INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 13, No. 2, p. 226-231, 2018

RESEARCH PAPER OPEN ACCESS

Assessment of production potential of sisal (*Agave sisalana*) under three watering conditions in Pakistan

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Key words: Alternate fiber, Agave sisalana, production potential.

http://dx.doi.org/10.12692/ijb/13.2.226-231 Article published on August 30, 2018

Abstract

Pakistan is a leading cotton producer and provides cotton fiber as only source of thread for the countrymen as well as an export commodity for earning foreign exchange. Extreme biotic and abiotic stress conditions particularly under climate and edaphic changes are hindering the profitable cultivation and harvesting of thread from cotton. To cope with these challenges, alternate means of producing fiber can be an attractive approach through which utilities of thread other than consumption in textiles mills can be fulfilled. Keeping in view the importance of natural fiber, present study was planned to check the adaptability of sisal as an alternate fiber crop that may be grown aside cotton. Sisal was grown under three watering levels at Directorate of Farms, University of Agriculture, Faisalabad, Pakistan. Findings envisaged that plant growth was slow due to its perennial nature. Significant differences were observed in all growth and phonological parameters under all the watering conditions. In addition, plants propagated through suckers were found to be quick in growth as compared to those established from bulbils. Results depicted that 10 irrigations of 2-3 acre inches per annum, increased plant height, number of leaves per plants, days to first leaf emergence, days to 1st fully expanded leaf, days to 2nd leaf emergence followed by sisal plants applied with 5 irrigations in terms of respective growth and phonological traits. So, it could be recommended that sisal is a potential alternate fiber crop that utilizes less irrigation water and could be a better textile crop.

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Introduction

Sisal (*Agave sisalana*) is native to Mexico (Sharma and Varshney, 2012). Sisal is a hardy plant that grows well in hot cum humid and dry climatic conditions particularly unsuitable for rearing of conventional crops. Sisal is multifaceted crop having impact from fiber production to environmental sustainability. Leaves of the sisal contain excessive moisture with rigid and fleshy pulp. Sisal has also been utilized in paper, textile, filters, carpets, mattresses and wall coverings (Machin, 2008). By-products of sisal fiber extraction can be used for preparing bio-gas, pharmaceutical ingredients and building material. Nowadays, climate change has become a major threat and sisal is anticipated as climate mitigation plant because sisal absorbs more carbon dioxide than it produces (Elzebroek, 2008). During processing, it produces mainly organic wastes and leaf residues that can be used to generate bio-energy, animal feed, fertilizer and ecological housing materials. In addition, Sisal is 100% biodegradable and any product of it is having aseptic significance with antiallergenic potential.

Optimization of production technology and development of fiber extraction methodology can make sisal crop an exportable commodity of Pakistan. Moreover, its adaptability in the local environment needs community mobilization for its effective assimilation in the cropping scheme of the arid and desert environments. Hence fiber based needs of the ever-increasing population of Pakistan can be alternately expedited through cultivation of this valuable crop. Subject project was being executed with the objective to make farming community aware of economic worth of this crop and to popularize this crop for its cultivation in arid regions of the country as a cash crop so that need of rough fiber may be amicably fulfilled.

Material and methods

Crop husbandry and sowing strategy

Project experiments were conducted at Directorate of Farms located at U-Road of the University of Agriculture, Faisalabad. Well drained soil was selected to exclude any of the growth limitations either subject to water logging or salinity, sodicity etc. Soil was manipulated to sow the sisal plants on ridges, flat surface and on beds with a sowing geometry mentioned below:

i. Ridge Sowing: 75cm apart ridges made using ridger with 50cm distance between plants
ii. Flat Sowing: 75cm apart rows and 50 cm distant plants
iii. Bed Sowing: Plantation was done on both sides of 75cm wide beds at 50cm distance

Sisal plants were transplanted either by their suckers collected from wild reservation near Mandra Tehsil Gujar Khan district Rawalpindi (33.34'58"6 N; 73.23'82"75E) or its bulbils being collected from suburbs of Jauharabad, District Khushab (9km, Jauharabad-Muzafargarh Road) (32.21'37"60 N; 72.24'50"04E) and Kalar Kahar (19 km, Kalar Kahar-Khushab Road near Noorpur Sathi), Chakwal (24 March 2016). Four leaves having suckers were preferably selected from the wild reservations. A total of 450 suckers were transported from Mandra to Faisalabad whereas, 400 bulbils were collected from Chakwal and Khushab districts (28 March 2016). The suckers were planted in the field as dense plantation whereas, bulbils were initially grown as nursery under the mango orchard shade for three months and were kept under observation in this duration. These suckers and bulbils were transplanted on ridges, beds and flat land during second week of July, 2016 in order to understand their growth behavior, phenology and leaf yield. Sandy loam textured fertile tract with six months' pre-plantation fallow history was selected and engaged for sisal plantation purpose. Soil analysis was carried out with findings as depicted in the table 1.

Table 1. Analysis of experimental area.

1.	Clay	5.0%
2.	Silt	23.0%
3.	Sand	72.0%
4.	pH	8.4%
5. (mEq. /100g d.wt)	Cation Exchange capacity	8.0%
6. capacity	Maximum water holding	34.4%

Irrigation Application

Sisal plants were irrigated keeping in view the conditions of the plants as observed visually by succulence of top leaves. Plants underwent light irrigations however, usual and unusual patterns of rainfall added to applied irrigation water. A total of 6 irrigations were applied during the first year of plantation. It was observed that the leaves when become fully mature, they tended towards wilting from their tips backward. A black layer emerged from the tips of the older leaves and receded backward. During this experiment, bed plantation of bulbils was done on plot size (25x30ft each) on 75cm wide beds and on both sides of the bed by keeping 50cm distance between plants within the rows. Irrigation levels i.e. 5, 10 and 15 irrigations per annum (2-3 acre inches/irrigation) were applied to treatment plots replicated thrice for unbiased response assessment and were compared with no irrigation treatment using randomized complete block design (RCBD).

Days to first leaf

Days to emergence of first leaf was taken at time when half of the plant maintains first leaf. Five plants were selected randomly from each replication and days to first leaf were recorded and averaged.

Days to four leaves

Four leaf stage of the crop was determined by randomly selected plants in which half of the population was observed with four leaves emerged.

Days to multiple leaves

This stage comes after four leaves stage when new leaves emerged on the plant following four leaf stage (multiple leaves). Days to multiple leaves stage were calculated from emergence of seedling to days when ½ of the randomly selected plants set multiple leaves.

Days to maturity

Days to maturity of leaves were the time when leaves start yellowing (Necrosis) of their tip or near to tip leaf region. In each plot the time of maturity was recorded from different sites and then average was calculated.

Leaf diameter (cm)

Leaf diameter was measured by using screw gauge from bottom, mid and near the tip of the leaves of selected five plants and then average was calculated.

Plant height (cm)

Five plants were selected from each plot randomly. Plant height was measured from ground level to tip of the top leaf with the help of a meter rod at maturity stage and their average was calculated.

Results

Mean squares exposed significant effect of stand establishment method of sisal plants for their plant height, leaf area and number of leaves per plant in respect of both sucker as well as bulbil plantations when grown under bed, ridge and flat practices.

Table 2. Effect of Sowing Method and Stand Establishment Methods on Growth of Sisal.

Treatment	Plant Height (cm)		Leaf Area (cm^2)		No. of Leaves	
	Suckers	Bulbils	Suckers	Bulbils	Suckers	Bulbils
Ridge	29.0 C	24.3 D	7.6 D	6.60 E	7.3 C	5.3 D
Flat	39.6 A	30.6 C	12.0 A	8.90 C	12.0 A	8.0 C
Bed	33.3 B	28.3 C	9.90 B	8.63 C	9.3 B	7.3 C

Tallest plants were recorded in plants emerged from suckers under flat conditions followed by suckers planted on beds (Table 2). Bulbils sown under flat and bed strategies along with suckers planted on ridges followed these two combinations. Least plant height was recorded in ridge sown bulbils.

For leaf area measurements of sisal plants, flat sown suckers gathered the maximum value (cm^2) followed by bed planted suckers whereas bulbils planted on flat and bed surfaces ranked third with at par leaf area values. For number of leaves, similar trend of treatment combinations was exposed by the statistical analysis in which the largest leaf number was counted in the plants emerged from suckers grown on flat surface followed by bed planted suckers whereas rest of the combinations gathered lesser number of leaves.

Days to first leaf emergence

Significantly different duration was recorded for emergence of first leaf both in sucker and bulbil plantations when sown on flat and bed surfaces or on ridges (Fig 1). In general, bulbils took longer time for first leaf emergence as compare to suckers. Quickest emergence of first leaf was recorded in flat and bed planted suckers with statistically similar duration followed by ridge planted suckers.

Similarly, flat and bed sown bulbils behaved statistically similar for emergence of first leaf while ridge planted bulbils took longer duration to form first leaf.

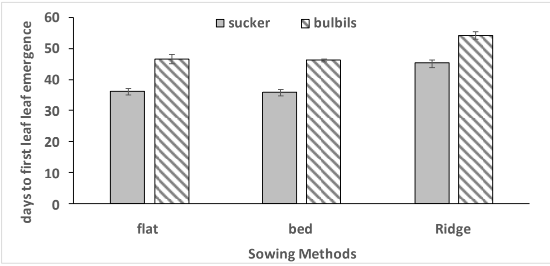

Fig. 1. Effect of sowing method and stand establishment method on days to first leaf emergence in sisal.

Days to first fully expanded leaf

As revealed in the fig. 2, more time was taken by the sisal plants to form fully extended first and true leaf when spread through bulbils under all three sowing geometries while sucker based plantations of sisal established their first completely extended leaf in lesser time under all three sowing methodologies.

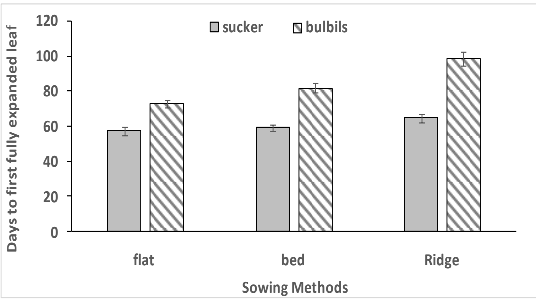

Fig. 2. Effect of sowing method and stand establishment method on days to first fully expanded leaf in sisal.

Days to second leaf emergence

Fig. 3 exposed the significantly affected suckers and bulbils plantations when grown on flat surface, beds and ridges for second leaf emergence. Least days were taken by sisal suckers being grown under flat and bed sowing methods followed by suckers grown on ridges for emergence of second leaf. Bulbils of sisal took comparatively more time to emerge second leaf.

Days to second fully expanded leaf

As exposed in the fig. 4, significantly more time was taken by the sisal plants to form fully expanded second leaf when propagated through bulbils under all three sowing strategies while sucker based plantation of sisal gathered second fully expanded leaf in lesser time span in ridge, flat and bed sowing strategies.

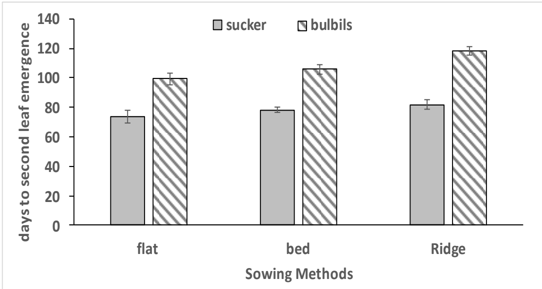

Fig. 3. Effect of sowing method and stand establishment method on days to second leaf emergence in sisal.

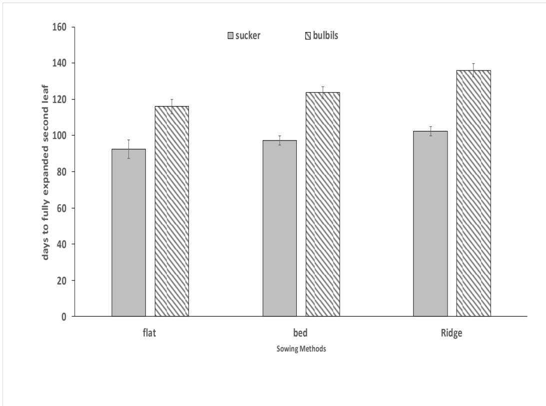

Fig. 4. Effect of sowing method and stand establishment method on days to second fully expanded leaf in sisal.

Standard mean differences showed significant differences for Leaf diameter (LD), Leaf area (LA), Number of leaves (NL), Leaf length (LL), and Plant height (PH) exhibited highly significant effect of irrigation on these traits.

Table 2. Effect of irrigation levels on growth and yield of sisal.

Treatments	LD (cm)	LA (cm^2)	NL	LL (cm)	PH (cm)
I_0 (Control an^{-1})	0.22 B	5.17 B	11.33 B	31.67 B	40.00 B
I_1 (5 irrig. an^{-1})	0.24 A	6.50 A	15.00 A	36.67 A	41.67 A
I_2 (10 irrig an^{-1})	0.19 C	4.50 C	8.33 C	28.00 C	36.00 C
I_3 (15 irrig an^{-1})	0.17 D	3.66 D	6.67 D	25.00 D	33.33 D
LSD (0.05)	0.0179	0.60	0.3457	2.1835	1.4891

LD= leaf diameter'; LA=leaf area; NL=No. of leaves; LL=leaf length; PH=plant height.

Significant difference among irrigation treatments was observed for leaf area, leaf length, leaf count per plant, leaf diameter and sisal plant height (Table 2). Furthermore, thickest leaves were recorded in control i.e. no irrigation treatment followed by plants exposed to five irrigations. Sisal plants exposed to ten irrigations attained leaf diameter, leaf area, number of leaves, leaf length and plant height lesser than those grown under control conditions and applied with five irrigations. However, least values of these parameters were recorded in fifteen irrigation treatment.

Discussion

Pakistan is a developing country and facing many crises such as water shortage, lack of economic stability, most importantly energy crisis propelled textile owners and cotton growers to shift in secure zones that led cotton growers move towards short duration crops. Under this scenario, major portion of textile industry shifted in Bangladesh that created a gap in source and sink relationship of country economy (Govt. of Pak., 2016-17). Keeping in view the importance of fiber, present investigations were carried out to explore alternate fibers to meet textile demand. Commercial cultivation of sisal on unproductive and barren lands can provide strong basis to build up sustainable rural economy as the crop consumes intensive labor during harvesting and processing. Sisal can also help us to mitigate the changing climatic conditions of the country by putting less burden on water resources. Present study showed that sisal is drought resistant crop and can be grown on unfertile soils and in tropical regions thus converting these poor lands into cultivable ones (Nichols *et al.*, 2000; Parsons and Darling, 2000). The production of sisal crop on deserted lands of the country may bring the economic prosperity for the economically vulnerable farm communities in an eco-friendly manner (Berman *et al.*, 2006). It has been observed that marginal soils in semi-arid areas are very much appropriate for sisal production (Somerville *et al.*, 2010; Davis *et al.*, 2011). It was also found from the results of the study that nearly 40% less water was sufficient to successfully grow sisal, hence growing of drought tolerant crops like sisal in these areas is the need of the hour (Ramankutty *et al.*, 2008; Vorosmarty *et al.*, 2010; Borland *et al.*, 2014).

Intense evapotranspiration and less rainfall are considered major hurdles for successful cultivation of many C_3 and C_4 crops in these areas (Borland *et al.*, 2009). *Agave sisalana* is CAM plant that has enough potential to be successfully grown in warm and dry regions of the world (Yang *et al.*, 2015). Having the rosette arrangement of leaves enables this plant to absorb maximum light for photosynthesis (Nobel, 2010). Wide range temperature and CO_2 adoptability makes it a 'specialist crop' for conservation agriculture (Sarkar *et al.* 2010).

Conclusion

Extreme biotic and abiotic stress conditions particularly under climate and edaphic changes are hindering the profitable cultivation and harvesting of thread from cotton. To cope with these challenges, alternate means of producing fiber can be an attractive approach through which utilities of thread other than consumption in textiles mills can be fulfilled. Keeping in view the importance of natural fiber, present study was planned to check the adaptability of sisal as an alternate fiber crop that may be grown aside cotton. The thick cuticle layer help sisal plant to maintain water status by reducing epidermal transpirational water loss. Sisal has significant potential that utilizes less irrigation water and could be used as alternate fiber crop. The production of sisal crop on deserted lands of the country may bring the economic prosperity for the economically vulnerable farm communities in an eco-friendly manner. So, it could be strongly recommended that agricultural extension should play its role through community mobilization to promote sisal cultivation in Pakistan.

Acknowledgement

This research project was funded by Higher Education Commission of Pakistan.

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