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Influence of Climatic Factors and Soil Types on Seed Weight and Oil Content of Jatropha Curcas in Guangxi, China

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Abstract

The seed weight and oil content of accessions of Jatropha curcas collected from 21 locations in different climatic zones of Guangxi province, China and their correlation with climatic factors and soil types were analyzed. There were significant differences ($P<0.05$) in 100-seed weight and oil content between locations. Maximum 100-seed weight was 71.0 in seeds collected from S21 and the minimum weight was 59.0g in S10. Oil variability ranged from 34.10% in S12 to 55.50% in S21. The seed weight and oil content of J. curcas in acid soil types were significantly higher than those in calcium soil types. Seed weight and oil content were positively correlated with the mean annual sunshine duration (Sa), the mean annual temperature (Tmean), mean minimum daily temperature of the coldest month (Tmin), mean maximum daily temperature of the warmest month (Tmax) and the mean annual evaporation (Ea) ($p<0.01$), while were negatively correlated with altitude and the mean annual precipitation (Pa) ($p<0.01$). The ecological requirements of J. curcas are more fertile soil and more humid and have a higher Tmin than its commonly believed ecological requirements, and therefore point towards cautious selection of plantation sites, especially in karst and subtropical regions.

key words: Jatropha curcas; Oil content; Seed weight; Climatic factor; Soil type; Correlation analysis; Guangxi

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1. Introduction

Bio-diesel is a fast-developing alternative fuel in many developed and developing countries of the world (Divakara et al., 2010). It is estimated that global bio-diesel production is set to reach some 24 billion litres by 2017 (OECD-FAO, 2008). *Jatropha curcas L.* is a typical bio-diesel plant (Foidl et al., 1996; Kumar and Sharma, 2008), which produces seeds rich in oil and easily convertible into bio-diesel meeting international standards (Azam et al., 2005). It is estimated that 40% of the total consumption of energy would come from biomass energy in the world in 2015 (Zhou and Meng, 2007; Amigun et al., 2008). Currently, *J. curcas* is becoming an important multipurpose species (such as oleaginous crop, drug plant, ecological conservation tree and so on) and is cultivating at a large spatial scale in tropical and subtropical areas (e.g. India, China) for biofuel production, agroforestry and other afforestation programmes (Kaushik et al.,2007; Carvalho et al., 2008;Wen et al.,2010).

With the large scale development of *J. curcas*, the risk of unsustainable practices is becoming more and more serious. For example, *J. curcas* plantations were entirely froze to death from extreme cold in early 2008 in Guangxi province, which is cultivated in northeastern of Guangxi, with frost risk (Wen et al.,2010). In addition, the plantation of *J. curcas* is not only the seed yield and oil content low but even non-flowers and non-fruits (i.e. Hainan and Guizhou provinces of China). It is important to understand the relationship between the growth, seed yield, oil content of *J. curcas* with environmental conditions for a large scale cultivation and utilization in *J. curcas*, otherwise the large scale development might hold the risk of unsustainable practices (Achten et al., 2008; Maes et al., 2009).

The relationship between the seed yield and oil content of *J. curcas* with climate and soil conditions is of great potential in improving growth and promoting seed yield and oil content, unfortunately no much work has been done in this research. However, several studies have reported the distribution, climate growing conditions, ecological requirement, seed traits and oil content etc. (Heller,1996; Openshaw,2000;Katwal and Soni,2003;Ginwal et al.,2005;Kaushik et al.,2007;Maes et al.,2009; Wen et al.,2010). The objective of the present study was to study the variation in seed weight and oil content of accessions in 21 locations collected from Guangxi province of China and their relationship with climate and soil types.

2. Material and methods

An extensive survey was conducted to select the candidates plus trees (CPTs) of *J. curcas* from different locations of the southwest in Guangxi province of China. The selection was made on major distribution regions i.e., the southwest of Guangxi and phenotypic characters of economic interest i.e., number of capsules per cluster, crown spread, height, girth, yield potential, ages etc. A total of 21 locations (sites) were selected from latitude ranging 22°07′–24°14′ N and longitude 105°03′–107°24′ E and altitude 172m-903m. In each site, the morphological observations of the selected 10 trees were recorded, including the total height of the standing trees, basal girth, crown spread, age and yield. Soil type was also recorded.

From each site CPT_{1-10} mature capsules were collected during December 2006. One kilogram seed was collected from each site CPT_{1-10} to provide potentially useful seed weight variation. Seeds from capsules were extracted through manual threshing. The seeds were further cleaned through winnowing. The seeds were separated from the fruit which is moist, cleaned and stored in muslin bags at ambient conditions. All seed lots were dried under similar temperature and humidity conditions to reach a constant weight. For seed weight five samples of seeds including 100 seeds each, were taken from each seed lot and measured for weight and expressed in grams. The oil content of seeds was estimated by GB/T5512-85 method using three replicates for each seed lot (Administration of the People's Republic of China,1985).

Of the 6 bioclimatic variables available from Guangxi Climate Material (1970-2000), the mean annual sunshine duration (*Sa* [h]), the mean annual precipitation (*Pa* [mm]), the mean annual evaporation (*Ea* [mm]), the mean annual temperature (*Tmean*), mean minimum daily temperature of the coldest month (*Tmin*) and mean maximum daily temperature of the warmest month (*Tmax* – all in ℃) were selected (Guangxi Climate Bureau,2001) and calculated for each location.

3. Results

3.1 Seed weight and oil content

The 21 sites showed significant variability for 100 seed weight and oil content (Table 1). For 100 seed weight (71.0 g) the top ranking accession was S21 closely followed by S03 and S04. The top ranking accessions differed significantly with all the remaining accessions (df=20, $p<0.000$). Minimum 100 seed weight (56.9 g) was recorded in S10. Oil content variability was also recorded among the different accessions. It varied from 34.10% in S12 to 55.50% in S21 (Table 1) and the top accession occurred significant different with all the remaining accessions (df=20, $p<0.000$).

3.2 Seed weight and oil content with soil types studies Maintaining the Integrity of the Specifications

There were significant differences in 100-seed weight and oil content between the two soil types (p=0.013 for seed weight; p=0.001 for oil content) (Fig. 1). The seed weight and oil content of *J. curcas* in acid soil types were significantly higher than those in calcium soil types.

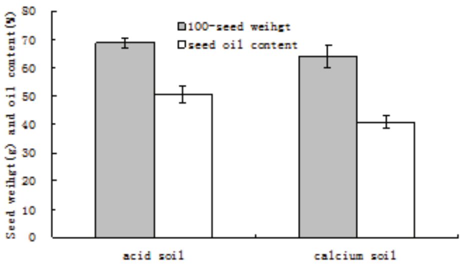

Fig. 1 The seed weight and oil content of J. curcas in different soil types (n=6; only including sites of below 300m of the above sea level)

3.3 Seed weight and oil content with climate factors studies

Altitude and climate factors had a significant ($p<0.05$) effect on seed weight and oil content of *J. curcas*. In general, seed weight and oil content were positively correlated with S_a, T_{mean}, T_{min}, T_{max} and E_a, while were negatively correlated with altitude and P_a (Table 2).

4. Discussion

Seed weight and oil content is the most important economic traits of Jatropha, the potential biodiesel crop. Kaushik et al.,(2007) studied the variation in seed trait and oil content in 24 accessions collected from different agroclimatic zones of Haryana state in India, there was a significant difference in seed weight and oil content between accessions, ranging from 49.20 to 69.20g for 100-seed weight and from 28.0 to 38.8% for oil content. In the present study, we observed large variation of seed weight and oil content for Jatropha accessions from 21 locations in the southwest Guangxi of China, the 100-seed weight range from 56.9 to 71.0g with a CV (Coefficient of variation) of 7.76% and the oil content range from 34.1 to 55.5% with a CV of 14.53%. Therefore, Guangxi Jatropha accessions possess the larger variation and the value of oil content, and are the key germplasm for Jatropha breeding programs in China.

Climate factors (e.g., temperature, precipitation, sunshine etc.) had a significant effect on growth, distribution, productivity, seed yield and oil content of plants. Maes et al., (2009) reported the climatic conditions in area of jatropha natural distribution of herbarium specimens and in 83 jatropha plantations worldwide, it is indicated that 95% of the specimens grew in areas with P_a above 944 mm year^{-1} and T_{min} above 10.5 ℃ and T_{mean} range was 19.3–27.2℃. They also described that the climatic conditions at the plantations were different from those of the natural distribution specimens for all studied climatic variables (except T_{max}), and roughly 40% of the plantations were situated in regions with a drier climate, and 28% of the plantations were situated in areas with T_{min} below 10.5℃. In this study, the climate conditions at the accessions were inside the above range for all climate variables i.e., T_{mean} range was 18.7–22.3℃, T_{max} 24.3-28.6℃, T_{min} 9.9-15.5℃, P_a and E_a above 1000 mm year^{-1}. The observed rainfall preferences indicate that jatropha is not common in regions with arid and semi-arid climates. In Guangxi, jatropha were mainly grew in regions with semi-arid and semi-moist climate regions (Wen et al.,2010). Jatropha is frost sensitive and sheds its leaves immediately after frost (Sahoo et al.,2009). The average extreme low temperature of 21 locations in Guangxi province was below -1.0℃, Jatropha plantations usually hold the risk of damage due to frost.

Jatropha can grow in both the acid soil and calcium soil types. Jatropha plantations in calcium soil areas hold the risk of aridity (seasonality), low seed weight and oil content or irrigation requirement.

In conclusion, the ecological requirements of *J. curcas* are more fertile soil and humid, and have a higher T_{min} than its commonly believed ecological requirements, and therefore point towards cautious selection of plantation sites, especially in karst and subtropical regions.

5. Acknowledgment

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Table 1 The geographic location and coordinates of collection sites of environmental factors and seed weight and oil content in Jatropha curcas

Sites	latitude	longitude	Altitude (m)	*Sa* (*h* year^{-1})	*Tmean* (℃)	*Tmin* (℃)	*Tmax* (℃)	*Pa* (*mm* year^{-1})	*Ea* (*mm* year^{-1})	Soil type	100-seed weight (g)	Oil content (%)
S01	23°28′	107°24′	300	1652.2	21.5	13.2	28.1	1368.3	1574.5	calcium	65.3	43.5
S02	23°33′	107°17′	172	1936.9	22.0	10.2	28.5	1142.0	1933.9	acid	67.3	50.5
S03	23°54′	106°37′	173	1948.5	22.2	15.5	28.2	1107.8	1697.2	acid	70.5	55.3
S04	24°14′	106°18′	213	1828.5	20.9	11.9	27.1	1158.2	1679.0	acid	70.1	45.2
S05	24°07′	106°26′	190	1948.5	22.2	15.5	28.2	1107.8	1697.2	acid	67.3	46.7
S06	23°41′	106°45′	376	1933.4	22.1	12.6	28.6	1064.7	1955.8	calcium	67.4	42.7
S07	23°37′	106°46′	530	1573.2	19.5	11.1	25.7	1461.9	1275.6	calcium	59.6	38.8
S08	23°24′	106°45′	600	1573.2	19.5	11.1	25.7	1461.9	1275.6	calcium	59.8	43.3
S09	23°15′	105°46′	903	1454.1	18.7	9.9	24.3	1433.7	1159.9	acid	58.8	37.6
S10	23°15′	105°46′	739	1454.1	18.7	9.9	24.3	1433.7	1159.9	acid	56.9	35.9
S11	23°13′	105°43′	603	1454.1	18.7	9.9	24.3	1433.7	1159.9	acid	57.3	37.6
S12	23°09′	105°40′	478	1454.1	18.7	9.9	24.3	1433.7	1159.9	acid	58.5	34.1
S13	23°03′	105°03′	340	1454.1	18.7	9.9	24.3	1433.7	1159.9	acid	58.6	36.8
S14	23°13′	106°14′	330	1542.9	19.1	9.9	25.0	1566.3	1467.9	acid	56.9	37.7
S15	22°55′	106°45′	264	1584.7	21.4	12.9	27.6	1355.2	1618.0	calcium	59.9	39.7
S16	22°53′	106°36′	225	1584.7	21.4	12.9	27.6	1355.2	1618.0	calcium	59.6	40.6
S17	22°50′	107°07′	194	1675.1	22.3	13.8	28.1	1146.4	1523.2	calcium	66.8	43.4
S18	22°50′	107°07′	227	1675.1	22.3	13.8	28.1	1146.4	1523.2	calcium	67.0	38.9
S19	22°35′	106°67′	215	1755.7	22.1	14.0	28.2	1349.8	1342.6	acid	66.3	50.5
S20	22°08′	106°56′	289	1547.6	21.3	13.8	28.1	1377.6	1380.4	calcium	65.2	38.2
S21	22°12′	106°66′	221	1842.6	22.0	12.8	28.2	1099.5	1761.8	calcium	71.0	55.5

Table 2 Correlation coefficient between seed weight and oil content with altitude and climate factors (n=21)

Characters	Altitude	S_a	T_{mean}	T_{min}	T_{max}	P_a	E_a
Seed weight	-0.684**	0.873**	0.849**	0.710**	0.836**	-0.890**	0.738**
Oil content	-0.568**	0.835**	0.694**	0.560**	0.681**	-0.676**	0.652**

(**significant at 1% level.)