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Effect of water regimes, nitrogen and phosphorus on crop growth, yield and economics of aloe (*Aloe barbadensis*)

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ABSTRACT

The experiment was conducted during 2006–08 to study the effect of water regimes, nitrogen and phosphorus on crop growth, yield and economics of aloe (*Aloe barbadensis* Mill.). The results revealed that the crop growth parameters (plant height and plant spread), yield attributes (number of harvested leaf, weight of leaf, leaf length, width and thickness of leaf), number of suckers, chlorophyll content of leaf, nitrogen and phosphorus content in soil, net returns and benefit: cost ratio were significantly affected with individual treatment. There was statistically significant increase in yield of leaves/ha (155.53 and 140.10%) and number of suckers arises (164.88 and 42.41%) due to irrigation scheduled at IW: CPE ratio of 0.3 over IW: CPE ratio 0.1 in both the years (2006–07 and 2007–08), respectively. The maximum net returns, (₹1 52 429/ha. and ₹ 2 05 445/ha) and highest benefit : cost ratio (3.99 and 5.32) was also recorded in same treatment.

Key word: *Aloe barbadensis*, Benefit : cost ratio, Irrigation, Medicinal plant, Suckers

Aloe (*Aloe barbadensis* Mill.) is an important and traditional medicinal plant belonging to family Liliaceae. Aloe is a crassulacean acid metabolism (CAM) plant. It possess the succulent habit. The succulent plant (Aloe) accumulates large quantities of water and uses it slowly during dry periods. For this reason the plants are resistant to drought condition to much extent. Aloe despite being identified as a new plant resource with the most promising prospects in the world remains a disregarded plant. Indian aloe is a rich source of over 200 naturally occurring substances, such as vitamins, sugars, calcium, sodium, nitrogen, amino acids, enzymes, acids and minerals. Traditionally, aloe is extensively used for medicinal purpose, particularly for urine-related problems, pimples and ulcers. Aloin and its gel are used as skin tonic and have a cooling and moisturizing affects so it is used in preparation of creams, lotions, shampoos and allied products (Singh *et al.* 1995). Generally, crop is raised under rainfed condition with low input management under marginal and sub-marginal soils having low organic matter and poor soil fertility status. So water stress and nutrient are the most important factors for lower productivity of this crop. Scheduled irrigation not only increases the productivity of quality leaf but also help in synchronized, uniform growth and the sucker production of aloe crop. Van Schaik *et al.* (1997) reported that irrigation is an essential factor for continuous vegetative growth and high yield of *Aloe barbadensis* Mill., when drought stress was severe. The recent criteria of scheduling irrigation based on the evaporative demand of the atmosphere may prove highly useful in drought-prone area for efficient management of water. According to Singh (2002) the water-use efficiency of different crops was increased when irrigation scheduled on the basis of IW : CPE ratio. Besides water, it is well documented that nutrients are another important factor which directly affect vegetative growth and yield of the aloe crop. A judicious application of nitrogen and phosphorus fertilizer help in quantum and quality production in aloe crop. Nitrogen is extremely important in crop plant, being a constituent of protein, nucleic acids, amino acids and it is also an integral part of chlorophyll. But its severe deficiency is detrimental to growth and production of aloe plants. Therefore, application of nitrogen is essential in the soil for proper plant growth and development of aloe (Massiah *et al.* 1998, Pareek *et al.* 1999). In addition to this good supply of phosphorus is associated with increased root growth and early maturity of crop, besides imparting disease resistance (Tisdale *et al.* 1995). About 98% soils of cultivated area in India need phosphorus fertilization for good harvest. Keeping in view the above facts, an experiment was conducted to study the effect of water regimes, nitrogen and phosphorus on crop growth, yield and economics of aloe for working out ideal levels of irrigation, nitrogen and phosphorus for maximizing economic returns.

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MATERIALS AND METHODS

The field experiment was carried out on one-year old aloe plants during 2006–08. The soil was alkaline with sandy loam texture at *p*H 8.0, organic carbon 0.22%, available N 139 kg/ha, P 15.4 kg/ha and K 190.0 kg/ha. Experimental treatments comprised 36 treatment combinations consisting by three levels of irrigation (0.1, 0.2 and 0.3 IW: CPE), 4 levels of nitrogen (0, 50, 100 and 150 kg/ha.) and three levels of phosphorus (0, 25 and 50 kg ha.). The experiment was conducted in split-plot design with three replications. The sub-subplot size was 2.4 m×2.4 m with 60 cm×60 cm spacing between rows and plants. The total numbers of plants in each sub-subplot were sixteen. Irrigation was applied based on the ratio of depth of irrigation water (IW) application and cumulative pan evaporation (CPE). Irrigation with the measured quantity of 50 mm water in each irrigation was given at different cumulative pan evaporation values under different irrigation treatments. The quantity of irrigation water was measured by a 90° V-notch weir constructed on main water channel. Nitrogen was applied in the form of urea in four equal doses, one basal dose and three split doses, i.e. one week after each picking (three months interval) of pads while the entire dose of phosphorus in the form of single super phosphate was applied at the root zone as basal dose in July the by a hand driven dibbler during both years of experimentation. All crop bounded cultural practices were followed as per the package of practices (Saroj *et al*. 2004). All the observations on vegetative growth and yield parameters were recorded at the time of harvesting from randomly selected five plants in each plot for data collection. The pads were harvested quarterly. The annual total pad yield obtained in four pickings during a year has been presented on hectare basis. Leaves were weighed, length, width and thickness determined by standardized methods. Gel and bagasses were separated by using a laboratory roll processor and weighed. Chlorophyll content of leaves was estimated by the method of Arnon (1949). The available nitrogen of soil calculated through alkaline permanganate method (Subbiah and Asija 1956). The available phosphorus of soil was determined by the procedure outlined by Olsen *et al.* (1954). The net return was calculated by subtracting cost of each treatment from the gross returns. Total cost of cultivation and gross returns were calculated from average input cost and average market price of the leaf and suckers produce during the period of investigation and benefit:cost ratio = gross income/cost of cultivation. To test the significance of variance in the data obtained from crop growth yield and economics of variance technique (Fischer 1950) for split-plot design was adopted. Significance of difference among the treatments effect was tested through 'F' test and critical difference (CD) was calculated, wherever the results were significant.

RESULTS AND DISCUSSIONS

Effect of water regimes

Different frequency of water regime significantly affected the plant height and plant spread during both the years of experimentation. There was significant increase in plant height (41.43 and 34.68%) and plant spread (54.46 and 49.84%) due to irrigation scheduled at IW : CPE ratio 0.3 over IW : CPE ratio 0.1 in both the years of experimentation, respectively (Table 1). The higher available moisture status in soil favorably influences the uptake of nutrients which maintains the cell turgidity, cell elongation, photosynthesis

Table 1 Effect of water regimes, nitrogen and phosphorus levels on crop growth parameters and yield attributes of Aloe

Treatment	Plant height (cm)		Plant spread (cm)		Leaves/plant		Harvested leaves/ plant		Average weight of leaf (g)	
	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08
Water regime (IW: CPE)										
0.1	34.80	38.63	36.30	38.06	6.94	7.31	3.59	4.04	179.23	195.27
0.2	41.70	44.68	45.98	47.35	9.14	9.96	4.63	5.24	213.04	268.61
0.3	49.22	52.03	56.07	57.03	11.70	11.90	5.82	5.90	272.04	291.14
CD (*P*=0.05)	2.941	4.413	2.963	4.390	0.857	0.860	0.300	0.415	9.353	14.398
Nitrogen level (kg/ha)										
0	38.06	41.43	39.64	42.21	8.23	8.73	4.09	4.39	190.25	227.23
50	39.95	43.68	45.73	47.32	8.98	9.74	4.53	4.99	212.18	246.14
100	43.84	46.39	48.77	50.61	9.56	10.18	4.94	5.34	244.50	273.96
150	45.79	48.93	50.25	51.13	10.27	10.58	5.17	5.52	252.40	282.11
CD (*P*=0.05)	5.088	5.727	4.662	5.316	1.035	1.233	0.573	0.635	24.758	26.271
Phosphorus levels (kg/ha)										
0	39.59	42.18	43.55	44.40	8.41	8.99	4.24	4.40	208.90	239.55
25	41.94	45.22	46.43	47.44	9.48	10.04	4.79	5.17	227.16	257.41
50	44.18	47.93	48.32	50.36	9.88	11.13	5.02	5.61	248.25	275.13
CD (*P*=0.05)	5.011 (NS)	5.720	4.662	5.301	1.035	1.201	0.560	0.623	24.750	26.150

Table 2 Effect of water regimes, nitrogen and phosphorus levels on yield attributes, yield and suckers characters of Aloe (*Aloe barbadensis* Mill.)

Treatment	Length of leaf (cm)		Width of leaf at centre (cm)		Thickness of leaf at centre (cm)		Yield/ha (tonnes)		Suckers arises/plant	
	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08
Water regime (IW: CPE)										
0.1	32.45	40.84	5.93	6.84	0.700	0.817	17.99	21.62	1.68	4.22
0.2	40.40	48.08	6.35	7.30	0.902	1.006	27.71	38.44	3.08	5.59
0.3	49.69	54.54	7.32	8.42	1.545	1.622	45.97	51.91	4.45	6.01
CD (*P*= 0.05)	2.941	4.413	0.798	0.786	0.101	0.102	2.100	3.562	0.305	0.581
Nitrogen level (kg/ha)										
0	36.86	42.22	5.76	6.59	0.904	1.020	22.23	27.05	2.55	4.50
50	38.74	46.97	6.39	7.44	1.001	1.109	27.44	35.30	2.91	5.15
100	43.10	50.67	6.77	7.81	1.102	1.217	34.78	42.07	3.25	5.54
150	44.70	51.42	7.20	8.23	1.188	1.246	37.77	44.879	3.57	5.90
CD (*P*= 0.05)	4.732	5.552	0.836	0.948	0.107	0.124	2.215	2.736	0.243	0.576
Phosphorus levels (kg/ha)										
0	38.22	44.35	6.01	6.84	0.993	1.083	26.22	30.53	2.89	4.20
25	41.14	47.90	6.57	7.59	1.055	1.158	31.65	38.38	3.10	5.65
50	43.18	51.22	7.04	8.12	1.099	1.204	33.81	43.05	3.22	5.97
CD (*P*= 0.05)	4.730	5.500	0.830	0.940	0.108	0.123	2.202	2.705	0.242	0.575

and respiration at optimum level, leading to favourable growth and development of plant in terms of plant height and spread as observed in the present study. Singh *et al.* (2001) strongly supported this finding that fresh biomass production of palmarosa (*Cymobopogon martini* L.) was increased with increase in number of irrigations. Neeraja *et al.* (2001) also reported that basil irrigated at 0.75 IW: CPE ratio with the application of 200 kg nitrogen/ha gave maximum herbage. Significantly, the highest number of leaves/plant (11.70 and 11.90), number of harvested leaves/ plants (5.82 and 5.90), average weight of leaf (272.04 and 291.14 g), length of leaf (49.69 and 54.54 cm), width of leaf at centre (7.32 and 8.42 cm), thickness of leaf at centre (1.545 and 1.622 cm), yield of leaves/ha (45.97 and 51.91 tonnes), number of suckers arises/plant (4.45 and 6.01) and gel weight/ ha (14.84 tonnes and 18.51) were reported during both the years (2006–07 and 2007–08), respectively (Table 1, 2, 3).

Significant increase was observed due to application of frequent irrigations (0.3 IW : CPE) as compared to delayed irrigation (0.1 IW : CPE) with respect to number of leaves/ plant (68.59 and 62.79%), average weight of leaf (51.78 and 49.09%), length of leaf (53.12 and 33.54%), width of leaf at centre (23.44 and 23.09%), thickness of leaf at centre (120.71 and 98.53%), yield of leaves (155.53 and 140.10%), number of suckers (164.88 and 42.41%) and gel weight of leaf (170.30 and 154.96%). This might be due to maintenance of soil moisture at higher level which enhanced the uptake of nutrients by the plants. The greater uptake of nutrients, higher photosynthesis and biosynthesis of assimilates and their translocation to lower parts of leaf, ultimately enhancing the leaf size, weight, thickness and gel percentage contributed to increase yield/plant and per unit area. These results are in agreement with the findings of Singh *et al.* (1996) who reported that irrigation at 0.1 IW: CPE gave significantly higher herb yield of geranium (*Pelargonium* sp.). Singh (2002) reported that sweet basil irrigated at 0.75 IW: CPE ratio gave maximum herbage and oil yield.

The total chlorophyll content in aloe leaves increased significantly with the application of frequent irrigation (0.3 IW: CPE) as compared to delayed irrigation (0.1 IW: CPE). The highest chlorophyll content of aloe leaves (0.441 mg/g fresh tissue and 0.451 mg/g fresh tissue) during 2006–08 was recorded at the time of leaf harvest with application of frequent irrigation (0.3 IW: CPE) and the lowest chlorophyll content was recorded in delayed irrigation (Table 3). This might be due to the fact that maintaining soil moisture at optimum levels which enhances the uptake of nitrogen by plants. The greater uptake of nitrogen increases chlorophyll synthesis in leaves.

The nitrogen and phosphorus content in soil was decreased significantly with the application of frequent irrigation (0.3 IW: CPE) as compared to delayed irrigation (0.1 IW: CPE). The nitrogen content in soil was at par with treatment of medium level irrigation (0.2 IW: CPE). Maximum decrease in nitrogen (5.73% and 3.08%) and phosphorus (16.53% and 14.44%) content in soil were recorded with frequent irrigation (0.3 IW: CPE) as compared to delayed irrigation (0.1 IW: CPE) (Table 3). This might be due to maintenance of adequate soil moisture which enhances the uptake of nitrogen and phosphorus by aloe plants resulting reduction in the nitrogen and phosphorus content in the soil. These results are in conformity with the findings of Pareek *et al.* (1999).

Table 3 Effect of water regimes, nitrogen and phosphorus levels on gel weight, chlorophyll content of leaf, nitrogen and phosphorus content in soil and economics of Aloe (*Aloe barbadensis* Mill.)

Treatment	Gel weight/ha (tonnes)		Chlorophyll content of leaf (mg/g fresh tissue)		Nitrogen content in soil (kg/ha)		Phosphorus content in soil (kg/ha)		Net returns (Rs/ha)		Benefit: cost ratio	
	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08
Water regime (IW: CPE)												
0.1	5.49	7.26	0.414	0.410	137.80	145.05	18.33	20.28	36632	1,11,781	0.99	3.02
0.2	8.65	13.37	0.423	0.419	133.62	141.79	17.31	19.37	89,251	1,74,358	2.37	4.65
0.3	14.84	18.51	0.441	0.451	129.90	140.58	15.30	17.35	1,52,429	2,05,445	3.99	5.32
CD (*P*= 0.05)	0.841	0.963	0.013	0.010	4.240	4.413	0.839	0.867	12,364	7,941	0.182	0.581
Nitrogen level (kg/ha)												
0	6.91	9.34	0.393	0.393	123.37	130.90	17.75	19.81	67,139	1,27,584	1.80	3.43
50	8.61	12.28	0.410	0.411	129.16	137.71	17.37	19.43	84,705	1,57,998	2.24	4.24
100	11.03	14.73	0.438	0.443	136.02	145.92	16.62	18.45	1,02,268	1,78,118	2.72	4.68
150	12.10	15.85	0.460	0.462	146.55	155.36	16.19	18.32	1,16,971	1,91,745	3.02	4.96
CD (*P*= 0.05)	0.703	0.925	0.056	0.056	18.517	19.436	2.660 (NS)	4.410 (NS)	4,346	13,090	0.123	0.405
Phosphorus levels (kg/ha)												
.056												
0	8.26	10.65	0.419	0.419	134.50	144.55	15.49	16.45	81,846	1,24,561	2.19	3.34
25	10.01	13.41	0.426	0.427	133.73	142.22	16.65	18.65	95,349	1,75,903	2.52	4.66
50	10.72	15.08	0.433	0.435	133.09	140.65	18.81	21.90	1,01,118	1,91,119	2.63	4.99
CD (*P*= 0.05)	0.703	0.925	0.060 (NS)	0.060 (NS)	21.500 (NS)	23.700 (NS)	2.811	3.104	4,346	13,090	0.123	0.405

NS- Non- significant

As far as economics is concerned, the frequent application of irrigation (0.3 IW: CPE) gave significantly higher net returns (₹ 152 429/ha and ₹ 205 445/ha) and highest benefit: cost ratio (3.99 and 5.32) as compared to delayed irrigation (0.1 IW: CPE) in both years of experimentation, respectively (Table 3). Frequent irrigation (0.3 IW: CPE) maintains soil moisture at optimum level resulting higher yield of leaves. These results are in agreement with the finding of Singh (2000) whre reported the herbage and oil yield of geranium was significantly increased when soil moisture maintained at 0.6–0.9 IW: CPE.

Effect of nitrogen

Application of nitrogen at maximum level (150 kg/ha) significantly enhances the plant height and plant spread over the control. However, treatment level 50 kg, 100 kg and 150 kg nitrogen/ha were found statistically non-significant with plant height and plant spread during both the years (Table 1). Further higher nitrogen content (150 kg/ha) treatment registered maximum plant height (45.79 and 48.93 cm) with increase (20.31 and 18.10%) and plant spread (50.25 and 51.13 cm) with increase (26.76 and 21.13%) over control in both the years (2006–07 and 2007–08), respectively. The enhancement in plant height and plant spread as a result of application of nitrogen might be due to fact that nitrogen is involved in the chlorophyll synthesis and protein metabolism resulting in deep green colour of the foliage which might have favoured photosynthesis activities in the leaves leading to the formation of amino acids, proteins, chlorophyll, alkaloids and amides. These complex compounds are responsible for building-up of new tissues and are associated in a number of metabolic processes. Which in turn, favour better development of plant. These results are in close agreement with the observations of Farooqui *et al.* (1991) in davana (*Artemisia pallens* Wall.) observed higher plant height with higher level of nitrogen up to 240 kg/ha and Khandelwal *et al.* (2003) observed that application of 120 kg nitrogen/ha increased the plant height (225 cm) and number of branches/ plant in henna (*Lawsonia inermis* L.).

The plants that are treated with 150 kg nitrogen/ha exhibited higher crop growth and yield. Significant increase was observed due to application of 150 kg nitrogen as compared to control with respect to number of leaves/plant (24.79 and 21.19%), number of harvested leaves/plant (26.40 and 25.74%), average weight of leaf (32.66 and 24.15%), length of leaf (21.26 and 21.79%), width of leaf at centre (25.00 and 24.88%), thickness of leaf at centre (31.41 and 22.15%), yield of leaves/ha (69.90 and 65.88%), number of suckers/plant (40.00 and 31.11%), gel weight of leaf (75.10 and 69.70%) in both the years (2006–08) (Tables 1, 2, 3).

The positive response of various yield attributes to nitrogen fertilizer could be ascribed to overall improvement in growth attributes such as plant height and plant spread. Significant increase in yield attributes and yield might also be due to the fact that nitrogen supply helped in the fully expansion of leaf and chlorophyll content which might have accelerated the photosynthetic rates subsequently increased the supply of carbohydrates to the plants or better availability of nitrogen might have also favoured the metabolism and auxin activities in the plant and ultimately resulted in increased number of leaves, size of leaves and finally total yield of leaves and gel. The present trend of increase in yield of leaves and gel with application of nitrogen is in close conformity with the finding of Massiah *et al.* (1998) who observed that leaf length, width and thickness were highest with higher level of nitrogen in *Aloe vera*. Pareek *et al.* (1999) also reported that maximum fresh weight of pads (43.95 tonns/ha) was recorded with the higher dose (124 kg/ha) of nitrogen in *Aloe barbadensis*.

The maximum chlorophyll (0.460 mg/g fresh tissue and 0.462 mg/g fresh tissue) content in leaves was found in 150 kg nitrogen/ha, followed by 100 kg nitrogen/ha and minimum for control in both the years (2006–07 and 2007–08) of experimentation (Table 3). Chlorophyll content of the leaves was increased significantly with the application of nitrogen. It is possibly due to the fact that an improved nutritional environment as well as its utilization in the plant system might have led to enhanced translocation of nutrients in leaves and increased chlorophyll content in leaves. These results are in agreement with the finding of Yepaz *et al.* (1993) in aloe, Khan *et al.* (1993) Hernandez *et al.* (2002) in aloe.

While soil nitrogen was increased, phosphorus content was decreased due to application of various levels of nitrogen during both years of experimentation (Table 3). Application of 150 kg nitrogen/ha improves soil nitrogen status significantly over control, but the medium levels of nitrogen (50 kg/ha and 100 kg/ha) have non-significant difference with highest level (150 kg/ha) of nitrogen. The phosphorus content of soil was non-significantly decreased with respect to increase is the nitrogen levels. The highest increase in nitrogen content (18.78 and 18.68%) and decrease in phosphorus content (8.78 and 7.52%) was recorded in application of 150 kg nitrogen/ha as compared to control during 2006–07 and 2007–08 (Table 3). Applying higher rate of nitrogen increases root system with respect to plants growth, due to highly developed root system plants absorption of phosphorus adequate from soil and reduces the phosphorus content from aloe field. Results earlier have been reported in aloe crop by Yepaz *et al.* (1993).

Application of 150 kg nitrogen/ha proved profitable and showed maximum net returns (₹ 116 971 and ₹ 191 745/ha) and benefit: cost ratio (3.02 and 4.96) for the first and second year of experimentation, respectively due to high yield obtained (Table 3). This treatment was significantly superiour to rest of the treatments during first year but in second year of experimentation this treatment benefit : cost ratio showed at par with 100 kg nitrogen/ha.

Effect of phosphorus

Phosphorus is the second important nutrient after nitrogen in plant nutrition. Its application not only increases the yield but also improves the crop quality and imparts resistance to plant disease. Significant differences were recorded due to application of 50 kg phosphorus/ha on plant height during 2007–08 and plant spread during 2006–07 and 2007–08 over the control. The plant height during 2006–07 did not differ significantly. The maximum increase in plant height (11.59 and 13.63%) and plant spread (10.95 and 13.42%) was recorded during both the years of experiment, respectively with application of 50 kg phosphorus/ha as compared to control. Supplementation of phosphorus in soil even though experimental plot already contains 15.4 kg available phosphorus/ha owing to it a major constituent of plant cell nucleus and growing root tips helped in cell division and root elongation. The well developed root system might have helped the plants to absorb more water and plant nutrients from deeper layer of the soil. Increased metabolic activities of plants as a result of greater nutrient uptake ultimately helped the plant in its vigour growth and development leading to increase plant height and plant spread.

Application of phosphorus 50 kg/ha exhibited significant increase in total number of leaves/plant (17.47% and 23.80%), number of harvested leaves/plant (18.39% and 27.50%), average weight of leaf (18.83% and 14.85%), length of leaf (12.97% and 15.49%), width of leaf at centre (17.13% and 18.71%), thickness of leaf at centre (11.01% and 11.48%), yield of leaves (28.94% and 41.00%), number of suckers/plant (11.41% and 42.14%) and gel weight (29.78% and 41.60%) over control (Table 1, 2 & 3). The increase in yield attributes might be due to vital role of phosphorus in energy formation reaction and metabolic processes of plant, resulting in greater photosynthesis, protein synthesis and carbohydrate metabolism, which in turn helps in increasing accumulation of biomass in the leaves, increased leaf weight.

Despite the lack of significant statistical difference, it should be noted that Table 3 showed a clear increase in chlorophyll content of leaf and decline in nitrogen content in soil under plants fertilized at all applied doses of phosphorus. The results of both the years of experimentation suggested the significant influence in phosphorus content in soil with application of 50 kg phosphorus/ha. The maximum phosphorus content (18.81 kg/ha and 21.90 kg/ha) with increasing rate (21.43% and 33.13%) was recorded in 50 kg phosphorus/ha treatment as compared to control.

In Table 3, there was a statistically significant increase in net returns (23.54% and 53.43%) and benefit : cost ratio (20.09% and 49.40%) with application of higher dose of phosphorus (50 kg/ha) then the lower does (0 kg/ha) but the benefit : cost ratio at par with treatment of medium level phosphorus (25 kg/ha). Interaction effect of irrigation× nitrogen, irrigation×phosphorus, nitrogen × phosphorus and irrigation×nitrogen×phosphorus did not differ significantly with respect to crop growth, yield and economics of aloe (*A. barbadensis* Mill.).

It may be concluded that the aloe (*A. barbadensis* Mill.) should be fertilized with a dose of nitrogen 150 kg/ha and phosphorus 50 kg/ha for significant increase in economic yield. Further, it should be irrigated at IW: CPE ratio of 0.3 for maximum production and highest economic returns with higher benefit: cost ratio.

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