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PRODUCTION OF YIELD AND ACEMANNAN IN *ALOE* PLANTS UNDER PEDO-ECOLOGICAL STRESSES

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SUMMARY

Two species *Aloe barbedensis* and *Aloe ferox* were cultivated under different irrigation and salinity stress conditions in order to evaluate the yield attributes along with the content of acemannan. The experiment was laid in factorial randomized block design with three replications under pot culture study. The results suggested that high salinity stress alongwith moderate moisture stress condition of the soil were favorable for better growth and yield parameters of *Aloe* plants. Leaf weight, gel fillet percent, gel percent and acemannan content in both the *Aloe* species increased under these soil stress conditions. Various levels of salinity and moisture, individually effected the yield parameters. However, at every situation, *Aloe ferox* gave better performance relative to that of *Aloe vera*.

***Key words*: Acemannan, *Aloe ferox*, *Aloe* gel, *Aloe vera*.**

INTRODUCTION

The succulent xerophytic plant *Aloes* belonging to the family Lilliacae are cultivated extensively as herbal crop in semiarid and subtropical areas of India since long. Only the four out of more than 400 known species of *Aloes* have been proved to possess nutritional qualities. *Aloe vera* and *Aloe ferox* are regarded as the most beneficial to human health and thus they are most intensively studied and are cultivated for commercial purposes like medicinal, additive in food, beverages and cosmetics (Grover *et al.* 2002). Its specific uses as remedies to multitude of apathies, including dermatological problems (particularly burns and wounds), intestinal difficulties, immunostiulatory and other disorders (Panda 2002) have also been acknowledged. Much of beneficial activities observed in *Aloes* have been attributed to chemically and biologically active compound acemannan in the mucilaginous polysaccharide gel in leaves of the plants.

The main bioactive compound in the gel is a mucopolysaccharide, acemannan the acetylated mannans (Femenia *et al.* 1999). Numerous clinical studies have confirmed that the polysaccharide, a high molecular weight water-soluble compound, exhibits anti-inflammatory and immunostimulatory activities besides other numerous therapeutic importance. Thus there is a need to increase the concentration of acemannan in *Aloe* gel solid by virtue of improved cultivation practices. Amongst various pedo-ecological factors, soil reaction and moisture content play as determinants contemporary to genotypic make up of plant species (Beppu *et al.* 2004). Species variation between *Aloe vera* and *Aloe ferox* for distinct chemical compositions of gel (Femenia *et al.* 1999) and other yield attributes (Grindlay and Reynolds 1986) is also worthwhile. In view to above facts, the present experiment has been attempted to study the production of gel and polysaccharide in two distinct species of aloes *A. vera* and *A. ferox* cultivated under different salinity and desiccation levels of soil.

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MATERIALS AND METHODS

A pot experiment was conducted at Research Farm, College of Agriculture, Jabalpur during summer 2006-08. Two species *Aloe vera* and *Aloe ferox* were planted in 30 x 32 cm pot filled with sandy soil. One-year-old plants were treated with various soil stress conditions of desiccation (soil moisture) with salt (soil reaction) in factorial randomized design replicated thrice.

Salinity stress was maintained with NaOH / HCl monitoring every three days for various scheduled pH levels viz., 6.00, 6.50, 7.00 and 7.50 (optimum). For creating desiccation stress, the moisture levels in the soil were maintained every alternate days with irrigation of water measured as different crop coefficient values, viz. 0.20 (optimum), 0.30, 0.40 and 0.50. Required quantities of water for irrigation to achieve the scheduled crop coefficients were calculated by using the following equation (Hellman 2004).

$$\text{Required water (ml / 2days)} = \frac{\text{Evapotranspiration (loss of water ml/cm}^2\text{/day) x Crop coefficient (}k_c\text{)}}{\text{Soil water holding capacity}}$$

Pot experiment involved the following 32 treatment combinations

Treatment code	*Treatment combination*
T_1	*Aloe vera* + pH 6.0 + K_c 0.2
T_2	*Aloe vera* + pH 6.0 + K_c 0.3
T_3	*Aloe vera* + pH 6.0 + K_c 0.4
T_4	*Aloe vera* + pH 6.0 + K_c 0.5
T_5	*Aloe vera* + pH 6.5 + K_c 0.2
T_6	*Aloe vera* + pH 6.5 + K_c 0.3
T_7	*Aloe vera* + pH 6.5 + K_c 0.4
T_8	*Aloe vera* + pH 6.5 + K_c 0.5
T_9	*Aloe vera* + pH 7.0 + K_c 0.2
T_{10}	*Aloe vera* + pH 7.0 + K_c 0.3
T_{11}	*Aloe vera* + pH 7.0 + K_c 0.4
T_{12}	*Aloe vera* + pH 7.0 + K_c 0.5
T_{13}	*Aloe vera* + pH 7.5 + K_c 0.2
T_{14}	*Aloe vera* + pH 7.5 + K_c 0.3
T_{15}	*Aloe vera* + pH 7.5 + K_c 0.4
T_{16}	*Aloe vera* + pH 7.5 + K_c 0.5
T_{17}	*Aloe ferox* + pH 6.0 + K_c 0.2
T_{18}	*Aloe ferox* + pH 6.0 + K_c 0.3
T_{19}	*Aloe ferox* + pH 6.0 + K_c 0.4
T_{20}	*Aloe ferox* + pH 6.0 + K_c 0.5
T_{21}	*Aloe ferox* + pH 6.5 + K_c 0.2
T_{22}	*Aloe ferox* + pH 6.5 + K_c 0.3
T_{23}	*Aloe ferox* + pH 6.5 + K_c 0.4
T_{24}	*Aloe ferox* + pH 6.5 + K_c 0.5
T_{25}	*Aloe ferox* + pH 7.0 + K_c 0.2
T_{26}	*Aloe ferox* + pH 7.0 + K_c 0.3
T_{27}	*Aloe ferox* + pH 7.0 + K_c 0.4
T_{28}	*Aloe ferox* + pH 7.0 + K_c 0.5
T_{29}	*Aloe ferox* + pH 7.5 + K_c 0.2
T_{30}	*Aloe ferox* + pH 7.5 + K_c 0.3
T_{31}	*Aloe ferox* + pH 7.5 + K_c 0.4
T_{32}	*Aloe ferox* + pH 7.5 + K_c 0.5

The experimentation involving implication of pedo-ecological treatments of stresses was nurtured for 6 months duration on already established healthy plants. The healthy and succulent 3 leaves from each plant were selected, stripped off the stem, and washed with running tap water. The length, thickness and oven dry weight were recorded for each leaf, and calculated for the averages.

Harvested leaves were manually macerated in mortar and pestle, filtered in laboratory and *Aloe* gel was prepared using method described by Mebusela (1990). The *Aloe* leaves were taken in prewashed container with 50% isopropyl alcohol (IPA) for the shake of surface sterilization to get free from dirt and bacteria. The ensuing ringing with aqueous calcium hypochlorite solution containing 50 ppm free chlorine and 50% isopropyl alcohol (IPA) was also perfomed. The tips and butts were cut off to drain out yellowish bitter phenolic sap. After washing, leaves were weighed. The rinds of leaves were than removed, then mucilaginous, thick and semisolid material was collected as gel fillet. Gel fillet weight was recorded for each leaf. Gel fillet was liquefied and homogenized in a centrifuge at 1500 g and finally filtered through a filter paper Whatman No. 4 to separate interstitial fibers using a vacuum suction until all liquid was extracted as clear transparent *Aloe* gel liquid. Gel liquid was weighed. Contents of gel fillet yield and gel liquid were calculated adopting the following equations.

$$\text{Gel fillet yield (\%)} = \frac{\text{Weight of gel fillet (g)}}{\text{Weight of leaves (g)}} \times 100$$

$$\text{Gel fillet yield (\%)} = \frac{\text{Weight of gel liquid (g)}}{\text{Weight of gel fillet (g)}} \times 100$$

Total solid (gel powder) from the gel liquid was prepared using freeze-drying technique (Waller *et al*. 2004). This technique yielded gel powder of a highest quality which contained concentrated polysaccharide. Weight of the gel powder was recorded for further yield determination. The total solid yield was calculated using the equation below.

$$\textit{Aloe}\text{ gel solid yield (\%)} = \frac{\text{Weight of total solid (g)}}{\text{Weight of gel (g)}} \times 100$$

Acemannan, the acetylated mannans, in the gel polysaccharides was extracted and isolated by alcohol precipitation method (McAnalley 1990). *Aloe* gel was homogenized with ethanol (5: 95 w/v) and stirred for 20-30 minutes. The alcoholic *Aloe* gel mixture was then allowed to stand for four hours. The clear supernatant liquid was decanted or siphoned off without disturbing the precipitate at the bottom of the container. The solution was then placed into centrifuge buckets and centrifuged at 2000 g for 10 minutes. The precipitate was collected and washed with fresh ethanol. This fraction was then freeze-dried for 30 minute. Freeze-dried pellets of polysaccharide were weighed. For qualitative and quantitative estimation of acemannan(%), it was hydrolyzed to monosaccharide (Morrison 1988), derivatized into alditol acetate (Hoebbler *et al*. 1989) and finally quantified by gas liquid chromatography (t'Hart *et al*. 1989). The monosaccharide standard was derivatized as the alditol acetate adopting the same procedure and the chromatogram obtained with GLC was used to identify retention time and RF values.

RESULTS

Leaf weight: The effects of different stress combinations of various soil reactions (pH) and moisture levels (desiccation in terms of k_c) on leaf weight of *A. vera* and *A. ferox* are shown in Table 1. The leaf weight varied from range of 74.7 to 507.1 g for the respective plant species with an average weight of 265.4 g. In particular, the leaf weight of *A. vera* ranged from 74.7 to 449.5 g with the treatment combinations of pH 6.0 + k_c 0.5 and pH 7.5 + k_c 0.4, respectively (average 233.5 g weight). The treatment combinations pH 7.5 + k_c 0.4 and pH 7.5 + k_c 0.3 were the best producer (by 55.59% and 44.19%, respectively) over to the recommended treatment combination of pH 7.5 + k_c 0.2 (leaf weight 288.9 g). *A. ferox* species individually, in response to the various stress combinations of soil pH and k_c produced leaf of significantly variable leaf weight ranging from 85.7 g with treatment pH 6.0 + k_c 0.5 to 507.1 g with pH 7.5 + k_c 0.4 (average weight 297.2 g). The first ranked (by 31.48%) was followed by the group pH 7.5 + k_c 0.3, pH 7.0+ 0.4, pH 7.0 + k_c 0.3 and pH 7.5+ k_c 0.5 over that from the recommended treatment combination pH 7.5 + k_c 0.2 (leaf weight 385.7 g). Particularly lower pH values with moderately higher k_c levels yielded low weighted leaves. In respect of plant x soil pH interaction, the *A. vera* plant at recommended soil reaction condition with pH 7.5 produced leaves of maximum weight 380.9 g. Under decreased soil pH stress condition, *A. vera* exhibited reduction in leaf weight. The extent of reduced leaf weight was 67.37 % in case of reducing the pH from 7.5 to 6.0. In case of interaction plant x soil moisture levels (k_c), as the moisture level in soil was increased moderately, the leaf weight increased with a maximum weight by 57.05% with k_c 0.4 and followed by k_c 0.3 with 32.12% over that from the recommended moisture level k_c 0.2 (leaf weight 192.1 g). Higher level of moisture supplementation at k_c 0.5 reduced the leaf weight. Similar to *A. vera*, the leaf weight of *A. ferox* was also significantly decreased with decreasing pH values with maximum decrease by 61.47% at pH 6.0. Moderately higher moisture levels also favoured the higher leaf weight. The maximum

Table 1. Leaf weight (g) of *Aloe* plants under stress conditions of soil reaction (pH) and soil moisture (k_c)

***Aloe* species**	**Soil reaction (pH)**																				**Mean**
	6.0					**6.5**					**7.0**					**7.5**					
	Soil moisture(k_c)																				
	0.2	**0.3**	**0.4**	**0.5**	**Mean**	**0.2**	**0.3**	**0.4**	**0.5**	**Mean**	**0.2**	**0.3**	**0.4**	**0.5**	**Mean**	**0.2**	**0.3**	**0.4**	**0.5**	**Mean**	
A. vera	102.4	138.1	182.0	74.7	124.3	124.1	164.2	219.9	93.4	150.4	253.0	296.3	355.3	209.7	278.6	288.9	416.6	449.5	368.7	380.9	233.6
A. ferox	172.2	196.2	225.4	85.8	169.9	145.1	250.3	273.4	115.0	196.0	319.2	406.5	455.4	347.0	382.0	385.7	478.0	507.1	393.3	441.0	297.2
Mean	137.3	167.1	203.7	80.3	147.1	134.6	207.3	246.6	104.2	173.2	286.1	351.4	405.4	278.4	330.3	337.3	447.3	478.3	381.0	411.0	265.4
CV = 6.18%																					

Interaction *Aloes* x soil moisture

Aloes	**Soil moisture (k_c)**				**Mean**
	0.2	**0.3**	**0.4**	**0.5**	
A. vera	192.1	253.8	301.7	186.6	233.6
A. ferox	255.6	332.8	365.3	235.3	297.2
Mean	223.8	293.3	333.5	210.9	265.4

$SE_m \pm$ and $CD_{5\%}$

	Aloes	**pH**	**k_c**	**pH x k_c**
Aloes	2.36731 (6.685)	4.73333 (13.371)	4.73333 (13.371)	9.46666 (26.7)
pH		3.34711 (9.454)	6.69415 (18.909)	
k_c			3.34711 (9.454)	

Values out of parenthesis are $SE_m \pm$ and within parenthesis are $CD_{5\%}$

weight was recorded at k_c 0.4 by 42.92%, followed by k_c 0.3 with 30.20% over the recommended one k_c 0.2 (leaf weight 255.6 g). The treatment of k_c 0.5 showed the reduction by 7.94%. The above pattern of result was also observed in study of the interaction soil reaction pH x soil moisture k_c, higher soil pH with moderate moisture levels favoured the vegetative yield of the plants. pH 7.5 + k_c 0.4 produced highest leaf weight by 41.80 % followed by pH 7.5 + k_c 0.3, pH 7.0 + k_c 0.4 and pH 7.5 + k_c 0.5 with 32.61, 20.19 and 12.93%, respectively over that from recommended treatment combination pH 7.5 + k_c 0.2 (leaf weight 337.3 g). In overall view, *A. ferox* species produced leaves significantly more weight by 27.28% over that from *A. vera* (leaf weight 233.5 g). The highest leaf weight of *Aloe* plants 380.9 g was recorded at recommended pH 7.5. Low soil pH 6.0, produced leaves if reduced weight by 64.20%. However, as the soil moisture was increased moderately form the recommended level k_c 0.2, the leaf weight increased significantly, the maximum by 58.13% with k_c 0.4, followed by k_c 0.3 by 39.07%. But heavy moisture treatment at k_c 0.5 produced no better leaves.

Gel fillet: The gel fillet in the leaves varied from 12.16% to 61.62% with an average of 31.81% (Table 2). Gel fillet concentration in the leaves of *A. vera* ranged from 12.16 to 32.93% with the treatment combinations of pH 6.0 + k_c 0.5 and pH 7.5 + k_c 0.4, respectively (average 22.96%). The treatment combinations pH 7.5 + k_c 0.4 and pH 7.0 + k_c 0.4 were the statistically better producer (by 29.49% and 17.85%, respectively) over to the recommended treatment combination of pH 7.5 + k_c 0.2 (gel fillet 25.43%). Similarly, *A. ferox* species responded to various stress combinations of soil pH and k_c produced leaf of significantly variable gel fillet content varying from 25.56%with treatment pH 6.0 + k_c 0.5 to 61.62% with pH 7.5 + k_c 0.4 (average 40.67%). The soil environment, pH 7.5 + k_c 0.4 showed statistical superiority by 46.16% over that from the recommended treatment combination pH 7.5 + k_c 0.2 (42.16% gel fillet) in *A. ferox* plants. On individual basis for plant x soil pH interaction, the maximum gel fillet content 28.30% was observed at recommended soil reaction condition with pH 7.5 for *A. vera*. The plant cultivated under lower soil pH stress condition (towards soil pH 7.5 to

Table 2. Gel fillet (%) in leaves of *Aloes* under stress conditions of soil reaction (pH) and soil moisture (k_c)

Aloe species	Soil reaction (pH)																				Mean
	6.0					6.5					7.0					7.5					
	Soil moisture(k_c)																				
	0.2	0.3	0.4	0.5	Mean	0.2	0.3	0.4	0.5	Mean	0.2	0.3	0.4	0.5	Mean	0.2	0.3	0.4	0.5	Mean	
A. vera	18.04	19.89	18.29	12.16	17.095	21.61	22.59	22.26	14.38	20.208	22.99	26.73	29.97	25.28	26.242	25.43	29.14	32.93	25.68	28.295	22.96
A. ferox	31.45	33.29	28.23	25.56	29.633	37.25	37.97	37.77	34.28	36.818	38.02	48.53	53.09	42.32	45.491	42.16	55.81	61.62	43.32	50.726	40.67
Mean	24.75	26.59	23.26	18.86	23.36	29.43	30.28	30.01	24.33	28.513	30.51	37.63	41.53	33.80	35.87	33.79	42.48	47.28	34.50	39.51	31.81
CV = 4.54%																					

Interaction *Aloes* x soil moisture

Aloes	Soil moisture (k_c)				Mean
	0.2	0.3	0.4	0.5	
A. vera	22.02	24.59	25.86	19.38	22.96
A. ferox	37.22	43.90	45.18	36.37	40.67
Mean	29.62	34.24	35.52	27.87	31.81
CD will be correct					

SE_m± and $CD_{5\%}$

	Aloes	pH	k_c	pH x k_c
Aloes	0.20912 (0.589)	0.41727 (1.178)	0.41727 (1.178)	0.83415 (2.357)
pH		0.29530 (0.833)	0.59000 (1.666)	
k_c			0.29530 (0.833)	

Values out of parenthesis are SE_m± and within parenthesis are $CD_{5\%}$

6.0 values), yielded less gel fillet concentration by 39.61%. In case of interaction plant x soil moisture levels (k_c), the moderate k_c 0.4 moisture level in soil was found better to yield better gel fillet by 17.44 % and followed by k_c 0.3 with 11.67% over that from the recommended moisture level k_c 0.2 (gel fillet 22.02%). Higher moisture supplement k_c 0.5 showed negative performance by 11.99%. In same pattern to the *A. vera*, the gel fillet concentration of *A. ferox* was also significantly decreased with decreasing soil pH values. The maximum decrease was 41.58% at the lowest soil pH condition 6.0. Under moisture stress environment the maximum gel fillet in *A. ferox* plant was recorded with k_c 0.4 by 21.39%, followed by k_c 0.3 with 17.95% over the recommended one k_c 0.2 (gel fillet 37.22%). This moisture level at kc 0.5 treatments was of no significance as compared to the standard moisture level. Combined interaction of soil reaction pH x soil moisture k_c, with higher pH associated with moderate k_c significantly reflected favourable effect on concentration of gel fillet in the leaves. Soil pH 7.5 + k_c 0.4 produced yielded maximum gel fillet content by 40.26 % followed by pH 7.5 + k_c 0.3, pH 7.0 + k_c 0.4 and pH 7.0 + k_c 0.3 by 26.02, 23.20 and 11.63%, respectively over that from the standard one pH 7.5 + k_c 0.2 (gel fillet 33.71%). On the relative performance of plant species, *A. ferox* was proved significantly better by 77.13% over that from *A. vera* (gel fillet 22.96%). Maximum gel fillet in leaves of *Aloes* was 38.68% at soil pH 7.5. Lowering the soil pH from 7.5 to 6.0, produced decreased the gel fillet concentration significantly by 40.88%. However, as the soil moisture increased moderately form the recommended level k_c 0.2, the gel fillet increased significantly. The maximum was 20.00% with k_c 0.4, followed by k_c 0.3 by 15.68%. The heist moisture treatment at k_c 0.5, showed reduction in gel fillet content.

Gel production: The gel liquid content varied from 8.38 to 75.77% with an average of 35.90 % (Table 3). For individual species wise, the gel liquid production of *A. vera* ranged from 8.30 to 64.25% with the treatment combinations of pH 6.0 + k_c 0.5 and pH 7.5 + k_c 0.4,

Table 3. Gel (%) in leaves of *Aloes* under stress conditions of soil reaction (pH) and soil moisture (k_c)

Aloe species	Soil reaction (pH)																				Mean
	6.0					6.5					7.0					7.5					
	Soil moisture(k_c)																				
	0.2	0.3	0.4	0.5	Mean	0.2	0.3	0.4	0.5	Mean	0.2	0.3	0.4	0.5	Mean	0.2	0.3	0.4	0.5	Mean	
A. vera	10.91	18.017	14.44	8.38	12.94	25.72	26.14	14.44	20.39	21.67	27.96	36.38	58.02	32.14	38.63	34.41	56.74	64.25	51.76	51.79	31.26
A. ferox	24.64	26.83	25.64	15.62	23.18	31.07	33.04	32.70	30.80	31.90	37.36	60.84	65.44	40.15	50.95	38.36	68.87	75.77	41.49	56.12	40.54
Mean	17.78	22.43	20.04	11.99	18.06	28.40	29.59	23.58	25.60	26.79	32.66	48.61	61.73	36.15	44.79	36.38	62.81	70.01	46.63	53.97	35.90
CV = 4.74%																					

Interaction *Aloes* x soil moisture

Aloes	Soil moisture (k_c)				Mean
	0.2	0.3	0.4	0.5	
A. vera	24.75	34.32	37.79	28.17	31.26
A. ferox	32.86	47.40	49.89	32.02	40.54
Mean	28.80	40.86	43.84	30.09	35.90

$SE_m \pm$ and $CD_{5\%}$

	Aloes	pH	k_c	pH x k_c
Aloes	0.24623 (0.694)	0.49106 (1.388)	0.49106 (1.388)	0.98342 (2.78)
pH		0.34745 (0.981)	0.69501 (1.963)	
k_c			0.34745 (0.981)	

Values out of parenthesis are $SE_m \pm$ and within parenthesis are $CD_{5\%}$

respectively (with the average 31.26%). The influence of higher soil pH 7.5 with moderate moisture level k_c 0.4 was 86.74% better than that from the standard treatment combination of pH 7.5 + k_c 0.2 (gel liquid 34.41%). *A. ferox* species individually, in response to the various treatment combinations of soil pH and k_c produced leaf of significantly variable leaf gel contents ranging from 15.62% with treatment pH 6.0 + k_c 0.5 to 75.77% with pH 7.5 + k_c 0.4 (average 40.54%). The combination pH 7.5 + k_c 0.4 produced higher gel production by 97.54% than the recommended treatment combination pH 7.5 + k_c 0.2 (gel liquid 38.36%). Lower the pH values with high k_c levels yielded low concentration of gel liquid in leaves. In case of interaction plant x soil pH for *A. vera*, the maximum gel liquid content 51.79% was observed at recommended soil reaction condition at pH 7.5. This plant exhibited reduction in gel liquid production when cultivated under lower soil pH stress conditions (towards pH 7.5 to 6.0 values). The extent of reduction of this was 75.01% at pH 7.5 as compared to that from the standard one (51.79% gel fillet). Similar pattern was observed in the study of interaction plant species x soil moisture. The moderate moisture level at k_c 0.4 was found maximum gel liquid producer by 52.69% and followed by k_c 0.3 with 38.67% over that from the recommended moisture level k_c 0.2 (gel fillet 24.75%). High moisture supplement at k_c 0.5 was least good by 13.82% relative to the recommended one. Similar to the *A. vera*, the gel liquid of *A. ferox* was observed maximum 56.17% at higher soil pH 7.5. This content decreases with decreasing pH values, the maximum decrease by 58.73% at pH 6.0 as compared to that of the standard one pH 7.5 (56.17% gel fillet). Moderate moisture levels also favoured the gel production. The maximum by 51.83% was recorded at k_c 0.4, followed by k_c 0.3 with 44.25% over the recommended one k_c 0.2 (gel content 32.86%) and k_c 0.5 had negative benefit. For the interaction soil reaction pH x soil moisture, soil pH 7.5 + k_c 0.4 produced maximum gel liquid by 92.44% followed by pH 7.5 + k_c 0.3 with 72.65% over that from recommended treatment combination pH 7.5 + k_c 0.2 (gel liquid 36.38 %). The overall performance competition between both *Aloe* species *A. ferox* exhibited significantly better gel liquid by 29.69% over that from

A. vera (gel liquid 31.26%). The recommended soil pH 7.5 yielded 53.96% gel liquid and as the pH decreased the gel concentration also decreased significantly. But as the soil moisture increased form the recommended level k_c 0.2, the gel concentration increased significantly, the maximum by 52.22% with k_c 0.4, followed by k_c 0.3 by 41.88%. The heist moisture treatment also produced higher gel content over that of the recommended moisture level k_c 0.2 (gel content 28.80%).

Aloe gel solid: The effects of different treatment combinations of various soil reactions (pH) and moisture levels (k_c) on gel solid of *Aloes* ranged from 0.19 to 1.18% with an average of 0.53% (Table 4). *Aloe* gel solid concentration in *A. vera* ranged from 0.19% to 0.75% (average 0.41%) with the treatment combinations pH 6.0 + k_c 0.5 and pH 7.5 + k_c 0.3, respectively. The highest performance 60.21% was observed over that from the standard treatment pH 7.5 + k_c 0.2 (gel solid 0.47%). This was followed by group of treatment combinations pH 7.0 + k_c 0.3, pH 7.5 + k_c 0.4 and pH 7.0 + k_c 0.4 as exhibited by 43.19, 36.81, 22.77% more gel solid contents. Rest all other treatment combinations were statistically irresponsive to boost up the solid gel content as compared to that from the recommended one treatment combination (0.47% solid gel). Similar to *A. vera* species, *A. ferox* also responded to the various treatment combinations of soil pH and k_c to produce gel solid ranging from 0.31% with treatment pH 6.0 + k_c 0.5 to 1.18% with pH 7.5 + k_c 0.3 (with the average 0.65%). The combination pH 7.5 + k_c 0.3 recorded 58.37% increase over that from the standard treatment pH 7.5 + k_c 0.2 (*Aloe* gel solid 0.75%). The interaction plant x pH stated that at higher soil pH 7.5 (standard) the dry gel content was 0.57% in case of *A. vera* plant. But the lower pH exhibited adverse effects by 56.10% as the pH was declined to 6.0 relative to that from standard one. In case of interaction plant species x soil moisture, the solid gel content was found maximum at the moderate moisture level at k_c 0.3 by 36.79% and followed by k_c 0.4 with 10.62% over that from the recommended moisture level k_c 0.2 (dry gel 0.39%). The higher moisture supplement at k_c 0.5 exhibited a reduction by 20.73% over the recommended one. Similar to *A. vera*, in *A. ferox* also the soil gel was significantly maximum 0.91% at higher soil pH 7.5. The solid content decreased

Table 4. Solid gel (%) in leaves of *Aloes* under stress conditions of soil reaction (pH) and soil moisture (k_c)

***Aloe* species**	**Soil reaction (pH)**																				**Mean**
	6.0					**6.5**					**7.0**					**7.5**					
	Soil moisture(k_c)																				
	0.2	**0.3**	**0.4**	**0.5**	**Mean**	**0.2**	**0.3**	**0.4**	**0.5**	**Mean**	**0.2**	**0.3**	**0.4**	**0.5**	**Mean**	**0.2**	**0.3**	**0.4**	**0.5**	**Mean**	
A. vera	0.29	0.31	0.22	0.19	0.25	0.34	0.37	0.27	0.22	0.30	0.44	0.67	0.58	0.39	0.52	0.47	0.75	0.64	0.43	0.57	0.41
A. ferox	0.45	0.43	0.38	0.31	0.39	0.49	0.60	0.54	0.37	0.49	0.68	1.02	0.88	0.66	0.81	0.75	1.18	0.92	0.79	0.91	0.65
Mean	0.37	0.37	0.30	0.25	0.32	0.42	0.49	0.41	0.29	0.40	0.56	0.85	0.73	0.52	0.66	0.61	0.97	0.78	0.61	0.74	0.53
CV = 4.21%																					

Interaction *Aloes* x soil moisture

Aloes	**Soil moisture (k_c)**				**Mean**
	0.2	**0.3**	**0.4**	**0.5**	
A. vera	0.39	0.53	0.43	0.31	0.41
A. ferox	0.59	0.81	0.68	0.53	0.65
Mean	0.45	0.67	0.55	0.42	0.53

$SE_m\pm$ and $CD_{5\%}$

	Aloes	**pH**	**k_c**	**pH x k_c**
Aloes	0.00441 (0.01)	0.00815 (0.02)	0.00815 (0.02)	0.01515 (0.04)
pH		0.00552 (0.02)	0.01111 (0.03)	
k_c			0.00552 (0.02)	

Values out of parenthesis are $SE_m\pm$ and within parenthesis are $CD_{5\%}$

with decreasing soil pH values with maximum decrease by 56.72% at pH 6.0. Moderately lower moisture levels improved the dry gel production in leaves. The maximum gel was recorded at k_c 0.3 by 36.55%, followed by 15.06% with k_c 0.4 over the recommended one k_c 0.2 (dry gel content 0.59%) and k_c 0.5 exhibited negative effect. The interaction soil reaction pH x soil moisture was observed as the treatment combination pH 7.5 + k_c 0.3 to produce maximum dry gel by 59.21% followed by pH 7.0 + k_c 0.3 with 39.31% over that from recommended treatment combination pH 7.5 + k_c 0.2 (dry gel 0.61%). The relative performance of *A. ferox* exhibited significantly better for solid gel content by 58.64% over that from *A. vera* (dry gel 0.41%). The recommended soil pH 7.5 yielded 0.74% better gel solid. The dry gel content was also reduced significantly by 56.41% at pH 6.0. But in case of moisture application, the dry gel content was up to 36.68% with moisture level at k_c 0.3 as compared to that form the recommended one at k_c 0.2. This was followed by k_c 0.4 by 13.32%. The highest moisture application produced dry gel content by 14.34% less than that from the recommended moisture application at k_c 0.2 (dry gel content 0.49%).

Acemannan production: The table 5 revealed that the different combinations of various soil reactions (pH) and moisture levels (k_c) had effect on acemannan content in the leaves of *Aloes* species under study. The acemannan content varied from 14.7% to 92.4% for the respective species of *A. vera* and *A. ferox* with an average of 41.5%. Acemannan concentration in the leaf of *A. vera* ranged from 14.7 to 37.7% with the treatment combinations of pH 6.0 + k_c 0.2 and pH 7.5 + k_c 0.3, respectively (average 25.6%) (Fig. 1 & 2). The treatment combinations pH 7.5 + k_c 0.3 and pH 7.5 + k_c 0.4 were the best acemannan producers by 40.67 and 27.24%, respectively over that from the recommended one pH 7.5 + k_c 0.2 (acemannan 26.8%). Similarly, *A. ferox* showed the response towards acemannan content ranged from 31.4% with treatment pH 6.0 + k_c 0.5 to 92.4% with pH 7.5 + k_c 0.3 (average 57.4%) (Fig. 3 & 4). The soil environment of pH 7.5 + k_c 0.3 gained statistical superiority by 46.43% over that from the recommended treatment combination pH 7.5 + k_c 0.2 (63.1% acemannan). The other good scoring treatments were pH 7.5 + k_c 0.4, pH 7.0+ 0.3, pH 7.5 + k_c 0.5 and pH 7.0 + k_c 0.4 by 32.65, 26.62, 8.08 and 7.61%, respectively. The treatment combinations of lower pH

Table 5. Acemannan (%) in gel of *Aloes* under stress conditions of soil reaction (pH) and soil moisture (k_c)

***Aloe* species**	**Soil reaction (pH)**																				**Mean**
	6.0					**6.5**					**7.0**					**7.5**					
	Soil moisture(k_c)																				
	0.2	**0.3**	**0.4**	**0.5**	**Mean**	**0.2**	**0.3**	**0.4**	**0.5**	**Mean**	**0.2**	**0.3**	**0.4**	**0.5**	**Mean**	**0.2**	**0.3**	**0.4**	**0.5**	**Mean**	
A. vera	14.7	20.4	23.3	17.5	19.0	21.3	25.5	26.2	19.4	23.1	25.7	30.8	33.3	23.4	28.3	26.8	37.7	34.1	30.5	32.1	25.7
A. ferox	39.8	39.3	42.5	31.4	38.3	44.9	52.2	53.7	48.2	49.8	47.3	79.9	67.9	63.9	64.8	63.1	92.4	83.7	68.2	76.9	57.4
Mean	27.2	29.8	32.9	24.5	28.6	33.1	38.9	40.0	33.8	36.4	36.5	55.4	50.6	43.6	46.5	45.0	65.0	58.9	49.3	54.5	**41.6**
CV 4.21%																					

Interaction *Aloes* x soil moisture

Aloes	**Soil moisture (k_c)**				**Mean**
	0.2	**0.3**	**0.4**	**0.5**	
A. vera	22.0	28.6	29.2	22.7	25.7
A. ferox	48.8	66.0	62.0	52.9	57.4
Mean	35.5	47.3	45.6	37.8	41.6

$SE_m \pm$ and $CD_{5\%}$

	Aloes	**pH**	**k_c**	**pH x k_c**
Aloes	0.24611 (0.695)	0.49232 (1.390)	0.49232 (1.390)	0.98445 (2.781)
pH		0.34814 (0.983)	0.69607 (1.966)	
k_c			0.34814 (0.983)	

Values out of parenthesis are $SE_m \pm$ and within parenthesis are $CD_{5\%}$

values with higher k_c levels did not favoured the production of acemannan in the leaf gel. The interaction plant x soil pH affected the concentration of acemannan in gel. The maximum acemannan content of *A. vera* 32.1% was observed at recommended soil reaction condition at pH 7.5. When cultivated under lower pH conditions (pH 7.5 to 6.0), the plant yielded less acemannan content. The extent of reduction of this was 40.81% at pH 6.0. In case of interaction of plant x soil moisture levels, the moderate moisture level at k_c 0.4 was found to increase acemannan content by 32.94%, followed by k_c 0.3 with 30.30% over that from the recommended moisture level k_c 0.2 (acemannan 22.0%). Higher moisture stress k_c 0.5 depressed the formation of acemannan in the plant. Similar to *A. vera*, the acemannan content of *A. ferox* was also recorded maximum for acemannan content at recommended soil pH 7.5. The content was significantly reduced with decreasing soil pH values with maximum decrease by 48.59% at pH 6.0. Under the moisture stress environment the maximum acemannan content in *A. ferox* was 35.18% at k_c 0.3, followed by k_c 0.4 with 27.05% over the recommended one k_c 0.2 (acemannan content 48.8%). The content was also increased at higher moisture level at k_c 0.5, but to restricted percentage. Regarding combined interaction of soil reaction pH x soil moisture, the higher pH associated with moderately moderate moisture levels effected significantly the content of acemannan in the gel. However, soil pH 7.5 + k_c 0.3 produced acemannan at the maximum level by 44.44%, followed by the treatment combinations pH 7.5 + k_c 0.4, pH 7.0 + k_c 0.3 and pH 7.0 + k_c 0.4 with 30.89, 23.11 and 12.44%, respectively over that from recommended one pH 7.5 + k_c 0.2 (acemannan 45.0%). On the study of relative performance of the two species, *A. ferox* produced better acemannan content than that from *A. vera* (acemannan 25.6%). Maximum acemannan in gel of *Aloe* plants was 54.5% more as recorded at recommended soil pH 7.5 (54.6% acemannan). Lowering the soil pH from 7.5 to 6.0 decreased the acemannan content significantly by 47.52%. But as the soil moisture was increased form the recommended level k_c 0.2, the acemannan content increased significantly,

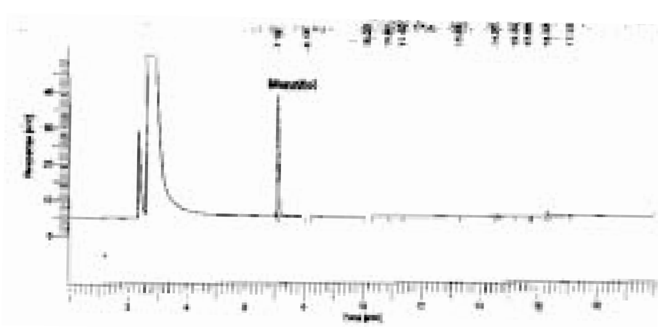

Fig. 1. Standard GC chromatogram showing mannitol (peak A)

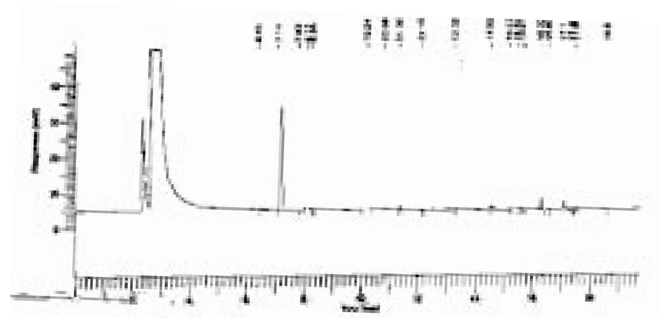

Fig. 2. GC chromatogram showing mannitol in sample of *Aloe vera* plant (peak C)

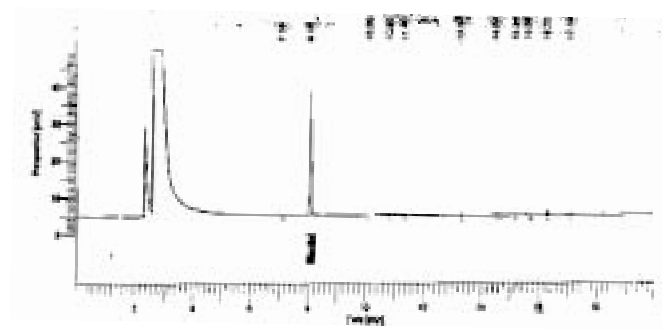

Fig. 3. GC chromatogram showing glucitol standard (peak B)

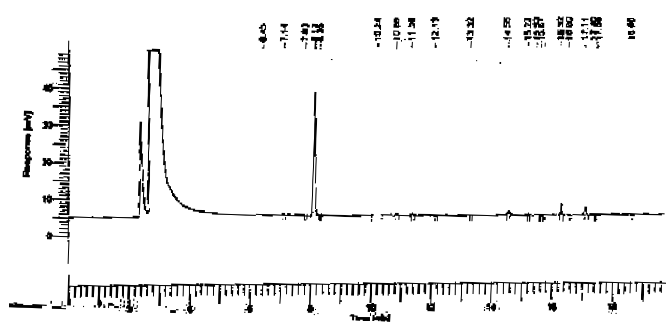

Fig. 4. GC chromatogram showing the glucitol in *A. ferox* sample (peak D)

with maximum by 33.24% at k_c 0.3, followed by 28.45% at k_c 0.4. However, at k_c 0.5, the acemannan content did not varied significantly when compared with that from the recommended one (35.5% acemannan).

DISCUSSION

The results showed that different treatments of pedo-ecological stresses of soil pH and desiccation had significant effect on the yield and biological active compounds of both *Aloe* plant species. Plant species, soil pH and desiccation interaction was the major factor, those exerted the influenced on yield of this medicinal crop. *A.ferox*, at higher soil pH (7.5) along with moderate moisture level exhibited relatively better performance than *A.vera* at same pH and moisture level interaction. However higher soil pH>7.0 and moderate moisture level at k_c 0.3 to 0.4 in soil was required for vegetative growth and production of *Aloe* plant. Sheteawi *et al.* (2001) also recorded higher leaf yield under higher salinity along with moderate moisture.

Soil pH and moisture stress individually also influence the yield attributes and polysaccharide concentration in both *Aloe* plant species. Under higher soil pH *Aloe* plants show good response while on reducing the soil alkalinity from pH=7.5 to 6.0, reduce the yield parameters viz: leaf weight, gel, *Aloe* gel solid and polysaccharide concentration. *Aloe* plant leaves are succulent grow well in alkaline soil because its succulent leaf better manage excess sodium that is key to improving plant productivity under higher soil pH. Twafik *et al.* (2001) reported similar result of yield parameters of *Aloe* plant under higher soil pH along with moderate moisture level. Zan *et al*. (2006) also reported the increase the production of acemannan polysaccharide percent in *Aloe* plant leaf under higher soil pH.

Similarly under moisture stress, on increasing moisture level from $k_{c,}$ 0.2 to 0.4 increases the yield of gel and polysaccharide composition that is due to presence of more water content in soil, thus vast amount of water move throughout the plant daily. Plants use more water and combine with carbon dioxide to form more carbohydrate such as polysaccharide. But *Aloe* leaves is succulent that store water longtime thus it dose not require excess water higher than k_c >0.4 moisture level. Therefore yield of gel increases upto higher moderate moisture stress at $k_{c=}$0.4 but dry gel solid did not recorded more upto k_c >0.3. Because of this reason its productivity is not increase up to k_c >0.4. Genet *et al.* (1991) also reported k_c = 0.3 to 0.4 was the best treatment based on crop coefficient under irrigation experiment for *Aloe* plant. Rodríguez-García *et al*. (2007) suggest that the high water content in the parenchyma maintains stomata opening despite water stress. In a subsequent period, the leaves that were submitted to water stress at the beginning showed stomatal opening reduction related to low soil water potential. The low soil water potential reduced leaf weight, plant growth rate, and leaf number, mainly in leaf growth during the experiment confirming the sensitivity of new leaves to water stress. Thus under low water stress showed lower productivity of liquid gel, dry gel and acemannan compounds.

Plant soil pH and Plant desiccation interaction also exerted effect on the yield of *Aloe* plants and polysaccharide composition. On comparing of both plant species under overall view *A. ferox* performed better than *A.vera*. Femenia *et al*. (1999) also reported *A.ferox* gel contain higher *Aloe* solid and more acemannan concentration than *A.vera* gel. International *Aloe* Science Council (2004) also certified the same variation in concentration of acemannan on dry weight of *Aloe* gel in both *Aloe* plant species (Anonymous 2004).

Above studied concluded that *Aloe* plant cultivated under higher soil pH (7.5) and moderate moisture soil stress (k_c 0.3 to 0.4) exhibited positive response on growth yield, viz. leaf weight, gel fillet, gel percent, *Aloe* gel solid and acemannan polysaccharide production. *Aloe* plant however, did not show good performance in growth, yield and biological active ingredients on further increase moisture stress (k_c > 0.4) and less soil pH stress (pH<7.0) of soil.

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