AATCC Review

24 January 2024: Received
08 February 2024: Revised
20 February 2024: Accepted
07 March 2024: Available Online

www.aatcc.peerjournals.net

Review Article Open Access

Phyllochron and Tillering Behavior Studies in Grass family (Gramineae): A Review

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ABSTRACT

The vegetative development in gramineae is characterized by the regular initiation and appearance of successive leaves. Phyllochron is the period of time between the emergence of one phytomer (a set of tiller, leaf, and root which emerges from the base of the plant) and the emergence of next other hands interval between similar growth stages of successive leaves on the same culm, has been used extensively to describe and understand development of rice plant and other grass family. A phyllochron is not a thing but rather a period of time, 5 days at best but usually longer, 12 phyllochrons before the plant begins initiating panicles and starts its reproductive phase. The first tiller off the main stem appears at the fourth phyllochron. The first tiller appeared when the third leaf was completely expanded and the emergence of the fourth leaf tip was initiated in the main stem. The rate of leaf initiation on the apical meristem and the rate of leaf appearance above the pseudostem or whorl are primarily controlled by biotic and abiotic factors that reflect on the growth and yield of crop plants.

Keywords: *Phyllochron, leaf initiation rate, biotic and abiotic factor, tillering behavior, productivity.*

INTRODUCTION

Phyllochron or leaf emergence rate which has been used to characterize the growth dynamics of cereals is defined as the time interval of leaf emergence [36]. An important plant development parameter is the leaf appearance rate (LAR), which is the number of days required for the emission of one leaf on mail culm [49]. Phyllochron or leaf appearance rate an important parameter in the production efficiency of agricultural crops and has been used in ecophysiological studies in plants [46]. The phyllochron can be determined in many ways, such as documenting the time of appearance of successive leaves on a culm or measuring the time it takes foe an individual leaf to grow. The latter method assumes that a leaf grows within the time of one phyllochron, which may be the case in some species, but not in others. That is, in some species leaf *n+1* may appear before leaf *n* has completed growth. In practice, the Haun scale [19] is often used to determine the phyllo chron during the vegetative development of grasses and is determined as Haun stage=$[L_n/L_{(n-1)}] + (n-1)$

Where L_n is the length of the youngest leaf blade above the collar of the subtending leaf, $L_{(n-1)}$ is the length of the blade of the penultimate (subtending) leaf, and n is the total number of leaves that are visible on the culm. By recording leaf lengths and documenting the Haunt stage of a culm on at least two dates, the phyllochron can be ascertained by dividing the time interval by the difference in the Haun stage on the two dates.

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DOI: https://doi.org/10.58321/AATCCReview.2024.12.01.258

As mentioned above, the interval between the events may be measured either in time (hours or days), thermal time (Growing Degree Days), or another meaningful measurement of time [20]. Leaf development in the mother culm and daughter tiller don't synchronize until the tiller has appeared. As described, the tiller bud is initiated and then, the first leaf emerges in the third plastochrons (time interval between successive leaf initiations) of the mother stem. During this time, the tiller bud produces a total of five foliage leaf primordia. Thereafter, leaf development on each tiller mimics that in the mother stem; tillers and the mother stem share similar phyllochrons and plastochrons. Under unfavorable conditions, many tiller buds become dormant. In such buds, marked decline in growth rate occurs just after they have produced two foliage leaf primordia. Appearance of the tillers (i.e., the emergence of the first foliage leaf from the leaf sheath of its subtending phytomer) is confined to the seventh plastrochron [24]. Leaf initiation in rice begins just after seed soaking. Each rice tiller produces 10-18 leaves in its life. Average duration between successive leaf appearances of 4 to 5 days before panicle initiation and 7 to 8 days afterwards [50]. The modeling of the phyllochron was first published in 1951 when Katayama (table 1) presented the growth rules while working leaf emergence on the main stem and tillers of rice, wheat, and barley.

This model was used for explaining the success of the SRI system which he had already developed empirically. When sufficient knowledge had been gained about phyllochron dynamics and the conditions under which rice plants could perform maximally, yield increased as high as 20-30 percent [11]. Studies to determine the phyllochron were performed for crops, such as sorghum [10], brachiaria [40], maize [46], [28], wheat [38], [33] and strawberry [39], [31].

The tillering of these crops depends on the cultivars and resources available for growth and development. On the other hand, excessive tillering lead to high tiller abortion, poor grain setting, small panicle size and finally reduced yield [12]. Higher tiller production has been found to be inversely proportional to the length of phyllochron [48]. Study of the tillering pattern and leaf emergence rate of cereal crops is a crucial need for selection and improvement of productivity. With this, the present review focuses on updating the knowledge about the phyllochron studies and tiller production on cereal crops based on abiotic and abiotic factors so as to increase the productivity level of rice and other gramineae crops.

TABLE 2: Distribution of rural women according to their role & status (n=200)

Phyllochron stage	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	Total
Main stalk		1											1
First row of tillers				1	1	1	1	1	1				6
Second row of tillers						1	2	3	4	5	6	5	26
Third row of tillers								1	3	6	10	15	35
Fourth row of tillers										1	4	10	15
Fifth row of tillers												1	1
Total number per phyllochron	0	1	0	1	1	2	3	5	8	12	20	31	84
Total	0	1	1	2	3	5	8	13	21	33	53	84	

Influence of cultivars on phyllo chron and tillering behavior

The development of the first four leaves on the main stem (period 9-20 days), the phyllochrons was 4.5 days and it was shorter 4.0 days over the 20-29 period, grew longer 6.4 days over the period 38-50 and increased rapidly thereafter (period 50-82 and 82-109 days) corresponding to 12th leaf to heading (15 leaf) in rice variety IR 64 [23]. Phyllochron variability among cultivars was also verified [10], and on wheat [38], barley [37] and strawberry [39]. Different results among cultivars are due to genetic differences. Therefore, the management of these cultivars tends to be differentiated due to the occurrence of variability in leaf development. Moreover, the grower may establish cropping planning for each cultivar with the number of leaves forecast model. There was variability in phyllochron and LAR among cultivars and sowing dates. These differences in phyllochron and LAR observed among cultivars can result from their genetic and physiological differences. Moreover, the differences in phyllochron and LAR among sowing dates can be the result of environmental conditions, mainly the photoperiod [15]. These variations in the LAR estimation among cultivars can be attributed to physiological differences [40]. The TNAU pre-release maize hybrids (CMH 08–282, CMH 08–337, CMH 08–350) produced 22 leaves while private hybrids (NK 6240 and 900 M Gold) produced only 18 leaves (Fig.1 and Fig.2). The highest phyllochron was observed in NK 6240 is 3.98 days and lowest in CMH 08-282 (2.95 days) [43].

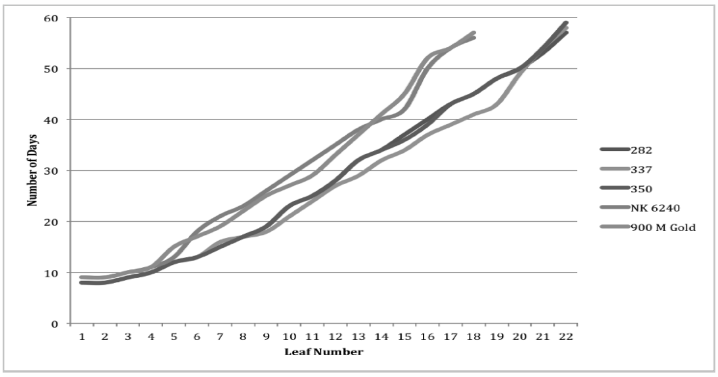

Fig. 1. The effect of phyllochron observed in the five maize hybrids (43)

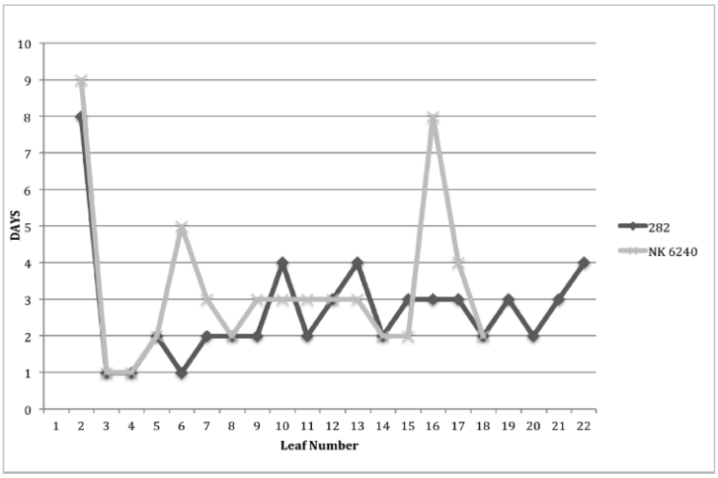

Fig. 2. Number of days taken to emergence of each leaf in CMH 08- 282 and NK 6240 (43)

Influence of age of seedlings on phyllo chron and tillering behavior

Transplanting young seedlings usually from 8 to 12 days and not beyond 15 days old, the exact limit depends on biological processes, measured in terms of phyllochrons [24]; and Nemoto *et al.*, 1995). For maximum tillering, the plant has to complete as many phyllochrons as possible during its vegetative phase [6]. Each tiller produces another two phyllochrons later under favorable growing conditions [44]. When seedlings stay for a longer period of time in the nursery beds, primary tiller buds on the lower nodes of the main culm become degenerated leading to reduced tiller production. When the seed is not planted too deep, tillering starts early in about a fortnight from sowing in case of direct seeding. But, transplanted rice takes little longer time period to start tillering as it first needs more time to recover from transplanting shock. When rice seedlings are transplanted at the right time in terms of age, tillering and growth proceed normally [32].

Irrespective of the nursery techniques the same age of seedling were produced similar phyllochron (table 5) and tillering behavior of rice [4]. Age and number of seedlings had significant effect on phyllochron at 4th, 8th, 9th, 10th and 11th phyllochron in two consecutive years.

Transplanting on 21 days after sowing with one seedling hill^{-1} took more time (6.6 days) to put-forth of new leaf and was on par with 21days after sowing with two seedlings hill^{-1} and 21 days after sowing with three seedlings hill^{-1} compared to others at 4th phyllochron. At 8th phyllochron 21 days after sowing with three seedlings hill^{-1} had taken maximum time (5.5 days) and it was comparable with 21 days after sowing with two seedlings hill^{-1} and 14 days after sowing with three seedlings hill^{-1}. Almost same trend was noted on 9th, 10th and 11th phyllochron [35].

Influence of crop geometry on phyllochron and tillering behavior

The maximum number of tillers produced by the rice plant is inversely proportional to the length of the phyllochron, which is dependent upon the extent of stresses. Wider spacing, availability of solar radiation, medium temperature, soil aeration, and nutrient supply promote shorter phyllochrons which increase the number of tillers in the rice plant [24]. SRI fields will look terrible for a month or more after transplanting, because the plants are so thin and small and widely spaced. In the first month the plant is preparing to the tiller, during the second month, serious tillering begins. In the third month, the field seems to explode with rapid tiller growth. To understand why, you need to understand the concept of phyllochrons, a concept that applies to members of the grass family, including cereals like rice, wheat, and barley [22]. The different types of planting pattern could be modified the phyllochron and tillering behavior of rice (table 2 to 4) [48].

Table 2. Phyllochron observations under square pattern of planting

Phyllochron stage	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	Total
Main stalk		1											1
First row of tillers				1	1	1	1	1	1				6
Second row of tillers								1	2	3	4	5	15
Third row of tillers								1	2	4	5	6	18
Fourth row of tillers										1	3	7	11
Fifth row of tillers												1	1
Total number per phyllochron	0	1	0	1	1	1	1	3	5	8	12	19	52
Total	0	1	1	2	3	4	5	8	13	21	33	52	

Table 3. Phyllochron observations under triangle pattern of planting

Phyllochron stage	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	Total
Main stalk		1											1
First row of tillers				1	1	1	1	1					5
Second row of tillers							1	2	3	4	5	6	21
Third row of tillers								1	2	4	7	10	24
Fourth row of tillers										1	2	5	8
Fifth row of tillers												1	1
Total number per phyllochron	0	1	0	1	1	1	2	4	5	9	14	22	60
Total	0	1	1	2	3	4	6	10	15	24	38	60	

Table 4. Phyllochron observations under oblong pattern of planting

Phyllochron stage	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	Total
Main stalk		1											1
First row of tillers				1	1	1	1	1					5
Second row of tillers							1	2	3	4	5	6	21
Third row of tillers								1	2	5	8	12	28
Fourth row of tillers										1	2	10	13
Fifth row of tillers												1	1
Total number per phyllochron	0	1	0	1	1	1	2	4	5	10	15	29	69
Total	0	1	1	2	3	4	6	10	15	25	40	69	

Plant stand establishment on decreased plant density, the rate of leaf appearance was higher and eventually resulted in the production of 4th and 5throw tillers on the main culm (table 5). This might be the actual reason for production of more tiller with wider spacing, at particular duration and correlated to yield [4].

Table 5. Influence of nursery techniques and crop geometry on Phyllochron of rice

Treatments	3rd-4th	4th-5th	5th-6th	6th-7th	7th-8th	8th-9th	9th-10th	10th-11th	11th-12th	Total number of phyllochron
Nursery techniques										
N_1- Mat nursery	4.3	4.8	4.8	4.4	4.9	4.8	5.2	5.7	8.1	13.3
N_2- Wet nursery	4.4	4.9	5.3	4.8	5.2	5.3	4.9	5.8	7.8	13.1
SEd	0.15	0.15	0.30	0.30	0.32	0.23	0.24	0.35	0.39	0.25
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cultivars										
C_1- CORH 3	4.5	5.0	4.9	4.5	4.8	4.8	4.9	5.6	7.9	13.1
C_2- ADT 43	4.3	4.8	5.2	4.7	5.3	5.3	5.1	5.8	7.9	13.3
SEd	0.15	0.15	0.30	0.30	0.32	0.23	0.24	0.35	0.39	0.25
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Crop Geometry										
S_1- 25 x 25 cm	4.5	5.0	5.3	5.1	5.5	5.8	5.8	6.5	8.1	12.9
S_2- 30 x 30 cm	4.3	4.8	5.2	4.6	5.1	4.9	5.0	5.4	8.0	13.3
S_3- 35 x 35 cm	4.4	4.9	4.7	4.2	4.5	4.3	4.3	5.3	7.6	13.3
SEd	0.22	0.22	0.30	0.28	0.35	0.34	0.30	0.34	0.30	0.39
CD (P=0.05)	NS	NS	NS	0.59	0.74	0.73	0.63	0.72	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

(N_1 & N_2 - 14 day seedlings)

Influence of environmental factors on phyllo chron and tillering behavior

Plant growth and development at 20°C and 28°C, linear relations were found between temperature and both the rate of progress towards panicle initiation and the rate of progress towards panicle emergence also found, the rate of leaf appearance was no greater at 28°C than at 24°C. Early transplanting preserves the potential for tillering and root growth that will be lost if transplanting is done after the start of the fourth phyllochron. Phyllochron decreased with increased day length from 124ºCd leaf $^{-1}$ at 8 h to 97ºC d leaf ^{1} at 16 hr photoperiod, respectively [13]. Further, the total number of leaves on the main stem decreased at anthesis with increasing photoperiod. The air temperature is the main weather factor that influences leaf development in plant [17]. Phyllochrons decrease with temperature, light intensity, CO2, and nutrition, whereas it increases with plant density. Humidity has different effects on the phyllochrons, depending on the temperature regime and rate of soil compact ability, seeding depth, vernalization and incident radiation, affect the leaf appearance rate [51]. Permanent cool season grasses and small-seeded cereals, produce one fully expanded leaf each 6-10 days if they are subjected to favorable conditions while, in Maize and warm season cereals, this rate is each 4-6 days [26]. The greater length of leaves in transplanted flooded plants than in aerobic direct-seeded plants may be attributed to the nursery effect. The developmental delay experienced in the nursery accelerates the rate of development after transplanting [9]. NaCl stress may be the reason for low leaf number by inhibiting leaf primordium formation. In the tillering stages of some rice varieties, leaf area indices and leaf area are also inhibited due to the effects of sodium salinity [18].

Table 1. Influence of environmental factors on phyllo chron in rice

Factor	Direction of change in phyllochron	Citation
Temperature	+ (above the optimum)	[8], [29]
	-	[26]
Nutrient availability	-	[21],[27], [43]
	0	[5]
Water	0	[5]
	+	[2], [41]
Salt	+	[1], [30], [34]
CO2	-	[7], [42]
Light quantity/duration	0	[29]
	+/0	[25]
	-	[14]
Light quality	- (slight)	[3]
	0	[45]

(+) means increase in phyllochron with increase in factor,
(-) means decrease in phyllochron with increase in factor and
(0) means no change in phyllochron with increase or decrease in factor.

Summary and Conclusions

The present study illustrated that understanding the phyllochron and leaf appearance rate of gramineae. Tillering in a graminae family has a major determinant for panicle production and as a consequence affects the total productivity. From the foregoing literature, it is concluded that wider spacing invariably promotes higher number of tillers.

On the other hand, closer spacing showed increased conversion efficiency of tillers unit area^{-1}. Existing research focused on alteration of intra-row spaces without altering the inter-row spacing. Decreasing the intra-row spacing levels tends to accommodate more number of plant population unit area^{-1}. Hence, it is integrate the crop geometry, age, number of seedlings and clear view on environmental factors affecting the phyllo chron and leaf appearance rate leading to increased tiller production and productivity of crops.

Reference

1. Abdullah, Z., Khan, M.A. and Flowers, T. (2001). Causes of sterility in seed set of rice under salinity stress. J. Agron. Crop Sci. 187, 25–32.

2. Baker, J.T., Pinter Jr P.T., Reginato R.J. and Kanemasu. E.T. (1986). Effects of temperature on leaf appearance in spring and winter wheat cultivars. Agron. J., 78: 605-613.

3. Barnes, C. and Bugbee. B. (1991). Morphological response of wheat to changes in phytochrome photoequilibria. Plant Physiol., 97: 359-365.

4. Baskar, P., Siddeswaran K. and Thavaprakaash N. (2013). Tiller Dynamics, Light Interception Percentage and Yield of Rice Cultivars Under System of Rice Intensification (SRI) as Influenced by Nursery Techniques and Spacing. Madras Agric. J., 100 (1-3): 747-750.

5. Bauer, A., Frank A.B. and Blank. A. L. (1984). Estimation of spring wheat leaf growth rates and anthesis from air temperature. Agron. J., 76: 829-835.

6. Berkelaar, D. (2001). SRI, The system of rice intensification: Less can be more. Retrieved 15th July, 2009, from http://www.echotech.org/network/modules.php?name=News&file=print &sid=461.

7. Boone, M.Y.L. and Wall. G.W. (1990). CO_2 Enrichment and temperature effects on spring wheat. IV. Phyllochron intervals. In: Agronomy abstracts. ASA, Madison, WI. p.14.

8. Cao, W. and Moss, D.N. (1989). Temperature effect on leaf emergence and phyllochrons in wheat and barley. Crop Sci., 29: 1018-1021.

9. Clerget, B., Sidibe, M., Bueno, C.S., Grenier, C., Kawakata, T., Domingo, A.J., Layaoen, H.L., Palacios, N.G., Bernal, J.H. and Trouche, G. (2021). Crop-photoperiodism model 2.0 for the flowering time of sorghum and rice that includes daily changes in sunrise and sunset times and temperature acclimation. Annals of Botany 128: 97–113.

10. Clerget, B., Dingkuhn M., Goze, E., Rattunde H. F. W. and Ney B. (2008). Variability of phyllochron, plastochron and rate of increase in height in photoperiod-sensitive sorghum varieties. Annals of Botany, 101, 579-594.

11. De laulanie, (1993). The System of Rice Intensification in Madagascar. Tropiculture, (Brussela). 11: 110-114.

12. Dun, E.A., Ferguson, B.J. and Beveridge, C.A. (2006). Apical Dominance and Shoot Branching. Divergent Opinions or Divergent Mechanisms. Plant Physiology, 142 (3): 812–819.

13. Ellis, R.H., Qi, A. Summerfiled, R.J. and Roberts. E.H. (1993). Rates of leaf appearance and panicle development in rice: a comparison at three temperatures. Agricul. For. Meterol., 66: 129-138.

14. Friend, D.J.C., Fisher J.E. and. Helson. V.A (1963). The effect of light intensity and temperature on floral initiation and inflorescence development of Marquis wheat. Can. J. Bot., 41: 1663-1667.

15. Gabriela, G.C., Alberto, C.F., Bruna, M.A., André.L., Cleiton, A.W., Daniela B.U., Rafael, V. P., Jéssica, A.K. and Neu. I.M.M. 2017. Phyllochron and leaf appearance rate in oat. Crop Production and Management. Bragantia, Campinas, v.76, n.1: pp.73-81.

16. Goto, Y. and Satio, M. (1992). Analysis of the tillering behavior of the rice plant in the paddy field. I. The tillering pattern under two nitrogen levels of basal dressing. Japanese. J. Crop Sci., 61: 356-363.

17. Gramig, G.G. and Stoltenberg, D.E. (2007). Leaf appearance base temperature and phyllochron for common grass and broad leaf weed species. Weed Technology, 21: 249-254.

18. Haque, M.A., Rafii, M.Y., Yusoff, M.M., Ali, N.S., Yusuff, O., Datta, D.R., Anisuzzaman, M. and Ikbal, M.F. (2001) Advanced Breeding Strategies and Future Perspectives of Salinity Tolerance in Rice. Agronomy, 11, 1631.

19. Haun, J.R. (1973). Visual quantification of wheat development. Agron.J. 65:116-117.

20. Hermes, C.C., Medeiros, S.L.P., Manfron, P.A., Caron, B., Pommer, S.F. and Bianchi, C. (2001). Emission of leaf of lettuce in relation to the degree-day. Revista Brasileira de Agrometeorologia, 9, 269-275.

21. Hokmalipour, S., Seyedsharifi, R., Jamaati-e- Somarin, S.H., Hassanzadeh, M., Shiri-e- Janagard, M. and Zabihi-e-Mahmoodabad, R. (2010). Evaluation of Plant Density and Nitrogen Fertilizer on Yield, Yield Components and Growth of Maize. World Appl. Sci. J., 8(9): 1157-1162.

22. Itoh, Y., Sato, S. and Sano,Y. (2001). Developmental changes of phyllochron in near-isogenic lines of rice (Oryza sativa L.) with different growth durations. Euphytica ,119: 271–278.

23. Jaffuel, S. and Dauzat. J. (2005). Synchronism of leaf and tiller emergence relative to position and to main stem development stage in rice cultivar. Annals of Botany, 95: 401-412.

24. Katayama, T. (1951). Studies on tillering of rice, wheat and barley. Yokenndo, Tokyo.

25. Kirby, E.J.M. and Perry. M.W. (1987). Leaf emergence rates of wheat in a Mediterranean environment. Australian. J. Agri. Res., 38: 455-464.

26. Kostandi, S.F. and Soliman, M.F. (2008). J. Agronomy and Crop Sci., 167(1): 53-60.

27. Longnecker, N., Kirby E.J.M. and Robson. A. (1993). Leaf emergence, tiller growth and apical development of nitrogen-deficicient spring wheat. Crop Sci., 33: 154-160.

28. Martins, J. D., Carlesso, R., Petry, M. T., Knies, A. E., Oliveira, Z. B. and Broetto, T. (2012). Estimating the phyllocron in maize hybrids with different cycles of vegetative development. Ciencia Rural, 42, 777-783.

29. Masle, J., Doussinault, G., Farquhar G.D. and Sun. B. (1989). Foliar stage in wheat correlates better to photothermal time than to thermal time. Plant Cell Environ., 12: 235-247.

30. Mass, E.V. and Grieve. C.M. (1990). Spike and leaf development in salt-stressed wheat. Crop Sci., 30: 1309-1313.

31. Mendonça, H.F.C., Calvete, E.O., Nienow, A.A., Costa, R.C., Zerbielli, L. and Bonafé, M. (2012). Phyllochron estimation in intercropped strawberry and mono crop systems in a protected environment. Revista Brasileira de Fruticultura, 34, 15-23.

32. Mobasser, H.R., Tari, D.B., Vojdani, M., Abadi, R.S., Eftekhari, A. (2007). Effect of Seedling Age and Planting Space on Yield and Yield Components of Rice (Neda Variety) Asian Journal of Plant Sciences, Vol. 6(2), pp: 438-440.

33. Mohamed, A., Abd, E., Ashraf, A. and Abd, E. (2013). Predicting the effect of temperature on leaf appearance in seven spring bread wheat genotypes. World Essays Journal, 1, 137-141.

34. Munns, R., James, R.A. and Lauchli, A. (2006). Approaches to increasing the salt tolerance of wheat and other cereals. J. Exp. Bot., 57, 1025–1043.

35. Nandhakumar, M.R., Velayudham, K., Thavaprakaash, N. and Govindan, R. (2018). Assessment of phyllochron and tillers contribution to grain yield of rice. Oryza Vol. 55 No. 3, 2018 (438-444).

36. Nemoto, K., Morita, S. and Baba. T. (1995). Shoot and root development in rice related to the phyllochron. Crop Sci., 35 (1): 24-29.

37. Pržulj, N. M. and Momčilović, V. M. (2013). Effect of cultivar and year on phyllochron in winter barley. Journal of Natural Sciences, 125, 93-100.

38. Rosa, H.T., Walter, L.C., Streck, N.A. and Alberto, C.M. (2009). Thermal time methods and sowing dates in phyllochron determination in wheat cultivars. Pesquisa Agropecuária Brasileira, 44, 1374-1382.

39. Rosa, H.T., Walter, L. C., Streck, N.A., Andriolo, J.L., Silva, M.R. and Langner, J.A. (2011). Base temperature for leaf appearance and phyllochron of selected strawberry cultivars in a subtropical environment. Bragantia, 70, 939-945.

40. Santos, L.C., Bonomo, P., Silva, V. B., Pates, N.M.S., Silva, C.C.F. and Pires, A.J.V. (2009). Morphogenic characteristics of Brachiaria in response to different fertilization. Acta Scientiarum. Agronomy, 31, 221-226.

41. Selvakumar, S., Sakthival, S., Kamoshitha, A., Babu, R., Thiyageswari,S. and Raviraji,A. (2020). Study on physiological parameters and economics of rice cultivation under different establishment methods and water management practices. Current J.Applied Sci. and tech. 39 (20): 123-131.

42. Shaowu Hu, Wang Chen Kaicheng Tong, Yunxia Wang, Liquan Jing, Yulong Wang, Lianxin Yang .(2022). Response of rice growth and leaf physiology to elevated CO_2 concentrations: A meta-analysis of 20-year FACE studies. Sci Total Environ. 807 (Pt 3):151017.

43. Shoban Chakravarthy, K. and Jagannathan. R. (2013). Phyllochron in Five Maize Hybrids (*Zea mays* L.) at Different Nitrogen Fertilizer Levels. Madras Agric. J., 100 (Special issue): 353-354.

44. Singh, V.P, Shankar, U. and Bora, P. (2007). Feasibility Study to support System of Rice Intensification(SRI).Retrieved5th July,2009,fromhttp://dorabjitatatrust.org/Publications/pdfs/study% 20report.pdf

45. Skinner, R.H. and. Simmons. S.R. (1993). Modulation of leaf elongation, tiller emergence, and tiller senescence in spring barley by far-red light. Plant Cell Environ., 16: 555-562.

46. Streck, N.A., Lago, I., Samboranha, F.K., Gabriel, L.F., Schwantes, P. and Schons, A. (2009). Base temperature for leaf appearance and phyllochron of the BRS Missoes maize variety. Ciencia Rural, 39, 224-227.

47. Streck, N. A., Weiss, A., Xue, Q. and Baenziger, P. S. (2003). Incorporating a chronology response into the prediction of leaf appearance rate in winter wheat. Annals of Botany, 92, 181-190.

48. Veeramani, P., Durai R.S and Subrahmaniyan, K. (2012). Study of phyllochron - System of Rice Intensification (SRI) technique. Agricultural Science Research Journal Vol. 2(6) pp. 329 – 334.

49. Xue, Q., Weiss, A. and Baenziger, P.S. (2004). Predicting leaf appearance in field-grown winter wheat: evaluating linear and non-linear models. Ecological Modelling, 175, 261-270.

50. Yoshida, S. (1981). Fundamentals of rice crop science. IRRI. Los Banos, Philippines.

51. Younas, M.H. Rehman and Hayder, G. (2002). Magnitude of variability for yield and yield associated traits in maize hybrids. Asian J. Plant Sci., 1(6): 694-696.

