

**An assessment of potential feedstock crops for Bio-  
diesel production in the United Arab Emirates**

**THESIS**

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by

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## SYNOPSIS

Global warming has become more and more obvious over the past few years, pushing nations across the globe, including the UAE, to adopt green energy sources to supplement or replace their fuel needs. In this thesis three candidate bio-diesel feedstock crops, *Ricinus communis*, *Citrullus colocynthis* and *Brassica juncea* were compared in terms of their salinity tolerance, oil yield and oil quality when cultivated in the arid and saline conditions of the UAE. Eleven accessions of *Ricinus communis*, thirty-seven accessions of *Citrullus colocynthis* and five accessions of *Brassica juncea* were studied in field trials conducted at the International Center for Biosaline Agriculture (ICBA) research station in Dubai over a single season each. Three salinity treatments, at 5, 10 and 15 dS m<sup>-1</sup> were applied for *Ricinus communis*. *Citrullus colocynthis* was studied in a similar manner at the same three salinity levels but proved sensitive and were later assessed in a greenhouse trial at lower salinities (2 and 4 dS m<sup>-1</sup>). Diversity of collected accessions was studied in separate field trial over a period of one year. *Brassica juncea* field trial had a 15 dS m<sup>-1</sup> treatment and a treated waste water (TWW) treatment in addition to control. Response to salinity was observed by analyzing K<sup>+</sup>/Na<sup>+</sup> ratios in leaf tissue using ICP-OES. Seed and oil yield was recorded and solvent (n-hexane) extracted oil was analyzed for free fatty acid content, saponification value and kinematic viscosity in order to determine suitability of oil for bio-diesel production. The data obtained was statistically analyzed using methods such as ANOVA, Pearson correlation matrices, Principal Components Analysis and Hierarchical Clustering. Among the crops studied, no significantly salt tolerant accession was found. Extrapolated seed yield of *Ricinus communis* was between 1.5 and 3 tonnes/ha in the control treatment, and between 1.8 and 2.3 tonnes/ha in the 5 dS m<sup>-1</sup> treatment, which was not different to a statistically significant degree. The lack of significant effect on inflorescence characteristics and seed yield at 5 dS m<sup>-1</sup> in spite of sodium ion accumulation was an interesting observation. Seed yield and plant growth were both severely effected in the higher salinity treatments. *Ricinus communis* was found to be a suitable feedstock oilseed crop for the region when irrigated with water at low levels of salinity on the basis of oil yield (up to 1 tonne/ha), and established agricultural practices. The viscosity of the oil from this crop was however very high, and this is a drawback for its' use as bio-diesel feedstock without blending. *Citrullus colocynthis* accessions studied for salinity tolerance were extremely sensitive to

salinity. The crop had very high seed yields per plant (up to 374 gms) under irrigated conditions, but has to undergo selection and improvement before commercial-scale cultivation is feasible. Quality of oil from most of the studied accessions of *Citrullus colocynthis* was found suitable for bio-diesel production, and the plant extracts have medicinal properties that can make its cultivation economically feasible. Dormancy in *Citrullus colocynthis* seeds was also studied and a relatively effective pre-treatment was identified. The *Brassica juncea* accessions studied were not tolerant to salinity at 15 dS m<sup>-1</sup>, and were lower yielding (0.19 to 0.62 tonnes/ha, extrapolated), but yield increased by almost two-fold in the Treated Waste Water (TWW) treatment (0.57 to 1.1 tonnes/ha). *Brassica juncea* seed oil from all five accessions was found suitable for bio-diesel production. The results of this study sets a platform for exploring the potential of bio-diesel feedstock in the region.

The contents of this doctoral thesis is organized into twelve chapters as follows:

Chapter 1: Introduction- The research gaps identified and addressed in this thesis and the extensive survey of literature performed through the duration of the thesis is comprehensively described in this section.

Chapter 2: Germplasm collection- The first phase of the research involved obtaining germplasm of studied crops from different sources. The details of the accessions used and their sources and reasons for their selection are elaborated in this section.

Chapter 3: Establishment of field trials- The majority of the results of this research is based on field trials. This section details the randomized complete block design used for each trial, number of replicates, and the treatments applied. It also described field treatments, conditions, spacing and other details of the established trials.

Chapter 4: Germination studies- Germination efficiency is an important parameter in commercial cultivation due to possible seed loss that can be caused by dormancy. Conditions required for the germination of studied crops was thus studied as part of this work. Different pre-treatments were tested to break dormancy in *Citrullus colocynthis* dormancy such as manual scarification, stratification and potassium nitrite treatment and a suitable pre-treatment was identified. Crops respond to salinity in different ways during different stages of growth, due to this reason the response of all three studied species to salinity during germination was also studied.

Chapter 5: Morpho-agronomic evaluation of *Ricinus communis*- In this section the morphological characteristics recorded during field trials and important agronomic parameters studied are listed, methods of measurements are elaborated and the results presented and discussed. The response in all characteristics to different levels of salinity is presented, and the statistically significant differences among the eleven accessions studies and between treatments (Control, 5, 10 and 15 dS m<sup>-1</sup>) are identified using ANOVA. Response of the crop to salinity is described in terms of morphological response and variations in yield. Extrapolated yield data from the studied accessions is also presented and discussed. Yield in the control treatment was on par with global averages and tolerance to low level of salinity (5 dS m<sup>-1</sup>) was identified.

Chapter 6: Morpho-agronomic evaluation of *Citrullus colocynthis*- The morphological descriptors and agronomic characteristics that were studied in the germplasm diversity trial of *Citrullus colocynthis* are listed in this section. The statistically significant differences between accessions were identified by ANOVA and the data is presented. Significant variation was observed for most characteristics between accessions, implying diversity in the population studied. Yield and other agronomic parameters under irrigated conditions for this crop is also presented and discussed for all studied accessions. High yielding accessions with favourable growth characteristics were identified.

Chapter 7: Morpho-agronomic evaluation of *Brassica juncea*- The observed and recorded morphological and agronomic data for the five accessions studied in control, treated waste water (TWW) and 15 dS m<sup>-1</sup> treatments is presented in this section. The data was analysed using ANOVA and significant differences between control and salinity treatment and control and TWW treatment is presented and discussed. A significant increase in yield and growth in response to TWW treatment and decrease in response to salinity was observed. Yields in the control treatment was low compared to previously reported data.

Chapter 8: Water and Soil Analysis- Irrigation water electrical conductivity and pH was monitored regularly in order to control salinity at required level. The concentration of important solutes in waters water with respect to salinity stress such as sodium, potassium, calcium, magnesium and chlorides was determined using techniques such as flame photometry and titration methods. Soil electrical conductivity and pH was

analysed at the beginning and end of each trial in order to determine effects of salt accumulation in the field trials.

Chapter 9: Ion stress- The concentration of sodium and potassium ions in leaf tissue of plants sampled across treatments was analysed using ICP-OES in order to determine the contribution of ion stress to the plants' response to salinity and  $K^+/Na^+$  ratios were calculated. All analysis was performed in triplicate. All studied accessions of the three crops were observed to accumulate sodium in leaf tissue, leading to ion stress and decreased growth.

Chapter 10: Oil analysis- Oil extracted from all accessions and treatments by solvent extraction was analysed for acid value, free fatty acid content and saponification value using standard ASTM and EN methods. Physical characteristics of oil such as kinematic and dynamic viscosity, density and specific gravity were also determined in order to assess suitability of oil for use as bio-diesel feedstock and suitable accessions of each crop were identified on this basis.

Chapter 11: Statistical analysis- Since field trials, data collection and analysis was performed in replicates for multiple accessions over multiple treatments a large volume of data was generated as a result of the study. In order to interpret the data in a useful manner, statistical analysis (principle components analysis, correlation matrices and hierarchical clustering) was performed using tools such as Genstat and XLStat and the results are presented and discussed in this section.

Chapter 12: Conclusion- the conclusions of the assessment and comparison of all accessions of the three crops studied is presented in this section. The specific contributions of this doctoral thesis and future prospects for this research are discussed.