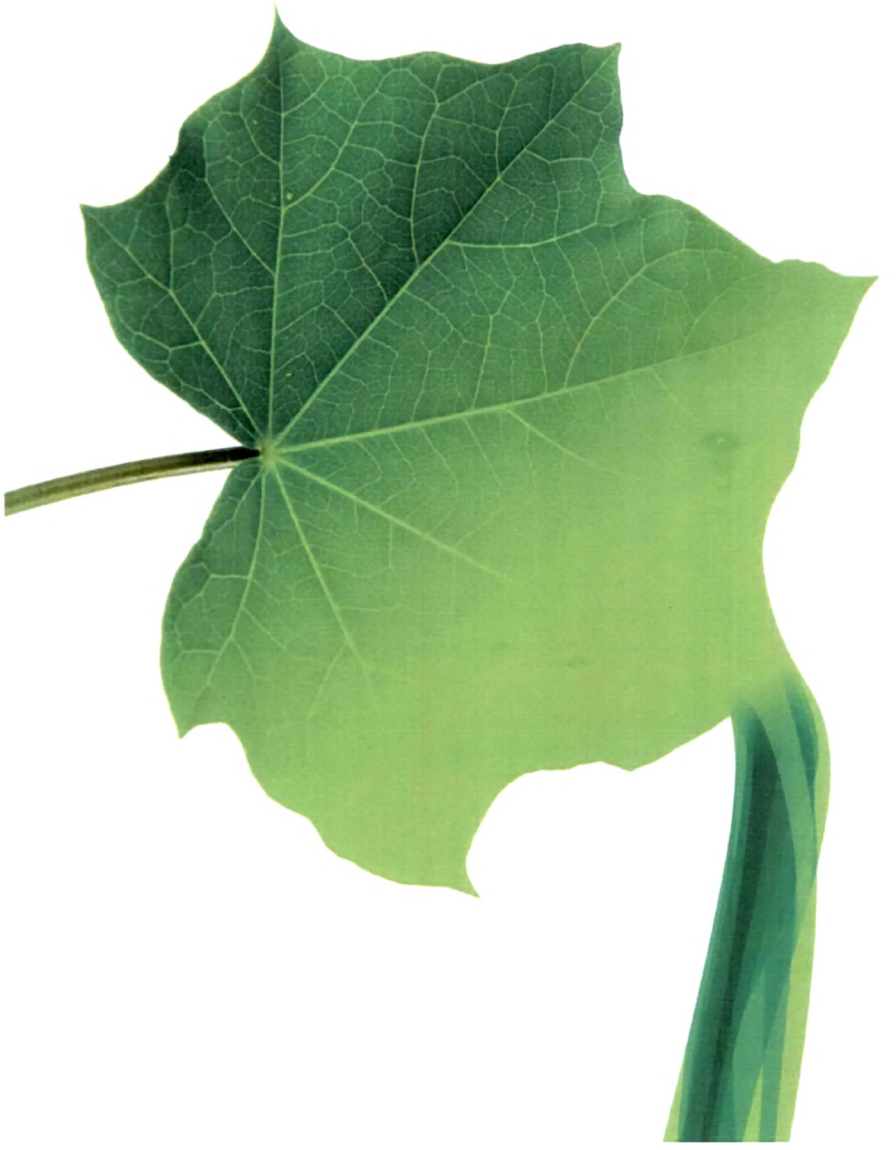
CHAPTER 3



Studies on Flower development, Fruit and Oil yield from Jatropha Plantations of different regions in Gujarat

Studies on Flower development, Fruit and Oil yield from Jatropha Plantations of different regions in Gujarat

3.1. Introduction

Jatropha curcas, a perennial shrub belonging to the Euphorbiaceae family, is a monoecious plant, which produces separate male and female flowers on the same plant. Jatropha is insect pollinated. It flowers during the rainy season with concentrated flowering from late July to late December. The plant produces flowers as racemose inflorescences, with dichasial cyme pattern. *Jatropha curcas* L. is monoecious with protandry. Normally, the inflorescences produce a central female flower surrounded by a group of male flowers, however depending on geographical location, occasionally a male flower could be seen in the center. Numerically, 1-5 female flowers and 25-93 male flowers are produced per inflorescence. The average ratio of male to female flowers is 29:1 (Solomon Raju and Ezradanam, 2002). Each inflorescence, once it begins flowering, flowers daily, and the flowering lasts for 11 days. The flowering pattern shows that the male flower appear and open first and remain open for a period of 8-10 days, whereas female flowers open for 2-4 days only (Prakash et al., 2007). The female floral bud appears between the second and sixth day after the male floral bud. The plant produces unisexual flowers, and on this basis, male/female flower ratio is calculated from the daily anthesis records. Inflorescence development can be studied by distinguishing features, which help to categorize the process into different stages from emergence of floral bud until complete bloom. The fruit development can also be monitored as different stages starting from fruit set to fruit maturation.

Male flowers are small, odourless and salver-shaped. Sepals and petals are five each and free; the latter are connivent at the flower base, which forms a short tube. Stamens are ten, diadelphous, arranged in two tiers of five each. The lower tier is free, while the upper tier is united. The anthers are yellow, dithecous and dorsifixed. Oval-shaped glands, five in number, are present at the villose flower base. The pollen

produced in the lower tier of stamens. The pollen grains are yellow, globular and inaperturate. They are around 89 µm in size in the lower tier of stamens and 81 µm in the upper tier of stamens. The floral base contains nectar in trace amount. The flowers drop off, by the third day.

Female flowers are quite similar to the male flower in shape, but are relatively larger. Sepals and petals are relatively larger. The styles and stigmas are three each, and the latter are bifid. The ovary has three carpels, each producing one ovule. The floral base is villose and contains five yellow elliptical glands under the ovary. The flowers open in synchrony. The stigmas are receptive after the flowers open and remain so for three days. The villous flower base secretes nectar in trace amount, which is almost the same in quantity as in male flowers. The unpollinated flowers fall off on the fourth day, while the pollinated ones remain in place; the sepals and petals gradually enlarge and protect the growing fruit until the latter reaches its full size.

After pollination, the fruit set rate found in selected inflorescences on distantly spaced plants varies from 37 to 61%. Some of the pollinated flowers initially develop fruits but later are aborted, depending on soil water and nutrient availability (Kumari and Kumar, 2007). Individual fruits begin development immediately following fertilization. Fruits grow to full size over a two-month period, with concentrated growth in the third to fifth week. The fruits are green first, later yellow and finally brownish black. The matured fruits dehisce passively and seeds fall off together with the capsule. The seeds are used for oil extraction.

In this chapter eight varieties of *Jatropha curcas*, one each from different locations (Bodal, Degama, Navsari, Himmatnagar, Kawant, Umeta, Vadodara and Padra), were selected for studying Inflorescence development, Fruit development, Seed weight, Seed oil yield and Fatty acid analysis. Plants in these fields were planted at a distance of two meters and observations were made for two-three months from emergence of floral bud until fruit. The land, which was used for *Jatropha curcas* plantations, is not fit for agriculture as per government of Gujarat certificate. The ages of

plants from all regions are around two years. The floral characters for male and female flowers were separately studied. The plants were observed for its flowering phenology, inflorescence development, sexual behaviour, fruit development, seed oil yield and fatty acid analysis. Here the results of observations made on flowering, fruit yield and oil yield from *Jatropha curcas* plantations found in our state of Gujarat are reported.

3.2. Results

3.2.1. Flower development and Flower sex ratio

Jatropha curcas plantation from different regions of Gujarat was selected for the study. We observed eight different plantations from regions such as Vadodara, Padra, Bodal, Degama, Himmatnagar, Navsari, Kawant and Umeta having the same age (two year old). The Flower and Fruit development pattern has been studied. Apart from this flower sex ratio, fruit yield, seed weight and oil yield has been studied.

Inflorescence development was divided into five different stages, which are described below:

Stage I: Initial appearance of floral bud

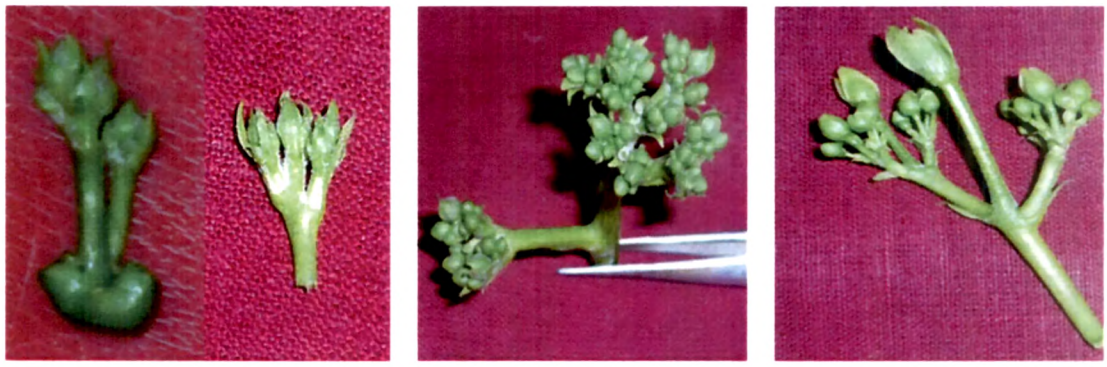
Stage II: Distinct appearance of flower bud

Stage III: Distinct appearance of Male and Female flower bud

Stage IV: Opening of Male flowers

Stage V: Opening of Female flowers

During inflorescence development, Stage I and II are primary in which male and female flower buds were not distinguished. Sex differentiation is not visibly seen in this stage. Male and Female flower bud were distinguished from Stage III. After further development, male and female flowers opened at Stage IV and V respectively, resulting in complete bloom (Figure 3.1).



Stage I Stage II Stage III

Stage IV Stage V

Figure 3.1: Different stages of Inflorescence development

Inflorescence developments from stage I to stage V were observed. Photographs were captured at 5X zoom with digital camera.

Inflorescence is well developed at Stage V were both male and female flowers are open. We calculated the number of both male and female flowers during Stage V from individual plantation. The total flowering, Male and Female flower ratio was also observed for each plantation (Table 3.1). Flower sex ratio varies depending on plantation region, geographical location, soil characteristics etc. Application of fertilizer also influences flowering and fruit yield.

Table 3.1: Total number of flowers and Sex ratio observed in inflorescence of *Jatropha curcas* plantation from different regions

Plantation regions	Total flowers in inflorescences	Total Male flowers	Total Female flowers	Ratio Female: Male
Vadodara	2058 ± 14.23	1978 ± 13.68	80 ± 1.55	1: 26
Padra	2084 ± 17.57	2010 ± 17.23	75 ± 1.34	1: 26
Bodal	2068 ± 16.05	1990 ± 15.48	78 ± 1.52	1: 26
Degama	2117 ± 18.24	2046 ± 17.82	74 ± 1.26	1: 28
Himmatnagar	2142 ± 19.24	2087 ±17.95	75 ± 1.28	1: 28
Navsari	2136 ± 18.48	2042 ± 14.33	79 ± 1.61	1:27
Kawant	2002 ± 12.91	1927 ± 11.36	66 ± 0.96	1:29
Umeta	2139 ± 18.09	2045 ± 11.24	76 ± 1.45	1:27

n= 20 inflorescences

Values are mean ± SEM. Ten plants were used for observation from each plantation. Above values are averages of ten plants from each plantation. In each plant at least, twenty inflorescences were observed.

Table 3.1 shows the total flower number and the sex ratio observed in Jatropha plantations from different regions of Gujarat. Total flowering and flower sex ratio from all plantations studied were the same. Flower sex ratio from Vadodara, Bodal and Padra are similar (1:26) than compared to other region. These regions are closer to each other than the other regions.

The time taken for complete inflorescence development was calculated from Stage I until the stage of complete bloom (Stage V). Initial period of inflorescence development that is Stage I and II were of longer duration than the Stage IV and V where distinct male or female characteristics could be observed (Table 3.2). Inflorescence development was studied for each plantation.

Table 3.2 shows the time taken for Inflorescence development. Initial two stages of inflorescence development were of longer duration. The stages were distinct, sex characteristics are observed which takes nearly fifteen days. Once the male and female floral buds appear, it takes fewer days for complete bloom. Time duration from Stage 1 to Stage V in each plantation is very similar. Time duration for Inflorescence development from Vadodara, Bodal and Padra are similar (37 days) than compared to other region. Other region such as Degama, Kwant and Umeta shows around 39 days for complete inflorescence development.

Table 3.2: Time scale of Inflorescence development of *Jatropha curcas* plantation from different regions

Plantation regions	Duration (in days) for inflorescence development					
	Initial appearance of floral bud (Stage I)	Distinct appearance of flower bud (Stage II)	Distinct Male and Female flower bud (Stage III)	Opening of Male flowers (Stage IV)	Opening of Female flowers (Stage V)	Complete bloom
Vadodara	9.00 ± 0.577	6.333 ± 0.333	4.667 ± 0.315	6.160 ± 0.463	9.467 ± 0.235	36.20 ± 1.068
Padra	7.00 ± 0.607	8.140 ± 0.233	6.907 ± 0.478	6.292 ± 0.583	10.578 ± 1.126	37.29 ± 1.171
Bodal	8.00 ± 0.571	7.33 ± 0.333	5.60 ± 0.467	7.10 ± 0.583	10.90 ± 1.365	37.93 ± 1.282
Degama	11.00 ± 0.675	8.23 ± 0.4333	4.20 ± 0.365	6.47 ± 0.361	9.00 ± 1.447	40.01± 1.198
Himmatnagar	9.50 ± 0.447	6.80 ± 0.365	5.40 ± 0.509	6.10 ± 0.871	9.60 ± 1.02	36.90 ± 1.02
Navsari	9.00 ± 0.688	6.133 ± 0.424	4.567 ± 0.326	6.180 ± 0.574	9.567 ± 0.346	37.80 ± 1.126
Kawant	8.80 ± 0.374	6.800 ± 0.271	4.800 ± 0.651	7.400 ± 0.244	10.600 ± 0.234	39.40 ± 1.77
Umeta	8.20 ± 0.394	9.00 ± 0.447	5.20 ± 0.753	6.60 ± 0.164	9.20 ± 0.264	38.10 ± 2.02

n= 50 floral buds

Values are mean ± SEM; ten plants were used for observation from each plantation. In each plant atleast, five floral buds were used for observation from emergence until to complete bloom. Results showed in table are mean of fifty floral buds.

3.2.2. Fruit development and Fruit yield

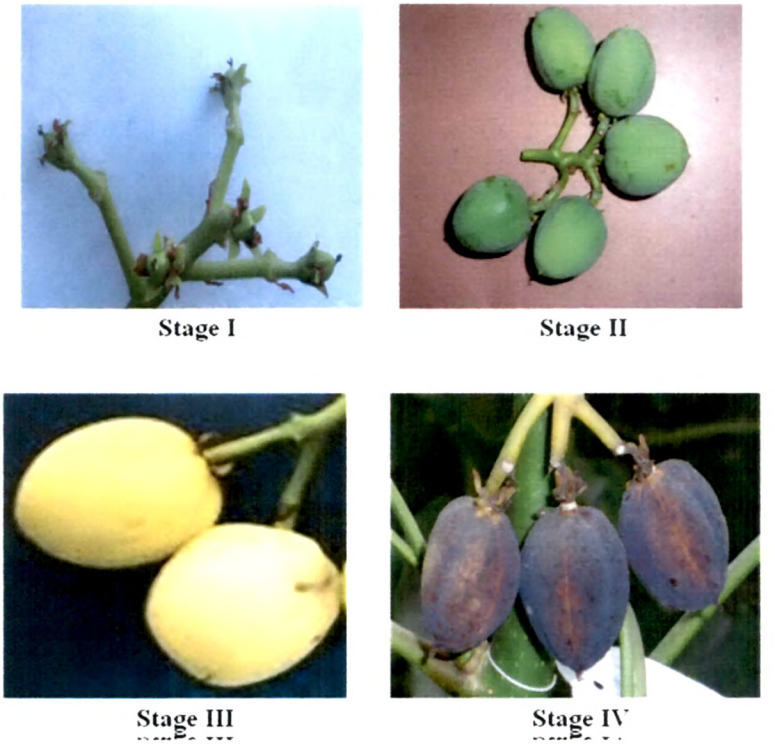


Figure 3.2: Different stages of Fruit development. Fruit developments from stage I to stage IV were observe Photographs were captured at 5X zoom with digital camera.

We categorized fruit development into four different stages, which are as below:

Stage I: Emergence of fruit after pollination

Stage II: Appearance of Green colour immature big fruit

Stage III: Yellow colour mature fruit

Stage IV: Brown colour dry fruit

Table 3.3: Time scale of Fruit development in *Jatropha curcas* plantation from different regions

Plantation regions	Duration (in days) for fruit development				
	Emergence of fruit after pollination (Stage I)	Appearance of Green colour immature big fruit (Stage II)	Yellow colour mature fruit (Stage III)	Brown colour dry fruit (Stage IV)	Total days for fruit maturation
Vadodara	22.80 ± 1.030	48.60 ± 1.077	25.80 ± 1.020	30.10 ± 1.022	127.8 ± 1.414
Padra	20.82 ± 1.231	51.10 ± 1.054	26.90 ± 1.120	35.12 ± 1.041	135.4 ± 1.327
Bodal	26.14 ± 2.011	49.50 ± 1.275	28.60 ± 1.040	32.20 ± 1.031	137.1 ± 1.112
Degama	25.30 ± 1.024	47.90 ± 1.047	27.50 ± 1.030	33.16 ± 1.124	132.6 ± 1.245
Himmatnagar	24.20 ± 1.010	48.20 ± 1.024	22.90 ± 1.170	31.10 ± 1.050	128.3 ± 1.426
Navsari	21.41 ± 1.126	46.60 ± 1.082	26.90 ± 1.080	32.70 ± 1.045	126.7 ± 1.114
Kawant	22.75 ± 1.041	52.60 ± 1.067	28.80 ± 1.029	36.10 ± 1.012	139.3 ± 1.234
Umeta	23.50 ± 1.051	49.90 ± 1.122	27.80 ± 1.028	31.10 ± 1.121	133.8 ± 1.524

n= 50 bloom of fruits/plantation

Values are mean ± SEM; ten plants were used for observation from each plantation. In each plant at least, five fruit blooms immediately after pollination until maturation were used for observation. Results showed in table are fifty blooms of fruits from each plantation.

As shown in table 3.3, Fruit development was categorized into four different stages. Initial two stages are immature phase of fruit development, which appeared immediately after pollination. Initial phase of fruit development took longer than the latter phase of fruit maturation. The first two stages of fruit development take around seventy to eighty days. The last two stages where maturation of fruit takes place are of shorter time duration. It takes around fifty to sixty days for maturation. Finally, complete duration of fruit development from pollination to maturation takes three months. Fruit development was faster in Navsari, Vadodara and Himmatnagar region plants while it took longer for fruit maturation in the regions of Bodal and Kwant.

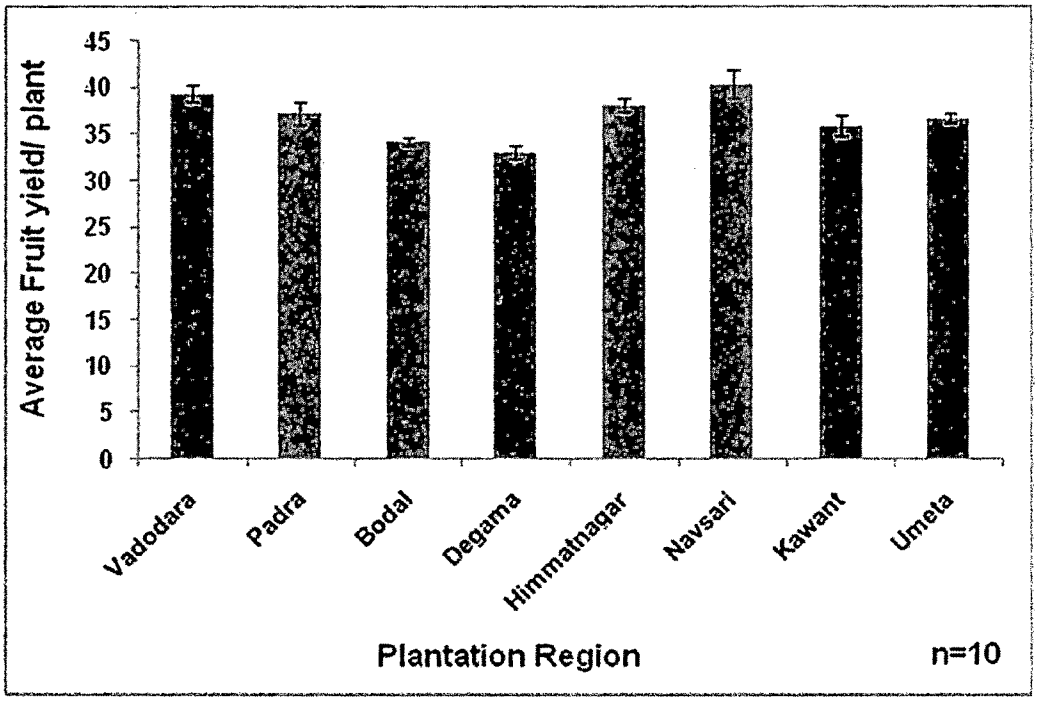


Figure 3.3: Fruit yield from *Jatropha curcas* plantation of different regions

The average number of fruit yield was calculated from each plant. Values are mean ± SEM; ten plants were used from each plantation. In each plant at least, ten fruit blooms immediately after pollination until maturation were used for observation.

As shown in figure 3.3, Average numbers of fruit per plant were calculated during stage II of fruit development and this was observed for three months after pollination. Bodal and Degama region shows lower fruit yield compared to other regions. All the regions except Bodal and Degama shows similar fruit yield.

3.2.3. Seed weight, Oil yield and Fatty acid analysis of seeds

After fruits were completely developed, they were collected from each plantation and seeds were harvested by removing seed coat. Seeds were dried at room temperature for few days and weighed before oil extraction. Oil was extracted from seeds to determine its yield. The oil was also characterized for its fatty acid composition. The method for oil extraction is as mentioned in Materials and Methods section.

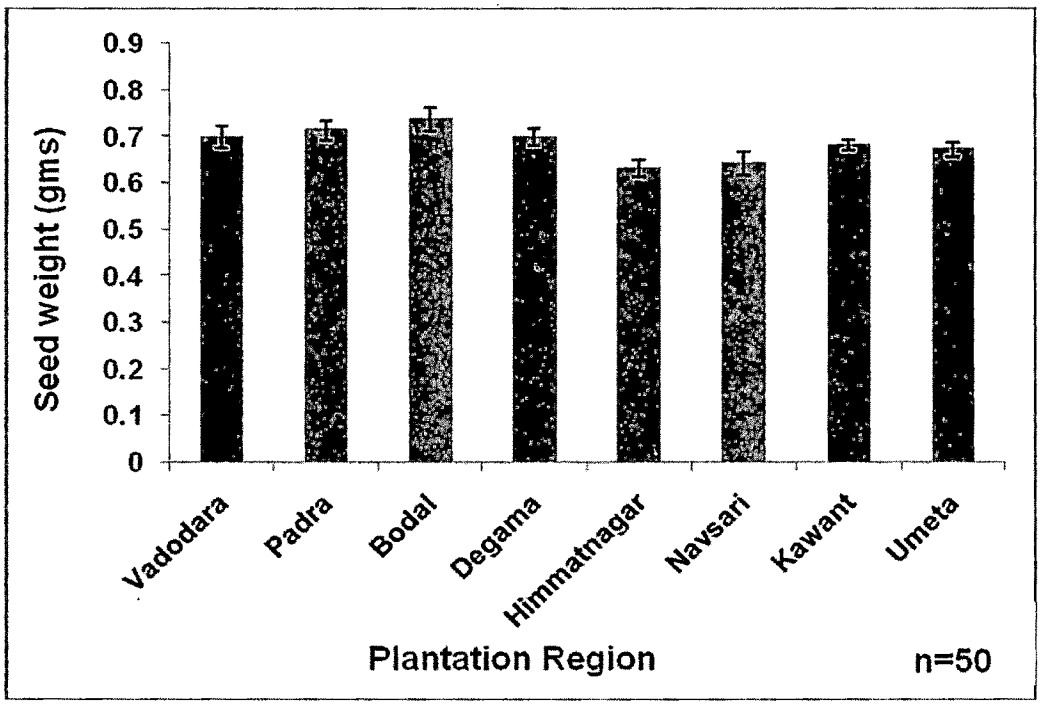


Figure 3.4: Seed weight from *Jatropha curcas* plantation of different regions

Seed weight was calculated after the complete maturation of fruits. Fifty seeds were collected from each plantation. Seeds were dried at room temperature and weighed. Values

represented are the mean of values of 50 seeds and bars indicate SE. Seed weight from different region of plantations is similar.

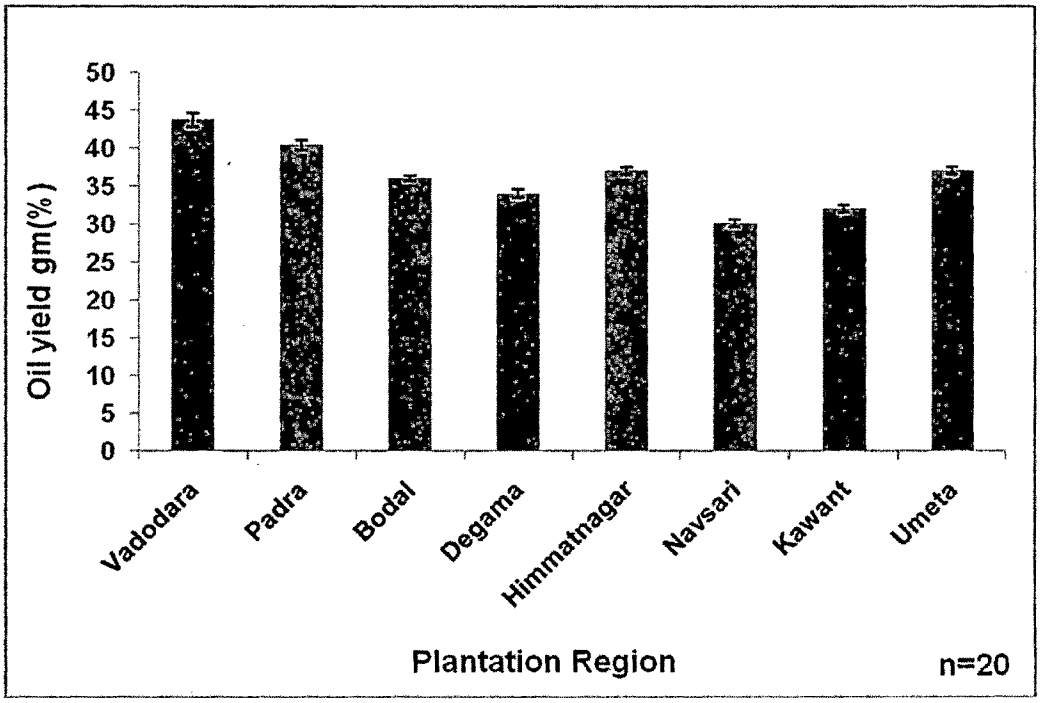


Figure 3.5: Oil yield from *Jatropha curcas* plantation of different regions

Dry mature seeds were analysed for oil content after removal of seed coat using the method of Bligh and Dyer, 1959 as mentioned in Materials and Method section. Values represented is the mean of 20 replicates and bars indicate SE.

As shown in figure 3.5, Seeds from Vadodara and Padra region shows higher oil yield as compared to other region seeds. Bodal, Degama, Navsari and Kawant shows lower oil yield. This indicates that geographical and soil factors could affect the oil yield and its characteristics.

Table 3.4: Fatty acid analysis of seed oil of *Jatropha curcas* plantation from different regions

Fatty Acids Composition (gm %)	Bodal	Degama	Himmat nagar	Navasari	Kawant	Umeta	Vadodara	Padra
Myristic acid	0.13	------	0.24	------	0.07	0.06	0.07	0.06
Palmitic acid	13.09	12.92	15.40	15.41	13.29	13.71	13.29	13.71
Palmitoleic acid	0.66	0.71	0.81	0.78	0.77	0.82	0.77	0.82
Stearic acid	8.47	9.39	7.62	10.44	------	5.67	------	5.67
Oleic acid	41.08	39.94	39.34	35.80	43.86	36.16	43.86	36.16
Linoleic acid	34.05	36.09	35.21	35.14	39.24	43.06	39.24	43.06
Linolenic acid	0.29	0.30	0.80	1.24	1.02	0.62	1.02	0.62

Fatty acids were analysed after extraction of seed oil. Fatty acid analyses from seed oil were done by Gas Chromatography as mentioned in chapter 2. Values are represented as g (%).

Oil from all regions was analysed for Fatty acid composition as shown in table 3.4. Oleic acid, Linoleic acid and Palmitic acid are the major fatty acids present in the *Jatropha curcas* seed oil. There is no significant change seen in fatty acid composition. In regions such as Degama and Navsari, Myristic acid is absent while Stearic acid is absent in Kwant and Vadodara regions.

3.3. Discussion

3.3.1. Flower development and Flower sex ratio

The study of flower, fruit and seed morphological characters of the natural populations is often considered useful step in the study of the genetic variability. There were no significant variation observed in flower sex ratio and flower development. Hence, it can be interpreted that there does not seem to be much variation in *Jatropha curcas* flowering and morphological characters within Gujarat region. This could be due to fact that the species grown is the same. Molecular markers could be used to confirm this.

3.3.2. Fruit development and Fruit yield

Fruit development and fruit yield was studied from different plantations. A significant difference was observed among the accessions for fruit development and fruit yield. Variation in *Jatropha curcas* fruit morphological characters could be due to fact that the species grows over different range of rainfall, temperature and soil type. Various ecotypes/provenances/fruit sources of *Jatropha curcas* have been shown to exhibit variation in fruit morphological traits (Kaushik et al., 2003; Ginwal et al., 2005; Kumar et al., 2003).

3.3.3. Seed weight, Oil yield and Fatty acid analysis

Seed weight, oil yield and fatty acid analysis were studied from different regions of plantation. There were significant variation observed for seed weight, oil yield and fatty acid analysis in the *Jatropha curcas* plantations studied. Differences in seed morphological characters and oil yield could be due to fact that the species grows over a wide range of rainfall, temperature and soil type. Similar variation has also been reported

in Azadirachta indica (Jindal et al., 1999; Kaura et al., 1998; Kundu et al., 1998), Acacia nilotica (Gera et al., 1976), and Acacia catechu (Kumar et al., 2004). The seeds from those regions having more seed weight and oil content may be used for further improvement programme. The improvement in germination and seedling growth through seed weight alteration has been reported in case of Hardwickia binnata (Ponnammal et al., 1993), H. binnata and Cholosphospermum mopane (Kaushik et al., 2001) and *Jatropha curcas* (Kauhsik et al., 2003).

Genotypic and phenotypic correlation between various characters under study helps to reveal the magnitude of correlation at genotypic level in correspondence to their phenotypic correlations. Such differences clearly indicate the genotypic association among the characters. Similar findings between seed weight and oil yield have been reported in Azadirachta indica, Acacia nilotica and Acacia catechu (Jindal et al., 1999; Kaura et al., 1998; Kundu et al., 1998, Gera et al., 1976 and Kumar et al., 2004).