BAM on analyzing the RDO of each species, it was found that *Ficus benghalensis* (48.51) was the most dominant tree species with the highest value of RDO *Delonix regia* (8.94) and *Engenia praecox* (8.51) had the second and third place, respectively, followed by other species viz. *Euclyptus sp.* (7.45), *Cedrela toona* (7.23), *Albizzia stipulata* (6.38), Callistemom sp. (6.38) *caryota urens* (3.40), *citrus maxima* (1.91), and *eryhrina suberosa* (1.49) while analyzing the importance value index of each species, it was found that *Ficus benghalensis* (73.09) was the most dominant tree species with the highest value of IVI *Euclyptus sp.*(56.61) *Albizzia stipulata* (44.93) *Cedrela toona* (27.47) had the second and third place, respectively followed by *Delonix regia* (25.32), *Caryota urens* (21.72), *Engenia praecox* (16.70) *Callistemom sp.* (14.58), *Citrus maxima* (10.11), *Erythrina suberosa* (9.68)

TABLE 2
SPECIES IN STUDY AREA UNDER IN SAGO VILLAGE

SL.NO	SPECIES	TOI	TNI	D	BA	F%	RF	RD	RDO	IVI
1	*Azadirachta indica*	1	2	0.2	0.023	10	6.67	7.14	6.19	20.00
2	*Caryota urens*	1	1	0.1	0.0008	10	6.67	3.57	0.22	10.45
3	*Cedrela toona*	2	2	0.2	0.0047	20	13.33	7.14	1.27	21.74
4	*Celtis timorensis*	4	9	0.9	0.0137	40	26.67	32.14	3.69	62.50
5	*Citrus maxima*	1	3	0.3	0.003	10	6.67	10.71	0.81	18.19
6	*Couroupita guianensis*	1	3	0.3	0.0396	10	6.67	10.71	10.66	28.04
7	*Delonix regia*	1	3	0.3	0.15	10	6.67	10.71	40.39	57.77
8	*Elaeocarpus floribundus*	2	2	0.2	0.007	20	13.33	7.14	1.88	22.36
9	*Fagus sylvatica*	1	2	0.2	0.1225	10	6.67	7.14	32.98	46.79
10	*Ficus benghalensis*	1	1	0.1	0.0071	10	6.67	3.57	1.91	12.15
	Total	15	28	2.8	0.3714	150	100.00	100.00	100.00	300.00

SAGO village on analyzing the RDO of each species, it was found that *Delonix regia* (40.39) was the most dominant tree species with the highest value of RDO*Fagus sylvatica* (32.98), *Couroupita guianensis* (10.66) and *Azadirachta indica* (6.19) had the second and third place, respectively, followed by *Celtis timorensis* (3.69), *Elaeocarpus floribundus* (1.88), *Cedrela toona* (1.27), *Citrus maxima* (0.81), *Ficus benghalensis* (1.91) *Caryota urens* (0.22)while the analyzing the important value index of each species, *Celtis timorensis* (62.50) was the most dominant tree species with the highest value of IVI*Delonix regia* (57.77) *Fagus sylvatica* (46.79), and *Couroupita guianensis* (28.04) had the second and third place, respectively, followed by other species viz. *Elaeocarpus floribundus* (22.36), *Cedrela toona* (21.74), *Azadirachta indica* (20.00), *Ficus benghalensis* (12.15) and *Caryota urens* (10.45)**.**

TABLE 3
SPECIES IN A STUDY AREA UNDER IN GORI VILLAGE

SLNO	SPEIES	TOI	TNI	D	BA	F(%)	RF	RD	RDO	IVI
1	*Albizzia stipulata*	6	18	1.8	0.05	60	31.58	40.91	1.54	74.03
2	*Bischofia javanica*	2	3	0.3	0.23	20	10.53	6.82	6.61	23.95
3	*Cinnamomum zeylanicum*	1	1	0.1	0.01	10	5.26	2.27	0.21	7.74
4	*Docynia indica*	1	1	0.1	0.02	10	5.26	2.27	0.47	8.01
5	*Ficus benghalensis*	1	1	0.1	2.87	10	5.26	2.27	83.93	91.46
6	*Gmelina arborea*	2	3	0.3	0.14	20	10.53	6.82	3.93	21.27
7	*Pyrus pashia*	5	16	1.6	0.06	50	26.32	36.36	1.83	64.51
8	*Spondias mangifera*	1	1	0.01	0.05	10	5.26	2.27	1.49	9.03
	Total	19	44	4.31	3.42	190	100.00	100.00	100.00	300.00

GORI village on analyzing the RDO of each species, it was found that *Ficus benghalensis* (83.93)was the most dominant tree species with the highest value of RDO *Bischofia javanica* (6.61), *Gmelina arborea* (3.93), had the second and third place, respectively, followed by otherspecies viz. *Pyrus pashia* (1.83), *Albizzia stipulata* (1.54), *Spondias mangifera* (1.49), *Docynia indica* (0.47), *Cinnamomum zeylanicum* (0.21) while the analyzing the Importance Value Index of each species, it was found that *Ficus benghalensis* (91.46) was the most dominant tree species with the highest value of IVI *Albizzia stipulata* (74.03), *Pyrus pashia* (64.51), had the second and third place, respectively, followed by *Bischofia javanica* (23.95), *Gmelina arborea* (21.27) *Spondias mangifera* (9.03), *Docynia indica* (8.01) and *Cinnamomum zeylanicum* (7.74)

TABLE 4
SPECIES IN STUDY AREA UNDER IN KADI VILLAGE

SLNO	SPECIES	TOI	TNI	D	BA	F(%)	RF	RD	RDO	IVI
1	*Albizzia stipulata*	3	5	0.5	0.035	30	16.67	15.63	1.29	33.58
2	*Areca catechu*	1	2	0.2	0.009	10	5.56	6.25	0.33	12.14
3	*Bambox ceiba*	1	1	0.1	0.039	10	5.56	3.13	1.44	10.12
4	*Callistemon sp.*	1	1	0.1	0.005	10	5.56	3.13	0.18	8.86
5	*Caryota toona*	6	11	1.1	0.029	60	33.33	34.38	1.07	68.78
6	*Citrus maxima*	3	6	0.6	0.022	40	22.22	18.75	0.81	41.78
7	*Tectona grandis*	1	4	0.4	2.529	10	5.56	12.50	1.66	13.46
8	*Ficus benghalensis*	1	2	0.2	0.045	10	5.56	6.25	93.21	111.27
	TOTAL	17	32	3.2	2.7132	180	100.00	100.00	99.99	299.99

Kadi village on analyzing the RDO of each species, it was found that *Ficus benghalensis* (93.21)was the most dominant tree species with the highest value of RDO *Tectona grandis* (1.66), *Bambox ceiba* (1.44), had the second and third place, respectively, followed by other species viz. *Albizzia stipulata* (1.29), *Caryota toona* (1.07), *Citrus maxima* (0.81), *Areca catechu* (0.33), *Callistemon sp.* (0.18)while the analyzing the Importance Value Index of each species, it was found that *Ficus benghalensis* (111.27) was the most dominant tree species with the highest value of IVI *Caryota toona* (68.78), *Citrus maxima* (41.78), had the second and third place, respectively, followed by *Albizzia stipulata* (33.58), *Tectona grandis* (13.46) *Areca catechu* (12.14), *Bambox ceiba* (10.12) and *Callistemon sp* (8.86)

3.3 Diversity indices (Shannon wiener's diversity and Simpson's dominance index) for tree.

TABLE 5
SHANNON WIENER'S DIVERSITY INDEX

SITES	KADI	GORI	SAGO	BAM
H'	1.8	1.45	2.08	2.09

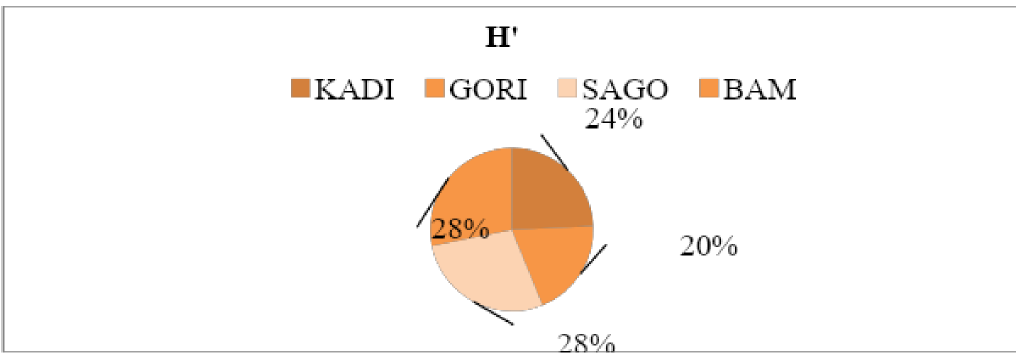

FIGURE 1: ***shannon wiener's diversity index***

TABLE 6
SIMPSON'S DOMINANCE INDEX

SITES	KADI	GORI	SAGO	BAM
cd	0.18	0.36	0.05	0.21

SIMPSON'S DOMINANCE INDEX

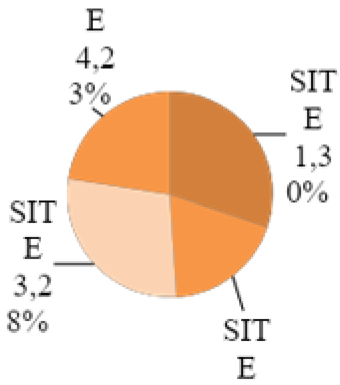

FIGURE 2: Simpson's dominance index

IV. SOCIO-ECONOMIC CHARACTERISTICS OF RESPONDENTS OF VILLAGES IN THE STUDY AREA

Based on information from interview, questionnaires were designed to collect the data from different villages.

4.1 Age

Age distribution of respondents is given in the Table 3.1. The age of respondents was categorized as young, middle and old. Majority of the respondents i.e. 73 (60.83%) were old in age followed by 37 (30.83%) of middle aged and 10 (8.34%) were young.

TABLE 7
DISTRIBUTION OF RESPONDENTS ON THE BASIS OF AGE

S. No.	Category	Number of respondents	Percentage
1	Young (21-35)	10	8.34
2	Middle (35-45 years)	37	30.83
3	Old (>45 years)	73	60.83
	Total	120	

4.2 Education

The data in the Table 3.2 gives information about education level of the respondents. It was revealed from the interview that maximum number of respondents i.e. 67 (55.83%) had education up to 12th, followed by primary and above 12th i.e. 27 (22.50%) and 15 (12.50 %), respectively whereas 11 (9.17%) was illiterate.

TABLE 8
DISTRIBUTION OF RESPONDENTS ON THE BASIS OF EDUCATION

S. No.	Category	Number of respondents	Percentage
1	Illiterate	11	9.17
2	Primary (1 to 8th)	27	22.50
3	Intermediate (9 to 12th)	67	55.83
4	Above (12th)	15	12.50
	Total	120	

During informal discussion it was found that education facility was well in the village & nearby area. But the education level of women till the day was less than the man because the women were fully involved in the agriculture as well as household activities. In the studied villages it was observed that majority of the respondents were aware of the economic and environmental benefits of agroforestry practices and had favorable attitude towards those practices. It may be due to the fact that significant portions of household members are literate in the study area.

High educational level in family can improve acceptance of agroforestry practices, Infect educated members of family can improve awareness of farmers about benefits and advantages of agroforestry systems and results in high acceptance level for this land use option. According to census 2011-2012, the percentage of literacy rate was 72.42%. Out of this the male literacy rate was found to be 69.73% and female literacy rate 62.19%

4.3 Type of house

Data regarding type of house of respondents has been presented in Table 3.4. It was observed that majority of the respondent 101 (84.17%) resided in kutcha houses, followed by 13 (10.83%) respondents who were residing in mixed (pucca+kutcha) house. Only 6 (5%) respondents had pacca house.

TABLE 9
DISTRIBUTION OF RESPONDENTS ON THE BASIS OF TYPE OF HOUSE

S. No.	Category	Number of respondents	Percentage
1	Pucca	6	5.00
2	Mixed	13	10.83
3	Kutcha	101	84.17
	Total	120	

4.4 Occupation

Data regarding main source of income for the households has been presented in Table 3.5. It was observed that maximum number of household family about 55 (45.83%) belongs to the farming which was the primary source of income whereas 31 (25.83%) belongs to service class followed by 19 (15.83%) families that were dependent in the business for their livelihood, followed by wage labors 15 (12.5%) families.

TABLE 10
DISTRIBUTION OF RESPONDENTS ON THE BASIS OF PRIMARY OCCUPATION

S. No.	Category	Number of respondents	Percentage
1	Service	31	25.83
2	Business	19	15.83
3	Farming	55	45.84
4	Wage labor	15	12.50
	Total	120	

4.5 Annual income

Data regarding main source of income for the household has been presented in Table 3.6. It was observed that majority of the household i.e. 94 (78.33%) belonged to the Above Poverty Line followed by 26 (21.67%) respondents who were found Below Poverty Line.

TABLE 11
DISTRIBUTION OF RESPONDENT ON THE BASIS OF ANNUAL INCOME

S. No.	Category	Number of respondents	Percentage
1	Above Poverty Line (APL)	94	78.33
2	Below Poverty Line (BPL)	26	21.67
	Total	120	

4.6 Land holding

Data regarding land holding pattern in the study area has been represented in the Table 3.7 and Fig.7. The farmers of the four villages of the study sites were categorized on the basis of availability of land, the categorization was large (>10nali), marginal (6-10nali) and small (<5nali). The present study reveals that majority of respondent i.e. 76 (63.335) had maximum land, whereas 25 (20.83%) and 19 (15.83) of them had marginal and small land. Household size is a parameter that determines the quantity of products required from neighboring natural resources. In the studied villages maximum of the respondent i.e. 56.67, had small sized family.

TABLE 12
DISTRIBUTION OF RESPONDENTS ON THE BASIS OF LAND HOLDING PATTERN

S. No.	Category	Number of respondents	Percentage
1	Large (>10nali)	76	63.33
2	Marginal (6-10nali)	25	20.83
3	Small (<5nali)	19	15.83
	Total	120	

A similar study was conducted by Roy et al., (2009) in Bhagar, Tola and Maniagar villages of Dhauladevi block in Almora district of Arunachal Pradesh during 2011-12. Sixty farmers were selected randomly. Ten variables viz. category, age, education, occupation, social participation, landholding, herd size, farming experience, annual income and material possession were selected to assess the socioeconomic status. Agriculture was the sole occupation of 25 percent farmers whereas others had subsidiary occupations like labour, shop keeping, driving etc. Majority of the farmers were in middle-age category (70%).The average age of the respondents was obtained 42 years. Most of the farmers had medium level of education (63.33%).

V. CONCLUSION

The Study of agroforestry system and socio-economic status of the farmer in Leparada district of Arunachal Pradesh through survey about the prevailing agroforestry system practiced by the farmers in the district, their phyto-sociological aspects of some selected tree species and their socio-economic status of the farmers leads to the conclusion that,

The practice of Agrisilviculture is the most prominent practice of agroforestry system in the surveyed area followed by agrosilvopastoral and Agro-horticulture. It also reveals that the four villages Bam, Sago, Kadi and Gori have excellent practices of Agri silviculture upon all Agroforestry systems predominantly with trees of Cajanus cajan, Mesus ferrea and bambusa. and crop plant of pulses, oil crops, oilseeds, Oryza sativa, Brassica campestris. Agrisilvicuture with the combination of Agro-horticulture tree species like Prunus persica Prunus domestica, Citrus limon recorded. In Phyto sociological aspects it was found that Ficus benhalensis was most dominant tree in three out of four sites, followed by Delonix regia in one of the selected village. Agroforestry systems and practices associated with them plays an important role in securing the sustainable livelihood of the rural people in Arunachal Pradesh.

REFERENCES

[1] Ahmed, A. 2012. Analysis of forest vegetation in Ranikhet, Kumaon Himalayas, Uttarakhand, India. Ind. J. Fund. Appl. Life Sci. 2 (4): 16-23.

[2] Anderson, J.W. and S.R. Bridges, 1998. Dietary fiber contents of selected foods. Am. J. Clin. Nutr., 47(3): 440-447.

[3] Angami, A., P.R. Gajurel, P. Rethy, B. Singh and S.K. Kalita, 2006. Status and potential of wild edible plants of Arunachal Pradesh. Ind. J. Tradit. Bot., 5(4): 541-550

[4] Arnold JEM & Dewees PAA, (1999). Trees in managed landscapes: factors in farmer decision making, In: *Agroforestry in Sustainable Agricultural Systems*, edited by Buck LE, Lassoie JP & Fernandes EC, (CRC Press, Lewis Publisher, Boca Raton Florida, USA), .

[5] Arora, R.K. and A. Pandey, 1996. Wild Edible Plants of India: Diversity, Conservation and use. NBPGR, New Delhi.

[6] Arora, R.K., 1981. Native Food Plants of the Northeastern Tribals, In: Jain S.K. (Ed.), Glimpses of Indian Ethnobotany, Oxford & IBH Pub. Co., New Delhi, pp: 91-106.

[7] *Arunachal Pradesh gets 25th district called Shi Yomi". www.telegraphindia.com*. Retrieved 16 February 2019.

[8] Arunachalam A, Khan ML & Arunachalam K, (2002).Balancing traditional *jhum* cultivation with modern agroforestry in eastern Himalaya- A biodiversity hotspot, *Curr Sci*, 83 (2) 117

[9] Basu, J. P. 2014. Agroforestry, climate change mitigation and livelihood security in India. New Zealand Journal of Forestry Science 44(1): 3-10.

[10] Bhatt, V., Purohit, V.K. and Negi, V. 2010. Multipurpose tree species of Western Himalaya with an agroforestry prospective for rural needs. Journal of American Science. 6(1):73-80

[11] Bijalwan, A. 2012. Structure, composition and diversity of horticulture trees and agricultural crops productivity under traditional Agri-Horticulture System in mid hill situation of Garhwal Himalaya, India. American Journal of Plant Sciences. (3) 480-488.

[12] Bijalwan, A. 2013. Vegetation status of agroforestry systems in Tehri District of Garhwal Himalaya, India. Asian J. of Sci. And Technol. 4 (12): 11-014.

[13] Bijalwan, A., Sharma, C. M. and Kediyal, V.K. 2011. Socio-economic status and livelihood support through traditional agroforestry systems in and mountain agroecosystems of Garhwal Himalaya, India. Indian For. (9)1423-1430.

[14] Bijalwan, A., Sharma, C. M. and Sah, V. K. 2009. Productivity status of traditional agri silviculture system on northern and southern aspects in mid-hill situation of Garhwal Himalaya, Inda. J. For. Res. 20 (2) : 137-143.

[15] Borthakur, S.K., 1996. Wild Edible Plants in Markets of Assam, India, An Ethnobotanical Investigation, In: Jain, S.K. (Ed.), Ethnobotany in Human Welfare. Deep Publications, Shahadra, Delhi, pp: 31-34.

[16] Campbell, BM, Clarke, JM and Gumbo, DJ (1991). Traditional agroforestry practices in Zimbabwe. Agroforestry Systems 14:99-111.

[17] Dagar, J.C. and Tewari, J.C. 2016 Agroforestry research developments: anecdotal to modern science. In: Agroforestry Research Development Nova Publishers, New York. 5(2): 1-45.

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