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Impact of sowing and harvest times and irrigation regimes on the sennoside content of *Cassia angustifolia* Vahl

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ABSTRACT

Cassia angustifolia Vahl is known for the production of leaves and pod shells containing high-value glycosides (sennosides) with enormous medicinal properties to cure constipation in all over the world. However, data on its agricultural practices is limited. The present study aim to optimize the sowing time, moisture regime, and harvesting date at sub-tropical conditions for getting maximum marketable produce. Experiments were performed over two years (2016 and 2017) into two sets. First one comprised of seven dates of sowing, and second experiments having four moisture regimes and four dates of harvest. In sub-tropical north Indian conditions, 15 March was the best sowing date with highest biological yield (17.446 q ha^{-1}), sennoside content (2.18% in leaves and 3.26% in pods), and sennoside yield (45.943 kg ha^{-1}). The 20% available soil moisture with 90 days of harvesting time was suitable for the maximum biological yield of senna (17.296 q ha^{-1}). The maximum net return (67,989.0 Rs ha^{-1}) was observed at 20% available soil Moisture (ASM) condition at 90 days harvesting. Hence, the study recommended that the 15 March sowing date, 20% available soil moisture and 90 days harvest for the *Cassia angustifolia* Vahl. provide more income to the farmers and industry. Development of cost-effective package of practices leading to the quality assurance will encourage its cultivation and availability of raw material to the industry.

1. Introduction

Cassia angustifolia Vahl., which is also known as Indian senna or Tinneyvelley senna, a well known medicinal plant belongs to family Fabaceae. Senna is one of the most widely used herbal laxatives and finds great value in different systems of medicine (Rama Reddy et al., 2015; Tripathi, 1999). Its leaves are used for the treatment of habitual constipation and as a safe purgative which increases the peristaltic moment in the colon (Anon, 1966). Senna is also utilized for its antimicrobial, anticancer and antioxidant properties, and due to its potential uses in the number of drugs, senna finds a good demand in international market. India exports the plant of *Cassia angustifolia* Vahl. to various countries like Germany, Italy, Netherlands, Canada, Mexico, Australia, Japan, etc. Sennosides A and B isolated from leaves and pods ranged from 1.5 to 3.0% in these parts of the plant (Anon, 1985; Husain, 1992). It is commonly cultivated in warm climatic condition and marginal soils of India, Yemen and Hadramaut province of Southern Arabia and the opposite coast of Somalia. In India, it is one of 3 medicinal plants having the largest share in export, i.e., Senna, Isabgol and Opium poppy. It accounts for about 75% of international trade, whereas, 25% demand is met by Alexandrian senna (*Cassia acutifolia*). In India, annual production of *Cassia angustifolia* Vahl. is about 6000–7500 t of leaves and pods, 80% of which is exported and earning to the tunes of 350 to 360 million (Sastry et al., 2015). Senna cultivation is done in Rajasthan, Tamil Nadu, Gujarat, and in some parts of Andhra Pradesh of Indian states. Crop production especially the quality of senna is badly affected in traditional growing regions, leading to lots of quality complaints and the reduction in export. The important factors which influence the quality of produce are leaf blight by *Phyllostica* spp. and leaf spot by *Alternaria alternata* (Sastry et al., 2015) due to the rainy season crop as humid environment supports these problems. Senna cultivation is also possible in the sub-tropical plains of north India as a summer season crop during March to June (Dry period). This practice is useful for producing quality material with higher productivity per unit area and per unit time and for avoiding the fungal attack, which is more prevailed during the rainy season. However, very little information is available on optimum pre and post-harvest practices on this crop for these potential growing regions. Sowing time imposes a great role to obtain maximum yield. Therefore, it is important to find out the suitable date at which the sowing of senna

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seed is best for better yield, as well as the quality of this high-value medicinal crop. The performance of any crop is dependent on several environmental factors like temperature, humidity, rainfall, sunshine, and topographic condition of the cultivation area. Optimum sowing time is a must for gaining good seed germination as well as obtaining superior, and high-quality plant produce in the term of yield as well as secondary metabolites (alkaloids and glycosides). Too early and too late planting, both constitute poor germination and stunted crop growth. The optimization of irrigation is important to produce optimum fresh herb and seed yield because water is a major component of the fresh produce and affect both the quantity and quality of the crop. In the case of medicinal plants, water deficit may cause changes in the biomass yield and composition of their essential oils and secondary metabolites. The effects of different water regimes on yield, secondary metabolites, morphological and physiological characteristics of different medicinal plants have been reported so far. Moisture level in the soil for the cultivation of medicinal crops also has a very critical role in their quality parameter because moisture stress possesses a great influence on yield as well as sennoside content in senna as reported by Ahmed et al. (2014). Moisture stress found to increase sennoside content (Gupta, 1988). Besides the date of sowing and moisture level, harvesting time of a medicinal crop is also a very crucial parameter for quality standards. The leaf picking at different crop stages influences the sennoside content in senna leaves (Upadhyay et al., 2011). According to Tripathi, 1999, senna is a hardy crop and can be grown even in saline and rainfed condition. The proper time of sowing for senna to harvest the crop before the onset of monsoon as well as to get maximum yield with better quality along with proper utilization of irrigation water and date, at which it should be harvested, is not optimized yet for the subtropical plains of North India. Keeping in view above problems and prospects, experiments were conducted to optimize date of sowing, moisture regime and harvesting date for senna with the Objectives i) to improve the yield of leaves and pods, ii) to obtain high sennoside yield and iii) to find cost-effective agro-practice for senna cultivation under sub-tropical climatic condition.

2. Material and methods

2.1. Experimental site

The experiments were conducted for two consecutive years 2016 and 2017 at the experimental farm of the CSIR-Central Institute of Medicinal and Aromatic Plants, Lucknow, located at 26°5´ N latitude 80°5´ E longitude with an elevation of about 120 m above mean sea level under the sub-tropical plains of north- India. The soil of the experimental plot was sandy loam in texture having moderate fertility with 7.7 pH. Weather (temperature, relative humidity, and rainfall) prevailed during the experimental period of both the years has been presented in Fig. 1

2.2. Treatments and experimental design

Two field experiments were conducted consisting of different variables as described below.

2.2.1. Collection of seeds

Seeds used in experiments were collected from the experimental farm of CSIR-CIMAP, Lucknow. Seeds were belonging to variety "Sona" developed by CSIR-CIMAP, especially for northern Indian plains.

2.2.2. Experiment no. 1. Study on optimizing the date of sowing

The experiment comprises seven dates of sowing starting from 1st March, 8th March, 15th March, 22nd March, 29th March, 5th April and 12th April, were evaluated under randomized block design with three replications, in an individual plot size of 11.4 $m^{2.}$ Soil moisture level was about 60% (Available Soil Moisture) at the time of sowing. Before sowing, N, P and K applied (as recommended) through Urea, SSP and MOP respectively, was thoroughly mixed within the soil at the time of ploughing, and then plots were leveled. After that, seed sowing was done and, the line to line spacing was maintained at 45 cm apart. After 25 days of sowing, thinning was done to manage the plant to plant distance of 15 cm distant. All intercultural operations were carried out as per need. Harvesting was done at 90 days after sowing.

2.2.3. Experiment no. 2. Study on optimizing the moisture regimes and harvesting date

For optimization of moisture regimes, four levels of moisture, i.e., rainfed (no irrigation), 20% ASM, 40% ASM, and 60% ASM were imposed, and harvesting was done at four dates, i.e., 60, 75, 90, and 105 days after sowing. These treatments were evaluated in a split-plot design with four replications with a plot size of 11.4^{-2}. Sowing was done in the second week of March and line to line spacing was maintained at 45 cm apart and plant to plant distance was 15 cm (maintained by thinning after 25 days of sowing) and first irrigation was provided, after that, irrigations were applied as per treatments and 15 days before harvesting, withdrawal of irrigation was made.

In experiment 1, the main objective was to optimize the date of sowing with respect of already practiced date of harvest, whereas in the experiment 2, different moisture regimes were taken as main treatments aiming at optimization of moisture regimes with respect of period of maturity, as the quality influenced significantly by different moisture regimes in a number of medicinal crops. Hence, harvesting of crop at different period of growth and development was essential to optimize date of harvest for getting highest yield with superior quality of the produce.

2.3. Plant sampling and biometric observations

For recording observation on plant height, the number of branches, leaf area index, five plants were selected randomly (excluding border plants to avoid border effect) from each plot at the time of harvest. These plants were harvested from10 cm above the ground and data on the fresh weight of the plant, stem weight, leaf weight, pod weight, and flower weight (if present) were recorded per plant basis. After that, these plant parts were kept under the shade for drying and after 8–10 days (constant weight), dry weight was recorded. After drying, pod: leaf ratio and pod + leaf: stem ratio was also calculated.

2.4. Harvesting

In the first experiment, harvesting was done after 90 days of sowing with the respective date of sowing. In the second experiment, harvesting done at different dates as per the treatments (After 60 days, after 75 days, after 90 days and after 105 days of sowing). For the estimation of herbage yield, harvesting was done as per treatments, and the total weight of each plot was calculated, and weight of sampled plants was also added to herbage yield to the respective treatments. Then, the herb was left for drying in the shade for 8/10 days (to constant weight), dry weight of leaves, stem, and pod was recorded.

2.5. Sennoside determination

Chemical analysis was done through the HPLC method as described by Rama Reddy et al. (2015) with slight modification. Powdered samples of dry leaves and pods (300 mg) were extracted in 30 mL of 70% methanol in water by sonication (25 °C) for 20 min for three times. The samples were filtered through the 0.45 μm membrane before injection into the chromatography system. HPLC analysis was performed on a Waters HPLC system equipped with an SPD-M20 A photodiode array detector. For all separation symmetry, 98 C18 column (4.6 mm × 250 mm, 5.0 μm particle size) was used. The mobile phase consisted of (A) methanol:water:acetic acid (20:80:0.1, v/v/v) and (B)

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