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Growth, Yield and Quality of Ecotypes of *Aloe vera* L.

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Aloe vera L. is extensively used in preparation of medicines, cosmetics and food supplements. In this study 21 ecotypes were evaluated and significant variation was observed among the ecotypes for growth, yield and quality parameters. Ecotype TVM recorded the highest leaf yield per plant of 1597.37 g and gel yield of 1731.60 g with the gel quality parameters viz., moisture (99.20%), acidity (3.93), total solids (0.81), soluble solids (0.71), fibre (0.10%) and reducing sugars (1553.70mg l^{-1}). Its superiority could be due to its genetic makeup, ability to absorb more nutrients from the soil and capability of capturing PAR and thereby enhanced assimilation of photosynthates. The highest dry latex (crude aloin) yield of 1.78g $plant^{1}$ was obtained from an ecotype TCY as its leaves possess more number of pericyclic cells in the vascular bundles and its inherent ability to divert its photosynthates towards the production of alkaloids. Suitable ecotypes for gel (TVM) and aloin yield (TCY) were identified.

Key words: *Aloe vera,* ecotypes, soluble solids, *Aloe* gel, aloin, reducing sugar

The delicate leaves of *Aloe vera* L. contain a very small quantity of viscous yellow fluid known as Aloe latex, embedded in the pericyclic cells of the vascular bundles. The dried latex known as aloin is used as laxative in traditional and modern medicines. *Aloe* gel is the mucilaginous substance obtained from the paranchymatous cells of fresh leaves of *Aloe.* The constituents of *Aloe* gel include saccharides, vitamins, minerals, amino acids, lipids, sterols and enzymes and have been known to possess important biological properties like anti-inflammatory, antibacterial, antitumour, infected wound healing etc.

With the increasing interest in natural products across the world the demand for medicinal plants and its trade is expected to grow upto US $ 5 trillion by 2050. *Aloe vera* is one among the few medicinal plants by virtue of its extensive medicinal, nutraceutical, cosmetic uses enjoy a major chunk of the market across the world (Yogeeswaran et al., 2005). Now it is collected from the wild source and thus this species is becoming commercially threatened due to injudicious and destructive harvesting from natural stands (Ghate, 2002). So far its commercial cultivation is not popular among the farmers due to the lack of knowledge on correct strain or ecotype of *Aloe vera* and its agronomic management (Hernandez-Cruz et al., 2002). Alagukannan and Ganesh (2006) reported the existence of variation among the *Aloe vera* ecotypes collected across south India in terms of growth, yield and quality characters. Since there is much diversity in *Aloe ve*ra, the cultivators unable to choose the best ecotype for commercial cultivation. Hence, an effort was made to evaluate the different ecotypes of *Aloe vera* for growth, yield and quality and to identify suitable ecotypes for gel and aloin yield under commercial cultivation.

Materials and Methods

By extensive exploration across south India both from research institutions and wild, 54 ecotypes were collected and after purging the identical ones 21 ecotypes were taken for further evaluation at Faculty of Agriculture, Gandhigram

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Rural University, TamilNadu during 2005- 06. Soil in the experimental field was sandy loam with the available NPK content of 56, 4.4 and 288 kg ha^{-1} respectively. Experiment was laid out in Randomized Block Design with 21 ecotypes and replicated twice. Field layout, randomization and allocation of different ecotypes to different plots of size 5.4 m^2 were carried out adopting statistical procedures as suggested by Panse and Sukhatme (1985). The uniform suckers of 15-18 cm long were planted at a spacing of 75x60 cm and necessary intercultural operations were done.

Four plants in each ecotype were randomly selected, tagged and observations on plant height (cm), plant spread (cm), number of suckers $plant^{-1}$, number of leaves $plant^{-1}$, leaf length (cm) and leaf width (cm) were made. Leaf volume was calculated as V = (L/12)3.14WT (Hernandez-Cruz et al.,2002). As *Aloe* plant resembles pineapple in leaf orientation, the 'D' leaf (longest leaf just fully grown) was selected for volume calculation. Growth rate in terms of gain in plant height and number of leaves produced per month were recorded.

Yield parameters such as leaf weight (g), leaf yield $plant^{-1}$ (g), gel yield $leaf^{-1}$ (g), gel yield $plant^{-1}$ (g), gel:peel ratio, latex yield $leaf^{-1}$(g), latex yield $plant^{-1}$(g), crude aloin $leaf^{-1}$(g) crude aloin yield $plant^{-1}$ (g) were recorded at two subsequent harvests. The inner gel was collected by filleting the leaves like a fish after removing the rind. Aloe latex was collected by giving a transverse cut at 2 cm above the base of leaf and allowed at slanting position in a pre weighed beaker for half-an-hour for the exudates to drain. The latex yield on wet and dry basis (crude aloin) was calculated immediately after draining and after 6 hours of solidification at ambient temperature, respectively. The quality parameters like moisture, gel acidity, total and soluble solids, fibre and reducing sugars contents were estimated by standard procedures as suggested by Yun-Tung and Strong (2002) from the translucent mesophyll tissues collected from each leaf and combined into a single composite sample. The data collected were subjected to statistical analysis by the method of analysis of variance (Panse and Sukhatme, 1985).

Results and Discussion

Growth parameters

Among the ecotypes evaluated, TCY recorded the highest significant value (79.31 cm) for plant height and it was followed by the ecotypes TVM (69.64cm) and GGM (60.93cm). Likewise TCY recorded the significant value of 85.38 cm and it was 76.56 in TVM and 73.32 in GGM for plant spread. The lowest values were recorded from ZMR (38.34cm) and KH (32.76cm) (Table 1). The highest number of suckers $plant^{-1}$ (11.38) was observed from an ecotype named IIHR AV-15 and it was followed by TVM (9.00) and GGM (8.75). The lowest number of suckers (4.88) $plant^{-1}$ was recorded from TCY. TCY recorded the highest number of leaves $plant^{-1}$ (29.50) and followed by TVM (25.63) and the lowest number of leaves $plant^{-1}$ was observed from IIHR – 4 (10.88). The number of leaves $plant^{-1}$ has great influence on growth and development of *Aloe* and it plays a vital role in the photosynthetic efficiency of the plant. As these two ecotypes TCY and TVM possess the highest spread and maximum number of leaves, it is presumed that the net leaf area exposed to sunlight could be greater and it is expected to produce higher photosynthates from these two ecotypes.

The longest leaf was recorded from the ecotypes TCY (63.10cm) and TVM (59.17cm). The same trend was observed for leaf width also. This could be due to the enhanced activity of cell division and cell enlargement in these two ecotypes. The lowest leaf length (43.59cm) was observed from the ecotype VNR and the lowest leaf width (4.40cm) was recorded from IIHR AV-15. It shows the difference in genetic constitutions and cell function in different *Aloe vera* ecotypes collected from various localities. These results are inconsonance with investigation on chromosome behaviours (like differences in the number of chiasmata and meiotic behaviour) attributed to genomic differentiation between populations of *Aloe vera* from different localities (Nodoushan et al., 2004).

Ecotype TVM recorded the highest leaf thickness of 2.74 cm and it was followed by GGM (2.41cm). It is an important character for

Table 1. *Per se* performance of *Aloe vera* ecotypes for growth characters at 240 days after planting

S.No.	Name of the ecotypes	Growth Characters									
		Plant height (cm)	Plant spread (cm)	No. of suckers plant^{-1}	No. of leaves plant^{-1}	Leaf length (cm)	Leaf width (cm)	Leaf thickness (cm)	Leaf volume (cm^3)	Growth rate	
										Height month^{-1}(cm)	No.of leaves month^{-1}
1	IIHR AV I	51.99	56.03	6.63	14.38	48.96	6.79	2.03	177.43	4.70	1.65
2	IIHR AV 2	55.88	43.48	6.38	16.75	49.24	6.04	1.73	136.12	5.43	1.83
3	IIHR AV 3	48.19	52.04	5.38	15.38	47.85	7.08	1.95	172.60	4.30	1.81
4	IIHR AV 4	47.36	48.90	5.88	10.88	51.58	7.81	2.02	211.46	4.01	1.07
5	IIHR AV 13	46.57	56.97	6.13	13.13	50.32	6.16	1.83	148.54	4.00	1.44
6	IIHR AV 15	52.45	47.34	11.38	14.25	45.19	4.40	2.01	104.43	4.95	1.55
7	GGM	60.93	73.32	8.75	14.00	51.17	6.78	2.41	217.81	5.99	1.61
8	ODC	49.07	43.93	5.38	14.13	45.78	7.54	1.92	161.07	4.39	1.56
9	SLM	54.75	57.55	5.63	17.50	48.96	7.90	2.10	212.69	5.16	2.03
10	KRR	56.18	64.94	6.00	15.88	48.16	7.78	1.53	199.82	5.37	1.81
11	KH	51.07	32.76	6.13	11.63	44.34	5.62	2.00	128.84	4.70	1.19
12	VNR	51.56	59.34	5.75	13.25	43.59	5.40	1.94	121.50	4.68	1.42
13	EDE	48.46	54.42	5.88	13.13	49.70	6.03	1.97	133.76	4.35	1.44
14	CBE	53.73	66.34	5.63	13.00	50.06	7.02	2.00	182.60	4.80	1.40
15	HSR	56.34	50.05	6.50	16.00	47.66	7.33	2.01	182.44	5.45	1.83
16	TVM	69.64	76.56	9.00	25.63	59.17	10.11	2.74	429.27	7.74	3.42
17	TCY	79.31	85.38	4.88	29.50	63.10	10.92	1.99	357.41	8.64	3.94
18	ZMR	46.40	38.34	6.00	14.38	40.89	6.96	2.04	149.85	3.99	1.58
19	KKL	55.76	57.37	6.50	16.75	46.42	7.19	1.89	163.55	5.41	2.03
20	KKAP	51.59	52.80	5.75	15.38	48.81	7.05	2.01	171.17	4.97	1.82
21	KL	47.26	48.57	6.25	15.00	49.53	7.31	2.02	190.97	4.18	1.65
	SEd	4.25	3.77	1.13	1.82	4.66	0.71	0.15	25.09	0.63	0.25
	CD (0.05)	8.87	7.87	2.37	3.80	9.72	1.47	0.31	52.35	1.32	0.52

production of higher weight of leaves thereby increasing gel yield. Though TCY was superior in all other characters, its leaf thickness (1.99cm) was not significant. The highest leaf volume of 429.27 cm^3 was recorded from the ecotype TVM, whereas the lowest leaf volume (104.43cm^3) was recorded from IIHR AV-15. Growth rate in terms of gain in height per month and number of leaves produced per month were the highest in TCY and TVM and it is significantly different from other ecotypes. The increase in leaf thickness and volume might be due to higher uptake of nitrogen from the soil, enhanced cell division and elongation as well as more synthesis of chloroplasts (Gnanavadivel, 2004).

Yield parameters

The ultimate objective of this study is getting higher yield in terms of leaf, gel and aloin. The number of leaves harvested $plant^{-1}$, single leaf weight, leaf yield $plant^{-1}$, gel and latex yield $plant^{-1}$ (Table 2) are extremely important yield attributes in *Aloe vera* under field condition. Obviously the highest number of leaves harvested $plant^{-1}$ (6.13), leaf weight (412.35g), leaf yield $plant^{-1}$ (2359.87g) was obtained from the ecotype TVM.

Gel yield is an important trait in determining the suitability of a particular ecotype to cosmetics and food industry. The leaves of ecotype TVM gave the highest gel content of 282.57 g $leaf^{-1}$ and 1731.60 g $plant^{-1}$ in first two harvests. Increased gel yield was obtained due to greater plant height resulting in higher number of leaves plant, leaf volume, leaf weight and photosynthetic rate etc. The present findings are in accordance with Pareek et al. (1999). The highest gel to peel ratio was obtained from three different ecotypes namely GGM (2.37:1), IIHR AV-13 (2.28:1) and TVM (2.20:1). Increased nitrogen and uptake from the soil by the root system of TVM plants could be the reason for its more gel content (Gnanavadivel, 2004). They are statistically significant and at par. In contrary the lowest gel peel ratio was recorded from TCY (0.88). Hence, though TCY showed its superiority for plant height, higher number of leaves, leaf weight and width, its gel content was non-significant.

Latex yield is an important trait in determining the suitability of ecotypes to medical industry. TCY recorded the highest latex yield of 2.22 g $plant^{-1}$ on wet and 1.78 g $plant^{-1}$ on dry basis. The increased latex yield in TCY could be due to more leaf area ie., more leaf width and length and thereby more number of pericyclic cells in the vascular bundles besides its inherent ability to divert its photosynthates towards the production of more secondary metabolites – the alkaloids.

Quality parameters

There was no significant difference in gel acidity (p^H) of different ecotypes. However, the range of gel acidity estimated from 21 ecotypes was 3.93 to 4.49. The lower and desired acidity was obtained from the gel of ecotype TVM. In *Aloe vera*, organic acids accumulate as the result of Crasulacean Acid Metabolism (CAM) carbon fixation during the night. The lower pH in gel of TVM might be due to more accumulation of organic acids by the process of CAM. The acids are then used for the production of sugars (Bharucha and Joshi, 1957). As *Aloe vera* gel is the water storage organ of the plant, the water content estimated from the different ecotypes ranges between 99.20 (TVM and TCY) and 99.38 per cent (KL). Among the 21 ecotypes tested, TCY (0.81%), TVM (0.81%) and GGM (0.78%) recorded the highest percentage of total solids and they are at par. TVM and GGM showed its superiority over the other ecotypes by registering the values of 0.71 and 0.66 percent, respectively for soluble solids. The highest fibre content (0.21%) was estimated from TCY, whereas the reducing sugar content was the highest (1553.70mg l^{-1}) in TVM gel and it will be the reliable indicator for the quality of Aloe products especially health drinks.

To meet the ever increasing demand of *Aloe vera,* suggesting suitable types of *Aloe vera* for gel yield and latex yield is of immense importance. The ecotypes wildly collected from Tiruvannamalai (TVM) and Trichy (TCY) area of TamilNadu showed its superiority for quality gel and aloin yield respectively. By commercializing these two ecotypes, *Aloe vera* can be made to catch the

Table 2. ***Per se*** **performance of** ***Aloe vera*** **ecotypes for yield parameters***

S.No.	Name of the ecotypes	Leaf weight (g)	No. of leaves harvested plant^{-1}	Leaf yield plant^{-1} (g)	Gel yield leaf^{-1} (g)	Gel yield plant^{-1} (g)	Gel: Peel ratio	Wet latex leaf^{-1} (g)	Wet latex plant^{-1} (g)	Dry latex leaf^{-1} (g)	Dry latex plant^{-1} (g)
1	IIHR AV I	335.35	3.50	1185.31	205.98	719.79	1.60	0.32	1.09	0.17	0.60
2	IIHR AV 2	327.88	4.13	1328.44	204.53	844.18	1.66	0.26	1.05	0.15	0.63
3	IIHR AV 3	357.95	4.38	1524.71	228.03	996.68	1.76	0.24	1.03	0.14	0.61
4	IIHR AV 4	337.88	3.00	1147.84	221.45	664.34	1.91	0.30	0.89	0.16	0.48
5	IIHR AV 13	335.45	4.25	1353.78	233.12	990.74	2.28	0.27	1.15	0.14	0.59
6	IIHR AV 15	187.76	2.88	718.19	112.63	323.57	1.51	0.19	0.54	0.11	0.31
7	GGM	367.81	5.00	1690.10	258.49	1294.96	2.37	0.32	1.60	0.20	1.02
8	ODC	364.50	3.88	1424.15	216.98	840.33	1.47	0.26	1.01	0.16	0.61
9	SLM	351.88	4.00	1494.97	222.13	887.66	1.72	0.27	1.09	0.13	0.51
10	KRR	359.00	3.38	1307.21	207.25	701.08	1.37	0.28	0.92	0.17	0.57
11	KH	223.38	3.13	923.54	129.50	407.04	1.38	0.23	0.71	0.13	0.41
12	VNR	291.83	3.88	1167.60	170.17	657.32	1.41	0.30	1.15	0.18	0.67
13	EDE	350.31	4.25	1374.50	212.45	904.92	1.54	0.29	1.23	0.19	0.80
14	CBE	338.28	4.00	1314.47	201.16	808.34	1.49	0.33	1.30	0.20	0.79
15	HSR	332.98	4.13	1352.24	208.10	861.29	1.67	0.27	1.11	0.14	0.58
16	TVM	412.35	6.13	2359.87	282.57	1731.60	2.20	0.26	1.56	0.14	0.87
17	TCY	434.30	5.63	2042.81	202.13	1133.79	0.88	0.40	2.22	0.32	1.78
18	ZMR	350.25	4.25	1399.62	189.16	803.93	1.18	0.30	1.25	0.16	0.67
19	KKL	354.37	4.00	1348.84	196.99	787.51	1.26	0.24	0.96	0.14	0.55
20	KKAP	338.36	3.38	1234.54	208.70	703.71	1.62	0.31	1.04	0.17	0.57
21	KL	232.88	3.50	963.88	133.13	464.79	1.36	0.30	1.06	0.17	0.61
	SEd	16.43	0.44	150.91	8.14	99.23	0.15	0.03	0.15	0.02	0.09
	CD (0.05)	34.27	0.92	314.80	16.97	206.99	0.32	0.07	0.31	0.03	0.18

* Pooled data from first two harvests

Table 3. Quality parameters/composition of gel of different *Aloe vera* ecotypes

S.No.	Ecotypes	Moisture content (%)	Acidity (pH)	Total solids (%)	Soluble solids (%)	Fibre content (%)	Reducing sugar (mg l^{-1})
1	IIHR AV I	99.33	4.09	0.68	0.59	0.09	1219.50
2	IIHR AV 2	99.33	4.09	0.67	0.60	0.08	1330.40
3	IIHR AV 3	99.33	4.24	0.68	0.58	0.10	1280.51
4	IIHR AV 4	99.37	4.02	0.64	0.56	0.08	1240.40
5	IIHR AV 13	99.34	4.05	0.67	0.58	0.09	1302.90
6	IIHR AV 15	99.36	4.49	0.65	0.56	0.09	1038.62
7	GGM	99.23	3.97	0.78	0.66	0.12	1460.00
8	ODC	99.36	4.31	0.65	0.54	0.11	1321.55
9	SLM	99.34	4.10	0.67	0.57	0.10	1237.61
10	KRR	99.34	4.09	0.66	0.57	0.10	1317.61
11	KH	99.38	4.04	0.62	0.52	0.10	1134.35
12	VNR	99.35	4.07	0.65	0.56	0.09	1221.40
13	EDE	99.33	4.20	0.67	0.57	0.11	1231.40
14	CBE	99.35	4.00	0.66	0.58	0.08	1201.60
15	HSR	99.37	4.05	0.63	0.53	0.11	1087.62
16	TVM	99.20	3.93	0.81	0.71	0.10	1553.70
17	TCY	99.20	4.05	0.81	0.60	0.21	998.89
18	ZMR	99.34	4.00	0.67	0.57	0.10	1090.24
19	KKL	99.35	4.18	0.66	0.57	0.09	1201.18
20	KKAP	99.34	4.06	0.66	0.57	0.09	1165.35
21	KL	99.38	4.18	0.62	0.58	0.07	1201.35
	SEd	0.039	0.155	0.038	0.038	0.019	18.314
	CD (0.05)	0.082	0.324	0.080	0.079	0.040	38.202

best place as a cash crop. By bringing these two types into mainstream of cultivation, the extinction of wild *Aloe* population will also be prevented.

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