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Planting and harvest dates, and irrigation on fenugreek in the semi-arid high plains of the USA

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ABSTRACT

Fenugreek can be grown for medicinal purposes, as a spice or as an annual hay. Most fenugreek production is in India; none is grown in the USA. Practices suitable for growing fenugreek in the U.S. High Plains is unknown. The objectives were to identify the irrigation need, and planting and harvest dates in western Nebraska. Fenugreek was planted from early May to early June and harvested from late Aug to early Oct. Irrigation consisted of none, 15 and 30 cm. Height, flowering and fruiting, and seed and straw yields were measured. Later planting did not affect final height but delayed flowering and fruiting (late June to early Aug). Years differed due to weather variations. Seed and straw yields were greatest with later planting and with earlier harvest in 2013 and 2014. Irrigation affected yields primarily in 2013. The lowest yields were in 2015 when the agronomic parameters had the least effect probably due to the very wet spring conditions. For 2013 and 2014, maximum seed yields ranged from 1724 to 1886 kg ha^{-1}, and maximum straw yields ranged from 4352 to 4981 kg ha^{-1} when planted late, irrigated and harvested in late Aug or early Sep. Recommendations are that when May is very dry, plant near 1 June, irrigate and harvest in late Aug or early Sep, when May is slightly wet, plant in late May, do not irrigate and harvest early Sep, and when May is very wet, do not plant for seed and do not irrigate.

1. Introduction

Fenugreek (*Trigonella foenum-graecum* L.), an annual legume, has been known for millennia for its medicinal properties (Al-Habori and Raman, 2002; Zandi et al., 2015), e.g., treating Type 2 diabetes (Eidi et al., 2007). Currently, 75% of the world supply is produced in India, primarily in Rajasthan, and there is no production in the USA. Fenugreek would do well in light soil (sandy, sandy loam) and alkaline soil (pH 8–8.5) (Acharya et al., 2008; Petropoulos, 2002). Both these conditions characterize western Nebraska soils as well as that of Rajasthan. Furthermore, fenugreek requires less N than many crops (30–50 kg ha^{-1}) and does well under low rainfall (30–40 cm). It is considered drought resistant (Duke, 1986), and its relatively low precipitation requirement suggests suitability for the semi-arid conditions of the Great Plains as in Alberta, Canada (Acharya et al., 2008), Kansas (Obour et al., 2015), and western Nebraska. Fenugreek is a new crop for the western Hemisphere (Acharya et al., 2006) and two North American fenugreek cultivar developed were AC Amber and Tristar, targeted as annual forages for Alberta and Manitoba (Acharya et al., 2007; Thomas et al., 2011). The Canadian cultivars are shorter season, 120 day, as opposed to those used in India and therefore better suited for the shorter growing season of northern US and Canada. Fenugreek grows well where alfalfa (*Medicago sativa* L.) is grown (Petropoulos, 2002). It has a high dry matter yield (straw yield) suitable for silage with a nutritive value for cattle similar to that of alfalfa (Mir et al., 1998). Fenugreek would not be difficult to incorporate in a crop rotation with winter crops (Acharya et al., 2008). Under dryland conditions in Alberta, Tristar and AC Amber yields were not significantly different, but under irrigation at Lethbridge, Alberta, Tristar seed and straw yields were higher than AC Amber (Acharya et al., 2007). However, the suitability of either cultivar is unknown for seed and straw production in the High Plains of the USA, an area within the Great Plains of North America.

The objectives of this study were to identify planting dates, harvest dates and irrigation level for growing fenugreek in western Nebraska for highest seed and straw yields of the two Canadian cultivars. The interactions between planting, harvest and irrigation were determined. Besides yields, the effect of these parameters on plant height, flowering and fruiting dates, and seed size were measured.

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2. Materials and methods

2.1. Field conditions

In 2013, 2014 and 2015, fenugreek (*Trigonella foenum-graecum* L.) cultivars AC Amber and Tristar (Acharya et al., 2007) were conducted at the University of Nebraska's Panhandle Research and Extension Center, Scottsbluff, NE (lat. 41.9 N, long. 103.7 W, elevation 1126 m). A Tripp fine sandy loam soil at pH 8.0, considered in optimal range (Petropoulos, 2002). The organic matter content of the soil was 1%. Pre-plant soil N levels in the top 40 cm were 62, 45 and 19 kg ha^{-1} for each year respectively (Table 1). No fertilizer was added. Seeds were inoculated with a mixture of *Rhizobium leguminosarum biovar trifolii* and *Sinorhizobium metilioti* (N-Dure at 170 g/22.7 kg seed) just prior to planting (Petropoulos, 2002). Previous crops were sunflower (*Helianthus annus* L.), winter wheat (*Triticum aestivum* L.), and corn (*Zea mays* L.) for 2013, 2014 and 2015 respectively.

Soil water content in the top 40 cm prior to the start of irrigation was 16.6, 14.6 and 18.0% for each year respectively (Table 1) corresponding to 75, 66 and 82% of soil saturation. Rainfall and temperature were monitored by the High Plains Regional Climate Center (Changnon et al., 1990) and presented for each year by month with comparison to the 30-year mean in Table 1. Each year represented very different weather conditions. In May of 2013, rainfall was in extreme deficit with only 43 mm (Table 1). The year 2013 was considered a drought year with less than 50% average rainfall for the growing season, June, July and August. Temperature was above normal in May and during the growing season (Table 1). In 2014, May had slightly above normal rain but was dry during the summer and temperature was below normal for May and the summer (Table 1). May of 2015 experienced 173 mm of rain, more than double the normal amount (Table 1). Although June and August were dry, July rain was also much above normal, and as a result, the rainfall from June to August was near normal. The overall temperature for 2015 was near normal (Table 1). In 2015, the trial was exposed to a severe hail storm on July 27 that caused 30–40% defoliation.

Weed control was accomplished by application of trifluralin [1.4 l Trust (43% AI)/ha] one day after planting (pre-emergence) followed by a post-emergence application, 2–3 weeks after planting or 1–2 weeks after emergence, of imazamox [292 ml Raptor (12.1% AI)/ha] (Moyer et al., 2003). Fenugreek is insect tolerant (Acharya et al., 2008) and no insecticide was applied or needed. Nor was any fungicide applied or needed.

Plots consisted of four rows of which the center two rows were harvested. Rows were spaced 30 cm apart. Seeding rate was 22 kg ha^{-1} which in separate trials was determined to be within the optimal range (unpublished data). Planting was performed using a grass drill. In 2013, to promote germination, 6 mm of irrigation was applied a few days after each planting (Duke, (1986)). Plots were 15.25 m long of which 4.6 m was harvested at each harvest date. Harvesting was performed by manually undercutting the plants with a shovel after which they were bagged. Bags were stored in a hoop tunnel until dry. Plants were then weighed to determine straw yield and mechanically threshed using a combine, mimicking windrow harvesting. The seed was cleaned and weighed to determine seed yield.

2.2. Experimental conditions

This study contained three variables, planting date, harvest date and irrigation level. Planting dates were 7 May, 17 May and 28 May in 2013, 6 May, 20 May and 2 Jun in 2014, and, due to high rainfall, 15 May, 1 June and 8 June in 2015. Harvest dates were 20 Aug, 10 Sep and 2 Oct in 2013, 19 Aug, 10 Sep and 2 Oct in 2014, and 26 Aug, 9 Sep, and 25 Sep in 2015. Three irrigation levels were tested, no irrigation (rain-fed), half-irrigated (deficit irrigation) when 152 mm of water was irrigated, and fully-irrigated when 304 mm of water was added (Bhati, 1993). The target was to separate the irrigation levels by 152 mm of irrigation water during the growing season, June, July and August. Actual exposure, rain plus irrigation water are presented in Table 1. May rainfall is reported in Table 1 as well as it may have impacted the results. In 2013, May was very dry; in 2014, it was slightly above normal, and in 2015, May was very wet. Irrigation regimes commenced on 3 June 2013 due to the dry May conditions, and due to wetter conditions, on 3 July 2014 and on 2 July 2015. The aim was to separate the three irrigation levels by 152 mm of irrigation for the growing seasons.

2.3. Data collection

Plant height, flowering and fruiting data were taken weekly in June, July and August. Plant height was measured with a meter stick at two places in each of the two center rows in each plot. The percent flowering was visually estimated based on the number of open flowers versus total buds, open and closed, on plants. The percent fruiting was visually estimated based on the number of pods versus total flowers plus pods. Peak flowering or bloom, and peak fruiting or podding, were the dates at which the percent flowering and fruiting were the highest. Seed and straw yields were measured at each of the three harvest dates. Tristar seed harvested in Aug and Sep were measured for their weight and volume. Seed weight was determined by counting out 100 seeds and weighed. To determine seed volume, seed were poured into a 10-ml graduated cylinder to the 10 ml mark and weighed. Seed number in 1 cc was calculated by the weight of seed in 1 cc by the weight of a seed.

The two cultivars, AC Amber and Tristar, were planted side-by-side in a paired plot design within each planting date section. Within each replicate, planting date sections were placed in a 3 by 3 Latin Square. Irrigation level were the main plots and consisted of three replications placed in a 3 by 3 Latin Square. Data, comparing years, cultivars, planting dates, harvest dates, and irrigation levels, were analyzed using Proc ANOVA in SAS with means separated using least significant differences and inferences based on a 5% significance level (SAS Institute 2003) when $p < 0.05$. Possible interactions were determined as well. Years were significantly different with respect to plant height, flowering and fruiting peaks, and seed and straw yields.

3. Results

3.1. Growth and development

The final plant height for none and half irrigated plants in 2013 was significantly less than that in 2014 and 2015 (Table 2). This may be due to the drought in 2013 especially in May prior to irrigation (Table 1). Fully irrigated plants achieved the similar height regardless of year. There was no significant difference between the two cultivars nor between planting dates in any of the three years (Table 2). Irrigation level only affected height in 2013 when none irrigated plants were significantly shorter than fully irrigated plants (Table 2).

Peak flowering and fruiting dates were the same for both cultivars, AC Amber and Tristar. In 2013, comparing similar planting dates, flowering and fruiting peaked earlier than in 2014 and 2015 (Table 3). This may be attributable to the drought stress in 2013 (Table 1). Fruiting tended to peak one to two weeks after the flowering peak in all cases regardless of planting date or irrigation level (Table 3). Flowering and fruiting peaks were delayed with later planting dates. In 2013, irrigation did not affect peak flowering and