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Comparative performance of aloe (*Aloe barbadensis* M.) under open and polyhouse conditions as influenced by different harvest intervals

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Abstract
To study the growth and development of *Aloe barbadensis* M. in open and polyhouse environment and also to determine the proper harvest time of *Aloe barbadensis* M. in Assam condition, an experiment was carried out at the Medicinal and Aromatic Plants Block, Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat. A total of four treatments with five replications were laid out in a Randomized Block Design. The treatments comprised of: T0- Harvesting at an interval of two months (recommended practice), T1- Harvesting at one and a half months interval (after first harvest), T2- Harvesting at two and a half months interval (after first harvest) and T3- Harvesting at three and a half months interval (after first harvest) for both open and polyhouse conditions. The results showed that the different harvest intervals had significant effects on the growth and yield of Aloe. The maximum values for all the growth and yield parameters for both polyhouse and open conditions were observed in T3 treatment while the minimum values were observed in T1 treatment. Hence, it can be concluded that Aloe leaves harvested at three and a half months interval in polyhouse resulted in higher productivity and maximum benefit in subtropical climate like Jorhat, Assam.

Keywords: aloe, growth, harvesting, open, polyhouse, yield

Introduction
Aloe is an important monocotyledonous medicinal plant for centuries. Belonging to the family Liliaceae, the genus comprises of about 300 species (Reynolds, 1985) [6]. It is commonly called as 'Burn plant', 'Nature's sun screen' or 'Nature's tonic' because it is very much effective against burns and is gaining importance as skin tonic in the cosmetic industry. This miracle plant contains more than 200 constituents which are beneficial to humans like anthraquinones, amino acids, sterols, hormones, vitamins, minerals, enzymes, saponins, lignin, polysaccharides etc. The plant is xerophytic in nature and is mostly grown in warm tropical areas and cannot survive freezing temperatures. *Aloe barbadensis* M. is an industrially important cultivated species. The useful parts of the plant are leaves which contain a gel (Yagi and Takeo, 2003; Hamman, 2008) [3, 8]. The gel of *Aloe barbadensis* M. has various pharmacological and medicinal value. It possesses various biological and physiological activities in cosmetology and medicine such as healing ability of skin burns and cutaneous injuries, prophylactic effect against radiation, leucopenia, antiulcer, inhibitory action against some bacteria and fungi, inflammation-inhibiting effect, inhibition of the prostaglandin synthesis by anthraquinone-type compounds, and inhibition of the AIDS virus by acemannan (Hernandez-Cruz *et al.*, 2002; Ramachandra and Srinivasa, 2008) [5, 4].
The cultivation of *Aloe barbadensis* M. has acquired great commercial importance for medicinal products and cosmetics processing in North Eastern India also. Since, North-East Region receives heavy rainfall and the crop is a dry land crop, the prospects remain growing *Aloe barbadensis* M. in polyhouse condition. However, information on growth and yield of the crop is scanty in North East India, both in open and polyhouse cultivation. Keeping on view the importance of the crop in NE Region, the experiment was carried out to study the growth and development of *Aloe barbadensis* M. in open and polyhouse environment and also to determine the proper harvest time in Assam condition.

Materials and Methods
The experiment was conducted in existing plantation of Aloe in the Medicinal and Aromatic Plants (MAP) Block, Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat. The design of the experiment was Randomized Block Design (RBD) with four treatments and five replications. Each treatment included five plants. Two sets of experiment were conducted. One under open condition and another under polyhouse.

The plantation was done at a total area of 600 m^2 (Open-300 m^2, Polyhouse-300 m^2). Plant to plant spacing was 60 cm whereas row to row spacing was 45 cm. Irrigation was given at intervals during dry periods. The plants were manured with 450 kg FYM, 3.26 kg urea, 9.38 kg SSP and 2.50 kg MOP once during the period of experiment. Urea, SSP and MOP were applied as basal dose. The applied manuring doses were same for both polyhouse and open cultivation. The plots were kept free from weeds throughout the growing period. Manual weeding was carried out in both open and polyhouse conditions. No serious pests and diseases were observed in both open and polyhouse conditions during the course of experiment and as such no plant protection chemicals were used in the experimental site. The first harvesting was done 12 months after planting. After that it was regularly done at different intervals according to different treatments. The matured leaves from bottom side were harvested manually in the morning hours using a clean sharp knife. The leaves were cut closer to the stem. The harvested leaves were washed with water. Then the leaves were packed in big polybags separately for each treatment and brought to the laboratory to carry out further analyses. First, the plant height, leaves per plant, matured leaves per plant, leaf length, leaf diameter and leaf thickness were measured. Fresh weight of gel was measured by a digital balance. Gel was separated from peel using a spoon and kept in a hot air oven at 70°C for two days. Then, gel dry weight, gel powder yield, gel per leaf and total leaf yield were calculated. Observations made during field experimentation and data obtained from laboratory determinations relating to growth and yield aspects were subjected to analysis of variance. The data generated during the experiment were statistically analyzed using Randomized Block Design (RBD).

Results and Discussion

The pronounced effect of harvesting at different intervals was noted on plant growth characters (Table 1 - 2). The maximum values for all the growth characters were observed in T3 [Harvesting at three and a half months interval (after first harvest)] followed by T2 [Harvesting at two and a half months interval (after first harvest)] whereas, the minimum values were recorded in T1 [Harvesting at one and a half months interval (after first harvest)] for both open and polyhouse cultivation. This might be because of the climatic and growing conditions. The results were in agreement with the finding of a two year study by Wang and Strong (1993) [7] in *Aloe vera* plants. They found that fluctuations in several physical and chemical properties are attributed to seasonal and grower influences. Seasonal fluctuations have been attributed to water availability. The growth parameters recorded in polyhouse environment were comparatively better than the cultivation done in open condition. This may be due to the fact that North East region receives heavy amount of rainfall annually and Aloe is a dryland crop. So, when the plants were grown under polyhouse environment, they were protected from receiving heavy precipitation and under a regulated environment in the polyhouse the plants flourished well with increase in plant height, leaves per plant, matured leaves per plant, leaf length, leaf diameter and leaf thickness. Also, enhanced temperature effect inside polyhouse, especially in winter made the difference.

It is also evident from Table 2 that, gel fresh weight and gel dry weight were recorded the maximum in T3 [Harvesting at three and a half months interval (after first harvest)] while the values were recorded minimum in T1 [Harvesting at one and a half months interval (after first harvest)] for both polyhouse and open conditions. The increase in the gel weight parameters was associated with increased plant growth characters. This may be due to geographical location as well as the growing conditions. The qualitative and quantitative composition of the gel of the leaves surely plays a very important physiological role in the retention of water, and then in the maintenance of the water supply for cell synthesis and leaf growth (Del Viso *et al*., 2009) [2].

The maximum gel powder yield, gel per leaf and total leaf yield were recorded in T3 [Harvesting at three and a half months interval (after first harvest)] whereas, the lowest values were recorded in T1 [Harvesting at one and a half months interval (after first harvest)] for both polyhouse and open conditions (Table 3). This might be due to the enhancement in the growth parameter attributes which resulted in improved crop productivity. The yield of Aloe plants depends on many factors such as the climatic, edaphic, irrigation, soil water availability for the roots etc. Yield depends to a large degree on the content of photosynthetically active pigments. Cushman and Bohnert (1997) [1] reported that the amount of gel in the leaves is positively and significantly correlated with the morphological characters i.e. plant height and leaf size. The results clearly indicated that selection for yield component of Aloe depend upon big sized plants with large thick fleshy leaves. So, these results indicated the importance of size of the plant and size of the leaves as the main morphological characters suitable for selection of plant types for good yield.

Economics is the most important single factor which decides the adoption of any improved practices by the farmers. In other words, a treatment should not only be effective but, also should be profitable preposition. Only then it can be employed by the growers.

Hence, from Table 4 - 5 it can be noted that the maximum yield resulting in maximum benefit: cost ratio was obtained from harvesting at three and a half months interval (T3) followed by harvesting at two and a half months interval (T2) and the minimum benefit: cost ratio was obtained from harvesting at one and a half months interval (T1) for both polyhouse and open conditions. However, polyhouse cultivation recorded the maximum benefit: cost ratio than open cultivation.

So, from the findings of the present investigation it can be concluded that Aloe leaves harvested at three and a half months interval in polyhouse resulted in higher productivity and maximum benefit in subtropical climate like Jorhat, Assam.

Table 1: Effect of different harvest intervals on plant height, leaves per plant, matured leaves per plant and leaf length under polyhouse and open conditions

Treatments	Plant height (cm)		Leaves per plant		Matured leaves per plant		Leaf length (cm)	
	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open
T_0: Harvesting at an interval of two months (recommended practice)	48.87	29.40	11.91	6.48	7.84	2.74	38.72	22.73
T_1: Harvesting at one and a half months interval (after first harvest)	42.41	24.87	10.04	3.51	5.33	2.19	35.31	18.63
T_2: Harvesting at two and a half months interval (after first harvest)	50.15	32.42	12.31	6.77	9.66	4.85	40.96	25.62
T_3: Harvesting at three and a half months interval (after first harvest)	59.76	37.27	13.84	9.54	11.64	6.50	47.61	30.21
S.Ed	1.74	1.10	0.74	0.43	0.11	0.14	2.20	1.47
$C.D_{(0.05)}$	3.80	2.40	1.61	0.93	0.25	0.31	4.79	3.20

Table 2: Effect of different harvest intervals on leaf diameter, leaf thickness, gel fresh weight and gel dry weight under polyhouse and open conditions

Treatments	Leaf diameter (cm)		Leaf thickness (cm)		Gel fresh weight (g)		Gel dry weight (g)	
	Polyhouse	Open	Polyhouse	Polyhouse	Polyhouse	Open	Polyhouse	Open
T_0: Harvesting at an interval of two months (recommended practice)	4.19	1.90	1.27	0.60	55.77	12.65	1.14	0.27
T_1: Harvesting at one and a half months interval (after first harvest)	3.62	1.84	1.20	0.52	48.68	12.33	0.69	0.19
T_2: Harvesting at two and a half months interval (after first harvest)	4.57	2.86	1.35	0.66	61.63	14.24	1.25	0.45
T_3: Harvesting at three and a half months interval (after first harvest)	5.17	3.07	1.53	0.74	75.83	17.10	1.37	0.63
S.Ed	0.24	0.17	0.06	0.04	3.40	1.19	0.04	0.02
$C.D_{(0.05)}$	0.52	0.36	0.14	0.08	7.40	2.60	0.08	0.05

Table 3: Effect of different harvest intervals on gel powder yield, gel per leaf and total leaf yield under polyhouse and open conditions

Treatments	Gel powder yield (g/100g)		Gel per leaf (g)		Total leaf yield (fresh weight kg)	
	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open
T_0: Harvesting at an interval of two months (recommended practice)	0.56	0.37	46.77	8.72	4.15	0.88
T_1: Harvesting at one and a half months interval (after first harvest)	0.45	0.24	34.88	7.50	3.40	0.67
T_2: Harvesting at two and a half months interval (after first harvest)	0.76	0.46	54.52	8.83	4.60	0.97
T_3: Harvesting at three and a half months interval (after first harvest)	0.85	0.52	71.07	13.10	5.11	1.24
S.Ed	0.02	0.03	6.49	1.17	0.20	0.05
$C.D_{(0.05)}$	0.04	0.07	14.13	2.55	0.45	0.10

Table 4: Economics of cultivation (Polyhouse)

Treatments	Yield (kg/ha)	Gross expenditure	Gross return	Net return	B:C
T_0: Harvesting at an interval of two months (recommended practice)	324.99	132799.92	368700.08	235900.16	1.78
T_1: Harvesting at one and a half months interval (after first harvest)	150.00	137512.32	325752.28	188239.96	1.37
T_2: Harvesting at two and a half months interval (after first harvest)	406.66	117765.12	434364.08	316598.96	2.69
T_3: Harvesting at three and a half months interval (after first harvest)	453.66	87695.52	593573.68	505878.16	5.77

Sale price of Aloe fresh leaves = Rs. 20 per kg and Aloe powder = Rs.60 per 100 g

Table 5: Economics of cultivation (Open)

Treatments	Yield (kg/ha)	Gross expenditure	Gross return	Net return	B:C
T_0: Harvesting at an interval of two months (recommended practice)	152.66	132755.04	342354.16	209599.12	1.58
T_1: Harvesting at one and a half months interval (after first harvest)	80.00	137467.44	296297.16	158829.72	1.16
T_2: Harvesting at two and a half months interval (after first harvest)	185.66	117720.24	376928.96	259208.72	2.20
T_3: Harvesting at three and a half months interval (after first harvest)	214.66	87650.64	445438.56	357787.92	4.08

Sale price of Aloe fresh leaves = Rs. 20 per kg and Aloe powder = Rs.60 per 100 g

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