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Review Article

GEI STUDY ON WHITE SANDALWOOD (SANTALUM ALBUM L) FROM THE ENVIRONMENT IN NEPAL AND INDIA

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A B S T R A C T

White Sandalwood (*Santalum album L.)* belongs to the family santalaceae which is most precious timber wood worldwide. Though it is wild species since ancient time of human civilization, now, it has become a domesticated culture in tropics and subtropics world. Indeed there are more than seventy species under the genus Santalum in the world but, Santalum album, an indigneous white sandal species is the best one in the globe. Its immense beneficial uses attracted the present days Scientist's to draw their special attention for the mass propagation of this precious timber plant around the globe as and where it is adapted. Keeping all these views in mind we have started a venture to undertake the adaptation problem and to study the environmental as well as edhapic factors from the gardens of Nepal and India. Seedlings were grown in different gardens of Nepal and India providing them uniform agronomical measures or their proper growth and development. All the Phenotypiccharacters viz plant height (cm), Branches per plant (no), basal girth (cm), leaf length (cm) and leaf breadth (cm) were critically studied in each garden year wise. It is mentioned here that six types of plant species were selected for its propagation in all those gardens. The types of plants have been mentioned in this text of the paper. From the experiment it is evident that very good responses towards growth and development though there was a variation in soil environment. The qualitative aspects were also studied from the forest garden of both the countries. In this case we followed the model as proposed by Comstock and Robinson (1952a) for enumerate the stability analysis as well as GEI interaction of the crop over the environments.

The aims and objectives of this study were to observe the pattern of growth and development of different types of the genus prevailing over the location. The GEI interaction data and their peculiarity over the location has been cited in this context.

INTRODUCTION

Sandalwood (White Sandal) is the fragrant heartwood of some species of genus *Santalum*. The widely distributed and economically important *Santalum* genus belongs to family Santalaceae, includes 30 genera with about 400 species, many of which being completely or partially parasitic (John,1947). The word Sandal has been derived from Chandana (Sanskrit), Chandan (Persian), Savtador (Greek) and Santal (French). There are references of Sandalwood in Indian mythology, folklore and ancient scripts. „Chandana" the Sanskrit name ascribed to *Santalum album* L. was known and used in India from the earliest historic times and is frequently mentioned in the ancient Sanskrit writings, some of which dated before Christian era.

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Kautilya"s Arthashastra (320 B.C.) considered Sandal as one of the important forest products to increase royal revenue. Charaka Sanhitha, the major text book of internal medicine in Ayurveda (300 B.C.) quotes uses of Sandal over 160 time in the entire text. In treatment of major diseases like fever, piles, hemorrhagic conditions, diabetes, dropsy, mental disorders, management of poisons & skin disorders widespread uses of sandal is seen. Susrutha Samhita (150 B.C.) a great text on Indian wisdom on surgical procedures, equally preferred sandal for the management of wounds. Sandal fumigation is indicated in warding off evils and organisms, which contaminate the wounds. Such fumigations hasten the wound healing & surgical wards remain aseptic. Dusting of wounds with sandal for early healing is common. In the Amarkosha (Lexicon 3rd or 4th Century A.D.) sandal is mentioned and it is said that „Vina-malayamanyathrachandanamvivarditha" [Majumdar, 1941]. The extraction and disposal of sandal came under the Forest Department in 1864 in Mysore state [Adkoli, 1977]. In Karnataka (formerly Mysore) the forest working plan

for sandal extraction were prepared for HunsurTalik in 1910, Heggadadevanakote in 1920 and Narasimharajapura in 1926. In 1871, the parasitic nature of sandal was reported by John Scott. Watt (1893) described the technique of raising sandal seedlings in tile pots in the nurseries and planting in the field. McCarthy (1899) first noticed the spike disease of sandal in Coorg. Brandis (1903) suggested that though sandal is a root parasite, it may derive part of its nutrition from the soil as well. Barber (1905) noted that haustoria formation occurred only on certain roots of sandal and not on all of them. This plant forms a non-obligate relationship with a number of host plants (Nagaveni& Vijayalakshmi,2004).

There is atleast 3 kinds of Sandal namely White Sandal (*Santalum album)* called "Sweta Chandana", Red Sandal (*Pterocarpus santalinus)* called "Rakta Chandana"and interior Sandal Ku-chandana (*Adenantherapavonina)*. These plants belong to different species and families and have different properties as evidenced from their synonyms. Sandal is a moderate sized evergreen large shrubs or small trees (*S. spicatum*) to tall trees of 12-15 m. in height (*S. album* in India and *S. paniculatum*in Hawaii) and the girth of 1.0 -2.4 m. (Sen Sarma, 1982). The species (*S. album)* is distributed from Indonesia in the West to Juan Fernandez Islands in the East and from Hawaiian Archipelago in the North (30o N) to New Zealand in the South (40o S). It is believed that Sandal was introduced to India from Timor in Indonesia (Shetty, 1977).

Ecologically sandal has adapted various agro - climatic and soil conditions for *in situ* regeneration with an exception of waterlogged areas and very cold places. In India, 8 Sandal growing areas have been identified as potential provenances of Sandal on the basis of population density, phenotypic characteristics, latitude, longitude and eco-climate (Jain *et al*., 1998). The provenances vary in climate and edaphic preference since they are located in different localities of South and Central India. The state of West Bengal is cited in the map of occurrence and distribution of *Santalum album* L. in India (Srinivasan *et al*., 1992).

MATERIALS AND METHODS

MATERIALS

Sandalwood seeds: Seeds of *Santalum album* L. were collected from Hirbundh mouza of Hirbundh Range under Bankura (South) Forest Division during the month of November-December and May-June of 2011 and 2012 for experimentation. Simultaneously, seeds of *S. album* were also procured from Institute of Wood Science and Technology, Bangalore in the month of February, 2012 for the same experimentation purposes.

1. **Chemicals :** Gibberellic acid (GA3)
2. **Apparatus:** Container, Markin cloth, Polypots, Hycopots**.**
3. **Miscellaneous:** Soil samples (for analysis), Sandalwood Samples (for oil and santalol content analysis), Sand, Bricks, Seive, FYM, Water, etc.
4. Meteorological Informations of Bankura District.

Table I Temperature regime (Degree Cel.) in Bankura, W.B, India.

Month	2016		2017		2018		2019	
	Max	Min	Max	Min	Max	Min	Max	Min
JAN	27	09	27	09	27	09	27	09
FEB	32	11	34	09	32	09	32	11
MAR	39	14	38	15	37	16	39	14
APR	43	20	42	19	38	18	43	20
MAY	44	24	45	22	43	21	44	24
JUN	39	24	37	22	41	23	39	24
JUL	38	24	37	25	35	25	38	24
AUG	35	23	34	24	35	24	35	23
SEP	34	24	36	24	35	22	34	24
OCT	34	16	35	20	34	18	34	16
NOV	32	11	32	13	32	16	32	11
DEC	32	11	32	13	32	16	32	11
TOTAL	**429**	**211**	**429**	**205**	**421**	**217**	**429**	**211**

Table II Monthly rainfall in the district of the site (Deg. Cel.), Bankura, WB

Month	Normal	2016	2017	2018	2019
JAN	17	20	03	07	16
FEB	12	13	40	15	12
MAR	19	07	09	04	19
APR	27	04	57	66	27
MAY	65	52	76	77	65
JUN	198	213	247	183	198
JUL	272	331	255	471	272
AUG	293	332	445	386	293
SEP	246	358	139	384	246
OCT	122	18	95	00	122
NOV	15	99	00	00	15
DEC	03	06	00	00	03
TOTAL	**1289**	**1453**	**1366**	**1687**	**1289**

Table III Temperature regime (Degree Cel.) in Nepal

MONTH	2016		2017		2018		2019	
	Max	Min	Max	Min	Max	Min	Max	Min
JAN	26	05	27	04	24	02	24	01
FEB	30	07	34	06	29	03	29	04
MAR	37	10	38	13	34	09	34	07
APR	41	20	38	09	35	12	35	11
MAY	42	24	39	20	40	18	40	17
JUN	37	24	35	18	38	20	38	21
JUL	36	24	34	17	32	22	32	21
AUG	33	23	31	16	31	23	31	23
SEP	32	24	33	15	30	22	30	24
OCT	31	16	32	14	29	21	29	21
NOV	30	11	30	12	26	19	26	18
DEC	27	10	26	08	22	02	22	02
Total	**402**	**198**	**397**	**152**	**370**	**172**	**370**	**170**

Table IV Monthly rainfall in the district of the site (Deg. Cel.), Nepal

MONTH	Normal	2016	2017	2018	2019
JAN	20	40	03	42	08
FEB	19	33	40	35	45
MAR	28	17	09	19	15
APR	42	09	57	11	62
MAY	69	182	76	184	81
JUN	299	211	247	214	252
JUL	292	539	355	541	359
AUG	339	412	445	412	449
SEP	366	438	139	476	143
OCT	222	118	95	129	104
NOV	105	29	10	43	51
DEC	203	96	00	101	00
Total	**2824**	**2124**	**1467**	**2207**	**1569**

Six types of this genus taken for the experiment

Pecularities were observed in leaf shape, leaf size, colour, thickness, texture and flowering seasons. The seadling planted in different forest gardens have been shown foliar variations. Leaves are opposite, and opposite decussate, sometimes show whorled arrangement. The leaf shape varies from lanceolate to ovate or elliptical (Kulkarni and Srimathi 1982). Two consipicuous types of white sandal trees are observed where from the seeds were collected in Hirbandh forest garden which are as follows:

Table II Morphogenetic peculiarities of *S album* L

S.No.	Characterstics	Observation-1	Observation-2
1st Type	Leaf shape	lanceolate	Ovate
2nd Type	Leaf Length	5.5cm	5.5cm
3rd Type	Leaf Width	1.7cm	2.7cm
4th Type	Leaf colour	Light green	Deep green
5th Type	Leaf thickness	Less thick	More thick
6th Type	Leaf texture	Less glossy	More glossy

METHODS

Statistical calculations done as follow by Sharma (1995) for the Genotypic Environmental Interaction analyses based on means: first, Comstock and Robin's Model, and second, Wricke's Models of Ecovalance.

Lay-out and Design: Randomized Block Design (RBD) Lay-out and design was followed as laid down by Panse and Sukhatme (2005).

Soil Test: As recommended by IARI Soil Testing Kits.

RESULTS AND DISCUSSION

The following data of the phenotopic characters were observed and tabulated In the following tables

1. Plant Height (cm) overaged over 5 samples per plot of each type for 6 types of white sandal plant*Santalum album* L.[Table no: 1.1]
2. Branches / plant (no) overaged over 5 samples per plot of each type for 6 types of white sandal plant *Santalum album* L. [Table no: 2.1]
3. Basal girth (cm)overaged over 5 samples per plot of each type for 6 types of white sandal plant *Santalum album* L. [Table no: 3.1]
4. Leaf length (cm)overaged over 5 samples per plot of each type for 6 types of white sandal plant *Santalum album* L. [Table no: 4.1]
5. Leaf breadth (cm)overaged over 5 samples per plot of each type for 6 types of white sandal plant *Santalum album* L. [Table no: 5.1]

Similarly all the tables [Table 1.2 to Table 5.7]towards anova for G*E, total for g, l and g*l, total y and g*y, total l*y, ANOVA for GxE interaction estimates of variance components and heritability .

Table 6 Soil tests reports and macronutrients (Soil Samples)

Location	PH	OC %	Available ammo. N_2	Available N (PPM)	Available K(PPM)	Available P(PPM)
Hetauda, Nepal	7.1	High	Medium	High	Very	Normal
Biratnagar, Nepal	6.9	High	Low	High	Very high	Blank
Bagaldhara, India	7.0	Medium	Low	Normal	High	Blank

Quality Assessment (oil content) of sandalwood

Quality of sandalwood depends on the oil and alcohol (Santalol) content of the heartwood. The oil content of the sandalwood very much dependable on the components available in the soil where the plant was grown in our case. In our case the oil content of sandalwood was estimated collecting wood samples from the stand/ stock of Hirbandh forest range office, Bankura south division, India and the standing stock wood samples from Hetauda and Biratnagar gardens in Nepal. These wood samples were analyzed in the institute of wood science and technology (IWST), Bangalore, India. The results show that the heartwood contents α-santalol=59.40% and β-santalol= 30.25% in Hirbandh, India and α-santalol= 60.1% and 59.9% ; β-santalol= 30.5% and 30.9% from the wood sample of Hetauda and Biratnagar, Nepal respectively (Das and Tah 2014). The quality of the heartwood of sandal have been cited in a table given below:

Table 7 Quality Assessment (oil content) of sandalwood

Sl.no	Name of Chemical	Content%
Hetauda	α- santalol	60.1%
	β-santalol	30.5%
	Total Santalol	90.6%
	Oil content	4.2%
Biratnagar	α- santalol	59.9%
	β-santalol	30.9%
	Total Santalol	90.8%
	Oil content	4.1%
Bagaldhara	α- santalol	59.40%
	β-santalol	30.25%
	Total Santalol	89.65%
	Oil content	4.0%

DISCUSSION

In this context, it has been found that the total replication value over the location was found to be greater in case of Biratnagar location than the second position location was Bagaldhara. In case of total g, l and gxl (table 1.2, 2.2, 3.2 4.2 and 5.2), it has been found that the location three was the highest adaptive zone but, location 1 and location 2 were the 2nd and 3rd position of locations. According the phenotypic data the plant height played an important major role. That's why we considered plant height as the constant phenotypic character in all cases. Considering all the characteristics features it has been summarized as follows:

Bagaldhara, India >Hetauda, Nepal> Biratnagar in regard to stem girth. But, in case of plant height it has been observed that Bagaldhara, India >Biatnagar, Nepal>Hetauda, Nepal.

owever, in context to the calculation of all the locations, there were a mixed model of tendencies in regard to growth and development at this stage. Indeed, after 20 to 25 years there might be a nice observations to complete each and every location but, Bagaldhara has a specific constant steady role for growth and development in a regular manner.

There are some relevant references on this aspect viz. Zhang and Zhou (2010) who worked on Salicylic acid in plant disease resistance over the locations. Bent *et al* (1994) worked on *Arabidopsis thaliana*for the repeat class of plant disease resistance genes and its establishment and variations over the locations. Once again Zipfel *et al* (2004) observed the bacterial disease resistance in *Arabidopsis thaliana.* Lawton *et al* (1996) enumerated the Benzothiadizole induces disease resistance. Bruce at el (2014) found out the new hypotheses on seed-to-seed growth and development on *Arabidopsis thaliana* and their physiological growth of patterns over the locations. Yetisen *et al* (2011) published a new assay study on pollen tube germination. Abbott and Gomes (1989) focused the population genetics structure and out-crossing root of *Arabidopsis thaliana*. Das (2013), Das and Tah(2014, 2015 and 2016) also observed the locational variation and the effect of different edaphic factors on white sandalwood in different forest garden of West Bengal.

Table 1.1 Plant height (m) over K=5 samples/plot for 6 types of white sandal in 3 locations for 2 years' plantation having 3 replications

T /R	Location – 1 [Hetauda]								Location – 2 [Biratnagar]								Location – 3 [Bagaldhara]							
	Year – 1				Year - 2				Year - 1				Year - 2				Year – 1				Year - 2			
	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ
1	5.0	7.7	7.5	20.2	10.0	12.0	11.1	33.1	3.8	4.9	5.9	14.6	3.8	4.0	5.3	13.1	10.0	10.0	12.0	32.0	7.0	14.0	1.0	22.0
2	7.0	8.0	8.4	23.4	11.0	12.4	11,5	34.9	3.9	4.3	5.7	13.9	33.5	4.3	5.9	13.7	12.0	12.0	11.0	35.0	11.2	13.7	9.0	34.0
3	7.0	3.0	4.5	14.5	10.5	11.8	12.0	34.3	3,8	4.6	5.6	14.0	3.3	4.9	5.2	13.4	10.0	9.0	10.1	29.1	18.0	11.3	1.07	30.37
4	6.5	5.5	6.4	18.4	10.4	11.5	12.3	34.2	4.1	4.1	5.9	14.1	4.0	3.9	5.0	12.9	7.0	12.0	14.0	33.0	14.3	15.2	11.0	40.5
5	6.0	6.3	7.2	19.5	10.7	11.9	12.4	35.0	4.2	5.0	6.0	15.2	3.9	4.5	5.5	13.9	6.0	10.7	8.0	30.7	10.0	4.9	16.9	31.8
6	7.0	6.9	7.1	21.0	11.3	12.0	10.8	34.1	3.5	5.2	6.1	14.8	4.1	4.4	5.3	13.8	7.0	6.0	8.0	21.0	18.6	13.6	9.8	42.0
Σ	38.5	37.4	41.1	117.0	63.9	71.6	70.1	205.6	23.3	28.1	35.2	86.6	22.6	26.0	32.2	80.8	52.0	65.7	63.1	180.8	79.1	72.7	49.67	201.17

$TR_1 = 279.4$,$TR_2 = 301.5$, $TR_3 = 291.37$, GT= 872.27

Tables >	1.2: Total for g, l and gxl			1.3: Total for y and gxy				1.4: Total for lxy		
Variety	L-1	L-2	L-3	Variety	Year-1	Year-2	Loc	Yr-1	Yr-2	Σ
A	TAL1= 53.3	TAL2=27.7	TAL3= 54.0	A	TAY1= 66.8	TAL2= 68.2	1	GT1= 117.0	GT2= 205.6	**T11= 322.6**
B	TBL1=58.3	TBL2 =27.6	TBL3= 69.8	B	TB Y1= 72.3	TBL2 = 83.4	2	GT3= 86.6	GT4= 80.8	**T12= 167.4**
C	TCL1= 48.8	TCL2=27.4	TCL3= 59.47	C	TC Y1= 57.6	TCL2= 78.07	3	GT5= 180.8	GT6= 201.17	**T13= 381.97**
D	TDL1= 52.6	TDL2=27.0	TDL3= 73.5	D	TD Y1= 65.5	TDL2= 87.6	**Σ**	**384.4**	**487.57**	**871.97**
E	TEL1= 54.5	TEL2=29.1	TEL3= 62.5	E	TE Y1= 65.4	TEL2= 80.7				
F	TFL1= 55.1	TFL2=28.6	TFL3= 63.0	F	TF Y1= 56.8	TFL2= 89.9				
Σ	**322.6**	**167.4**	**382.27**	**Σ**	**384.4**	**487.87**				

Table 2.1 Basal Girth of Plant (cm) over K=5 samples/plot for 6 types of white sandal in 3 locations for 2 years' plantation having 3 replications

T /R	Location – 1 [Hetauda]								Location – 2 [Biratnagar]								Location – 3 [Bagaldhara]							
	Year - 1				Year - 2				Year - 1				Year - 2				Year – 1				Year - 2			
	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ
1	30.0	34.0	16.0	80.0	48.0	58.0	66.0	172.0	9.1	11.5	13.0	33.6	14.0	22.0	16.0	52.0	80.3	66.1	42.0	188.4	10.8	6.5	4.3	21.6
2	36.0	25.0	27.5	88.5	80.0	52.0	80.0	212.0	8.4	16.0	11.1	35.5	17.0	25.0	20.2	62.2	9.8	16.0	15.2	41.0	9.8	18.6	3.5	31.9
3	10.0	29.9	25.9	64.9	60.0	82.5	68.5	211.0	11.6	10.9	11.9	34.4	15.0	26.0	24.5	65.5	7.6	50.0	15.8	73.4	7.8	9.2	4.8	21.8
4	32.0	39.0	38.7	109.7	42.0	72.0	48.0	162.0	11.9	11.8	11.6	35.3	14.5	17.0	25.7	57.2	48.6	52.3	58.0	158.9	3.7	19.6	18.6	41.9
5	26.0	40.0	45.5	111.5	72.0	70.5	77.5	220.0	11.0	8.4	8.4	27.8	16.0	21.0	23.5	60.5	36.3	42.9	18.8	98.0	17.3	14.8	19.3	51.4
6	36.5	44.5	39.5	120.5	60.0	66.5	59.5	186.0	13.0	10.5	9.1	32.6	16.0	27.0	27.5	70.5	33.2	21.0	9.8	64.0	15.4	13.2	18.0	46.6
Σ	170.5	211.5	193.1	575.1	362.0	401.5	399.5	1163.0	65.0	69.1	65.1	199.2	92.5	138.0	137.4	367.9	215.8	248.3	159.6	623.7	64.8	51.9	68.5	215.2

$TR_1 = 970.6$,$TR_2 = 1150.3$, $TR_3 = 1023.2$, GT= 3144.1

Tables >	2.2: Total for g, l and gxl of *S. album* L.			2.3: Total for y and gxy of *S. album* L.				2.4: Total for lxy of *S. album* L.		
Variety	L-1	L-2	L-3	Variety	Year-1	Year-2	Loc	Yr-1	Yr-2	Σ
A	TAL1= 252	TAL2=85.6	TAL3=21.0	A	TAY1=188.4	TAL2= 245.6	1	GT-1= 575.1	GT2= 1163.0	**T11= 1738**
B	TBL1= 300.5	TBL2= 97.7	TBL3=72.9	B	TB Y1= 165.0	TBL2= 306.1	2	GT3= 199.2	GT4= 367.9	**T12= 567.1**
C	TCL1= 275.9	TCL2= 99.9	TCL3=95.2	C	TC Y1= 172.7	TCL2= 298.3	3	GT5= 623.7	GT6215.2	**T13= 838.9**
D	TDL1= 271.7	TDL2= 92.5	TDL3=200.8	D	TD Y1= 303.9	TDL2= 261.1	**Σ**	**1398.0**	**1746.1**	**3144.1**
E	TEL1= 331.5	TEL2= 88.3	TEL3=149.4	E	TE Y1= 237.3	TEL2= 331.9				
F	TFL1= 306.5	TFL2=103.1	TFL3=110.6	F	TF Y1= 217.3	TFL2= 303.1				
Σ	**1738.1**	**567.1**	**838.9**	**Σ**	**1398.0**	**1746.1**				

Table 3.1 Branches/Plant (no) over K=5 samples/plot for 6 types of white sandal in 3 locations for 2 years' plantation having 3 replications

T /R	Location – 1 [Hetauda]								Location – 2 [Biratnagar]								Location – 3 [Bagaldhara]							
	Year - 1				Year - 2				Year - 1				Year - 2				Year – 1				Year - 2			
	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ
1	6	6	6	118	10	12	9	31	2	4	2	8	4	5	4	13	85	27	15	127	6	18	8	32
2	6	8	7	21	9	10	12	31	3	5	2	10	3	6	7	16	14	18	44	76	9	12	23	44
3	5	9	8	22	5	10	11	26	2	2	3	7	4	7	6	17	10	8	12	30	10	16	25	51
4	6	5	8	19	7	11	10	28	2	3	2	7	5	4	5	14	19	15	18	52	30	21	24	76
5	5	6	5	16	6	10	11	27	3	4	3	10	7	4	4	15	7	21	14	42	4	4	11	19
6	5	5	6	16	5	12	10	27	1	3	3	7	6	5	5	16	21	33	25	79	9	7	22	38
Σ	33	39	40	112	42	65	63	170	13	21	15	49	29	31	31	91	156	122	128	406	68	79	113	260

$TR_1 = 341.0$,$TR_2 = 357.0$, $TR_3 = 390.0$, GT= 1088.0

Tables >	3.2: Total for g, l and gxl			3.3: Total for y and gxy				3.4: Total for lxy		
Variety	L-1	L-2	L-3	Variety	Year-1	Year-2	Loc	Yr-1	Yr-2	Σ
A	TAL1= 49.0	TAL2= 31.0	TAL3= 159.0	A	TAY1= 153.0	TAL2= 76.0	1	GT1= 112.0	GT2= 170.0	**T11= 282.0**
B	TBL1= 52.0	TBL2= 26.0	TBL3= 120.0	B	TB Y1= 107.0	TBL2 = 91.0	2	GT3= 49.0	GT4= 91.0	**T12= 140.0**
C	TCL1= 48.0	TCL2= 24.0	TCL3= 81.0	C	TC Y1= 59.0	TCL2= 94.0	3	GT5= 406.0	GT6= 260.0	**T13= 666.0**
D	TDL1= 47.0	TDL2= 24.0	TDL3= 128.0	D	TD Y1= 78.0	TDL2= 118.0	**Σ**	**567.0**	**521.0**	**1088,0**
E	TEL1= 43.0	TEL2= 25.0	TEL3= 61.0	E	TE Y1= 68.0	TEL2= 61.0				
F	TFL1= 43.0	TFL2= 23.0	TFL3= 117,0	F	TF Y1= 102	TFL2= 81.0				
Σ	**282.0**	**143.0**	**666.0**	**Σ**	**567**	**521.0**				

Table 4.1 Leaf length (cm) over K=5 samples/plot for 6 types of white sandal in 3 locations for 2 years' plantation having 3 replications

T /R	Location – 1 [Hetauda]								Location – 2 [Biratnagar]								Location – 3 [Bagaldhara]							
	Year - 1				Year - 2				Year - 1				Year - 2				Year – 1				Year - 2			
	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ
1	5.4	6.1	6.0	17.5	8.0	8.2	9.0	25.2	5.5	7.0	6.5	19.0	8.0	8.0	9.1	25.1	9.0	6.0	8.0	23.0	8.0	9.0	8.3	25.3
2	5.3	5.2	6.1	16.6	9.0	8.4	8.5	25.9	5.6	6.2	6.0	17.8	8.5	8.5	8.7	25.7	6.0	7.0	9.0	22.0	4.0	8.0	7.0	19.0
3	5.5	6.4	5.0	16.9	8.5	8.0	7.0	23.5	6.5	6.3	6.0	18.8	8.8	8.4	9.0	26.2	8.0	7.0	6.0	21.0	8.0	9.0	8.2	25.2
4	6.0	6.3	7.0	19.3	7.0	8.2	8.0	23.2	7,0	7.5	7.0	21.5	8.4	8.7	9.0	26.1	7.0	5.0	7.0	19.0	7.6	8.3	8.1	24.0
5	6.3	5.7	8.0	20,0	8.3	8.1	8.4	24.8	7.1	7.1	6.9	21.1	8.9	8.9	9.3	27.1	8.0	8.2	8.3	24.5	9.0	8.4	6.6	24.0
6	5.8	5.5	7.2	18.5	8.2	8.3	8.3	24.8	7,0	6.8	7.0	20.8	9.0	9.0	9.7	27.7	5.0	7.0	7.3	19.3	8.0	7.4	7.0	22.4
Σ	34.3	35.2	39.3	108.8	49.0	49.2	49.2	147.4	38.7	40.9	39.4	119.0	51.6	51.5	54.8	157.9	143.0	40.2	45.6	128.8	44.6	50.1	45.2	139.9

$TR_1 = 361.2$,$TR_2 = 267.1$, $TR_3 = 273.5$, GT= 901.8

Tables >	4.2: Total for g, l and gxl			4.3: Total for y and gxy				4.4: Total for lxy		
Variety	L-1	L-2	L-3	Variety	Year-1	Year-2	Loc	Yr-1	Yr-2	Σ
A	TAL1= 42.7	TAL2= 44.1	TAL3= 48.3	A	TAY1 = 59.5	TAL2= 75.6	1	GT-1= 108.8	GT2= 147.4	**T11= 256.2**
B	TBL1= 42.5	TBL2 = 43.5	TBL3= 41.0	B	TB Y1 = 56.4	TBL2= 70.6	2	GT3= 119.0	GT4= 157.9	**T12= 276.9**
C	TCL1= 40.4	TCL2= 45.0	TCL3=46.2	C	TC Y1= 56.7	TCL2= 74.9	3	GT5= 128.8	GT6= 139.9	**T13= 268.7**
D	TDL1= 42.5	TDL2= 47.6	TDL3=43.0	D	TD Y1 = 59.8	TDL2= 73.3	**Σ**	**356.6**	**445.2**	**801.8**
E	TEL1= 44.8	TEL2= 48.2	TEL3= 48.5	E	TE Y1 = 65.6	TEL2= 75.9				
F	TFL1= 43.3	TFL2= 48.5	TFL3=41.7	F	TF Y1 = 58.6	TFL2= 74.9				
Σ	**256.2**	**276.9**	**268.7**	**Σ**	**356.6**	**445.2**				

Table 5.1 Leaf breadth (cm) over K=5 samples/plot for 6 types of white sandal in 3 locations for 2 years' plantation having 3 replications

T /R	Location – 1 [Hetauda]								Location – 2 [Biratnagar]								Location – 3 [Bagaldhara]							
	Year - 1				Year - 2				Year - 1				Year - 2				Year – 1				Year - 2			
	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ	I	II	III	Σ
1	2.5	3.9	2.5	8.9	2.8	4.1	4.2	11.1	2.3	2.9	2.6	7.8	3.4	3.0	4.1	10.5	2.4	2.5	3.6	8.5	2.4	2.5	2.3	7.2
2	2.6	2.5	2.6	7.7	3.1	3.8	4.1	10.9	2.4	2.5	2.7	7.6	3.0	3.4	4.0	10.4	2.8	3.2	2.4	8.4	2.2	2.5	2.9	7.6
3	2.5	3.0	2.8	8.3	3.5	4.0	4.4	11.9	2.2	2.4	2.9	7.5	3.1	3.6	4.0	10,7	2.7	2.3	2.1	7.1	3.8	3.6	3.3	10.7
4	2.7	2.6	2.7	8.0	3.3	3.9	4.5	11.7	2.5	2.0	2.0	6.5	3.3	3.5	3.9	10.7	2.6	3.1	3.2	8.9	4.1	7.6	3.9	15.6
5	2.5	2.6	2.4	7.5	3.4	3.7	4.6	11.7	2.4	2.2	2.1	6.7	3.2	3.5	3.7	10.4	3.9	3.9	2.0	9.8	3.3	3.1	2.8	9.2
6	2.7	2.5	2.8	8.0	3.7	4.0	4.9	12.6	2.1	2.1	2.4	6.6	3.5	3.7	3.9	11.1	4.3	4.1	2.8	11.2	2.6	2.5	2.1	7.2
Σ	15.5	17.1	15.8	48.4	19.7	23.5	26.7	69.9	13.9	14.1	14.7	42.7	19.5	20.7	23.6	63.8	18.7	19.1	16.1	53.9	18.4	21.8	17.3	57.5

$TR_1 = 105.7$,$TR_2 = 116.3$, $TR_3 = 114.2$, GT= 336.2

Tables >	5.2: Total for g, l and gxl			5.3: Total for y and gxy				5.4: Total for lxy		
Variety	L-1	L-2	L-3	Variety	Year-1	Year-2	Loc	Yr-1	Yr-2	Σ
A	TAL1= 20.0	TAL2= 18.3	TAL3= 15.7	A	TAY1= 25.2	TAL2= 28.8	1	GT-1= 48.4	GT2= 69.9	**T11= 118.3**
B	TBL1= 18.6	TBL2= 18.0	TBL3= 16.0	B	TB Y1= 23.7	TBL2= 28.9	2	GT3 42.7	GT4= 63.8	**T12= 106.5**
C	TCL1= 20.2	TCL2= 18.2	TCL3= 17.8	C	TC Y1= 22.9	TCL2=33.3	3	GT5= 53.9	GT6= 57.5	**T13= 111.4**
D	TDL1=19.7	TDL2= 17.2	TDL3= 24.5	D	TD Y1= 23.4	TDL2= 38.0	**Σ**	**145.0**	**191.2**	
E	TEL1= 19.2	TEL2= 17.1	TEL3= 19.0	E	TE Y1= 24.0	TEL2= 31.3				
F	TFL1= 20.6	TFL2= 17.7	TFL3= 18.4	F	TF Y1= 25.8	TFL2= 30.9				
Σ	**118.3**	**106.5**	**111.4**	**Σ**	**145.0**	**191.2**				

Table 6 ANOVA for GXE interaction

S.V.	df	SS	MSS	Expectations
Rep(r)	r-1	RSS	RMS	--
Loc (l)	l-1	LSS	LMS	---
Year(y)	y-1	YSS	YMS	---
L x y	(l-1)(y-1	LYSS	LYMS	---
Gen (g)	(g-1)	GSS	GMS	$\Delta^2 e+r\delta^2gly+ry\delta^2gl+rl\delta^2gy+rly\delta^2eg$
G x l	(g-1)(l-1)	GLSS	GLMS	$\Delta^2 e+r\delta^2gly+ry\delta^2gl$
G x y	(g-1)(y-1)	GYSS	GYMS	$\Delta^2 e+r\delta^2gly+ry\delta^2gl+rl\delta^2gy$
Gxlxy	(g-1)(l-1)(y-1	GLYSS	GLYMS	$\Delta^2 e+r\delta^2gly$
Error(e)	(r-1)(gly-1)	ESS	EMS	$\Delta^2 e$
Σ				

Table 7 ANOVA for GXE interaction (calculated value)

S.V.	df	MSS				
		X_1	X_2	X_3	X_4	X_5
Rep(r)	2	3.399	237.09	17.34	76.79	0.875
Loc (l)	2	341.74	10433	2068.71	-785.68	0.97
Year(y)	1	99.13	1121.97	19.59	-1504.72	19.76
L x y	2	62. 50	6952.32	345.68	795.78	2.90
Gen (g)	6	4.116	110.03	83.27	-314.23	0.50
G x l	12	2.932	284.57	61.47	158.61	0.65
G x y	6	6.421	409.41	88.47	315.90	0.94
Gxlxy	12	22.166	219.201	119.08	-153.97	0.87
Error(e)	42	4.900	69.45	58.88	-1.96	0.39
Σ	**85**					

Table 8 Estimates of variance components and h2

Estimate	X_1	X_2	X_3	X_4	X_5
$\delta^2 g$	-1.52	-44.61	-10.32	-35.26	-0.10
$\delta^2 e$	4.11	69.45	58.88	-1.96	0.39
$\delta^2 gl$	-3.20	10.89	-9.60	52.09	-0.03
$\delta^2 gy$	-1,74	21.13	-3.40	52.20	0.007
$\delta^2 gly$	5.75	49.19	20.06	-50.67	0.160
δ^2 p	-0.59	-6.50	-89.46	-8.82	-0.018
h^2_{BS}	2.54	6.86	2.07	3.99	6.053

Comment

GEI model is used specially for evaluating the germplasm whether it is adapted in location or not? In this case we have clearly evidence and noted the potentiality of location as per their capability on higherarchial basis. The environmental fluctuation has also been observed and mention hereunder.

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