



Effect of integrated nutrient management on growth and yield of *Aloe barbadensis*

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ABSTRACT

A field experiment was conducted during 2011-2012 at research farm of Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu, to find out integrated nutrient management technique suitable for increasing leaf and gel yield in *Aloe barbadensis* Mill. At the inception of the experiment, the soil was sandy-clay loam in texture, slightly alkaline in reaction having low status of available N and medium in available P and K. The growth and yield attributes were best in substitution of 50 per cent (75 kg/ha) of recommended dose of N (150 kg/ha) through vermicompost + biofertilizer (*Azotobacter*) while, yield was slightly less in 50 per cent substitution of recommended dose of N with FYM + biofertilizer (*Azotobacter*) but were statistically at par with each other. Although sole application of N@ 150 kg/ha had a significant increase in yield over 100% substitution of N with vermicompost + *Azotobacter* and farmyard manure + *Azotobacter* combinations, but 50 per cent and 75% substitution combinations recorded a significantly higher yield than sole application of N, Vermicompost + *Azotobacter* and farmyard manure + *Azotobacter*, respectively. The combination of organic, inorganic and biofertilizers is not only superior over application of manures or fertilizers alone for achieving higher growth and yield but also in maintaining the fertility status of soil.

Key words: *Aloe barbadensis*, *Azotobacter*, Integrated nutrient management, Yield attributes

Medicinal plants have a great importance nowadays as they are moving from fringe to mainstream use in healthcare and disease remedies being free from side effects. Widespread use of medicinal plants for health providing elements has generated bulk demand which cannot be met from their wild source. Cultivation of medicinal plants is the only alternative to conserve their natural diversity with sustainable supply. Thus medicinal plants can be an important component of cropping scheme in the tropics and sub-tropics especially under rainfed conditions, where agricultural production is predicted to suffer due to global warming. The diversification of the traditional cropping pattern with medicinal plants as one of the component would provide raw material to the industry vis-a-vis livelihood to the farming community. Aloe (*Aloe barbadensis* Mill.) is among the various medicinal plants which can be cultivated in dryland areas. It can survive long periods of drought due to its ability to avoid water loss by closing stomata. *A. barbadensis* is in high demand owing to its therapeutic, cosmetic and nutraceutical

properties. Besides this, the species is widely used in pickle industry in Jammu region of J&K State. The dried leaf juice is laxative due to the presence of aloin, which is a mixture of glucosides. It is also effective in the treatment of cancer, intestinal ulcer and has a modulating effect on Human Immunodeficiency Virus-HIV (Anselm 2004). The aloe gel (mucilaginous pulp of leaf parenchyma) is widely used in cosmetic industry as a skin tonic (Ni *et al.* 2004). It also contains 08 essential (isoleucine, leucine, lysine, methionine, phenylalanine, threonine, valine and tryptophan) and 11 of the 14 secondary amino acids that human body needs, hence aloe juice is used as tonic. With increasing demand of this species, commercial cultivation is the priority. Besides identification of superior strains/lines among the population, fertilizer management is an important strategy to increase the yield of economic parts of any species. Many workers have studied the effect of inorganic fertilizers on aloe yield and suggested the doses of NPK for its cultivation. However, the information on the influence of conjunctive use of organics, bio-fertilizers and inorganic fertilizers on *A. barbadensis* is scanty. Hence, a field study was taken up to bridge the gap in our understanding.

MATERIALS AND METHODS

A field experiment was carried out at Experimental Farm

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of Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu, during 2011-2012 on sandy-clay loam soil. The farm is located within the university campus at an altitude of 332m above mean sea level. The experimental site falls under sub-tropical zone of Jammu division of Jammu and Kashmir State, with hot dry summers, hot humid rainy and cold winter months. The maximum temperature rises upto 45°C during May and June and minimum falls to 1°C during winter. The experiment was conducted under randomized block design with ten treatments and three replications (treatments' detail is mentioned in Tables 1-4). The soil was sandy-clay loam with pH 7.6, low available N (253.26 kg/ha), medium in P (16.07 kg/ha) and K (165.32 kg/ha). To meet the requirement of N through organic sources, the doses of manures [Farmyard manure (FYM) and vermicompost] were calculated based upon their individual nitrogen content. In the present study, nitrogen content of FYM and vermicompost were recorded as 0.6 per cent and 2.0 per cent, respectively. Raised beds of size 1.8 × 1.8m² were prepared and plantlets of *Aloe barbadensis* were planted at a spacing of 60cm × 45cm, thereby accommodating twelve plants per plot. Nitrogen (N) was given in the form of urea and was applied with farm yard manure and vermicompost at the time of planting on 15 February 2011. *Azotobacter* was applied twice during the growth period of crop i.e. at the time of planting and before onset of monsoon. Observations were recorded on 15 randomly selected plants per treatment (5 plants per replication) in the last week of November. N, P and K contents were analysed in soil and plant following standard procedures and uptake was calculated by multiplying it with the respective biological yield.

RESULTS AND DISCUSSION

Growth and yield parameters

Of late there is a resurgence of interest in organic farming worldwide keeping in view the deleterious effect

of chemical fertilizers on soil health. However, organic farming suffers from the drawback of low content and slow release of plant nutrients, limited availability, high transformation costs etc. Integrated nutrient management which involves the conjunctive use of organic, inorganic and biofertilizers is the solution not only to sustain the agricultural production system but also to maintain soil health. From the present investigation, it is clear that fertilization significantly influenced the growth and yield attributing characters. Growth and yield components of *Aloe* varied significantly between different treatment combinations (Tables 1 and 2). The results envisaged that application of organic fertilizers was necessary to achieve good growth and yield. Chemical fertilizers though showed improvement over control, proved inadequate compared with integrated nutrient management, i.e. organic manures (vermicompost and FYM) in conjunction with inorganic and biofertilizer (*Azotobacter*). Among the different combinations of fertilizers and manures, application of vermicompost @ 3.75 t/ha alongwith 75 kg N/ha and *Azotobacter* (T₆) has significantly increased the growth parameters over control (Table 1) and resulted in maximum plant spread (74.26cm), leaf length (60.27cm), leaf width (7.14cm) and number of leaves/plant (15.33). However, growth parameters observed under T₅ (FYM @ 15 t/ha alongwith 75 kg N and *Azotobacter*) and T₉ (Vermicompost @ 5 t/ha and 50 kg N) were almost statistically at par with T₆. Singh (2011) reported similar findings in coriander. Higher growth under integrated nutrient management might be due to the fact that for performing necessary physiological functions to buildup different yield attributes these nutrients, inorganic and organic which have been integrated in present study were possibly responsible for synthesizing necessary enzymes, proteins, chlorophyll and for the translocation of photosynthates. These findings were also supported by Gupta *et al.* (2011) in black henbane. The application of FYM @ 30 t/ha and *Azotobacter* (T₃) resulted in significantly higher number of suckers per plant compared to control (T₁) and inorganic

Table 1 Effect of manures and fertilizers on growth parameters

Treatment	Plant spread (cm)	No. of suckers/plant	Leaf length (cm)	Leaf width at base (cm)	Leaf thickness at base (cm)	No. of leaves/plant
T ₁ (control)	38.51	1.87	36.68	4.21	1.16	9.11
T ₂ [150 kg N (Recommended dose)]	55.17	3.98	50.67	6.47	1.24	12.89
T ₃ [30 t FYM/ha + <i>Azotobacter</i>]	43.26	5.75	43.26	5.43	1.20	11.44
T ₄ [7.5 t VC*/ha + <i>Azotobacter</i>]	48.20	5.11	47.92	6.06	1.20	12.67
T ₅ [75 kg N + 15 t FYM/ha + <i>Azotobacter</i>]	70.34	3.19	58.91	7.06	1.26	14.55
T ₆ [75 kg N + 3.75 t VC/ha + <i>Azotobacter</i>]	74.26	2.78	60.27	7.14	1.28	15.33
T ₇ [50 kg N + 20 t FYM/ha + <i>Azotobacter</i>]	59.50	4.44	52.94	6.53	1.20	13.22
T ₈ [50 kg N + 20 t FYM/ha]	57.67	4.68	51.05	6.47	1.23	13.00
T ₉ [50 kgN + 5 t VC/ha + <i>Azotobacter</i>]	67.11	3.23	56.25	6.67	1.25	14.33
T ₁₀ [50 kg N + 5 t VC/ha]	63.28	3.67	54.22	6.62	1.24	13.89
CD (P=0.05)	8.33	0.84	6.08	0.53	NS [#]	1.97
SEm (P<0.05)	2.82	0.28	2.06	0.17	0.06	0.67

*Vermicompost, [#]Non-significant

Table 2 Effect of manures and fertilizers on yield parameters

Treatment	No. of harvestable leaves/plant	Fresh weight/leaf (g)	Latex/leaf (g)		Latex/plant (g)		Gel yield/leaf (g)	Gel yield/plant (kg)	Leaf: gel ratio	Leaf yield/plant (kg)
			Wet	Dry	Wet	Dry				
T ₁ (control)	4.95	108.27	0.22	0.11	1.10	0.52	50.80	0.26	1.96	0.56
T ₂ [150 kg N (Recommended dose)]	6.00	145.96	0.29	0.15	1.80	0.96	74.16	0.52	1.71	0.87
T ₃ [30 t FYM/ha + <i>Azotobacter</i>]	5.45	125.63	0.27	0.14	1.64	0.84	59.09	0.37	1.83	0.69
T ₄ [7.5 t VC/ha + <i>Azotobacter</i>]	5.88	136.15	0.29	0.15	1.74	0.92	66.71	0.46	1.75	0.75
T ₅ [75 kg N + 15t FYM/ha+ <i>Azotobacter</i>]	6.79	166.36	0.37	0.18	2.78	1.38	85.56	0.69	1.55	1.08
T ₆ [75 kg N + 3.75 t VC/ha+ <i>Azotobacter</i>]	7.10	171.45	0.38	0.19	2.99	1.52	94.31	0.77	1.51	1.13
T ₇ [50 kg N + 20 t FYM/ha+ <i>Azotobacter</i>]	6.21	152.69	0.32	0.16	2.15	1.07	76.35	0.56	1.66	0.91
T ₈ [50 kg N + 20 t FYM/ha]	6.09	147.70	0.31	0.15	2.10	1.03	75.23	0.54	1.69	0.89
T ₉ [50 kgN + 5 t VC/ha + <i>Azotobacter</i>]	6.44	159.33	0.34	0.17	2.50	1.26	81.67	0.63	1.59	0.95
T ₁₀ [50 kg N + 5t VC/ha]	6.37	156.79	0.34	0.17	2.29	1.19	79.20	0.60	1.60	0.94
CD (P=0.05)	1.01	10.85	NS	NS	0.50	0.39	8.34	0.10	0.15	0.12
SEm (P<0.05)	0.34	3.68	0.06	0.07	0.17	0.13	2.83	0.03	0.05	0.04

fertilizer alone (T₂). These results are in agreement with Hernández-Cruz *et al.* (2002) and Hasanuzzaman *et al.* (2008), who have reported higher number of suckers under integrated nutrient management than control. Fertilization, not only influenced the growth but also the yield and its attributing characters. Inorganic fertilizers have significantly increased the yield and its contributing factors over control. This observation is in concurrence with finding of Barandozi *et al.* (2011), where higher values of yield contributing parameters were obtained with the application of inorganic fertilizers in Iranian *Aloe barbadensis*. Integrated nutrient management proved better compared to organic or inorganic fertilizers alone. Higher values of harvestable leaves/plant (7.10), fresh weight/leaf (171.45 g), wet latex/plant (2.99 g), dry latex/plant (1.52 g), gel yield/leaf (94.31g), gel yield/plant (0.77 kg) and leaf yield/plant (1.13 kg) were recorded in T₆ compared to other fertilizer combinations, however, T₆ was statistically at par with T₅ (Table 2). Increase in the growth and yield characteristics with conjunctive use of organic and inorganic fertilizers rather than their sole application reported in the present investigation is in consonance with earlier studies of Saha *et al.* (2005) in *Aloe barbadensis*.

This combination of fertilizers improved the Aloe plant growth by providing the essential nutrients resulting in maximum cell growth and turgidity which influenced the leaf growth. In the initial phase of growth, nitrogen would be available after quick release from chemical fertilizers, which might not be available in the next phase due to leaching losses. Under such circumstances, slow and steady release of nutrients from vermicompost would be available to plant for remaining cycle of its growth. Moreover, organics, besides supplying macro- and micronutrients, have also solubilizing effect on native soil nutrients due to the action of organic acids produced during decomposition and resulted in higher growth attributes. Application of manures increased the supply of easily assimilated major as well as micronutrients to plants besides

mobilizing unavailable nutrients into available form. Our findings support the results of Godara (2014) in fennel.

The increased latex (aloin) yield could be due to more leaf area, i.e. more leaf width and length and thereby more number of pericyclic cells in the vascular bundles resulting in production of more secondary metabolites – the glucosides. Increased gel yield was obtained due to greater plant spread (resulting in greater exposure to sunlight and production of higher photosynthates), higher number of leaves and leaf weight. The lowest leaf:gel ratio was obtained in T₆. Increased nutrient uptake from the soil by the root system could be the reason for its more gel content (Ganesh and Alagukannan 2009), thereby resulting in decrease in leaf:gel ratio, i.e. more gel content/leaf. Although application of FYM with *Azotobacter* (T₃) increased the growth parameters significantly compared to control, but the increment was significantly less than inorganic fertilizer (T₂) and vermicompost + *Azotobacter* (T₄). This might be due to the lack of sufficient moisture in soil required for decomposition of FYM besides slow release and their uptake by the crop.

The present study also revealed non-significant increase in growth and yield of aloe as a result of *Azotobacter* inoculation. The treatment T₇ (with *Azotobacter*) although, gave higher values for growth and yield parameters, but was statistically indifferent to T₈ (without *Azotobacter*). Similar trend was observed in T₉ and T₁₀. The higher values of growth and yield parameters in T₇ and T₉ as a result of *Azotobacter* inoculation might be attributed to growth substances produced by *Azotobacter* and released continuously in the minor rhizosphere *vis-a-vis* increasing the ability of absorption of nutrients. The results obtained are in confirmation with the findings of Gayathri *et al.* (2004) who reported increased number of leaves, leaf area and stem girth in *Limonium caspia* with application of biofertilizers, vermicompost and inorganic fertilizers. Similar results of increase in growth with *Azotobacter* inoculation have also been reported by

Table 3 Effect of manures and fertilizers on NPK uptake by plant (kg/ha)

Treatment	Nitrogen uptake	Phosphorus uptake	Potassium uptake
T ₁ (control)	23.91	11.57	16.35
T ₂ [150 kg N (Recommended dose)]	45.45	25.40	34.31
T ₃ [30 t FYM/ha + <i>Azotobacter</i>]	37.34	17.86	21.62
T ₄ [7.5 t VC/ha+ <i>Azotobacter</i>]	40.65	21.14	29.27
T ₅ [75 kg N + 15 t FYM/ha+ <i>Azotobacter</i>]	79.02	36.58	48.38
T ₆ [75 kg N+3.75 t VC/ha + <i>Azotobacter</i>]	83.68	43.27	50.03
T ₇ [50 kg N +20 t FYM/ha+ <i>Azotobacter</i>]	54.95	28.61	40.82
T ₈ [50 kg N + 20 t FYM/ha]	52.06	27.20	39.94
T ₉ [50 kg N + 5 t VC/ha + <i>Azotobacter</i>]	72.43	33.93	43.41
T ₁₀ [50 kg N + 5 t VC/ha]	66.53	30.46	41.27
CD (P=0.05)	11.84	6.49	7.05
SEm (P<0.05)	4.01	2.20	2.39

Table 4 Effect of manures and fertilizers on soil fertility status after harvest of the crop

Treatment	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
T ₁ (control)	198.17	14.80	155.75
T ₂ [150 kg N (Recommended dose)]	254.11	15.20	157.40
T ₃ [30 t FYM/ha + <i>Azotobacter</i>]	263.96	16.05	165.94
T ₄ [7.5 t VC/ha+ <i>Azotobacter</i>]	256.62	15.89	160.38
T ₅ [75 kg N + 15 t FYM/ha+ <i>Azotobacter</i>]	249.43	15.78	159.38
T ₆ [75 kg N + 3.75 t VC/ha+ <i>Azotobacter</i>]	246.79	15.80	158.61
T ₇ [50 kg N + 20 t FYM/ha+ <i>Azotobacter</i>]	264.09	16.00	161.73
T ₈ [50 kg N + 20 t FYM/ha]	260.16	15.30	159.67
T ₉ [50 kg N + 5 t VC/ha+ <i>Azotobacter</i>]	252.72	14.95	159.07
T ₁₀ [50 kg N + 5 t VC/ha]	250.83	15.90	158.00
CD (P=0.05)	4.34	NS	NS
SEm (P<0.05)	1.47	0.12	0.09
Initial status	253.26	16.07	165.32

Patel *et al.* (2013) in cumin.

NPK uptake by plants and fertility status of soil after crop harvest

The different treatments of manure and fertilizers increased the N, P and K concentrations (%) in *Aloe barbadensis* over the control. Though the treatments were not significantly different, T₆ and T₅ increased N, P, K concentrations (%) in plant as compared to other fertilizer combinations (Table 3). Plant NPK uptake was maximum in T₆ (75 kg N+ 3.75 t VC + *Azotobacter*) and the minimum was in control (T₁). Higher biomass production may be ascribed as the most pertinent reason for higher uptake of nutrients. Higher availability of nutrients due to residual effect of organic sources thereby improving physiological and metabolic functions inside the plant might have been responsible for better nutrient uptake. The findings confirm the reports of Mahapatra *et al.* (2007) and Manhji *et al.* (2014).

Incorporation of manures and fertilizers in soil significantly increased the available nitrogen in soil after the harvest of crop over control (Table 4). T₇, T₃, T₈, T₄ and T₂ not only increased the available N in the soil over the control but also over its initial status (253.56 kg/ha). The lower nutrient status under control than the initial value could be due to non application of either manures or fertilizers and the existing status was nothing but the native status left over after the uptake by the plant. Under chemical fertilization, N content was slightly higher but P and K contents were lower than initial status of soil. This is not due to the plant uptake alone, but may be due to leaching of N and K. The higher contents of available NPK

in soil after harvest of the crop were observed in manures alone and under integrated nutrient management.

Maximum contents of NPK in soil after harvest of crop were observed in T₇ followed by T₃. The increase in available N may be ascribed to mineralization of partially or fully immobilized N by farm yard manure in soil, nitrogen fixation by *Azotobacter* besides application of inorganic fertilizers in T₇. However, there was a substantial increase in available N in soil in T₉ (252.72 kg), T₁₀ (250.83 kg), T₅ (249.43 kg) and T₆ (246.79 kg) over control, but was slightly less or almost at par with the initial status of soil (253.56 kg/ha). The decrease in available nitrogen may be attributed to higher crop removal of nitrogen, as is evident from higher per cent nitrogen concentration in plants (Table 3) in T₉, T₁₀, T₅ and T₆. Non-significant and slight increase in available P of soil may be due to greater mobilization of native soil P, contribution through added manures, mineralization of organic P and production of organic acids making soil P more available. On the other hand, increase in available K of soil may be due to organic residues, the solubilizing action of certain organic acids produced during decomposition of organic residues and greater capacity of organic manures to hold K in the available form. These results are in close conformity with those reported by Joy *et al.* (2005) in black musli and Naik and Babu (2007) in guava.

From the present investigation it may be concluded that combination of organic, inorganic and biofertilizers is superior over application of manures or fertilizers alone for achieving higher growth and yield. Application of vermicompost @ 3.75 t/ha or FYM @ 15 t/ha alongwith 75 kg N per hectare (½ of recommended dose) and *Azotobacter*

is beneficial not only to increase yield of Aloe but in maintaining the fertility status of soil.

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