PLASTOCHRON INDEX, LEAF PLASTOCHRON INDEX AND HAUN INDEX IN AGROECOLOGICAL STUDIES OF *ALLIUM HOOKERI* THW. ENUM DURING KHARIF SEASON

BIMOLA DEVI NAOREM [1], SANGBANBI DEVI NINGTHOUJAM [2], RAGHUMANI SINGH SERAM [3].
Research Scholar, C.T. University, Ahmedabad, Gujarat [1],
Associate Professor, Department of Botany, Imphal College, Imphal, Manipur, India [2],
Associate Professor, Department of Botany, United College, Chandel, Manipur, India [3]

Abstract - *The potential of Haun Index, Plastochron index and Leaf plastochron index in exploration to the status of crop with relation to the physiology, growth and development of agriculturally important in Allium hookeri Thw. Enum (Manipuri – Maroi Napakpi), a perennial green leafy herbal spice for the kharif season of the two consecutive cropping years was investigated. The occurrences of critical developmental events in growing plant population including the sink, source and transition status of leave, duration of sink to source, transition process and the number of leaves under transition at a given time were vividly analysed.*

Index Terms – *Allium hookeri, perennial, Haun index, Plastochron index, Leaf plastochron index, sink, source, transition.*

I. INTRODUCION

It is well known fact that leaf elongation, epidermal and palisade growth, expansion of lamina surface, relative elemental rates of lamina growth and other aspects in a plant are the developmental processes and investigated as a function of the leaf plastochron index (LPI) [1]. Plastochron index (PI), a continuous developmental scale based on leaf number, is a key feature in understanding the physiology, growth and development of agriculturally important and current model plant species [2,3]. Further, all above ground organs in a plant usually originate from the shoot apical meristem (SAM) [4]. SAM produces lateral organs in a regular spacing (phyllotaxy) and regular timing i.e. the plastochron; thus convergent the idea of many biologist [5,6].

Allium hookeri Thw Enum of Liliaceae family, locally known as "Maroi napakpi" is an important green leafy spice widely used as herbal spice and medicinal purpose. The plant has hardly any bulb instead much reduced underground rhizome produces fibrous roots [7]. The leaves are thick evergreen, linear with prominent midribs, basal leaves membranous and shorter than the tall sub trigonous escape. Edible parts are the thick, flat, green leaves with prominent midrib and white fibrous roots [8].

Plants grown under uniform condition normally attained the morphological and physiological development status in leaves of same plastochron age. Consequently plastochron index permits the adjustment of plant development and metabolism for age effects. Further, the plastochron index inevitably used to demonstrate that the rate of net photosynthesis, dark respiration, enzyme production, C^{14} distribution [9,10]. Furthermore plastochron index extended the use of morphological indices to semi deterrent nature species [11]. However, plastochron index in *Allium hookeri* have not yet been fully investigated. Henceforth, the present work have undertaken with the objectives: to determine leaf length to test the effectiveness of the plastochron index, leaf plastochron index, Hauns index etc. during kharif season.

II. MATERIALS AND METHODS

The experiment was conducted on farmer's experimental field at Moirangkampu Sajeb Loukol in Imphal East district, Manipur. (Latitude $23^0 56'$N to $25^0 44'$N and $93^0 02'$E to $94^0 47'$E, altitude 790 m above the M.S.). Detailed observation on leaf emergence, leaf length and sequences of leaves of *Allium hookeri* were conducted when crop growth had been achieved but main leaves had not fallen during kharif season of cropping year 2014 and 2015 respectively.

Meteorological data were collected from Imphal International Airport, Imphal and ICAR, Lamphelpat, Imphal, the nearest meteorological stations from the experimental field.

Experiment

Allium hookeri, local variety, was planted at 1st week of June each year at a spacing of 25 × 25 cm plant to plant and row to row. Plots of the experimental field were 1.25×1.25m and arranged in a randomized block design with three replications. Irrigation was supplied when needed to cope water stress to the planting test crop. No insecticides and fungicides were applied but manual weed control was practiced althroughout the season.

Field records

Twenty plants were randomly marked within each sub plot to record the main leaf length and number. Measurements were taken daily althroughout the investigation period.

The choosen leaves represented the full ranges of development from extremely young to fully mature lamina. The lengths of leaves were recorded directly and the plastochron index and other requirement were computed using generalized formulae.

Haun's index (HI), an observational developmental index based on relative proportion of leaf lamina and average maximum length, was determined following Haun [12].

$$HI = (n-1) + Ln/(Ln-1) \quad (1)$$

Where, n was the number of leaves that have appeared on the shoot.

Ln-1 was the blade length of the penultimate (subtending) leave.

Ln was the blade length of the youngest expanding leaf that is emerging from the sheath of the penultimate leaf.

The Plastochron index (PI) was calculated by using the formula of Erickson and Michelini [2]

$$PI= n+(\ln L_n-\ln R)/\ln L_n - \ln L_{n+1} \quad (2)$$

Where, L_{n+1} was the length (mm) of a leaf or organ just shorter than R mm

L_n was the length of the next leaf that was slightly longer than R

n was the serial number of leaf/organ for which PI is being calculated

R was the reference length of organ or leaf.

A reference length of 30 mm was found to be appropriate for the present test species.

The PI was therefore equivalent to the distance in time between two successive leaves reaching 30 mm.

The Leaf Plastochron Index (LPI) was determined by using the formula -

$$LPI = PI - a \quad (3)$$

Where, "a" was the serial number of the chosen leaf

PI was the plastochron index

The daily thermal time (THt), the accumulation of temperature from crop emergence (first visible leaf tip stage) was calculated using the formula

$$THt = [(Tmax+Tmin)/2 - Tb] \quad (4)$$

Where, Tmax was the daily maximum air temperature, Tmin, the daily minimum air temperature and Tb the base temperature of 0^0C. [13,14]

The number of days per increment in LPI (LPI_d) was calculated by using the equation

$$LPI_d =(Ln_i-Ln_o)/d \quad (5)$$

Where, Ln_o was the first measured LPI of Ln

Ln_i was the second measured LPI of Ln

d was the number of days between measurements

Plastochron ratio, "a", the increases of a single organ during plastochron was determined by using formula following Richards [15]

$$a=Ln/(Ln+1) = LOn/LOn+1 \quad (6)$$

Erickson [16] pointed out that the ratio of Ln/Ln+1 was introduced the variable "a" termed plastochron ratio by Richards [15] and reiterated this relative plastochron rate of elongation in their original article the natural log of "a" symbolized by "ρ" represents the relative plastochron rate of leaf elongation.

Thus ρ= Natural log "a" (7)

Where, a was the plastochron ratio.

Data analysis

All observed information during the investigation was recorded and data were analyzed statistically.

III. RESULTS AND DISCUSSION

Haun index of *Allium hookeri* for kharif season of 2014 and 2015 was presented in Table 1(a) & 1(b). The validity of the Haun's index i.e. $0 \leq Ln/Ln \leq 1$, were accessed, examined and proved the validity {Table 1 (a) & (b)}.

The finding highlight the leaf primordium development was related to plastochronic age. In this connection Hauns index and the planstochron index in a study on seedlings of *Triticum aestivum* subjected to root stress induced by high resistance to penetration through the soil, determined that high resistance soil reduced rates of the short apex and leaf development but did not appear to have immediate effects on the pattern of development of newly initiated phytomers. The rate of leaf primordium development and associated node was related to plastochronic age. Effects on developmental patterns were first detected during the second plastochron of development. The ontogenic pattern of leaf elongation was affected during the next few plastochrons preceding leaf appearance [17].

The pattern of leaf appearance for *Allium hookeri* (local type) was consistent during kharif season of the both cropping years i.e. 2014 and 2015. In general, a leaf tip (n) became visible only after the matured leaf n-2 attends its maximum height. This indicated that leaf 'n-2' {(Figure 1(a) & Figure 1(b)} had reached its maximum length only when leaf tip of leave 'n' emerged. This is manifested in Figure 1(a) for cropping year 2014 and 1(b) for the cropping year 2015. Further, it is evident by plotting the leaf length against calendar days, thermal time and LPI {Figure 2(a) and Figure 2 (b)}. Then the observed regression accord Y=15.16 +13.26x with r^2 = 0.98 during 2014, and Y= 4.76 +13.09x with r^2 = 0.98 for 2015 and computed regression equation Y=15.57 + 0.49x with r^2 = 0.98 during 2014, and Y= 8.05 + 0.51x with r^2 = 0.98 for 2015 was accorded for corelation regression with leave length and GDD {Figure 3 (a) & (b) and Figure 4 (a) & (b)}. However, in case of leaf emergence, the pattern appeared to be independent of both the leaf that was emerging and attend its maximum length {Figure1 (a) and 1(b)}. In the present case, during the cropping season, 2014, the 6th leaf for that period of observation from the day of planting achieved its maximum height only when the 4th leaf emerged. In other words, the 6th leaf emerged only when the 4th leaf attend its maximum height in the test season (Figure 1(a)}. Thus it is evident that plastochron index exhibit better elucidation than that of calendar date in chronological studies of plant growth and development. During the cropping year 2015, 15th leaf emerged only when the 13th leaf reached its maximum length conversely 13th leaf reached its maximum length only when the 15th leaf had emerged in test kharif season {Figure1(b)}. The result clarified the existence of consequential scale of plastochron index on growth and development of a plant. The observed pattern was in agreement with the results reported in Zaid season of *Allium hookeri* [18]

Thus, for this genotype of *Allium hookeri* there were always two visible leaves expanding at the same time until the attainment of maximum length of leaf of the next to penultimate leaf. Hence leaf expansion takes 2 plastochron. However, this plastochron differs from wheat, where only one leaf is usually expanding [19].

The plastochron index and leaf plastochron index (LPI) of all the selected plants was worked out [20,2] thus substantiate the growth of the plants and authenticate the different status of growth and development of leaves. The PI ranges from 2.48 to 24.37 and 2.56 to 24.43 during kharif season of cropping years 2014 and 2015 respectively (Table 2).

The leaf plastochron index (LPI) accord -0.35 in minimum and 23.37 in maximum for the cropping year 2014 and for cropping year 2015, the minimum measured leaf plastochron index (LPI) was -0.36 and the maximum was 23.43{Table 3(a) and 3(b)}. The finding was in agreement with that of Ferris et.al. [21]. Further, the finding indicates that a new allium leaf forms from the encased SAM (Shoot Apical Meristem) and eventually emerges from the leaf sheath of the preceding leaf. The finding was in corroborative with the results of Itoh et.al. [22].

Regarding sink, transition and source, the LPI values vividly evince the status of leaves by incorporation with administering and dispensation of chemicals viz. 0 – 0.4 implies sink, 0.41 – 2 denotes transition and above 2 connotes source. Thus authenticated the existence of sink, transition and source independently to all observed leaves of plants in all the growing period of the seasons for both cropping years 2014 and 2015 {Table 3(a) & 3(b)}. Predominantly in average, in a tiller of the present test crop having 14 leaves, 1-2 leaves categorized to sink, 1-2 leaves in transition and 11 leaves classified under source {Table 3(a.1) and Table 3 (b.1)}. The findings emphasized the congruous appropriateness of LPI in assigning the growth of the plant with relation to status of the embodied chemicals within the leaves of the test crop. Further the investigation highlight the establishment of senescence in the growth and development of leaves of test crop when leaves procured LPI value of 9, the leave appearances to senescence stage even though they actively involving to activities of source to transition. Eventually, the finding evidence the senescence stage of leaves normally codified after acquiring LPI 9 and onwards, correspondingly the appearance of leaf changes from green to brown indicating the function of source-sink relationship within leaves of the tillers of the test crop. The finding was in accordance with the exhibition of allocations and transformation of chemicals in plant leaves [23,24,25,26,27]. Regarding agriculturally importance, the LPI values, over 6 indicates the right stage for harvesting of productive matured leaves by removing individual leaf from each tiller of a hill and from all hills of the field. Keeping leaves over LPI value of 9 alarmingly warned to the producers or farmers, not to underestimate the economic threshold of harvesting the test crop in maintaining the prime task of serialization of harvesting viz 1st, 2nd, 3rd till 26th harvesting of the test crop in the season as being the leaves approaches to critically senescence.

In this connection many disciplines of plantation and production have long been interested in monitoring leaf age for individual plants [28] and Leaf life span for many species [29,30]. Since harvesting of the test crop was practiced by removing only the matured leaves from each tillers of the hill and from all hills of the field comprising 26 times of the test season the role of LPI toward growth, development and production of test crop was highly significant.

Table 4 revealed the Plastochron ratio ranges from 4.67 to 38.33 for 2014 crop season and 5.63 to 29.75 for 2015 crop seasonconfirming the central tendency of yearly mean from 5.15 to 34.04 with mean from 19.60.

Further, Table 4 displayed the Plastochron rate of elongation (ρ) of the test crop with values ranges from 1.54 to 3.65 in kharif for 2014 and 1.73 to 3.39 in kharif for 2015 crop seasons verifying the convergent range from 1.63 to 3.52 with a mean of 2.58. Table 5 demonstrate the number of days per increment in LPI of test crop, *Allium hookeri* ranges from 0.15 to 0.19 for kharif seasons in both 2014 and 2015 cropping years exhibiting the numbers of days per increment never reached 1 and fluctuate in lesser degree. The meteorological parameters for both 2014 and 2015 cropping years are shown in Figure 5(a) & Figure 5(b).

The present finding evidence that the plastochron works including PI, LPI, PR, PR etc. of *Allium hookeri* have its uniqueness in adding new information to the vast ocean of knowledge of plant sciences and provides a new room for further investigation to different area of their applicability to applied sciences like post harvest, yield, yield parameters, agronomical techniques, environmental resources, the shoot, plant and other plastochron based research works. The finding also indicates the plastochron index of the *Allium hookeri* under non-adverse environmental conditions and subjected to enhancement of adequate management to development (plastochron) and production of leaves and tillers. Thus explains why agronomic practices of the green leafy herbal test spices (Allium) production needs more attention for more production of fresh leafy spices

Table 1 (a). Determination of Haun's Index of *Allium hookeri* for kharif season of cropping year 2014.

Years and season	n	L_n	L_{n-1}	n-1	L_n/L_{n-1}	HI_n	Remarks
	2	10	83	1	0.12	1.12	
	3	8	93	2	0.09	2.09	
	4	15	115	3	0.13	3.13	
	5	10	97	4	0.10	4.10	
	6	6	115	5	0.05	5.05	
	7	12	104	6	0.12	6.13	
2014, Kharif	8	11	100	7	0.11	7.11	$0 \leq L_n/L_{n-1} \leq 1$ are True
	9	5	94	8	0.05	8.05	
	10	15	70	9	0.21	9.21	
	11	6	97	10	0.06	10.06	
	12	14	82	11	0.17	11.17	
	13	10	97	12	0.10	12.10	
	14	5	98	13	0.05	13.05	
	15	16	96	14	0.17	14.17	
	16	8	92	15	0.09	15.09	
	17	10	110	16	0.09	16.09	
	18	5	108	17	0.05	17.05	
	19	10	113	18	0.09	18.09	
	20	5	121	19	0.04	19.04	
	21	8	113	20	0.07	20.07	
	22	4	121	21	0.03	21.03	
	23	12	98	22	0.12	22.12	
	24	3	115	23	0.03	23.03	

Haun's Index, $HI = (n-1) + L_n/L_{n-1}$ where, $0 \leq L_n/L_{n-1} \leq 1$

Table 1 (b). Determination of Haun's Index of *Allium hookeri* for Kharif season of cropping year 2015.

Years and season	n	L_n	L_{n-1}	n-1	L_n/L_{n-1}	HI_n	Remarks
	2	13	87	1	0.15	1.15	
	3	5	110	2	0.05	2.05	
	4	12	84	3	0.14	3.14	
	5	6	80	4	0.08	4.08	
	6	11	84	5	0.13	5.13	
	7	2	88	6	0.02	6.02	
	8	10	86	7	0.12	7.12	
	9	13	127	8	0.10	8.10	
	10	8	96	9	0.08	9.08	
2015, Kharif	11	16	90	10	0.18	10.18	$0 \leq L_n/L_{n-1}$
	12	10	100	11	0.10	11.10	≤ 1 are True
	13	5	94	12	0.05	12.05	
	14	8	85	13	0.09	13.09	
	15	14	104	14	0.13	14.13	
	16	7	117	15	0.06	15.06	
	17	12	80	16	0.15	16.15	
	18	4	99	17	0.04	17.04	
	19	8	97	18	0.08	18.08	
	20	10	105	19	0.095	19.095	
	21	4	119	20	0.03	20.03	
	22	9	110	21	0.08	21.08	
	23	10	116	22	0.09	22.09	
	24	5	118	23	0.04	23.04	

Haun's Index, $HI = (n-1) + L_n/L_{n-1}$ where, $0 \leq L_n/L_{n-1} \leq 1$

Figure1(a). Graphical presentation of *Allium hookeri* growth in leaf length (mm) against time for Kharif season of cropping year 2014 (from L1 -L24)

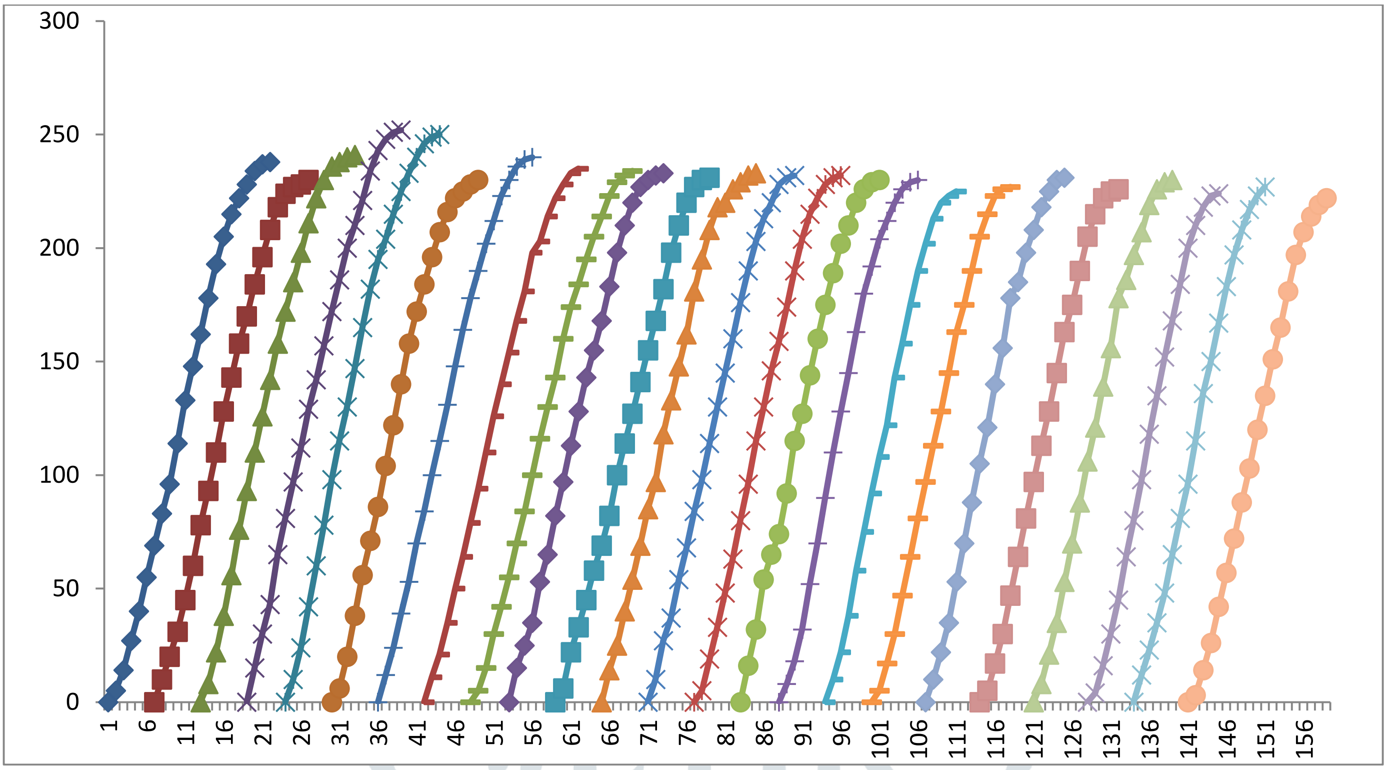


Figure 1(b). Graphical presentation of *Allium hookeri* growth in leaf length (mm) against time for Kharif season of cropping year 2015 (from L1 -L24)

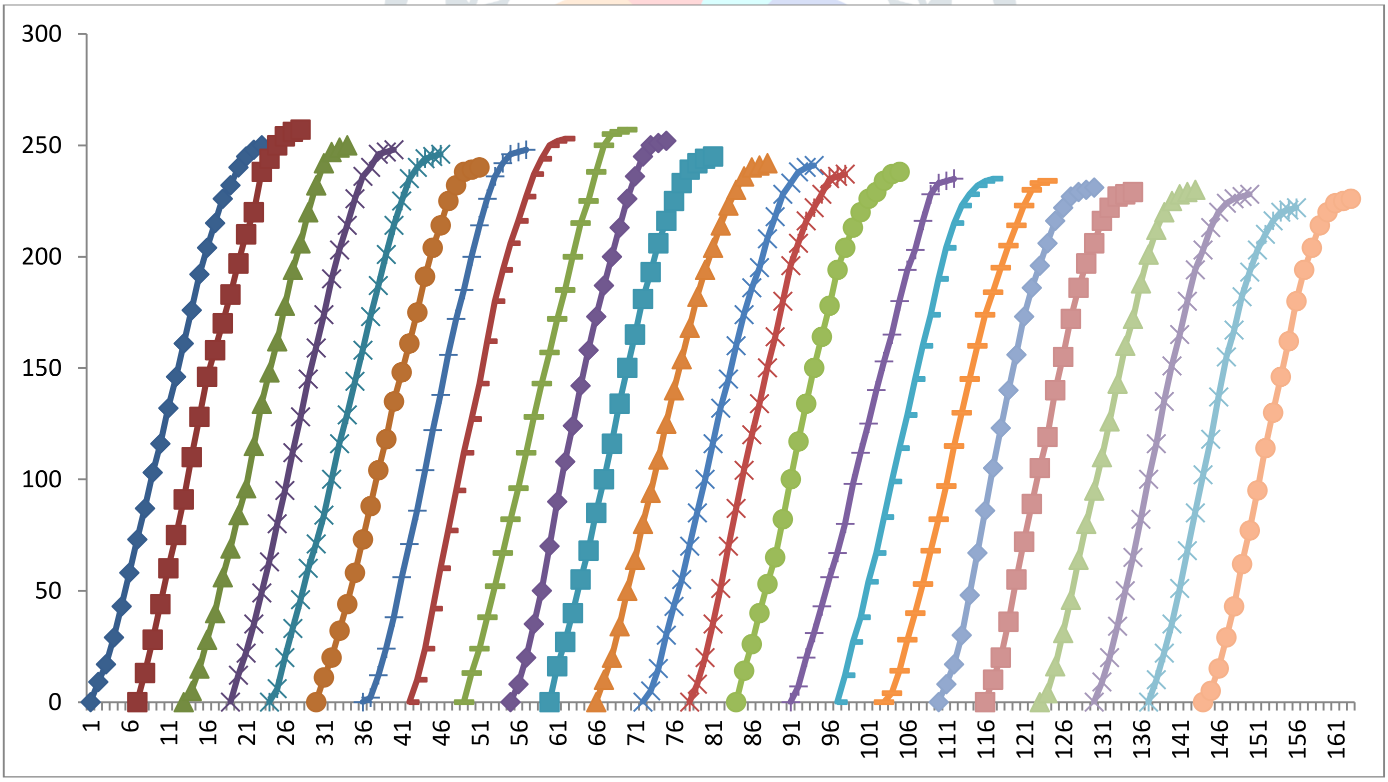


Figure2(a). Graphical presentation of (i) leaf length against calendar days (ii) leaf length against thermal time (GDD) (iii) Leaf length against LPI for *Allium hookeri* for kharif season of cropping year 2014.

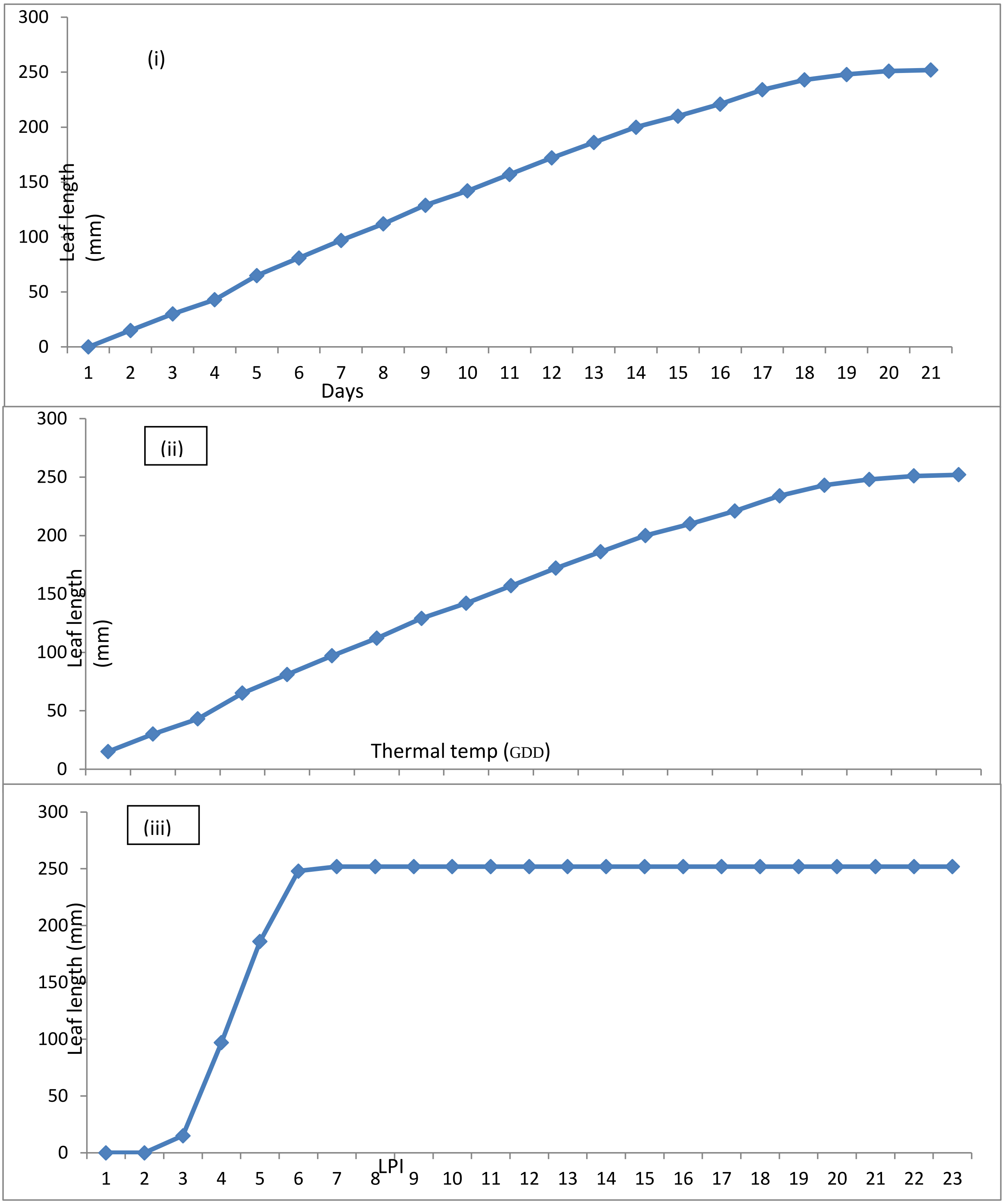
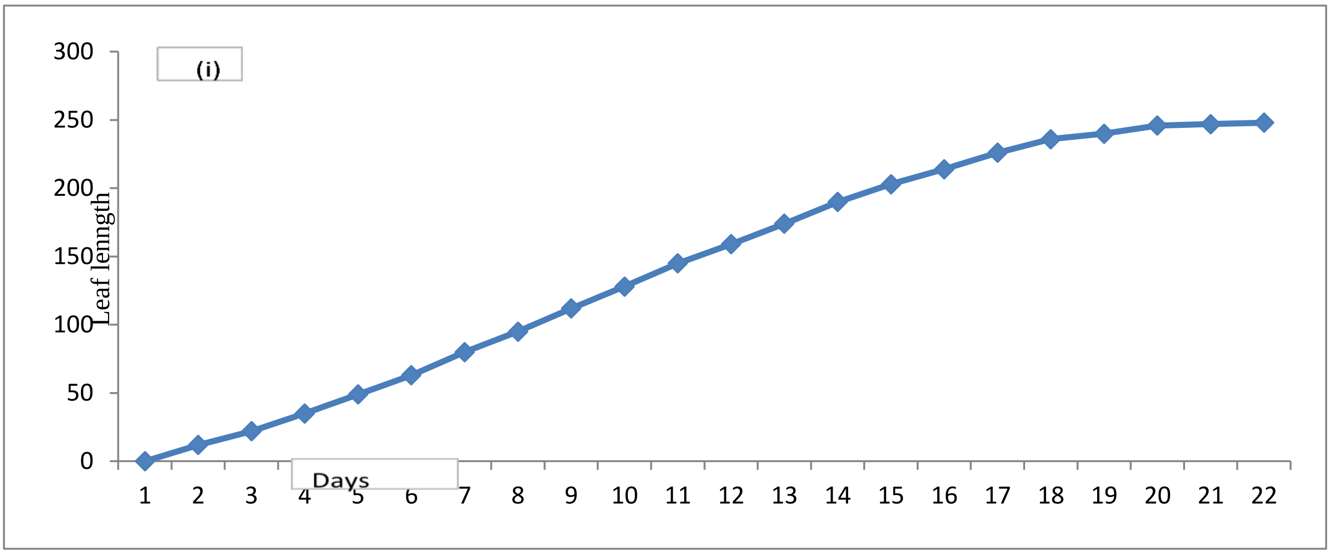
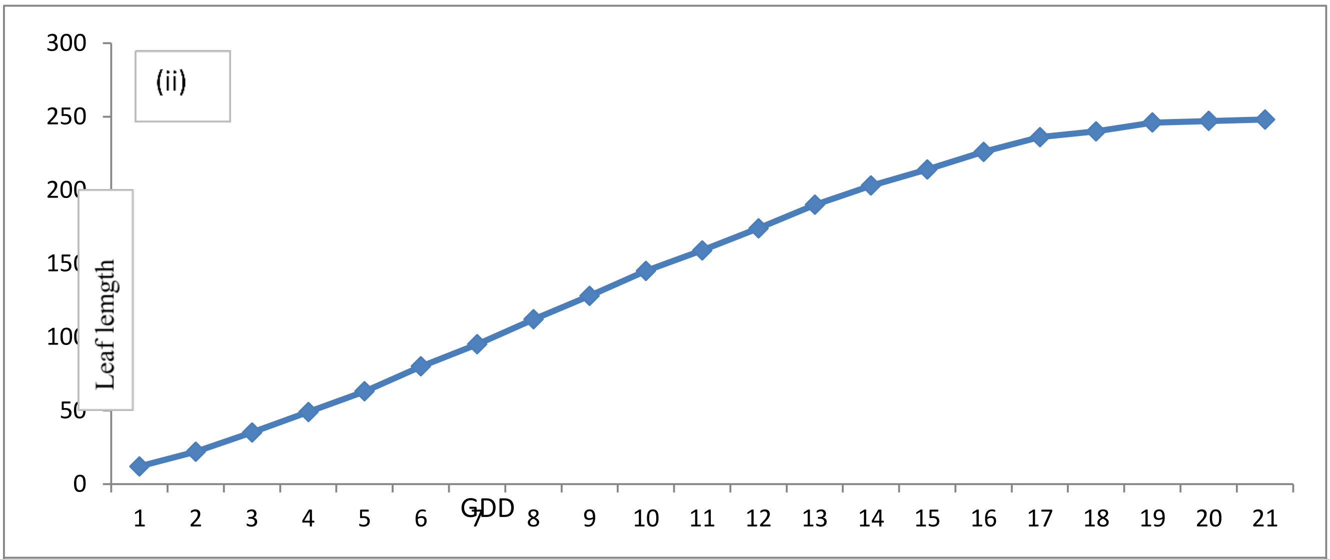


Fig.2(b). Graphical presentation of (i) leaf length against calendar days (ii) leaf length against thermal time (GDD) (iii) Leaf length against LPI for *Allium hookeri* for kharif season of cropping year 2015.





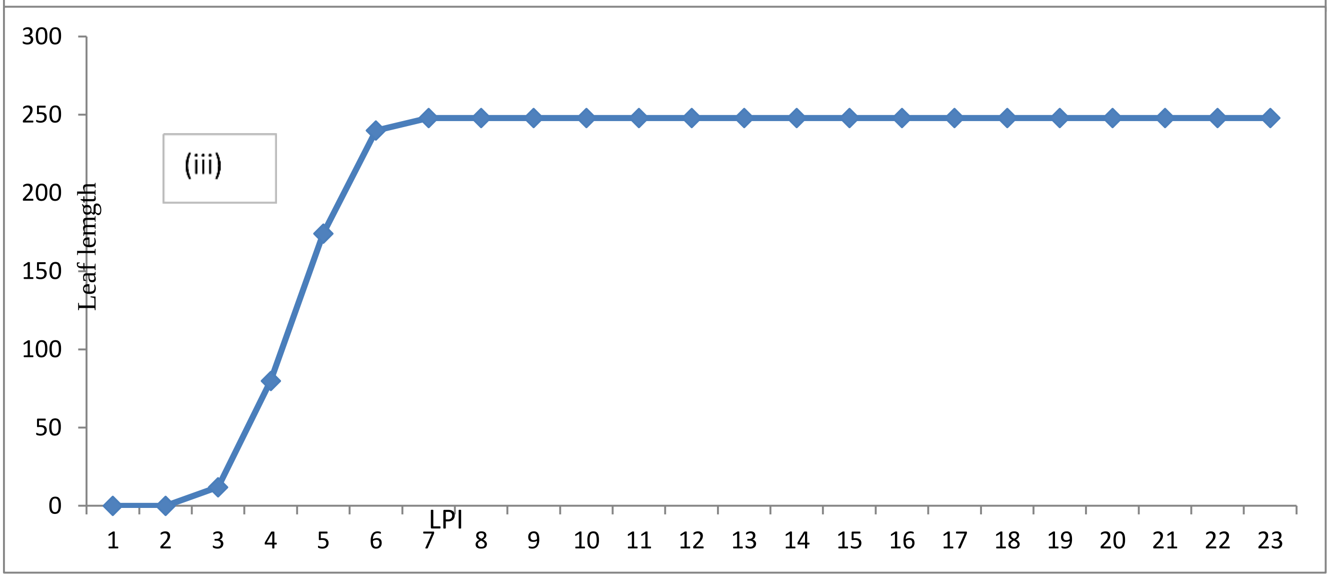


Table 2. Plastochron index (PI) of *Allium hookeri* for the crop season, kharif during cropping year 2014

Years				Remarks
2014		2015		
Leaves	PI	Leaves	PI	
L2	2.48	L2	2.56	
L3	3.46	L3	3.42	
L4	4.65	L4	4.53	

L5	5.51	L5	5.38
L6	6.45	L6	6.51
L7	7.57	L7	7.28
L8	8.55	L8	8.49
L9	9.39	L9	9.63
L10	10.55	L10	10.47
L11	11.42	L11	11.64
L12	12.57	L12	12.52
L13	13.52	L13	13.39
L14	14.40	L14	14.44
L15	15.65	L15	15.62
L16	16.46	L16	16.48
L17	17.54	L17	17.52
L18	18.42	L18	18.37
L19	19.55	L19	19.47
L20	20.44	L20	20.53
L21	21.51	L21	21.41
L22	22.41	L22	22.52
L23	23.56	L23	23.55
L24	24.37	L24	24.43

PI compute for the season

[Plastochron Index, $PI = n+(\ln L_n - \ln R)/(\ln L_n - \ln L_{n+1})$]

Table 3 (a). Leaf Plastochron Index (LPI) of *Allium hookeri* for kharif season of cropping year 2014

Days/ Leaf	Leaves																								Remarks
6	1.48	0.48	-0.52																						
12	2.46	1.46	0.46	-0.54																					
18	3.65	2.65	1.65	0.65	-0.35																				
23	4.51	3.51	2.51	1.51	0.51	-0.49																			
29	5.45	4.45	3.45	2.45	1.45	0.45	-0.55																		
35	6.57	5.57	4.57	3.57	2.57	1.57	0.57	-0.43																	
41	7.55	6.55	5.55	4.55	3.55	2.55	1.55	0.55	-0.45																
46	8.39	7.39	6.39	5.39	4.39	3.39	2.39	1.39	0.39	-0.61															
52	9.55	8.55	7.55	6.55	5.55	4.55	3.55	2.55	1.55	0.55	-0.45														
58	10.42	9.42	8.42	7.42	6.42	5.42	4.42	3.42	2.42	1.42	0.42	-0.58													
64	11.57	10.57	9.57	8.57	7.57	6.57	5.57	4.57	3.57	2.57	1.57	0.57	-0.43												
70	12.52	11.52	10.52	9.52	8.52	7.52	6.52	5.52	4.52	3.52	2.52	1.52	.052	-0.48											
76	13.40	12.40	11.40	10.40	9.40	8.40	7.40	6.40	5.40	4.40	3.40	2.40	1.40	0.40	-0.6										
82	14.65	13.65	12.65	11.65	10.65	9.65	8.65	7.65	6.65	5.65	4.65	3.65	2.65	1.65	0.65	-0.35									
87	15.46	14.46	13.46	12.46	11.46	10.46	9.46	8.46	7.46	6.46	5.46	4.46	3.46	2.46	1.46	0.46	-0.54								
93	16.54	15.54	14.54	13.54	12.54	11.54	10.54	9.54	8.54	7.54	6.54	5.54	4.54	3.54	2.54	1.54	0.54	-0.46							
99	17.42	16.42	15.42	14.42	13.42	12.42	11.42	10.42	9.42	8.42	7.42	6.42	5.42	4.42	3.42	2.42	1.42	0.42	-0.58						-ve indicates
106	18.55	17.55	16.55	15.55	14.55	13.55	12.55	11.55	10.55	9.55	8.55	7.55	6.55	5.55	4.55	3.55	2.55	1.55	0.55	-0.45					leaf primordia
113	19.44	18.44	17.44	16.44	15.44	14.44	13.44	12.44	11.44	10.44	9.44	8.44	7.44	6.44	5.44	4.44	3.44	2.44	1.44	0.44	-0.56				
120	20.51	19.51	18.51	17.51	16.51	15.51	14.51	13.51	12.51	11.51	10.51	9.51	8.51	7.51	6.51	5.51	4.51	3.51	2.51	1.51	0.51	-0.49			
127	21.41	20.41	19.41	18.41	17.41	16.41	15.41	14.41	13.41	12.41	11.41	10.41	9.41	8.41	7.41	6.41	5.41	4.41	3.41	2.41	1.41	0.41	-0.59		
133	22.56	21.56	20.56	19.56	18.56	17.56	16.56	15.56	14.56	13.56	12.56	11.56	10.56	9.56	8.56	7.56	6.56	5.56	4.56	3.56	2.56	1.56	0.56	-0.44	
140	23..37	22.37	21.37	20.37	19.37	18.37	17.37	16.37	15.37	14.37	13.37	12.37	11.37	10.37	9.37	8.37	7.37	6.37	5.37	4.37	3.37	2.37	1.37	0.37	-0.63	

Table 3 (b). Leaf Plastochron Index (LPI) of *Allium hookeri* for kharif season of cropping year 2015

Days/ Leaf	Leaves																								Remarks
6	1.56	0.56	-0.44																						
12	2.42	1.42	0.42	-0.58																					
18	3.53	2.53	1.53	0.53	-0.47																				
23	4.38	3.38	2.38	1.38	0.38	-0.62																			
29	5.51	4.51	3.51	2.51	1.51	0.51	-0.49																		
35	6.28	5.28	4.28	3.28	2.28	1.28	0.28	-0.72																	
41	7.49	6.49	5.49	4.49	3.49	2.49	1.49	0.49	-0.51																
48	8.63	7.63	6.63	5.63	4.63	3.63	2.63	1.63	0.63	-0.37															
54	9.47	8.47	7.47	6.47	5.47	4.47	3.47	2.47	1.47	0.47	-0.53														
59	10.64	9.64	8.64	7.64	6.64	5.64	4.64	3.64	2.64	1.64	0.64	-0.36													
65	11.52	10.52	9.52	8.52	7.52	6.52	5.52	4.52	3.52	2.52	1.52	0.52	-0.48												
71	12.39	11.39	10.39	9.39	8.39	7.39	6.39	5.39	4.39	3.39	2.39	1.39	0.39	-0.61											
77	13.44	12.44	11.44	10.44	9.44	8.44	7.44	6.44	5.44	4.44	3.44	2.44	1.44	0.44	-0.56										
83	14.62	13.62	12.62	11.62	10.62	9.62	8.62	7.62	6.62	5.62	4.62	3.62	2.62	1.62	0.62	-0.38									
90	15.48	14.48	13.48	12.48	11.48	10.48	9.48	8.48	7.48	6.48	5.48	4.48	3.48	2.48	1.48	0.48	-0.52								-ve indicates
96	16.52	15.52	14.52	13.52	12.52	11.52	10.52	9.52	8.52	7.52	6.52	5.52	4.52	3.52	2.52	1.52	0.52	-0.48							leaf primordia
102	17.37	16.37	15.37	14.37	13.37	12.37	11.37	10.37	9.37	8.37	7.37	6.37	5.37	4.37	3.37	2.37	1.37	0.37	-0.63						
108	18.47	17.47	16.47	15.47	14.47	13.47	12.47	11.47	10.47	9.47	8.47	7.47	6.47	5.47	4.47	3.47	2.47	1.47	0.47	-0.53					
114	19.53	18.53	17.53	16.53	15.53	14.53	13.53	12.53	11.53	10.53	9.53	8.53	7.53	6.53	5.53	4.53	3.53	2.53	1.53	0.53	-0.47				
121	20.41	19.41	18.41	17.41	16.41	15.41	14.41	13.41	12.41	11.41	10.41	9.41	8.41	7.41	6.41	5.41	4.41	3.41	2.41	1.41	0.41	-0.59			
128	21.52	20.52	19.52	18.52	17.52	16.52	15.52	14.52	13.52	12.52	11.52	10.52	9.52	8.52	7.52	6.52	5.52	4.52	3.52	2.52	1.52	0.52	-0.48		
135	22.55	21.55	20.55	19.55	18.55	17.55	16.55	15.55	14.55	13.55	12.55	11.55	10.55	9.55	8.55	7.55	6.55	5.55	4.55	3.55	2.55	1.55	0.55	-0.45	
142	23.43	22.43	21.43	20.43	19.43	18.43	17.43	16.43	15.43	14.43	13.43	12.43	11.43	10.43	9.43	8.43	7.43	6.43	5.43	4.43	3.43	2.43	1.43	0.43	-0.57	

Table 3 (a.1). LPI of *Allium hookeri* for Kharif season of cropping year 2014 showing sink (red box), transition (green box) and source (white box).

Days/ Leaf	Leaves									Remarks
6	1.48	0.48	-0.52							
12	2.46	1.46	0.46	-0.54						
18	3.65	2.65	1.65	0.65	-0.35					
23	4.51	3.51	2.51	1.51	0.51	-0.49				
29	5.45	4.45	3.45	2.45	1.45	0.45	-0.55			
35	6.57	5.57	4.57	3.57	2.57	1.57	0.57	-0.43		
41	7.55	6.55	5.55	4.55	3.55	2.55	1.55	0.55	-0.45	
46	8.39	7.39	6.39	5.39	4.39	3.39	2.39	1.39	0.39	-0.61

52	9.55	8.55	7.55	6.55	5.55	4.55	3.55	2.55	1.55	0.55	-0.45															
58	10.42	9.42	8.42	7.42	6.42	5.42	4.42	3.42	2.42	1.42	0.42	-0.58														
64	11.57	10.57	9.57	8.57	7.57	6.57	5.57	4.57	3.57	2.57	1.57	0.57	-0.43													
70	12.52	11.52	10.52	9.52	8.52	7.52	6.52	5.52	4.52	3.52	2.52	1.52	.052	-0.48												
76	13.40	12.40	11.40	10.40	9.40	8.40	7.40	6.40	5.40	4.40	3.40	2.40	1.40	0.40	-0.6											
82	14.65	13.65	12.65	11.65	10.65	9.65	8.65	7.65	6.65	5.65	4.65	3.65	2.65	1.65	0.65	-0.35										
87	15.46	14.46	13.46	12.46	11.46	10.46	9.46	8.46	7.46	6.46	5.46	4.46	3.46	2.46	1.46	0.46	-0.54									
93	16.54	15.54	14.54	13.54	12.54	11.54	10.54	9.54	8.54	7.54	6.54	5.54	4.54	3.54	2.54	1.54	0.54	-0.46								
99	17.42	16.42	15.42	14.42	13.42	12.42	11.42	10.42	9.42	8.42	7.42	6.42	5.42	4.42	3.42	2.42	1.42	0.42	-0.58							-ve indicates
106	18.55	17.55	16.55	15.55	14.55	13.55	12.55	11.55	10.55	9.55	8.55	7.55	6.55	5.55	4.55	3.55	2.55	1.55	0.55	-0.45						leaf primordia
113	19.44	18.44	17.44	16.44	15.44	14.44	13.44	12.44	11.44	10.44	9.44	8.44	7.44	6.44	5.44	4.44	3.44	2.44	1.44	0.44	-0.56					
120	20.51	19.51	18.51	17.51	16.51	15.51	14.51	13.51	12.51	11.51	10.51	9.51	8.51	7.51	6.51	5.51	4.51	3.51	2.51	1.51	0.51	-0.49				
127	21.41	20.41	19.41	18.41	17.41	16.41	15.41	14.41	13.41	12.41	11.41	10.41	9.41	8.41	7.41	6.41	5.41	4.41	3.41	2.41	1.41	0.41	-0.59			
133	22.56	21.56	20.56	19.56	18.56	17.56	16.56	15.56	14.56	13.56	12.56	11.56	10.56	9.56	8.56	7.56	6.56	5.56	4.56	3.56	2.56	1.56	0.56	-0.44		
140	23..37	22.37	21.37	20.37	19.37	18.37	17.37	16.37	15.37	14.37	13.37	12.37	11.37	10.37	9.37	8.37	7.37	6.37	5.37	4.37	3.37	2.37	1.37	0.37	-0.63	

Table 3 (b.1). Leaf Plastochron Index (LPI) of *Allium hookeri* for kharif season of cropping year 2015 showing sink (red box), transition (green box) and source (white box).

Days/ Leaf	Leaves																									Remarks
6	1.56	0.56	-0.44																							
12	2.42	1.42	0.42	-0.58																						
18	3.53	2.53	1.53	0.53	-0.47																					
23	4.38	3.38	2.38	1.38	0.38	-0.62																				
29	5.51	4.51	3.51	2.51	1.51	0.51	-0.49																			
35	6.28	5.28	4.28	3.28	2.28	1.28	0.28	-0.72																		
41	7.49	6.49	5.49	4.49	3.49	2.49	1.49	0.49	-0.51																	
48	8.63	7.63	6.63	5.63	4.63	3.63	2.63	1.63	0.63	-0.37																
54	9.47	8.47	7.47	6.47	5.47	4.47	3.47	2.47	1.47	0.47	-0.53															
59	10.64	9.64	8.64	7.64	6.64	5.64	4.64	3.64	2.64	1.64	0.64	-0.36														
65	11.52	10.52	9.52	8.52	7.52	6.52	5.52	4.52	3.52	2.52	1.52	0.52	-0.48													
71	12.39	11.39	10.39	9.39	8.39	7.39	6.39	5.39	4.39	3.39	2.39	1.39	0.39	-0.61												
77	13.44	12.44	11.44	10.44	9.44	8.44	7.44	6.44	5.44	4.44	3.44	2.44	1.44	0.44	-0.56											
83	14.62	13.62	12.62	11.62	10.62	9.62	8.62	7.62	6.62	5.62	4.62	3.62	2.62	1.62	0.62	-0.38										
90	15.48	14.48	13.48	12.48	11.48	10.48	9.48	8.48	7.48	6.48	5.48	4.48	3.48	2.48	1.48	0.48	-0.52									-ve indicates
96	16.52	15.52	14.52	13.52	12.52	11.52	10.52	9.52	8.52	7.52	6.52	5.52	4.52	3.52	2.52	1.52	0.52	-0.48								leaf primordia
102	17.37	16.37	15.37	14.37	13.37	12.37	11.37	10.37	9.37	8.37	7.37	6.37	5.37	4.37	3.37	2.37	1.37	0.37	-0.63							
108	18.47	17.47	16.47	15.47	14.47	13.47	12.47	11.47	10.47	9.47	8.47	7.47	6.47	5.47	4.47	3.47	2.47	1.47	0.47	-0.53						
114	19.53	18.53	17.53	16.53	15.53	14.53	13.53	12.53	11.53	10.53	9.53	8.53	7.53	6.53	5.53	4.53	3.53	2.53	1.53	0.53	-0.47					
121	20.41	19.41	18.41	17.41	16.41	15.41	14.41	13.41	12.41	11.41	10.41	9.41	8.41	7.41	6.41	5.41	4.41	3.41	2.41	1.41	0.41	-0.59				
128	21.52	20.52	19.52	18.52	17.52	16.52	15.52	14.52	13.52	12.52	11.52	10.52	9.52	8.52	7.52	6.52	5.52	4.52	3.52	2.52	1.52	0.52	-0.48			
135	22.55	21.55	20.55	19.55	18.55	17.55	16.55	15.55	14.55	13.55	12.55	11.55	10.55	9.55	8.55	7.55	6.55	5.55	4.55	3.55	2.55	1.55	0.55	-0.45		
142	23.43	22.43	21.43	20.43	19.43	18.43	17.43	16.43	15.43	14.43	13.43	12.43	11.43	10.43	9.43	8.43	7.43	6.43	5.43	4.43	3.43	2.43	1.43	0.43	-0.57	

Table 4. Plastchron Ratio "a" [a=Ln/Ln+1= Lon/Lon+1 will be >1] and "Relative Plastochron Rate of leaf elongation =lna = ρ" of *Allium hookeri* for the crop season, kharif of cropping years 2014 and 2015.

Year						Remarks
2014			2015			
Leaf nos.	a	ρ	Leaf nos.	a	ρ	
L2	8.3	2.12	L2	6.69	1.90	
L3	11.63	2.45	L3	22	3.09	
L4	7.33	1.99	L4	7	1.95	
L5	9.7	2.27	L5	13.33	2.59	
L6	19.17	2.95	L6	7.64	2.03	
L7	8.67	2.16	L7	44	3.78	True since ratio is greater than 1
L8	9.09	2.21	L8	8.6	2.15	
L9	18.8	2.93	L9	9.77	2.28	
L10	4.67	1.54	L10	12	2.48	
L11	16.17	2.78	L11	5.63	1.73	
L12	5.86	1.77	L12	10	2.30	
L13	9.7	2.27	L13	18.8	2.93	
L14	19.6	2.98	L14	10.63	2.36	
L15	6	1.79	L15	7.43	2.01	
L16	11.5	2.44	L16	16.71	2.82	
L17	11	2.40	L17	6.67	1.9	
L18	21.6	3.07	L18	24.75	3.21	
L19	11.3	2.42	L19	12.13	2.50	
L20	24.2	3.19	L20	10.5	2.35	
L21	14.13	2.65	L21	29.75	3.39	
L22	30.25	3.41	L22	12.22	2.50	
L23	8.17	2.10	L23	11.6	2.45	
L24	38.33	3.65	L24	23.6	3.16	

Table 5. Number of days per increment in LPI of *Allium hookeri* for the crop season, kharif of two consecutive cropping years 2014 and 2015.

Years						Remarks
2014			2015			
Sl.No.	Leaf No.	$LPI_d = (Ln_i - Ln_o)/d$	Sl.No.	Leaf No.	$LPI_d = (Ln_i - Ln_o)/d$	
2&5	3	0.18	3&4	3	0.17	$0.1 < LPI_d > 0.2$
10&11	6	0.19	12&14	6	0.19	
19&20	4	0.15	21&22	20	0.15	

Figure 3. Regression between (a) Days and Leaf length (mm) during Kharif 2014 (n= 20, A=15.16, B=13.26, r= 0.99, r^2 = 0.98) (b). Regression between Days and Leaf length (mm)during Kharif 2015 (n= 21, A=4.76, B=13.09, r= 0.99, r^2 = 0.98)

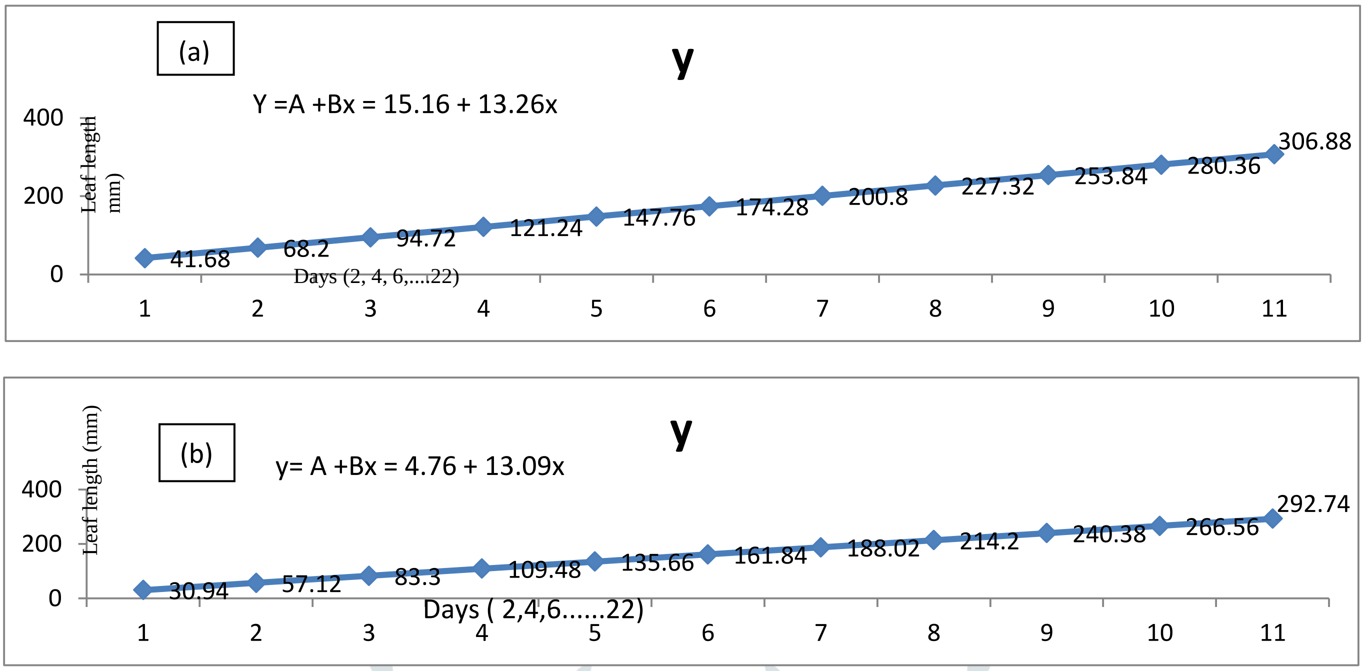


Figure 4 . Regression between (a). Thermal temp (GDD) and Leaf length (mm) during Kharif 2014 (n= 20, A=15.57, B=0.49, r= 0.99, r^2 = 0.98) (b) Thermal temp (GDD) and Leaf length(mm) during Kharif 2015 (n= 21, A=8.05, B=0.51, r= 0.99, r^2 = 0.98).

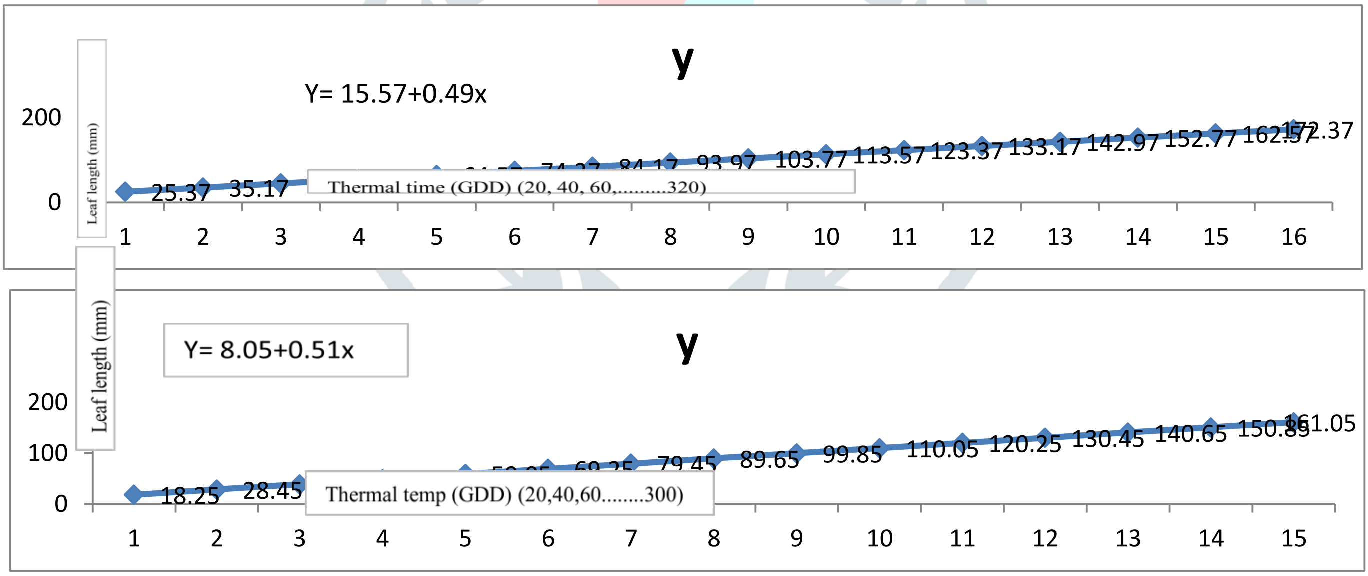
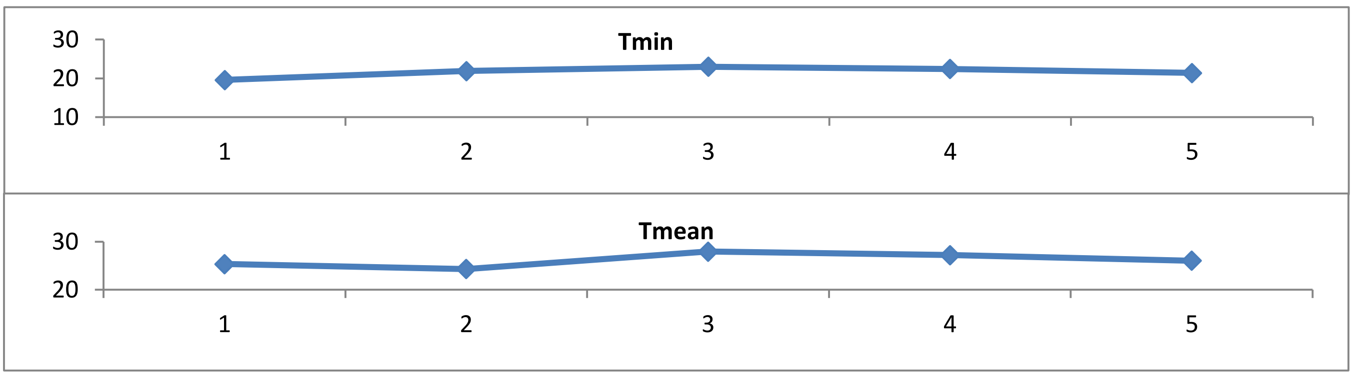


Fig. 5(a). Meteorological data (average) for kharif season of the cropping year 2014 (Tmax, Tmin, Tmean, RHmax, RH min, RH mean, Sunshine, rainfall, windspeed (km/hr).



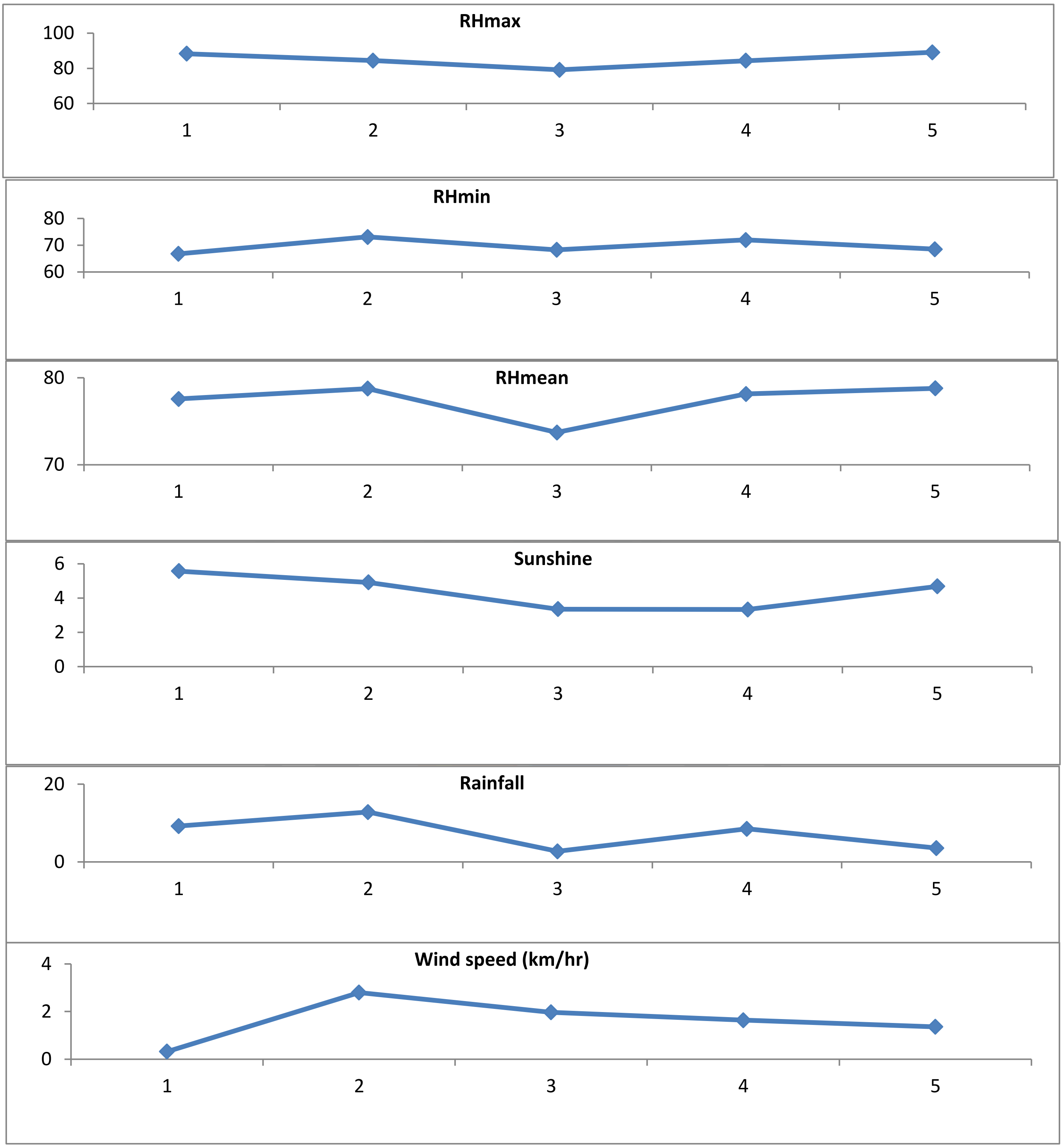
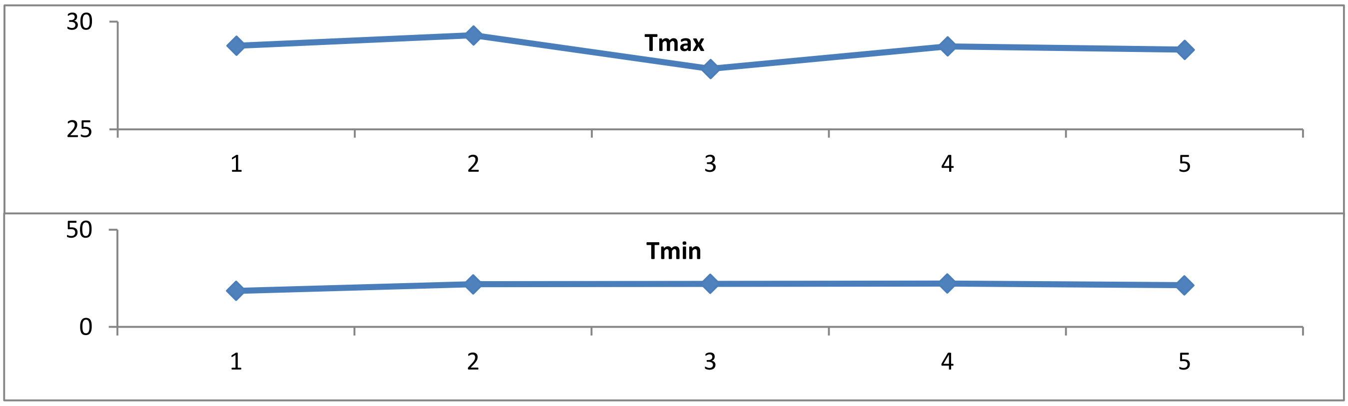
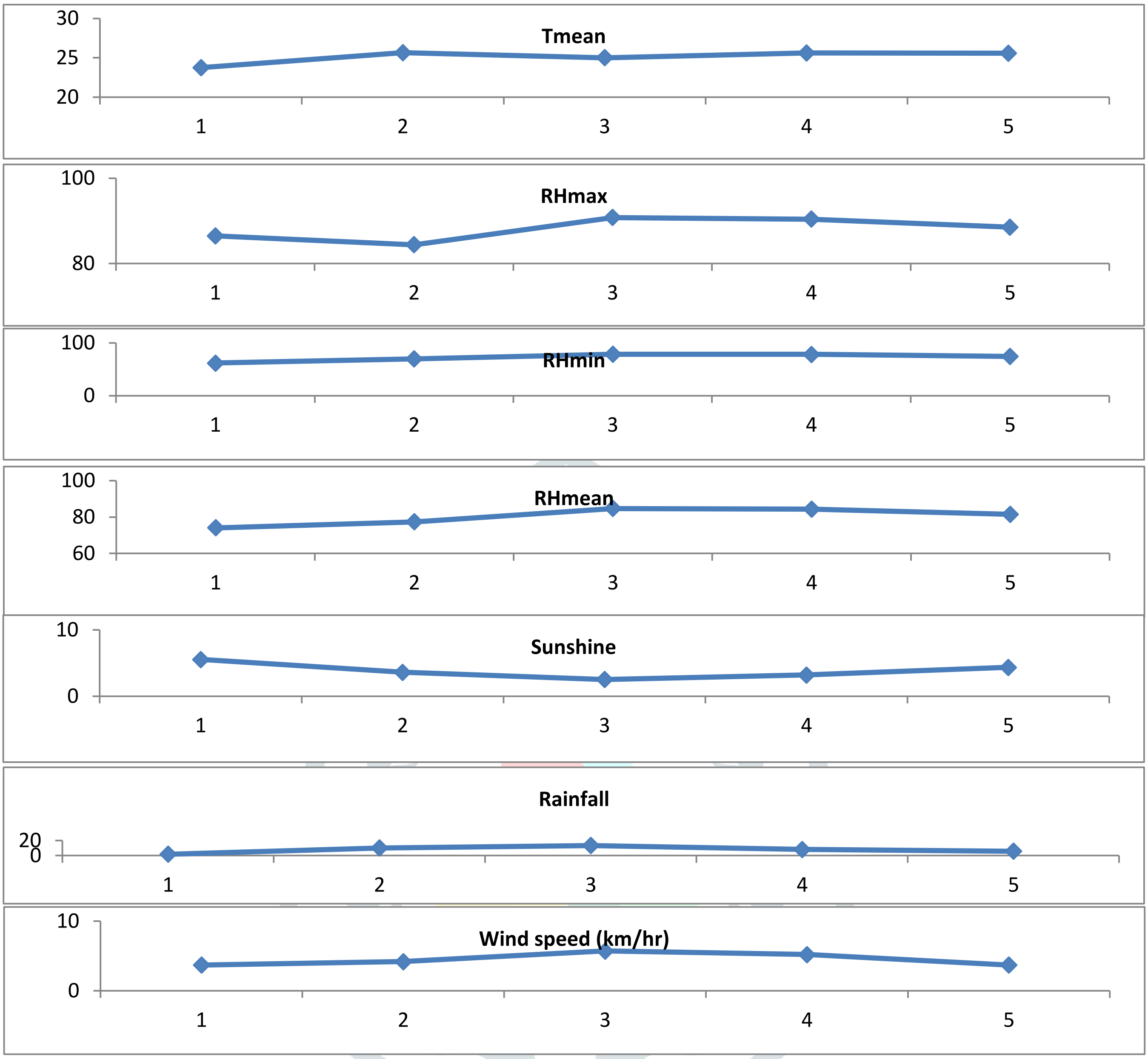


Fig. 5(b). Meteorological data (average) for kharif season of the cropping year 2015 (Tmax, Tmin, Tmean, RHmax, RH min, RH mean, Sunshine, rainfall, windspeed (km/hr).





IV. CONCLUSION

The present investigation show the extensive role of plastochron and plastochron allieds in crop (leafy) production of the test crop *Allium hookeri*. Variation in LPI values signifies the morphological status corresponding to allocation and transformation of chemicals, and effectively induces expected leaf age and leaf lifespan. PI highlights the evolutionary trait of leaf economic spectrum, the changes in leaf appearance due senescence.

V. ACKNOWLEDGEMENTS

We are grateful to Imphal International Airport, Imphal, and ICAR, Lamphelpat, Imphal for supplying the valuable meteorological data for our investigation purpose.

REFERENCES

1.Maksymowych, R. 1990. Analysis of growth and development of Xanthium. Cambridge University Press.
2.Erickson, R.O., and F.J. Michelini, 1957. The plastochron index. American Journal of Botany 44: 297-305.

3.Larson, P.R. and J.G. Isebrands. 1971. The plastochron index as applied to developmental studies of cottonwood. Canadian Journal of Forest Research 1: 1 – 11.

4.Steeves, T.A. and Sussex, I. M. 1989. Patterns in Plant Development. Cambridge University Press.

5.Lyndon, R.F. 1998. The Shoot Apical Meristem: Its growth and development. Cambridge Univ. Press, Cambridge, U.K.

6.Lintillac, P.M. 1984. Positional control in Plant Development ed Barlow, PW &Carr, DJ Cambridge Uni. Press, Cambridge, U.K.

7.Hooker, JD. 1978. Allium Hookeri. In: Flora of British India. Publisher Bishen Singh Mahendra Pal Singh, 23-A, New Connaught Place Dhera Dun. Vol. VI :341.

8.Singh, AJ. 1996. Vegetable in Manipur. In: A. Ibochouba Singh, Arrowhead paona bazaar, Imphal, Manipur, India, Padma Printers, 191.

9.Dickmann, D.I. 1971. Photosynthesis and respiration by developing leaves of cottonwood (*Populus deltoids* Bartr) Bot. Gaz. 132: 253-259.

10.Dickson R.E. 1986. Carbon fixation and distribution in young Populus deltoids trees. In Crown and Canopy Structure in Relation to Productivity. Eds. T. Fujimori and D. Whitchead. Forestry and Forest Products Res. Inst. Ibaraki, Japan, pp. 409-426.

11.Hanson, P.J., R.E. Dickson, J.G. Isebrands, T.R. Crow and R.K. Dixon 1986. A morphological index of Quercus seedling ontogeny for use in studies of physiology and growth. Tree Physiol. 2: 273-281.

12.Haun, J.R. 1973. Visual quantification of wheat development. Agronomy Journal 65: 116-119.

13.Gallaghar, J.N. 1979. Field studies of cereal leaf growth: I Initiation and expansion in relation to temperature and category Journal of Experimental Botany 30, 625-636.

14.Baker J.T. Pinter Jr., P.S., Regional, R.S. and Kanemasu, E.T. 1986. Effects of temperature as leaf appearance in spring and winter wheat cultivars. Agronomy Journal 78, 605-613.

15.Richards, F.T. 1951. Phyllotaxis: Its quantitative expression and relation to growth in the apex. Processings of the Royal Society of Edinburge, B. Biology 235: 510-564.

16.Erickson, R.O. 1976. Modelling of plant growth. Ann Rev Plant Physiol 27: 407-434.

17.Beemster, G.S.T. and Masle, J.1996. The role of apical development around the time of leaf initiation in determining leaf width at maturity in wheat seedlings (*Triticum aestivum* L.) with impeded roots. Journal of Experimental Botany 47: 1679-1688.

18.Naorem B.D., Ningthoujam S.D. and Seram R.S. 2018. Plastochron index, Leaf plastochron index and Haun index in Agroecological studies of *Allium hookeri* Thw. Enum. Souvenir of An International conference on Transforming Leadership for Global Social & Developmental Justice: Issues & Challenges, Imphal. pp.16.

19.Kirbi, E.J.M. 1993. Effect of sowing depth on seedling emergence, growth and development in barley and wheat. Field Crops Res. 35: 101-111.

20.Dickson, R.E. and Larson, P.R. 1981. C_4 fixation metabolic labeling patterns and translocation profiles during leaf development in *Populus deltoids*. Planta.152: 461– 470.

21.Ferris, R, Sabatti, M, Miglietta, F, Mills R.FF. and Taylor G 2001. Leaf area is stimulated in Pupulus by free air CO_2 enrichment through cell expansion and production. Plant Cell Environ 24:305-3115.

22.Itoh, J. I., Ken Ichi Nonomura, Kyoko Ikeda,Shinichiro Yamaki, Yoshiaki Inukai, Hiroshi Yamagishi, Hidemi Kitano, Yasno Nagato. 2005. Rice plant development: from zygote to spikelet. "Plant and Cell Physiology 46(1): 23-47.

23.Turgeon, R. 1989. The sink – source transition in leaves. Ann. Rev. Plant Physiol. Plant Mol. Biol., 40: 119-138.

24.Gagnon, M.J. and D.U. Beebe 1996. Establishment of a plastochron index and analysis of the sink to source transition in leaves of *Morocandia arvensis* (L.) DC. (Brassicaceae). Int. J. Plant Sci., 157:262-268.

25.Wilson KB, Boldocchi DD, and Hanson P.J. 2001. Leaf age affects the seasonal pattern of photosynthetic capacity and ecosystem exchange of carbon in a deciduous forest Plant, Cell & Environment 24:571-583.

26.Kitajima K, Mulkey SS, Samaniego M. and Wright SJ. 2002. Decline of photosynthetic capacity with leaf age and position in two tropical canopy tree species. American Journal of Botany 84:702.

27.Pantin F, Simonneau T. and Muller B 2012. Coming of leaf age: control of growth by hydraulic and metabolic during leaf ontogeny. New Phytologist 196: 349-366.

28.Field, C. 1983. Allocating leaf nitrogen for the maximization of carbon given: leaf age as a control on the allocation profram. Oecologia 56: 341-347.

29.Funk, J.L. and Cornwell, W.K. 2013. Leaf traits within communities: Context may affect the mapping of traits to function. Ecology 94: 1893-1897.

30.Osnas, J.L., Lichstein JW., Reich P.B. and Pacala SW. 2013. Global leaf trait relationships: mass, area, and the leaf economics spectrum. Science 340:741-744.