YRKESHÖGSKOLAN NOVIA

Cultivation and Management of *Jatropha curcas* L. by Smallholder Farmers in the Kenyan Districts Baringo and Koibatek

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Abstract

The subject of this thesis is the cultivation and management of the tropical oil-crop *Jatropha curcas* L. (physic/purging nut) by smallholder farmers in the Kenyan districts Baringo and Koibatek. The purpose of this study is to find out the main factors affecting plant development and growth in smallholders Jatropha farms in Baringo and Koibatek, and as a result of this study there is to be helpful information on how to proceed with the Jatropha plantations there.

The implementation of this study included interviews and field visits at 20 Jatropha farms in Baringo and Koibatek in autumn 2010, with focus on planting, irrigation, plant nutrition, intercropping, weeding, pest and disease management and pruning of Jatropha. The results show that irrigation and fertilization is needed for better growth rates, and that the small-scale farmers lack sufficient knowledge of the plant management and their impact on growth and yields. The occurrence of pests in the plantations should be treated with preventive methods, like proper management and good hygiene, rather than with chemicals.

The conclusions are that the Jatropha plant most probably will not be giving optimal yields in Baringo and Koibatek, but through improved irrigation, fertilization and other management the Jatropha plant will have better conditions to give a yield that matches the farmers' needs. Based on the results I recommend the client of this work, Farming Systems Kenya, to do some research on the farmers' adoption rates concerning the information given about the Jatropha plant, and on how to improve the rate of adoption amongst the farmers within the project.

Language: English Key words: Jatropha curcas, cultivation, management, plantation, growth, small-scale, farmer, Kenya

EXAMENSARBETE

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Utbildningsprogram och ort: Trädgårdsnäring, Esbo

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Titel: Odlingen och skötseln av *Jatropha curcas* L. av småbrukare i de Kenyanska distrikten Baringo och Koibatek / Cultivation and Management of *Jatropha curcas* L. by Smallholder Farmers in the Kenyan Districts Baringo and Koibatek

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Sammanfattning

Mitt examensarbete behandlar den tropiska oljeväxten *Jatropha curcas* L. (på svenska purgerbuske) och dess odling och skötsel hos småbrukare i distrikten Baringo och Koibatek i Kenya. Arbetets syfte är att få fram de huvudfaktorer som påverkar plantans utveckling och tillväxt i småbrukares odlingar i Baringo och Koibatek, för att få veta hur man skall gå vidare med odlingen av Jatropha.

Genomförandet skedde genom intervjuer och fältbesök vid 20 Jatropha-odlingar i Baringo och Koibatek under hösten 2010, och behandlar plantering, bevattning, gödsling, samodling, ogräs-, skadedjurs- och sjukdomsbekämpning samt beskärning av Jatropha. Resultaten visar att bevattning och gödsling behövs för bättre tillväxt, samt att småbrukarna saknar tillräcklig kännedom om skötselåtgärder och deras inverkan på tillväxten och skörden. Förekomsten av skadedjur i odlingarna bör åtgärdas, men framom kemiska medel skulle preventiva metoder, som rätta skötselåtgärder, kunna dra ner på skadedjurens inverkan betydligt.

Slutsatserna i detta arbete är att växten Jatropha troligtvis inte kommer att uppnå optimal skörd i områdena Baringo eller Koibatek, men genom förbättrad bevattning, gödsling samt andra skötselåtgärder har Jatrophan bättre förutsättningar att ge en skörd som motsvarar småbrukarnas behov. På basen av resultaten rekommenderar jag också att beställaren till detta examensarbete, organisationen Farming Systems Kenya, skulle forska litet i graden av informationsintaget bland småbrukarna, och eventuellt omstrukturera läroplanen för projekten för framtiden.

Språk: engelska Nyckelord: Jatropha curcas, odling, skötsel, tillväxt, småskalig, odlare, Kenya

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OPINNÄYTETYÖ

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Nimike: *Jatropha curcas* L.-kasvin viljely ja kasvun hallinta pienviljelijöiden keskuudessa Baringon ja Koibatekin alueella Keniassa / Cultivation and Management of *Jatropha curcas* L. by Smallholder Farmers in the Kenyan Districts Baringo and Koibatek

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Tiivistelmä

Opinnäytetyöni aiheena on trooppisen *Jatropha curcas* L.-öljykasvin viljely ja kasvun hallinta pienviljelijöillä Baringon ja Koibatekin alueella Keniassa. Opinnäytetyön tavoitteena on selvittää pääasiat, jotka vaikuttavat kasvin kehittymiseen ja kasvuun pienviljelijöiden viljelmillä, ja näin tuottaa tietoa ja ehdotuksia, miten edetä Jatrophan kasvatuksessa kyseisellä alueella.

Toteutin työn haastatteluina vieraillessani 20 pienviljelmällä syksyllä 2010. Keskityin pääasiallisesti Jatrophan hoitoon liittyviin tehtäviin, kuten istutukseen, kastelemiseen, lannoitukseen, sekaviljelyyn, rikkaruohojen, tuholaisten ja tautien torjuntaan sekä karsimiseen. Tulokset osoittavat, että Jatrophan riittävä kasvu vaatii kastelua ja lannoitusta, toisin kuin oli luultu. Pienviljelijöiden tiedot kasvin hoidosta sekä hallinnan vaikuttamisesta kasvuun ja satoon eivät ole myöskään riittävät. Tuholaisongelma viljelmillä pitäisi korjata mieluiten ehkäisevillä toimenpiteillä, kuten oikealla hoidolla, ei kemiallisilla torjunta-aineilla.

Johtopäätökset tehtyjen tulosten perusteella ovat, että Jatropha-kasvi ei todennäköisesti tuota optimaalista satoa Baringon ja Koibatekin alueella, mutta parantamalla kastelua, lannoitusta sekä muita hoitotapoja, Jatropha-kasvilla on paremmat edellytykset tuottaa sato, joka vastaa pienviljelijöiden tarpeita. Tulosten perusteella suosittelisin tilaajaa, Farming Systems Kenyaa, selvittämään ja tarkastamaan pienviljelijöiden informaation saannin ja sisäistämisen tason sekä mahdollisesti uusimaan opetussuunnitelman tulevaisuuden projekteihin.

Kieli: englanti Avainsanat: Jatropha curcas, viljely, hallinta, kasvu, pienviljely, viljelijä, Kenia

Svenskspråkig sammanfattning

Inledning

Klimatförändringen har diskuterats flitigt under de senaste åren, och olika lösningar för att minska utsläpp, upprätthålla den biologiska mångfalden och att hålla CO_2-utsläppen på skälig nivå har framförts. En av de stora frågorna gäller de fossila bränslena, vilket lett diskussionen in på biodiesel och plantan *Jatropha curcas* L., på svenska purgerbuske. Under början av 2000-talet sågs den som räddningen i bränslefrågan. Plantan sades växa snabbt, ge stor skörd, vara skadedjursresistent och vara väldigt anspråkslös gällande växtplats och skötsel. Dessa påståenden har senare visat sig vara inte helt sanningsenliga, och undersökningar gällande växten utförs i tropikerna över hela världen. Utrikesministeriet i Finland har finansierat ett treårigt projekt för bl.a. forskning i Jatropha-växten, dess odling och skötsel i distrikten Baringo och Koibatek i Kenya. Projektet koordinerades av Linnaseutu ry och Hämeen Ammattikorkeakoulu HAMK i Tavastehus, Finland, och genomfördes i samarbete med den icke-statliga organisationen Farming Systems Kenya (FSK) i Nakuru, Kenya. Syftet med projektet var att minska fattigdomen för småbrukare i dessa distrikt och samtidigt främja hållbar utveckling samt se till att värna om miljön.

För detta examensarbete har jag undersökt odlingen och skötseln av *Jatropha curcas* L. genom intervjuer med Jatropha-odlare och fältbesök i deras odlingar i distrikten Baringo och Koibatek i Kenya. Beställaren till examensarbetet är Farming Systems Kenya, och syftet med undersökningen är få fram huvudfaktorerna som påverkar Jatropha-plantans utveckling och tillväxt i småskaliga odlingar i områdena Baringo och Koibatek i Kenya, med fokus på plantering, bevattning, gödsling, samodling, bekämpning av ogräs, skadedjur och sjukdomar samt beskärning. Målet med undersökningen är att få fram tillförlitlig information som kan vägleda de nuvarande och kommande Jatropha-projekten i dessa områden.

Bakgrundsfakta om *Jatropha curcas* L.

Jatropha curcas L. är en perenn stor buske eller litet träd och hör till familjen *Euphorbiaceae*. Växten Jatropha härstammar antagligen från Centralamerika och Mexico och har därifrån spridit sig till Afrika och Asien, och idag finns Jarophan i de flesta tropiska och sub-tropiska områden. Jatropha-plantan blir vanligtvis ca tre till fem meter hög och kan bli upp till 50 år. Plantan genomgår en utvecklingsfas under de första fyra till fem första åren, varefter plantan torde vara fullt utvecklad och bära optimalt med frukt. Blomningen induceras av olika stressfaktorer, och efter pollination tar det ca 90 dagar innan frukterna är mogna. Frukterna är gröna som omogna, blir gula då de mognar och blir bruna då de torkar, de är ca 4 cm långa och innehåller vanligtvis tre frön. Fröna är svarta och ca 2 cm långa med en oljehalt på ca 32-40% i kärnan. Både fröna och oljan är giftiga och kan därmed inte användas i matlagning, vilket lett till att Jatrophan setts som ett potentiellt biodiesel-löfte. Jatrophan var först beskriven av Carl von Linné år 1753, och under historiens lopp har växten använts inom medicinen samt som häckplanta. Jatrophan är också effektiv mot erosion och fungerar som återvinnare av näringsämnen – pålroten hämtar näringsämnen från djupare jordlager upp till ytan. Jatrophan odlas ändå i första hand för oljans skull – den kan användas som bränsle att koka mat på, som bränsle i lampor och maskiner samt inom tvåltillverkning. Efter oljepressningen bör oljan filtreras eller centrifugeras, och kan sedan användas till förbränning samt för tillverkning av tvål - för att producera biodiesel krävs ytterligare reningsprocesser.

Globalt odlas Jatropha-växten mellan 30°N och 35°S, och i första hand för biodieselproduktion. Produktionen växer år för år och engagerar fler och fler organisationer. Produktion av olja från sojaböna, raps och palmolja är fortfarande större än för Jatropha-oljan, men Jatrophan visar de största ökningarna inom växtoljeproduktionen. Jatrophan introducerades i Kenya för ungefär ett sekel sedan, och har därefter odlats i landet, men för andra ändamål än för biodieselproduktion. I Kenya finns inga lokalt producerade fossila bränslen, och importen av dessa är väldigt kostsamma för landets ekonomi. Enligt litteraturen skulle produktion av biobränsle – t.ex. Jatropha - därför vara av stor vikt för landets ekonomi, och biodieselproduktionen borde därför utvecklas i Kenya. Utländska företag och organisationer har under de senaste åren påbörjat

Jatropha-projekt med kenyanska småbrukare, men småbrukarna har stött på problem både i form av små skördar och att det inte finns någon riktig marknad för Jatropha-fröna. The Government of Kenya gav år 2000 ut restriktioner om var och hur Jatropha-odlingen skulle ske. Bland annat får Jatrophan inte ersätta odling av matgrödor eller utgöra något hot mot matproduktionen i landet. En undersökning gjord år 2009 av GTZ om odling av Jatropha i Kenya visar att skördarna i de kenyanska småskaliga Jatropha-odlingarna ger avsevärt mindre skörd än vad litteraturen rapporterar. Jatropha-odlingarna som de undersökt ger inte någon vinst under de tio första åren, och GTZ rekommenderar därför inte att småbrukare börjar med Jatropha-odling – varken som monokultur eller i samodlingar – förrän vidare forskning i ämnet utförts. Endast odling av Jatropha som häck rekommenderas.

Odling och skötsel av *Jatropha curcas* L.

I litteraturen står det att Jatrophan behöver 300 mm regn årligen för att överleva, och en årlig nederbörd på 600 mm är minimum för att plantan skall ge skörd. Jatrophan tål torka bra och kan klara sig utan vatten i ca ett års tid, men då fäller den bladen och blommar inte. Optimal årlig nederbörd är mellan 1000-1500 mm, då Jatrophan får svåra problem med svamp och andra sjukdomar vid fuktigare förhållanden. Jorden bör vara väldränerad då Jatrophan inte tål att stå i vatten, och sandiga och luftiga jordar rekommenderas, medan tunga lerjordar bör undvikas. Planteringen skall helst ske i början av en regnperiod, och att först rensa bort ogräsen samt gräva planteringshål är rekommenderat. Rekommenderat plantavstånd för en monokultur är 3 x 2,5 m, - vilket gör 1333 plantor per hektar - då kortare plantavstånd på 2 x 2 m eller 2,5 x 2,5 m kräver bättre vatten- och näringstillförsel samt mer intensiv beskärning. Skörden varierar stort beroende på odlingsförållandena, klimatet och skötseln, men rör sig oftast runt 500 och 3500 kg frön per hektar och år.

Gällande skötseln står det i litteraturen att bevattning och gödsling kan öka skörden väsentligt. Den längre regnperioden från mars till juni är tillräckligt lång för att en god skörd skall kunna fås, medan den kortare regnperioden under hösten kräver tilläggsbevattning för god skörd. Bevattningssystem är väldigt dyra och kräver förstås en god vattenkälla. Som gödselmedel kan med fördel gödsel från

get eller ko användas, och om plantornas blad, beskärningsrester och fruktskalen lämnas kvar i planteringen behövs mindre gödsel än om de förs bort. Samodling med matgrödor är rekommenderat under de första åren av Jatropha-odling, men då krävs mer vatten och näring. Då Jatropha-plantorna vuxit sig stora och skuggar marken kan man endast samodla med växter som klarar sig i skugga. Regelbunden ogräsrensning rekommenderas vid odling av Jatropha, då ogräsen tävlar med Jatrophan om vatten, näring och ljus. Särskilt viktigt är det att hålla plantagen ogräsfri då plantorna är små och inte ännu etablerat sig. Beskärning av Jatrophan bryter den apikala dominansen och stimulerar lateral knopputveckling, och bör göras ca tre gånger innan plantan börjar förgrena sig av sig själv. Beskärningen är viktig eftersom flera grenar gör att mer skörd kan fås, och genom beskärning hålls plantorna tillräckligt låga för att kunna skördas för hand. Endast mogna frukter som är gula eller bruna skördas. Fröna i gröna, omogna frukter har en lägre oljehalt än de mogna frukternas frön. Efter skörd bör fruktskalen avlägsnas och fröna torka. För optimal kvalitet bör fröna torkas utspridda på torrt underlag i skuggan – solljus påverkar oljekvantiteten och -kvaliteten negativt. Fröna skall förvaras torrt, mörkt och svalt i icke-lufttäta behållare. Lagring för mer än åtta månader bör undvikas, eftersom frönas oljekvantitet och -kvalitet påverkas negativt av längre lagring, och också grobarheten försämras av långvarig lagring.

Jatrophan var sagd att vara närapå resistent mot skadedjur och sjukdomar, men det har visat sig att det finns en hel del skadedjur och sjukdomar som gärna angriper Jatrophan. I Kenya har det största problemet varit insekten *Aphthona sp. n. dilutipes*, som översatt från engelskans ”red-brown flea beetle” blir ungefär ”röd-brun jordloppa/skalbagge”, och som vuxen äter hål i bladen och som larv ger sig på plantans rötter. En annan insekt som rapporterats om i Jatropha-odlingar är *Stomphastis thraustica Meyrick*, som översatt från engelskans ”leaf miner” blir ungefär ”bladminerare”, och ger symptomen bruna fläckar på bladen och vita kokonger vid bladnerverna. Det forskas hela tiden i skadedjurs- och sjukdomsbekämpningen av Jatropha, men än finns det inga fastställda rekommendationer för t.ex. bekämpning.

Material och metoder

Distrikten Baringo och Koibatek ligger i provinsen Rift Valley mellan latituderna 0° och 30'N och longituderna 35°30'E och 36°30'E, höjden över havet är 1000-1500 m och jordarna är lerhaltiga. Den årliga nederbörden i Baringo är ca 700 mm, medan Koibateks årliga nederbörd är runt 800 mm. Medeltemperaturen är på båda ställena mellan 16°C och 33°C. Jatropha-projektet startade i Baringo år 2008, och samma år inrättades där en Jatropha-plantskola. Sammanlagt 61 småbrukare i Baringo och Koibatek har genom projektet börjat odla Jatropha, och planteringen av småplantorna skedde i huvudsak under våren 2010.

Som metod i min undersökning har jag valt den halvstrukturerade intervjun samt insamling av data i de intervjuades Jatropha-odlingar. Intervjuerna och fältbesöken gjordes under oktober till december 2010. Till min hjälp skrev jag ihop ett frågeformulär som jag fyllde i själv efter varje intervju. Intervjun var halvstrukturerad: öppna frågor som den intervjuade fick svara väldigt fritt på. Följdfrågor ställdes vid behov för att jag skulle få ihop tillräcklig information i alla ämnen. Den halvstrukturerade intervjun valdes som metod av flera skäl: utbildningsnivån i byarna är inte särskilt hög och därmed skulle frågeformulär som de själva skall fylla i inte ha fungerat. Genom öppna frågor hade jag chansen att få bredare och mer användbara svar än vid användningen av slutna frågor och vid en intervju kan man lätt ”kontrollera” svaren genom att ställa liknande frågor flera gånger eller omvandla det givna svaret till en ja/nej-fråga. Vid en del intervjutillfällen behövdes en tolk. God praxis och etiska regler för intervjuandet samt användningen av data togs i beaktande. Sammanlagt intervjuades 20 Jatropha-odlare, vilket utgör 33% av den totala mängden Jatropha-odlare i Baringo och Koibatek. Respondenterna valdes på basis av var deras odlingar låg, eftersom alla intervjuades odlingar även besöktes för datainsamling gällande bl.a. tillväxten. Till min hjälp vid fältbesöken hade jag ett formulär, där odlingens helhetsintryck, förekomsten av skadedjur och sjukdomar noterades, samt uppgifter om höjd, antal grenar, bladfärg, om och hur plantan blivit beskuren, blomning, antal frukter etc. för 10 plantor skrevs upp. Vid analyseringen av den insamlade datan gjordes först en narrativ översikt samt en kategori-analys, sedan användes en kvalitativ analysmetod och därefter ännu en kvantitativ analysmetod.

Resultat

Växten Jatropha var ny för alla småbrukare i Baringo och Koibatek då projektet började år 2008, så allt de vet om plantan har de lärt sig av Farming Systems Kenya eller erfarit själva under Jatropha-odlingens gång. Vid intervjutillfällena visste alla odlare att Jatropha är en oljeväxt, och de flesta sade också att den är giftig och att man kan använda oljan till att koka mat på, samt i lampor och maskiner. De gav också många exempel på hur de sparar tid och pengar: genom att använda Jatropha-oljan istället för paraffin, träkol eller ved. Inkomst tänkte de flesta sig att få genom försäljning av fröna, oljan eller småplantor samt genom tvåltillverkning och -försäljning. En av de tjugo intervjuade visste inte hur man kunde få inkomst av att odla Jatropha.

En del småbrukare planterade Jatropha redan under våren 2009 – som var ett ovanligt torrt år då regnperioden aldrig riktigt kom igång – vilket betydde att de plantorna gick in i ett vilostadium i väntan på regn. Under våren 2010, då den långa regnperioden inföll normalt, började dessa plantor sedan växa, och resten av Jatropha-odlarna planterade under våren 2010. Antalet plantor per odling varierar mellan 50 och 1000 st. med ett medeltal på ca 500 plantor. Före planteringen rensade de alla ogräs och grävde planteringshål, och i Koibatek använde sig en del odlare av traktor och plog för att få ett bra växtunderlag. Plantavståndet var mestadels 2 x 2 m, men även plantavstånd på 1 x 1 m och 2,5 x 2,5 m var vanligt. En av odlarna hade sått Jatropha-frön som vid intervjutillfället var större än de planterade småplantorna. Av 20 odlare samodlar 17 stycken Jatrophan med matgrödor som bl.a. majs, hirs, durra, bönor batat, och jordnötter. De säger alla att samodlingen varken påverkar Jatrophans eller matgrödans tillväxt negativt, tvärtom rensar de ogräs bättre i Jatropha-fältet p.g.a. samodlingen.

Bevattningen sker för hand, och de flesta odlarna vattnade plantorna vid planteringen. Hälften fortsatte vattna under ett par-tre månaders tid, medan andra hälften lät bli att vattna eftersom de planterat under den långa regnperioden. På grund av vattenbrist samt långa transportsträckor till fots tänker de flesta inte vattna sina Jatropha-plantor mer – endast ifall en riktigt svår torka utbryter säger några – eftersom de lärt sig att Jatrophan tål torka bra. I Baringo hade 90% av

odlarna gödslat med getspillning, medan andelen i Koibatek var lägre med 50%. Allt från en handfull till tre kilo sätts per planta och gödslingsgång, och antalet gödslingstillfällen årligen varierar mellan odlarna från en gång per år till varje månad. En del odlare hade inga planer alls på att gödsla sina Jatropha-odlingar.

Ogräsrensning är något varje odlare gör, men även här varierar antalet gånger per år från varje vecka till en gång per år. De flesta sade att de rensar då de ser att det behövs, men bland odlingarna fanns ett flertal närapå igenvuxna Jatropha-fält, och där verkade plantorna lida av ogräskonkurrensen. Beskärningen hade alla inte börjat med, eftersom plantorna i en del av planteringarna ännu var för små för att beskäras. En del odlare sade också att de inte visste vad beskärningen skulle vara bra för, eller hur den skulle göras. De som hade beskurit sina plantor hade använt sig antingen av kniv, *panga*s eller brutit av toppen för hand. De flesta beskar 5-20 cm av toppen då plantorna nått en höjd på ca en meter, men någon hade beskurit mer då plantorna nått två meters höjd och en annan hade beskurit toppen och även en del av sidogrenarna. På frågan om hur många gånger de planerat att beskära plantorna blev svaren allt mellan att de inte vet hur eller varför man skall beskära till en, tre eller sex gånger.

I varenda en odling i både Baringo och Koibatek fanns det jag antar vara den ”röd-bruna jordloppan/skalbaggen” (*Aphthona sp. n. dilutipes*), men skadan den gjort på plantagerna varierade från ett par hål i några av bladen till planteringar där endast ett par bruna blad fulla med hål fanns kvar. Endast en av odlarna hade försökt bekämpa denna skadegörare med kemiska bekämpningsmedel, de andra visste inte vad de skulle ta sig till för att bli av med ohyran. Ett annat skadedjurssymptom som fanns i de flesta odlingar var ett vitt nät runt en puppa på bladen, vilket skulle kunna vara ”bladmineraren” *Stomphastis thraustica Meyerick*. Exakt vad denna skadegörare gör är ännu oklart. Andra oidentifierade symptom i planteringarna var skrynkliga blad, ”sönderrivna” blad, röda små kvalsterliknande djur på bladen samt plantor med grå och ”mjöldaggiga” bladskaft och blomställningar samt med grå frukter med mörka savdroppar, vilka kunde bero på en svart-gul oidentifierad insekt.

Tillväxten var väldigt olika från odling till odling, och trots att nästan alla plantor var planterade vid ungefär samma tid (de plantor som planterades under 2009 var

fortfarande vid samma stadium ett år senare då de andra planterade sina plantor) varierade höjden från 10 cm till 3 m med medeltalet 95 cm. Antalet grenar varierade också kraftigt med allt från inga sidogrenar alls till ca 15 sidogrenar. På några av de beskurna, välväxande plantorna hade även sidogrenarna börjat förgrena sig. En del obeskurna, väldigt höga plantor (1,5-3 m) hade inte alls förgrenat sig utan istället börjat blomma. Blomningen startade som tidigast 4-5 månader efter plantering, men vanligare var att plantorna började blomma vid ca ett halvt års ålder. De flesta plantorna hade inte ännu blommat en enda gång. De plantor som var direktsådda växte otroligt snabbt jämfört med de planterade småplantorna, och började blomma redan som sju månader gamla. Skörden är som allra högst två kg frön vid en av odlingarna, och de flesta har inte ännu skördat något alls. De få som fått skörd har torkat fröna och lagrar dem i väntan på mer. En av odlarna använder fröna som lampa genom att sticka fröet på ett strå och tända det – ett frö brinner i ca fem minuter. Förväntningarna på odlingen av Jatropha är att bli självförsörjande på lampolja och olja för förbränning vid matlagning samt att få inkomst genom försäljning av fröna. Endast två odlare hade funderat på hur stora skördar de förväntar sig, och det handlade om 2,5 kg och 40 kg frön per planta per år. De största utmaningarna var de flesta överens om att var torka och skadedjuren.

Diskussion

Jatropha-odlingarna i Baringo och Koibatek har visat sämre tillväxt, senare blomning och mindre skörd än litteraturen säger att skulle vara normalt i liknande förhållanden. Frågan är om plantorna i Baringo och Koibatek någonsin kommer att få så stor skörd och inkomst som odlarna nu förväntar sig. Min undersökning visar liknande tendenser som beskrivs av GTZ med resultatet att Jatrophans skördar i småskaliga odlingar i Kenya är mycket mindre än vad som rapporterats i andra delar av världen.

Förökningsmaterialet som använts vid uppdrivningen av småplantor i plantskolan är av okänd härstamning, och kan vara en avgörande faktor för planttillväxt och skördemängderna, eftersom kvaliteten på förökningsmaterialet inverkar på just dessa saker. Faktum att småplantorna hölls längre i bäddarna i plantskolan kan ha gjort att plantornas tillväxt i plantskolorna avstannat och att det därför tagit längre

tid för plantorna att etablera sig i odlingarna. Förberedelserna före planteringen gjordes enligt rekommendationerna i litteraturen, men då de barrotade plantorna transporterades från Baringo till Koibatek är det möjligt att rötterna hunnit torka litet, vilket i sin tur kan ha påverkat tillväxten. Den årliga nederbörden ligger ovan gränsen för att ge skörd, men under de optimala förhållandena. Det har visat sig att Jatrophan behöver tillräckliga mängder vatten för att växa bra och ge god skörd, och eftersom mängderna vatten som Jatropha-plantorna i Baringo och Koibatek fått definitivt underskrider det optimala är det rätt klart att tillväxten är sämre än litteraturen säger. Det samma gäller gödslingen: trots att de flesta odlarna gödslar sina plantor är mängderna inte närapå tillräckliga om en bra tillväxt och en god skörd är målet. De korta planteringsavstånden samt samodlingen skulle dessutom kräva ännu intensivare bevattning och gödsling för att tillväxten och skörden skulle vara tillräckliga. Att hålla ogräsen i styr är ett måste i Jatrophans etableringsfas om man önskar god tillväxt – om plantan måste tävla om vatten, näringsämnen och ljus med ogräsen utvecklas plantan långsamt. En del odlingar i Baringo och Koibatek var rätt övervuxna av ogräs, vilket verkade inverka negativt på plantornas tillväxt.

Den väldigt varierande tillväxten och plantstorleken verkar bero på skillnader i tillgång på vatten och näringsämnen under plantans etableringsfas och vegetativa fas. Om det funnits för litet av dessa, har plantan gått in i ett tillstånd av stress, vilket försenat tillväxten. Beskärning främjar förgrening och gör att plantan fortsätter den vegetativa fasen – de långa plantor som inte förgrenat sig, men som börjat blomma, hade antagligen inte tillräckligt med vatten och näringsämnen för att ”kunna” växa vegetativt, utan skyndade mot den reproduktiva fasen och började blomma. De flesta odlare verkade inte vara medvetna om fördelarna med beskärningen, och hade därför låtit bli att utföra beskärning.

I alla odlingar i både Baringo och Koibatek fanns den ”röd-bruna jordloppan/skalbaggen” (*Aphthona sp. n. dilutipes*), som rapporterats vara ett stort problem i Jatropha-odlingar runt om i Kenya. I en del odlingar verkade den inte göra så stor skada, medan den i andra odlingar fått plantorna att fälla bladen och gå in i ett tillstånd av stress. Den vita nätkokongen som fanns i de flesta odlingarna, som troligen är ”bladmineraren” (*Stomphastis thraustica Meyrick*), har rapporterats i flera litteraturkällor. Den skada denna insekt gör är inte ännu

dokumenterad i Baringo och Koibatek. Ett samband mellan tillräcklig tillgång på vatten och näringsämnen och få skadedjursproblem noterades – de plantor som bevattnats och gödslats, och därmed också oftast vuxit sig större och starkare än de andra plantorna, verkade klara av skadedjursattacken bättre än svaga plantor.

Tiden för första blomningen och första skörden verkar omöjlig att fastställa, då så många olika faktorer verkar spela in: vatten-, och näringsämnestillgång, konkurrens av ogräs, skadedjursangrepp, beskärning till exempel. Den skörd som hittills uppnåtts är förstås bara början, och trots att första blomningen och skörden är senare än litteraturen säger betyder det inte att en god skörd inte kommer att uppnås - full skörd ska man räkna med först efter fyra till fem år. Förväntningarna på 2,5 kg och 40 kg per planta per år är däremot väldigt i överkant – i småskaliga Jatropha-odlingar i Zimbabwe räknar man med en skörd på ca 400 g per planta per skörd, vilket även i Baringo och Koibatek skulle vara mer realistiska mängder. De odlare som redan skördat och nu lagrar sina frön verkar inte vara medvetna om att kvaliteten på fröna snabbt blir sämre, vilket de borde upplysas om.

Eftersom jag hade en beställare till examensarbetet och de hade endast två Jatropha-grupper var valet av respondenter självklart. Metodvalet föll på den halvstrukturerade intervjun, eftersom jag hade möjligheten att få ut allra mest med den metoden. Att även göra fältbesök kompletterade intervjuerna på ett oumbärligt sätt i undersökningen. Under intervjuerna framkom att informationen Farming Systems Kenya lärt ut till odlarna inte alltid intagits av odlaren, och därför fanns det så många olika metoder för t.ex. beskärningen. För att kunna förbättra informationsintaget skulle jag därför rekommendera vidare forskning i det ämnet. Andra rekommendationer jag kan göra är att odlarna skulle vattna och gödsla sina Jatropha-plantor mer, särskilt i plantans utvecklingsfas, samt att de skulle lägga större vikt vid de andra skötselåtgärderna som ogräsrensning och beskärning, eftersom problemen med skadedjuren då troligen skulle minska. Slutsatserna av denna underökning är att Jatrophan behöver mer vatten och näringsämnen än de fått hittills, samt tillräcklig ogräsrensning och rätt beskärning för att en tillräcklig tillväxt och en troligtvis större skörd skall uppnås. Forskning i Jatropha-plantans vatten- och näringsbehov, samt forskning i skadedjurs- och sjukdomsbekämpning skulle också vara på sin plats. Viktigt att komma ihåg är dock att plantorna i

undersökningen är väldigt unga, och att inga definitiva slutsatser för den fortsatta utvecklingen kan göras.

Table of Contents

1 Introduction

In the last few years the climate change and how to conserve the environment appropriately have been big issues in the world. Different solutions for reducing pollution, reducing carbon dioxide emissions and conserving biodiversity have been discussed and projects have been implemented in many parts of the world. One of the big issues is about the fossil fuels, which have led to the discussions concerning the perennial oil-producing plant physic nut, *Jatropha curcas L*., here called Jatropha. This oil-producing plant has been promoted for bio-diesel production as a fast growing, high yielding, pest-resistant plant that is modest concerning environmental conditions and management. These claims have however not been factual. On plantations all over the world's tropical regions farmers are facing low yields because of lack of water and nutrients, and it has turned out that a lot of different pests and diseases are a big problem on Jatropha.

Research on this oil crop has been in the interest of many countries and organizations. In the semi-arid areas in Baringo and Koibatek districts in Kenya no research has been done on the possibilities for Jatropha cultivation. The Ministry of Foreign Affairs in Finland funded a three-year project (2008-2010) in these districts in Kenya with Jatropha cultivation, management and research as a big component. The project was maintained by the co-operating organizations Linnaseutu ry and HAMK University of Applied Sciences in Hämeenlinna, Finland, and the non-governmental organization Farming Systems Kenya (FSK) in Nakuru, Kenya. The objective of the project was to reduce poverty and to raise income for smallholder farmers in the areas and at the same time help conserving the environment.

For this thesis I have done research on the cultivation and management of *Jatropha curcas L*. through interviews with Jatropha farmers and Jatropha farm visits in the Baringo and Koibatek districts in Kenya. The client of this work is Farming Systems Kenya, and the purpose of this study is to find out the main factors affecting plant growth of *Jatropha curcas* L. in smallholder farmers' plantations in the Baringo and Koibatek areas in Kenya, including planting, irrigation, plant nutrition, intercropping, weeding, pest and disease management

and pruning. As a result of this study there is to be helpful information on how to proceed with the Jatropha plantations.

2 Background on *Jatropha curcas* L.

2.1 Botanical description and centre of origin

Jatropha curcas L. is a large shrub or a small tree belonging to the *Euphorbiaceae* family. Under normal conditions it reaches a height of three to five meters, but under favorable conditions a height of eight to ten meters can be reached. The Jatropha is a diploid species with 2*n*, or 22 chromosomes (Heller 1996, 7-10), and is not sensitive to day length (Benge 2006, 4). The life span of the Jatropha tree is about 50 years (van der Putten 2010, 1). The bark is smooth and brownish to grayish, and when the plant is cut milky, white sap appears. The branches contain latex, and the seeds are toxic. The leaves are alternately arranged on the stem; they are bright to dark green with a length and width of about 6 to 15 cm and have five to seven shallow lobes (Heller 1996, 10-11). In Figure 1 the different Jatropha plant parts can be seen. Dormancy is induced by fluctuations in rainfall and temperature or light, but is still not proved to be regular (Benge 2006, 3). Tewari (ref. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) 2009, 25; van der Putten 2010, 1) says that the plant is deciduous, which means it sheds its leaves under conditions of stress. Normally the seedling forms a taproot surrounded by four peripheral roots. Kobilke says that a plant propagated from cuttings (vegetative propagation) does not usually form this tap root (ref. Heller 1996, 10).

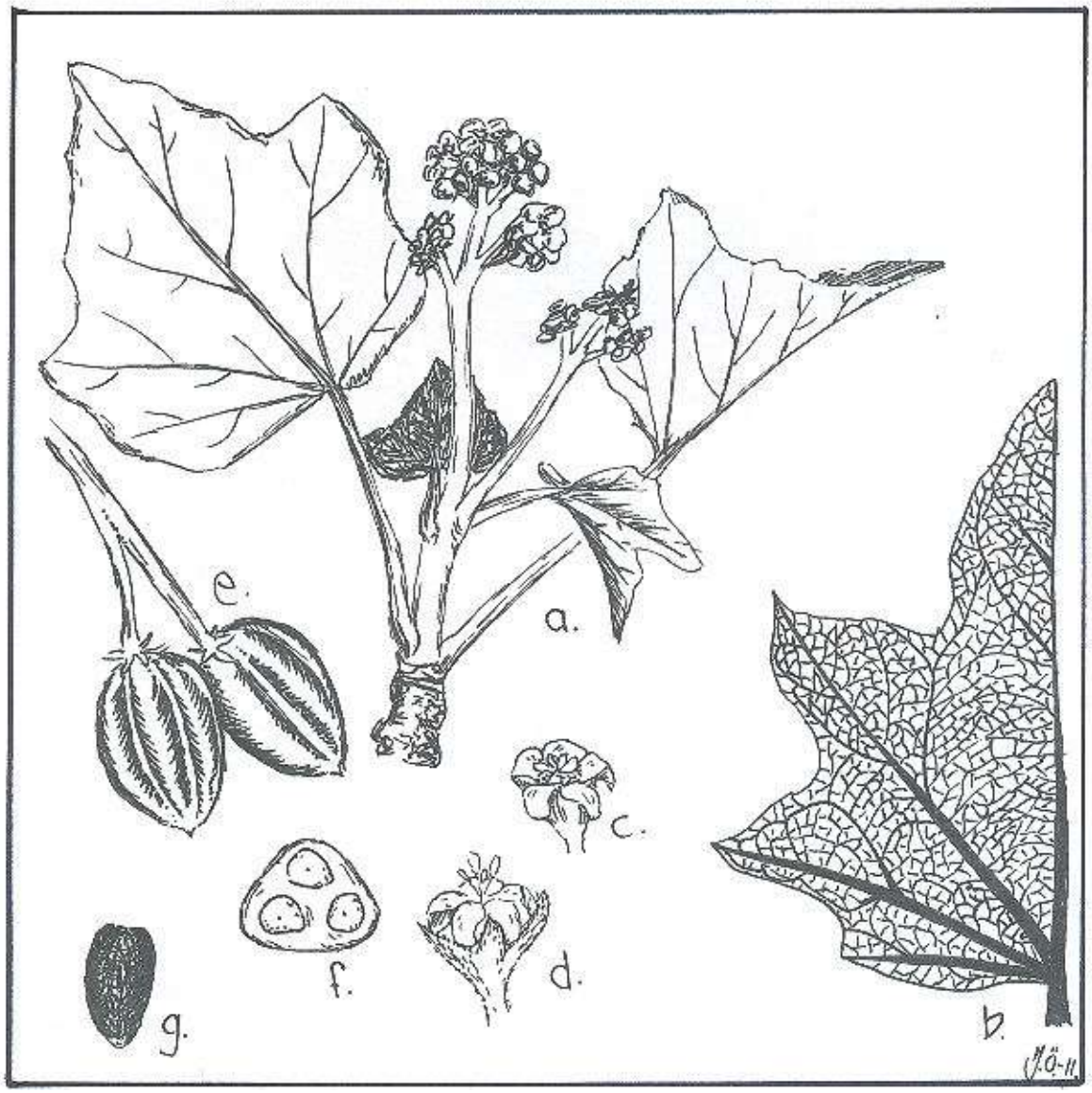

Figure 1. The plant parts of the Jatropha plant. a. Branch with leaves and flower buds, b. leaf veinature, c. female flower, d. male flower, e. fruits, f. cross cut of immature fruit & g. seed

There are five development stages of the Jatropha plant: juvenile, flower induction sensitive, reproductive, filling and flower induction insensitive (see Figure 2). During the juvenile stage the seed soaks water (called imbibition) and starts to germinate. The seedling appears above the ground (emergence) and develops roots and shoots (establishment). The juvenile stage lasts for about two and a half months. The stage of flower induction sensitive means that the flower induction can start if the environmental conditions are right. For example, high radiation, high average temperature or an average minimum temperature of >18°C, and sufficient rainfall can start this process. The reproductive phase means when the plant flowers. The filling phase comes after the pollination, when the fruit development starts and the fruit starts filling and ripening. The time between the

flower induction and harvest is about 90 days or three months. The stage of flower induction insensitive is a stage of dormancy that the plant can go into after harvest. This means that no flowering can start even if the environmental conditions are right. The exact mechanism of the reason to this stage is not known, but it is assumed the plant goes into this stage because of stress. (Franken 2010, 12).

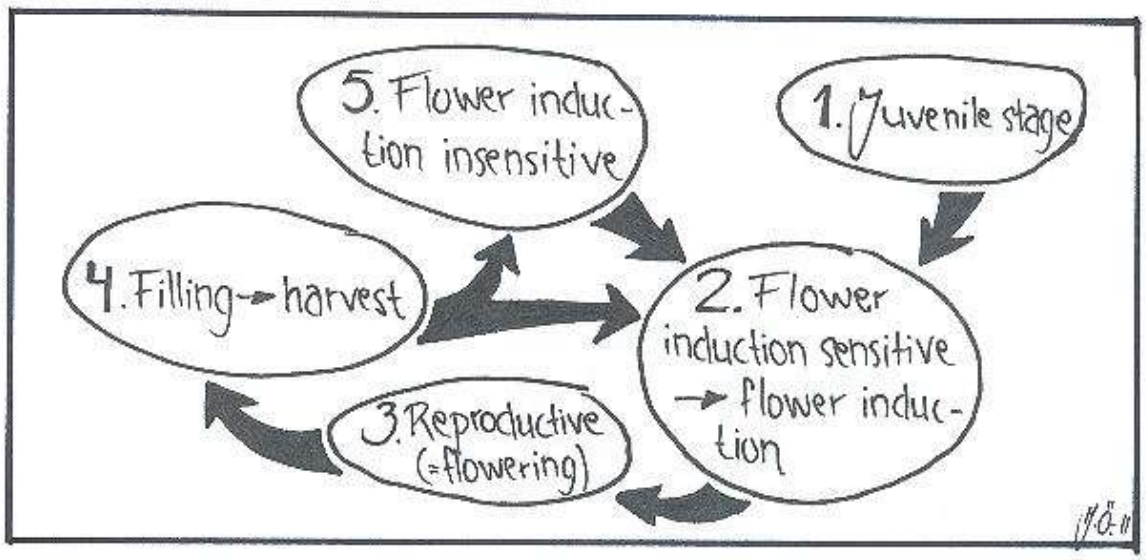

Figure 2. The development stages of Jatropha curcas L.

According to Dehgan and Webster (ref. Heller 1996, 10) Jatropha is monoecious, meaning there are both male and female flowers on the same plant, and the flowers unisexual, but also hermaphrodite flowers occur. The flowering is induced by stress factors such as temperature or drought, but the exact mechanism of the flower induction is not known. It is proved that high solar radiation (much sunlight) is needed for the plant to start flowering, in total shade the Jatropha plant never flowers or flowers only a little. The flowering usually starts at the end of a period of stress, but if there are no seasons, the rain is evenly distributed and the temperature stays the same all year round, the Jatropha will flower continuously. Under optimal conditions the Jatropha will flower the first time at an age of 3-6 months after the seeds are sown. The pollination is done by insects, apart from the case of the rare hermaphrodite flowers, which can be self-pollinating. After pollination the forming of a fruit begins (Heller 1996, 10-11).

The fruits are green, on average 40 mm long, ellipsoidal and fleshy, and they normally contain two to three seeds. Usually there are 5-20 fruits in one bunch at the end of the branch. The seeds are on average about 18 mm long, 12 mm wide and 10 mm thick, they are black and contain 32-40 % (average 34 %) of oil in the kernel. The kernel is 63 % of the seed weight and the shell 37 % of the seed weight. The seeds are ripe about 90 days after the flowers have been pollinated and the fruit turns yellow and hardens. After this the fruit turns brown, and becomes black and opens when it is fully dried. (Heller 1996, 10; van der Putten 2010, 2).

Jatropha seems to be native to Central America and Mexico, and have from there spread to Africa and Asia, probably with Portuguese seafarers via Guinea Bissau and the Cape Verde Islands. The “true” origin of Jatropha has still not been proved. There is no knowledge of exactly when Jatropha was introduced into Cape Verde, but that the plant was known before 1810 and that they exported Jatropha in 1836. There are about 170 known species in the genus Jatropha, which belongs to the tribe *Joannesiae* of *Crotonoideae*. Most of the Jatropha species are native to the New World, but there are approximately 66 species that are native to the Old World. The most species in the section *Curcas* are native to America, but there are two that are of East African origin, *J. afrocurcas* and *J. macrophylla*. (Heller 1996, 7 & 13).

The Jatropha plant was named in 1753 by the Swedish botanist Carl Linnaeus. The name Jatropha comes from the Greek words *iatrós* (doctor) and *trophé* (food), which shows the Jatropha has been used for medicinal purposes (Heller 1996, 6-7). In many countries Jatropha is known by a name meaning ‘the castor oil plant’, which shows that the oil has been the main purpose of planting Jatropha. Another common name is ‘hedge castor oil plant’, showing that it was used to be grown as a hedge (de Jongh 2006, 5). According to Münch and Schultze-Motel (ref. Heller 1996, 9) some common names for Jatropha are: physic nut, purging nut (English), mbono (Swahili) and purgerbuske (Swedish).

2.2 Uses and utilization

The Jatropha plant has many uses besides using the oil as biodiesel. The plant was first used as a medicinal plant for healing different kinds of injuries (Kumar & Sharma 2008, 5). The parts used for medicinal purposes are root, stem, bark, leaves, seeds and oil. The seeds have been used as purgative, therefore the English name ”purging nut” (Brittaine & Lutaladio 2010, 14). The seeds can also be strung on grass and be burned like candlenuts (Benge 2006, 5). The fruit shells can be used as fertilizer or for burning (Brittaine & Lutaladio 2010, 52-53). The latex is listed as homicide, piscicide and raticide, and it is reported to be strongly inhibitory to watermelon mosaic virus, and the bark contains tannins in quantities large enough to be commercially important (Benge 2006, 5).

Jatropha has been used as a hedge or living fence all over the world because the livestock and other animals do not eat it. The fence also functions as a barrier for livestock and animals to keep them away from houses, animals and crops, and shows the border of one's land property. The Jatropha is also very effective in preventing soil erosion, both concerning wind and water erosion. The Jatropha plant also gives green manure, because the developing of a taproot makes the plant able to reach the extract minerals in deeper soil layers and bring them back up to the surface again through leaf fall, fruits and other organic remains (Kumar & Sharma 2008, 4-5). In many countries the Jatropha is also used as support for plants like vanilla and pepper. In these plantations the yields are low, only about 200 kg per hectare, because of the special pruning needed (Henning 2009, 11). The wood of the Jatropha plant is not a good fire wood or suitable for charcoal making (Benge 2006, 9), and the wood is soft and hollow (Brittaine & Lutaladio 2010, 18-19). According to van Eijck (2010a, 81) the wood burns only after it has dried, because the stem contains white sap when fresh.

2.2.1 Use of the oil

The use of the fruits, or the seeds in the fruits, is mostly for producing oil. The results of a research done in Kenyatta University (Kenya) and Muhimbili University (Tanzania) on oilcrops for biodiesel are that Jatropha oil is a promising alternative, renewable and environmentally friendly fuel source, the oil’s parameters of methyl

esters indicate that it can be used directly in existing engines and the Jatropha oil has an energetic content close to conventional diesel fuels (Wagutu, Chhabra, Thoruwa, Thoruwa & Mahunnah 2009, 369).

The oil is called crude oil directly after it has been pressed. The crude oil contains solid material that needs to be removed, which can be done through filtration, sedimentation or centrifuging. Now the oil is ready for use in lamps and stoves, for soap making or for storage. It can be burned in slightly modified lamps and cooking stoves (Beerens 2010, 46), which reduces the use of fire wood, charcoal or petroleum (kerosene) in the rural areas. Jatropha soap can be made with the byproduct when making biodiesel: glycerine or with crude Jatropha oil (Kumar & Sharma 2008, 5). The soap making process is easy, and the only ingredients you need are Jatropha oil, water and caustic soda (Henning 2003, 22-26; 2009, 88). The cleaned Jatropha oil can also be used directly in slightly modified diesel engines, but then it is recommended to clean the oil more carefully: the oil must not contain particles larger than 5 µm (Beerens 2010, 46-53).

Biodiesel has characteristics very similar to fossil fuel, and it can be used in any diesel engine just as it is. To make biodiesel out of crude Jatropha oil, you should first clean the oil using the above mentioned methods, and after that the oil has to go through a magnesium silicate process, followed by water-washing or bubble-washing (Adriaans 2010, 77-81). Also a degumming or neutralizing process is needed, which takes away high amounts of free fatty acids (FFA) and phosphorous. After these processes the oil is ready for use or storage. In Europe the German DIN V 51606 norm for plant oil from year 2007 should be followed. (Beerens 2010, 47 & 55-56). During storage of the oil it is very important for the oil quality to avoid light, temperatures over 30ºC and contact with air (van Eijck 2010b, 56-57).

2.2.2 Use of the seed press cake

In the oil pressing process, only about 20-30% of the whole seed comes out as oil, the rest of the seed becomes what we call seed press cake. The press cake contains all the minerals from the seed (the SVO contain no minerals at all), and the energy content is high: 20-25 MJ per kg of press cake (van Eijck 2010a, 81).

The press cake is also very rich in proteins, but because it contains toxins like phorbol esters, curcine, trypsin inhibitors, lectins and phytates, it cannot be used as animal feed (Heller 1996, 10; GTZ 2009, 27). Delgado and Parado (ref. Kumar & Sharma 2008, 5) compare the nutrient content of Jatropha press cake and cow manure, and concludes that the press cake contains about three times more nitrogen, and one and a half times more phosphorus than cow manure. The potassium rate is almost the same.

Examples on use as energy are to use the press cake as biogas or to make briquettes out of them for burning. The press cake briquettes produce a lot of smoke when burned, and to increase the energy content of the briquettes and to reduce the weight, the Jatropha press cake briquettes can be “charcoalized” by burning the press cake without oxygen for making briquettes producing less smoke and burning more easily. The press cake can also be used as fertilizer or for making pesticides (van Eijck 2010a, 81-85). van Eijck (2010a, 81) says that theoretically, the best use of the press cake would be for energy because of the high energy content, rather than using it as a fertilizer, but Benge (2006, 9) says the use of the press cake is more valuable as fertilizer than it is in charcoal making.

2.3 Jatropha cultivation globally

The biofuel world market is steadily growing as more and more countries want to participate because of environmental and security aspects (International Energy Agency (IEA) 2004, 25-31). The amount of ethanol compared to the biodiesel produced in 2002 was 21,841 million liters to 1,503 million liters. The production of biodiesel gives a lot more employment than the production of fossil fuels, when the biofuel production requires 100 times more workers. In India and China the Jatropha oil production is growing rapidly, and although the soybean, rapeseed and palm oil are the biggest ones for production of biodiesel, the Jatropha shows the highest growth rates. In 2005 there were 3,524 million liters of biodiesel produced, compared to 1,503 million liters in 2002 (Muok & Källbäck 2008, 4-5).

Jatropha can be grown from 30 ºN to 35 ºS (see Figure 3). In many countries the Jatropha plant has been planted on a large scale through planting programs as it was promoted to be a biofuel crop with low agro-ecological demands. Most of these plantations are still in the pilot stage, and it is estimated that the total world area covered with Jatropha is about 100,000 hectares. It is assumed that India alone will have Jatrophaplantations on an area of 10 million hectares by 2030, both small-scale and large-scale, mostly on reclaimed wastelands. In Africa the countries with the biggest development projects for Jatropha for biodiesel production are Tanzania, Mali, Madagascar, Burkina Faso, Zambia, Ghana and Malawi. The total length of Jatropha hedges in the tropical regions of Africa is estimated to about 75,000 km, which could be yielding about 60,000 tons of seeds annually. In remote areas small-scale production and use of biodiesel from Jatropha is more promising than many of the predictions (Muok & Källbäck 2008, 4-5).

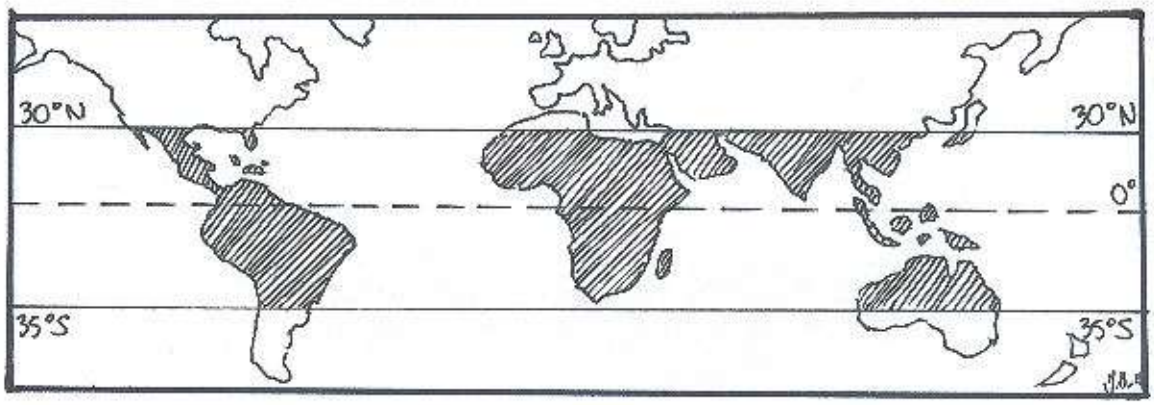

Figure 3. Jatropha can be grown between 30ºN and 35ºS

2.4 Jatropha cultivation in Kenya

The Jatropha plant seems to have been introduced to Kenya about a century ago (Muok & Källbäck 2008, 15) and has been grown in Kenya for many decades, but for other purposes than for bio-fuel production (GTZ 2009, 9). In 2009 GTZ (2009, 51) found Jatropha plants of 30 to 50 years or more wild or as fences in, for example, Nyanza Province, Rift Valley Province, Central Province, Eastern Province and in Coast Province. In the same research they also got information about the fact that Jatropha was used for medicinal purposes in Nyanza Province,

it was planted as a fence to keep elephants away in Eastern Province and in about the year 2000 Jatropha was planted in western Kenya as support plant for vanilla veins.

Kenya has no locally produced fossil fuels, and the import of huge amounts of fuel gives the country large costs every year. This is why Kenya needs to encourage wider adoption of renewable energy technologies (Muok & Källbäck 2008, 6-7) such as e.g. Jatropha production. GTZ (2009, 9) writes, that Jatropha has become known as a biofuel feedstock only in the past few years, and that especially smallholder farmers began planting the Jatropha, a plant promoted by many NGOs, without much information on either cultivation, management requirements or market for the seeds.

Kenya faces great problems with deforestation, desertification, soil erosion, degraded water quality and water shortage, domestic and industrial pollution and poaching. The Jatropha can be planted in most of the semi-arid areas, and in the agro-ecological zones III-IV in Kenya. It controls land degradation, reverses deforestation and also sequester carbon. Growing of Jatropha also increases the land cover, which is badly needed in the arid and semiarid lands (ASALs) in Kenya. Jatropha production may also play a role in controlling the rural urban migration through employment creation in the ASALs, which is 80 % of Kenya's total land mass and hosts 10 million people and 70 % of the land's livestock herd. (Muok & Källbäck 2008, 6-9).

In 2000 the Government of Kenya (ref. Muok & Källbäck 2008, 12) gave the following restrictions for where it is allowed to plant Jatrophas:

- there should be no threat to food production and no competition with food crops
- it should be planted mainly in areas with an average annual rainfall of 300-1500 mm
- the temperature should be between 20ºC to 32ºC
- the soils should be alkaline and low-fertility
- the altitude is to be between 0-1500 m above sea level.

In Kenya the Jatropha plant is now mainly grown in Thika, Kitui, Malindi, Nyanza, Namanga, Nakuru, Naivasha, Marakwet, Kajiado, Meru and in the coastal regions. About 3,860 acres were under Jatropha cultivation in Kenya in 2008 (Muok & Källbäck 2008, 16).

A research done by GTZ in 2009 (7) shows that the Jatropha yields in Kenya are much lower than has been reported in the literature. The claims that Jatropha has low nutrient requirements, is drought-tolerant, grows well under saline conditions and is tolerant or resistant to pests and diseases are shown to be incorrect for high oil production (Jongschaap, Montes Osorio, de Ruijter & van Loo 2010, 5-6). The results of the GTZ research show that a small Jatropha farm (1 acre) practicing monoculture or intercropping will not get any profit for at least the first ten years, assuming the selling price for seeds is 15 Kshs. per kg (GTZ 2009, 8, 47). The growing of Jatropha as a fence starts giving a profit after about three to four years, it is a sound investment for the farmers while it also serves as protection against wild animals and it is also no threat to food production (GTZ 2009, 8, 47-48, 131).

Based on these research findings GTZ (2009, 10, 131) conclude by saying Jatropha production in Kenya for now is uneconomical and they do not recommend smallholder farmers to start growing Jatropha as monoculture or intercropped with food crops until more research is done. The only form of Jatropha growing they can recommend for now is the fencetype. Also the Kenyan magazine *The Organic Farmer* Nr. 67 in December 2010 writes that the Kenyan Forestry Research Institute (KEFRI) and the World Agroforestry Centre (ICRAF) now have advised the Kenyan government to stop the promotion of Jatropha, as the Jatropha plant has little value when grown in plantations or as a single cash crop (Baumgartner & Kamau 2010, 8). Muok and Källbäck (2008, 51-53) writes more positively that there is a potential for biodiesel industry in Kenya, and that the expansion and development of the biodiesel industry would have positive development impacts on the economy, the people and the environment in Kenya. Important to remember is, that there is a great difference in talking about Jatropha production as a biodiesel crop and talking about the benefits for small-scale farmers growing Jatropha.

3 Cultivation of *Jatropha curcas* L.

3.1 Climate requirements

The Jatropha plant has been promoted as a high-yielding plant that can grow on any soil, and with very low requirements on amount of water, nutrients and management. The truth is that to grow well and to give high yields the Jatropha plant needs enough water, the right temperature and altitude, and also the soil type has to be right (Jongschaap *et al*. 2010, 1-6). The amount of annual rainfall Jatropha needs to survive is 300 mm according to Ouwens *et al*. (2007, 4) and 600 mm of annual rainfall is a minimum for producing fruits, but with these rain amounts it will also grow slowly and give poor yields. The Jatropha plant is drought-resistant, it can survive without water for a period of over one year (van der Putten 2010, 4), but in this time the plant sheds its leaves and no flowering or fruiting occurs (Brittaine & Lutaladio 2010, 27). After about one month of drought the plant starts inducing flowers. The optimal annual rainfall is 1 000-1 500 mm, but if it rains more than that the Jatropha will have huge problems with fungi and other diseases, and the roots might rot. The ecological conditions determine the length and the degree of injury of pests and diseases (Ouwens *et al*. 2007, 2-4).

3.2 Soil

The soil should be well-drained with an open and wellaerated structure. Sandy and loamy soils are most suitable, while claysoils are unsuitable for growing Jatropha on (Ouwens *et al*. 2007, 3). Franken (2010, 9) says that heavy soils like clay, clay loam, sandy clay, silt and silt clay loam can be used, but only if it is a very dry region, and there are no heavy rains in the area. The Jatropha plant dislikes permanent wetness, and waterlogged soils should be avoided (Ouwens *et al*. 2007, 2). Very light soils like sand, sandy loam and loamy sand, which dry very fast, require high organic matter application and application of nutrients (Franken 2010, 9). The soil should not be too acid or alkaline, and the pH value should range between 5.5 and 8.5 (Ouwens *et al*. 2007, 3; Franken 2010, 9).

3.3 Propagation

There are some genetic variations in different provinces in the world. Natural genetic variation is largest in the centre of origin: in Central America and in northern South America. Also the same seed source can give plants with morphological variations, for example differences in seed production. It is not known if this is caused by genetic or environmental factors. Therefore, it is very important to make a selection of high quality seed material for propagation. The seed should be selected from high-yielding provinces that have agro-ecological conditions similar to where you are planning to plant. You should select the largest and heaviest seeds with a moisture content of about 7 %, the seeds should be young (not over 6 months old), and they should have been stored cool, dark and dry. (Franken 2010, 13-14).

Propagation can be done through direct seeding in the field, by germinating the seeds in a nursery, by planting cuttings or by micro propagation (Benge 2006, 4; Franken 2010, 13-14). The most common way is to germinate the seeds in nurseries or in the field (Franken 2010, 14-16), and to propagate the seeds with seed treatment in a nursery or by direct seeding is recommended by Ouwens *et al.* (2007, 5). The germination takes 7-8 days if the humidity is right and the average temperature is > 25°C, if it is cooler the germination takes a few more days. The seeds that have not germinated in 10 days should not be used for the Jatropha plantation.

The advantages of direct seeding are optimal root development and very low costs while the disadvantages are that the young plants are often eaten by animals (the content of toxins in the seedlings for the first months is very low), the field should be free from weeds competing with the seedlings, and enough water is needed in the first three months for good growth. To germinate the seeds in a nursery is good from the point of view that the conditions are optimal and easily controlled, it is easy to remove plants showing abnormal growth and the plants are strong when transplanted to the field. The disadvantages are poor root development of the plants that are over one month old in polyprophytene bags, that pests and diseases spread very easily in a nursery and it requires more work and higher costs to transplant the plants to the field than it is to do direct seeding. To

germinate the seed directly in poly-bags (see Figure 4) also gives less work and is therefore less expensive than germinating in seedbeds and then transplant into the poly-bags. Germinating the seeds in seedbeds saves work and money compared to transplanting the seedlings into poly-bags (see Figure 5). (Franken 2010, 14-16).

Figure 4. Jatropha seedlings germinated in polybags

Figure 5. Jatropha seedlings germinated in seedbeds

The fastest way to develop high-yielding varieties is by propagation with cuttings (Benge 2006, 4). Nielsen says (ref. to Franken 2010, 16) that cuttings are fast growing, they are cheap if you already have Jatropha plants and they are clones of the mother plant. The risks connected with clones are that they are more susceptible to insect and disease infections (Benge 2006, 4). Another disadvantage is that the cuttings do not make a tap root, which means that the plant cannot access water and nutrients at deeper levels in the soil, and the plant is therefore not very drought-resistant (Benge 2006, 4; Franken 2010, 16). Because of the lateral roots Franken (2010, 16) recommends cuttings only for living fences, while Benge (2006, 5) notes that the lateral roots will compete with other nearby crops about water and nutrients. Using micropropagation you can produce a large number of plants with genetically desired characteristics that the chosen mother plant had. The problem with micro propagation is that the small plants need hormonal stimulation to induce the growth of vertically growing roots and not only laterally growing roots. Micro propagation also requires sophisticated technologies and chemicals, and this procedure with all the materials required for the process makes it very expensive. (Franken 2010, 16-17).

3.4 Planting

Before planting weeds need to be removed and planting holes dug. Planting holes should have been dug and made ready already before the rains (Franken 2010, 11), and tools like axe, *jembe/hoe* or *panga* (machete) can be used (GTZ 2009, 43). Gagnaux (2009, 34) reports that Jatrophas planted at the end of the rainy season have more problems with pests and diseases than if planted at the rain season's beginning. If irrigation is available, the planting can be done also in the dry season. The Jatropha plant needs water for a minimum period of three months after planting (Franken 2010, 12).

Weeds can be removed by hand or mechanically by plowing with a tractor. The planting holes should be at least 30 cm wide and 45 cm deep, and re-filled with soil and organic matter at a ratio of 50:50. It is recommended to add 10-20 grams of common NPK fertilizer (ratio 6:6:6 – 15:15:15) or 0.5 kg of manure per planting hole before planting. (Franken 2010, 11).

The recommended spacing for a Jatropha monoculture is 3 m x 2.5 m. This makes 1 333 plants per hectare (533.2 plants per acre), and it enables intercropping with food crops for the first few years of cultivation. A wider spacing leads to taller and larger trees, which need more intensive pruning to be low enough to harvest easily. Shorter spacing like 2.5 m x 2.5 m and 2 m x 2 m also requires more intensive pruning so that the plants do not grow into each other. With this spacing also better water and nutrient supply is needed. If you plan to do permanent intercropping with food crops you need a wider spacing. It is recommended to make rows with a plant spacing of 2.5 to 3 meters in the row, and a distance of about 4 m between the rows. With 4 m spacing between the rows it is possible to use a tractor (tractor 2 m and 1 m space for the *Jatropha* plants on each side). If you plant your *Jatrophas* as a living fence the recommended spacing is 25 cm in the row. You can use one or two rows, and between the rows the spacing should be 50 cm (Franken 2010, 11-12).

GTZ (2009, 38) reports that 40 % of the small scale Jatropha farmers in Kenya uses a plant spacing of 2 x 2 m, and 14 % use 3 x 3 m spacing. In Kutui in Kenya a plant spacing of only 1.5 to 2 m is used (Tomomatsu & Swallow 2007, 11).

3.5 Yields

The seed yields of Jatropha depend on many different factors, like the genetic material used for propagating the Jatropha plants, the agro-economical conditions, the amount of nutrients and water (Rijssenbeek 2010, 29-32). Franken (2010, 22-23) writes that Jatropha seed yields can differ between 250 and 6 000 kg per hectare per year, depending on water supply and soil fertility. The most normal yield is assumed to be between 500 and 3500 kg/ha/year. For example in Zimbabwe it is estimated that up to 400 g per shrub per harvest can be achieved, of course depending on the management (Tigere *et al*. 2006, 7-8). A research done in India on the effect of N and P fertilizations on the Jatropha yields show that the Jatropha seed yield is significantly influenced by N and P_2O_5 fertilization, and that fertilization of Jatropha promotes growth and yields (Patolia *et al*. 2007, 7-8). Jatropha yields increase with age (Ouwens *et al*. 2007, 2).

4 Management of *Jatropha curcas* L.

4.1 Irrigation

Franken (2010, 20-21) writes that irrigation can increase yield. The first rainy season is said to be long enough to give good yields, but the second rainy season is too short to give a yield. If irrigation is used to extend the second rainy season, it can increase the yield to 1,500 kg/ha (600 kg/acre). An irrigation system is very expensive to install, according to Franken (2010, 20) the cost of installation is at the very lowest 40,000 Kshs (400€) per hectare (or 16,000 Kshs (160€) per acre), and plus this comes the operational costs of about 30-40 Kshs (0.30-0.40 €) per mm per hectare, or 12-16 Kshs (0.12-0.16 €) per mm per acre. Of course, there has to be a good source of water even to consider this alternative.

For Jatropha production on a small-scale an irrigation system seems to be far too expensive, it does not give enough profit and for many small-scale farmers water is not available in such quantities that an irrigation system would be possible. In Kenya the small-scale farmers use mostly a free source of water for irrigation, and the watering is done mostly by hand (GTZ 2009, 39-40). In the GTZ research in

2009 hundreds of small-scale Jatropha farmers were interviewed and it came out that only about 50 % watered their plantations for some months after planting, and that only about 25 % continued watering after the first months. The irrigation rate was the highest for intercropped Jatropha plantations (40 %), medium for monoculture plantations (21 %) and the lowest for the Jatropha fences (10 %) (GTZ 2009, 39-40).

A survey done in Mozambique in 2009 showed that where the annual rainfall is between 600 and 800 mm and no constant irrigation is done, the germination rate is very low and the plants are more prone to disease, chock and stress. The conclusion of this was that irrigation is necessary in Jatropha plantations when the annual rainfall is only 600 mm and recommended when the annual rainfall is 800 mm. (Ribeiro & Matavel 2009, 40).

Franken (2010, 21) concludes by stating that irrigation makes sense only in show gardens, in production for special purposes, such as getting high-quality seeds for propagation, for scientific experiments, for plant breeding or in clonal gardens.

4.2 Plant nutrition

The Jatropha plant needs nutrients to grow to full size and to produce seeds (Franken 2010, 17). Mc Lea (2009, 20) says that nitrogen (N) is to be given at the beginning of the growing season, and potassium (K) should be given before flowering, while it has been proved that K plays an important role in the flowering. Franken (2010, 17) recommends building up the plant architecture in the first four years with NPK fertilization for roots, stem and leaves, and also for flower and fruit production, (see Table 1).

Table 1. The amounts of nutrients needed during the 4 year long establishment phase

Year	**1**	**2**	**3**	**4**	**Total**
Annual need	Kg/ha/year	Kg/ha/year	Kg/ha/year	Kg/ha/year	**For 4 years**
N	23	34	69	103	**229**
P_2O_5	7	11	21	32	**71**
K_2O	34	50	101	151	**336**

(Rijssenbeek ref. Franken 2010, 18)

After the first four years the nutrients should be there for maintenance of the plant and for fruit production. The nutrients removed during the harvest should be replaced, with for example fruit shells, husk from the oil production or residue from biogas production, to close the nutrient cycle. If these materials are put back into the field, hardly any fertilizer is needed. If these materials are not returned to the field, nutrients like nitrogen (N), phosphorous (P), potassium (K) and micronutrients have to be added. If the soil is very fertile, no fertilizers are needed. The amounts in Table 2 are based on Table 1 and the nutrient content of different fertilizers (Franken 2010, 18). For example goat manure has a manure nutrient concentration of 8.85 kg N/ton, 10.12 kg P_2O_5/ton and 10.66 kg K_2O /ton (Murphy 2006, 3). The requirements are based on sufficient N supply, and in general the other nutrients are enough if the amount of nitrogen is enough. The results in Table 2 fit poor soils (soils with only 50 % nutrients). Poorer soils need more fertilizers, soils that contain more nutrients need less fertilizing. (Franken 2010, 18.)

Table 2. Requirements of fertilizer during establishment phase based on the facts in Table 1 and the nutrient content of different fertilizers

Type of fertilizer	Y1	Y2	Y3	Y4	Total
Goat manure (t/ha)	2.6	3.8	7.8	11.6	**25.8**
Dry cow manure (t/ha)	5	6	12	18	**41**
Dry chicken manure (t/ha)	1	1.2	2.4	3.6	**8.2**
Vermicompost (t/ha)	1.2	1.7	3.4	5.2	**11.5**
Chemical fertilizer (16-4-16) (kg/ha)	140	210	430	640	**1420**
Urea (46% N) (kg/ha)	44	74	150	224	**492**

(Franken 2010, 18; Murphy 2006, 3.)

After the first four years the nutrient management should concentrate on seed production. When harvesting 1 ton of seeds the following amounts of nutrients are taken away from the field:

- 14.3-34.3 kg/ha nitrogen (N)
- 0.7-7-0 kg/ha phosphorous (P)
- 14.3-31.6 kg/ha potassium (K)

(Achten *et al*. 2008, 10).

If the press cake and the fruit shells are not returned to the field, the following amounts of nutrients need to be added to the Jatropha field to get a good yield (see Table 3) (Franken 2010, 18).

Table 3. Nutrients needed to replace the loss of 1,000 kg of seeds from a Jatropha field

Type of manure	**Amount needed**
Dry (solid) cow manure	7,000 kg
Dry (solid) chicken manure	1,300 kg
Vermicompost	1,650 kg
Chemical fertilizer (15-5-10)	220 kg
Chemical fertilizer (12-2-10)	270 kg
Urea (46 % N)	72 kg

(Franken 2010, 18.)

The optimal time for applying fertilizers is just before or during the start of the rainy season. The fertilizer is to be put in a circle around the plant with a maximum distance of 1 m from the stem. If an anorganic (artificial) fertilizer is used, the fertilizer should be mixed with the soil. It is better and more effective to use smaller amounts of anorganic fertilizers with a high frequency than to use large amounts with a low frequency. If large amounts of nitrogen fertilizers are used, it will lead to large NO_2 emissions. NO_2 is a greenhouse gas with a big global warming potential. If a lot of NO_2 is emitted, the Jatropha plantation does not reduce the carbon credits as it is supposed to do. (Franken 2010, 19).

If there is organic matter in the soil it leads to an enhanced cation exchange capacity (meaning that there is a lose binding of nutrients in the organic matter) and a better soil structure (Franken 2010, 19). The Jatropha plant responds positively to high organic matter contents in the soil, and applying of organic matter or organic fertilizer is therefore recommended (Ouwens *et al*. 2007, 3).

Mycorrhiza is a fungus living in symbiosis with plant roots. This fungus will increase the yields (Benge 2006, 4-5; Franken 2010, 19), because it taps organic substances (such as sugars and vitamin B), it makes nutrients available for the plant and also helps with the water uptake. It increases the water and nutrient uptake, and as a result the plant survives stressful conditions better (Benge 2006, 4-5). This fungus exists naturally, but never in plantations if not implemented there.

Usage of both mycorrhiza and fertilizer results in high yields and minimal nutrient losses (Franken 2010, 19).

A survey done by GTZ in Kenya in 2009 (40-41) shows that 50 % of the smallholder Jatropha farmers use some kind of fertilizer in their Jatropha plantations. Mainly organic fertilizers like manure and compost are used, 20 % use free organic fertilizers and 30 % buy it for about 1.1 Kshs/kg (compared to 60 Kshs/kg for chemical fertilizers). The average amount of organic fertilizer used was 1.87 kg per tree, and the very few using chemical fertilizers used mostly around 5 g per tree. In the survey it also came up that more organic fertilizing was applied in intercropped Jatropha plantations than in monoculture plantations. (GTZ 2009, 40-41).

4.3 Intercropping

The word intercropping means that you cultivate several different crops in the same field. An advantage of intercropping food crops with Jatropha is that the good management of the food crops also benefits the Jatropha plants. Intercropping requires enough water and fertilizer for both the Jatropha plants and the food crops while, for example, competition of water is very common if the field is dry. If the soil is poor in nutrients extra fertilizing is needed. It is also possible to intercrop Jatropha with fodder crops, but this is suitable only when the plants have grown big enough not to be disturbed by the grazing cattle. Do not intercrop Jatropha with cassava, because Jatropha is a possible host for several cassava diseases. (Franken 2010, 21).

The intercropping should start directly when planting the Jatrophas or when the Jatropha has established after about one month. Suitable crops for intercropping with Jatropha are annual or biannual crops that are low and do not shade the Jatropha plant. The management of Jatropha is very good when intercropping with food crops that give a yield in the first or second year. Examples of this kind of plants are beans, corn, peppers and peanuts. Legumes, like beans for example, are very good to intercrop Jatropha with, as the legumes are nitrogen-fixing plants and Jatropha is not. After about two years the Jatrophas should have grown big

and started to shade the ground, which means that intercropping is possible only with crops growing in total shade (Franken 2010, 21). Francis, Edinger and Becker (2005, 19) recommends intercropping with shade loving annuals like red or green peppers, grasses or tomatoes. When the Jatrophas have grown this big, there is also hardly any problems with weeds anymore either (Franken 2010, 21).

4.4 Weeding

Weeding is important to ensure the Jatropha plant's sufficient supplies of water and nutrients with no competition from weeds (GTZ 2009, 41). Nielsen says (ref. Franken 2010, 17) that the Jatropha plant can survive even overgrown by weeds, but if that is the case, the growth and the production of seeds will be minimal. The GTZ survey done in Kenya in 2009 (41) shows that 86 % of the small-scale Jatropha farmers weeded their plantations at least once a year, most of them weeded twice a year. Nielsen says (ref. Franken 2010, 17) that doing the weeding regularly is important, and that it is good to leave the weeds on the ground as mulch. The frequency needed for the weeding highly depends on what kind of weeds there are in the field. One good rule is that if the weeds start to shade the plants, or if the weeds grow as tall as the Jatropha plants, they should be removed right away. Because the Jatropha plants will grow big in about one to three seasons, weeding will not be a big issue after a couple of years when the plants shade the ground well (Franken 2010, 17).

4.5 Pruning

Pruning is done to remove the apical dominance, to stimulate lateral bud development (Mc Lea 2009, 23) to reach a large amount of branches where the fruits can develop, and to get a suitable plant size. It is important to keep the Jatropha plant low (about 2 m) and small, so that it will be easy to pick the fruits by hand, and so that there is no competition between the plants for nutrients, water, light and space. The goal of the pruning is to get many strong and lateral branches that can bear the fruit. In four to five years there should be about 200-250 lateral branches (Franken 2010, 19-20).

The pruning should be done only under dry conditions, because the plant is easily infected by bacterial, viral and fungal diseases when cut during the rainy season. A good time to prune is when the plant has shed its leaves, often meaning it is very dry. The cuts should be vertical so that the water runs off and does not get stuck, which easily happens if horizontal cuts are made. The first pruning should be done when the plants are at least 70 cm tall, which should be when the plants are around three to six months old. The plant should be cut vertically using a sharp knife at 30-45 cm above the ground, at 30 cm if the plant is small and at 45 cm if the plant is bigger. If the plant branches naturally there is no need to cut the main stem. The second pruning should be around one year after planting, when the plant has been showing good growth. The secondary and tertiary branches are cut down to one third of their length (2/3 is cut off). The third pruning is done about one year after the second pruning, and it is done in the same way as the second pruning was done. After this no more pruning is needed, because the plant now branches naturally. After eight to ten years it is recommended to cut the whole plant to 45 cm above the ground and then let it regrow. The regrowth will happen very fast because of the well-developed root system. The cut material can be left on the ground as mulch. (Franken 2010, 19-20).

According to the survey done in 2009 with small scale Jatropha farmers in Kenya the Jatrophas planted as fences were pruned much more often than the monoculture and intercropped Jatropha plantations, of which only 35-45 % were pruned 1-3 years after planting (GTZ 2009, 42).

4.6 Pests and diseases

The Jatropha plant was said not to have problems with pests or diseases – which is not factual: reports on pests and diseases on Jatropha from all over the world are increasing all the time (Nielsen 2010, 23). Problems with different insect pests, fungi, viruses, root rot, leaf spot and collar rot have been reported, and it is also a fact that the weaker the plants (because of lack of water and nutrients, poor soil) the more problems with pests they have (Ribeiro & Matavel 2009, 40). GTZ (2009, 28) reports that some Jatropha farmers in Kenya have very heavily infested plants

that have stopped producing leaves, flowers and fruits and remain in a state of stress.

In Africa, the biggest problem is the flea beetle (*Aphthona spp.*) eating the leaves and the larva penetrating the roots. Big problems with *Aphthona spp*. have been reported in Mozambique (Nielsen 2009, 72) and in different places in Sub-Saharan Africa (Mc Lea 2009, 28). There is the golden flea beetle and the yellow flea beetle (*Aphthona dilutipes*), which causes more damage than the golden flea beetle. The yellow flea beetle can damage a plantation to 100 % mortality, but have until now only been observed in Mozambique in Manica Province and in Malawi. Nielsen (2009, 72) reports that the red-brown flea beetle (*Aphthona sp. n. dilutipes*) has been found in Kenya (see Figure 6.). According to Sidumo (ref. Gagnaux 2009, 34) one way to get rid of the *Aphthona spp*. is to deep plow both after harvest and before the season begins. In this way the larvae might get physically damaged, or it ends up at the surface, where it dries out or is eaten by predators.

The leaf miner (*Stomphastis thraustica Meyrick*) has also been reported as a big problem in Jatropha plantations. The symptoms are brown leaf scars and cocoons on leaf veins (see Figure 7) (Shanker & Dhyani 2006, 162-163; Gagnaux 2009, 31-32). More pests and diseases on Jatropha are found in Appendix 1. Viruses are spreading very fast, and have become a big problem in, for example, India. In Africa, there are still not much viruses observed, and at least for now viruses are not a big problem there. The African Cassava Mosaic Virus could become a big problem if it is transferred by *Jatropha curcas*. For now it has only been reported on *Jatropha multifida* (Nielsen 2010, 24).

*Figure 6. The red-brown flea beetle (*Aphthona sp. n. dilutipes*) on Jatropha leaves*

*Figure 7. The leaf miner (*Stomphastis thraustica Meyrick*) has also been reported as a big problem in Jatropha plantations*

Grimm says (ref. Nielsen 2010, 24) that there is research going on about pest and disease control, but still there is no knowledge of the efficiency of various methods, also meaning there are no specific recommendations made yet. For small-scale farmers chemical pest control might be too expensive (Nielsen 2009, 72). Sidumo (ref. Gagnaux 2009, 35), for example, recommends preventive methods, locally available and organic pesticides.

Some preventative methods for avoiding problems with pests and diseases are to choose good plant material and to keep good hygiene. Choosing resistant Jatropha varieties would be a good way of preventing infections, but for now there is no systematic knowledge of resistant varieties. GTZ (2009, 28) report that Jatropha plantations in Kenya have a lot of pest problems especially during the rainy season, and a research done in Brazil shows that Jatropha planted at the end of the rainy season had more problems with pests and diseases than Jatropha planted at the beginning of the rain season (Nielsen 2009, 73), showing the time of planting affects the plant's tendency to have problems with pests and diseases later on. To disinfect the tools used for cutting and pruning before use is a good way of preventing diseases from spreading. It is advisable to use different tools for cutting or pruning Jatropha and cassava. Inspection should be done regularly, and infected plants should be taken away from the nursery or from the field. To minimize the damage on the Jatropha plants also helps the plants to keep healthy. Diseases and pests can be kept away also through wider spacing, like 3 m x 3 m, to have many small Jatropha fields separated from each other instead of one big field and through intercropping (Nielsen 2010, 24-25).

Some methods used for controlling pests and diseases on other crops are believed to work for Jatropha too, and experimentation is encouraged among the Jatropha growers to find local methods for controlling different pests and diseases. E.g. the Jatropha press-cake has pesticidal properties, and can be used on young seedlings, which have very low contents of toxins in their leaves (Nielsen 2010, 24-25). Sidumo (ref. Gagnaux 2009, 35) proposes organic pesticides like extracts from rubber tree and tobacco plant, and castor oil. In Appendix 3 more pests and diseases on Jatropha can be seen, as well as proposed pest controlling methods.

4.7 Harvesting

Harvesting of Jatropha seeds is done mainly by hand. This is because of the ripening characteristics of the fruits, in one bunch they ripen one by one. This makes it hard to find an easy way of mechanizing the harvest, and the hand picking makes the harvesting process very expensive. This again makes the prices of Jatropha oil very high. (Rijssenbeek 2010, 29-32).

Only the ripe fruits (yellow to brown) should be picked from one bunch at one time, while the oil content in the unripe, green fruits is much lower than in the ripe ones. An alternative to the expensive hand picking could be mechanized picking, but this option is still only under research. Different mechanical harvesting methods, because of increasing labor costs, are developing. Some techniques used for mechanical harvesting on other plants with similar fruit sizes are tree or stemshaking, use of nets, using strippers, robots with picking arms, vacuum cleaners or combinations of these methods and hand picking. In conclusion, the Jatropha plant gives low yield per hectare, the harvesting season is long, the fruit size small which requires handpicking causing high costs for both work and transport. (Rijssenbeek 2010, 29-32).

4.7.1 De-hulling of fruit

The word de-hulling means removing the fruit shell from the seeds. This is quite easy because of the shape, texture and size of the Jatropha fruits and no complicated technology is needed for this process. It is possible to do the de-hulling manually, semi-mechanically or fully mechanically. The manual way of de-hulling is highly time consuming, but it is easily maintained. The process happens in two steps: crushing and separation. The de-hulling process can be done both with fresh, yellow fruits and with dry, brown to black fruits. The fruits are put under pressure and friction to make the fruits open and the fruit shells to come loose. The advantage of crushing the yellow fruits is that they have a bigger mass, and are therefore easier to separate from the seeds. Separation of the seeds from the fruit shell can be done by hand with a sieve, for example, or mechanically with e.g. a rotating hollow cylinder. (Galema 2010, 32-35).

4.7.2 Drying and storage of the seeds

The transport of fresh seeds (not yet dried) is costly due to the higher weight, and therefore it is advisable and more beneficial to dry the seeds before transport. Direct sunlight has a negative effect on sowing seed viability, and therefore the seeds that are to be used for propagation should be dried in the shade. The drying area should be a concrete floor or simple agricultural plastic on the ground, the seed should not be dried in sacks. It is assumed that one seed needs 2 cm^2, which means that 1 000 seeds (which is 550-800 g of seeds) need a space of 0.2 m^2, and one kg of seed needs 0.25 m^2 (the average number of seeds per kg is 1,400). The seeds should dry until their moisture content is about 6 %, which is ideal when pressing the oil. How long the drying takes before this moisture content is reached depends on factors like temperature, sun, humidity and wind. (Galema 2010, 35-37).

It has been proved that the storage conditions affect the oil quality. Seeds for oil production need more dedicated storage conditions (to maintain a high oil quality) than the seeds for planting material need. For oil processing companies it is very important to get a continuous supply of seeds for pressing, and therefore it is important to know how to store these seeds right. Storage for more than eight months affects the oil quality and also the oil quantity, meaning storage for more than eight months should be avoided. Sunlight lowers the quality, the moisture content should be 5-7 %, and the storage should be properly aerated. The seeds can be stored in woven sacks, for example, in silos similar to those for storing maize. The seeds that are to be used as planting material should have a moisture content of 5-7 % when stored, and they are to be stored in a cool and dark place in containers that are not airtight. In tropical conditions, if the seeds are stored for 15 months or more, the viability goes down to below 50 %. At about 20ºC the seeds keep a good viability for about one year. The Jatropha seeds cannot be expected to be stored as long as the seeds from other common species because of the high oil content in the seeds. A good time for storage is about 7-8 months at the most, because the viability deteriorates after eight months. It is important to keep a low temperature in the storage. (Galema 2010, 35-37).

5 Material and methods

5.1 Background

The ECODE Jatropha project, funded by the Ministry of Foreign Affairs from Finland and carried out by Linnaseutu ry, HAMK University of Applied Sciences from Finland and Farming Sytems Kenya, started in 2008 in Baringo. The plant was introduced by Farming Systems Kenya in February 2008, and a Jatropha nursery was established in Baringo. Trainings on what kind of plant the Jatropha is, the use and utilization of the plant as well as nursery management, land preparation, planting, spacing, intercropping, water and nutrient management, weeding, pruning and pest management were held by Farming Systems Kenya starting in February 2008. In October 2009 the Jatropha introduction and training were started in Koibatek. In Figure 8 a map of Kenya and the locations of Baringo and Koibatek districts can be seen.

Figure 8. Baringo and Koibatek districts in Rift Valley Province, Kenya

The non-governmental organization Farming Systems Kenya, located in Nakuru, in Nakuru district, Rift Valley Province in Kenya is the employer that ordered this

research. During the period from the 13th of September 2010 to the 12th of January 2011 the data about the cultivation and management of Jatropha curcas L. was collected in the villages Kimoigut and Kitecho in Baringo and Koibatek districts, Rift Valley Province, Kenya. To avoid mixing the names up I am going to call them by the district names Baringo and Koibatek. Questionnaires for interviews and forms to fill in during the farm visits were made specifically for this research.

Farming Systems Kenya is working with smallholder farmers through different projects with the goal to reduce poverty through agricultural development, and the organization was formed through the initiative of the Africa Inland Church, Nakuru Region Lay People Fellowship of Nakuru Region Church Council in 1981. About 80 % of the farming communities in Kenya are smallholder farmers. In their work a suitable way of raising income for the farmers is found for every case as can be seen by the many different projects they undertake: for example, projects concerning food crops, greenhouses, water and sanitation, biogas, dairy goats and dairy cows, micro credit and HIV/AIDS positive people.

5.2 The climate conditions, soil type and the weather

The climatic differences between the two research areas can be seen in Table 4 below. No data on the climate conditions and soils in the specific rural villages was to be found, besides daily rainfall data from the last two years in Koibatek. No measurements on temperature or rainfall in the villages were done during the few months of data collection, and also no soil samples were taken. The data this chapter is based on was collected in the 70s from entire districts (Jaetzold & Schmidt 1983, 282-299), i.e. the actual climate condition and soil types in the villages can be quite different from the numbers presented in the table.

Table 4. Climate conditions and soil types in Baringo and Koibatek

	Baringo	**Koibatek**
Location	Kimoigut, Baringo District, Rift Valley Province	Kitecho, Koibatek District, Rift Valley Province
Latitudes	between 0^o and $0^o30'N$	between 0^o and $0^o30'N$
Longitudes	between $35^o30'E$ and 36^oE	between 36ºE and 36º30'E
Altitude	about 1500 m above sea level	about 1000 m above sea level
Annual rainfall	650-800mm	700-900 mm
Average temperature	15.7^oC - 33.7^oC (absolute minimum temperature: 10.2^oC)	18^oC - 28^oC
Agricultural zone	LM 5 (Lower Midland zone)	UM 5 (Upper Midland zone)
Soil type	clay loam	clay
Soil classification	lithisols and xerosols	vertisol or a solonchak

(Jaetzold & Schmidt 1983, 282-299)

The annual rainfall in the 60s and the 70s was around 650-800 mm in Baringo, and 700-900 mm in Koibatek (Jaetzold & Schmidt 1983, 283). Today we assume the rainfall is around the same, but with quite big annual variations. The Kenya Meteorological Department in the Ministry of Environment and Mineral Resources in Nakuru have a station measuring the daily rainfall in Koibatek, and from there we got data on the daily rainfall from November 2008 to December the 16th 2010 in that specific area. The annual rainfall in year 2009 in Koibatek was 627,8 mm, with a monthly average of 52.3 mm. In Figure 9 below the monthly rainfall variations in Koibatek in 2009 and 2010 are shown. In 2010 the information reaches the 16th of December, i.e. the data of the whole year is not complete, and the average could differ a little from what it now shows. The annual rainfall in 2010 in Koibatek was 1581.1 mm, with a monthly average of 131.76 mm. The annual rainfall difference in 2009 and 2010 is quite big: from 627.8 mm one year to 1581.1 mm the next year. This shows clear annual variations in the annual rainfall. Also

according to the inhabitants in Koibatek the year 2010 was an abnormally rainy year, year 2009 “normal” and 2008 abnormally dry.

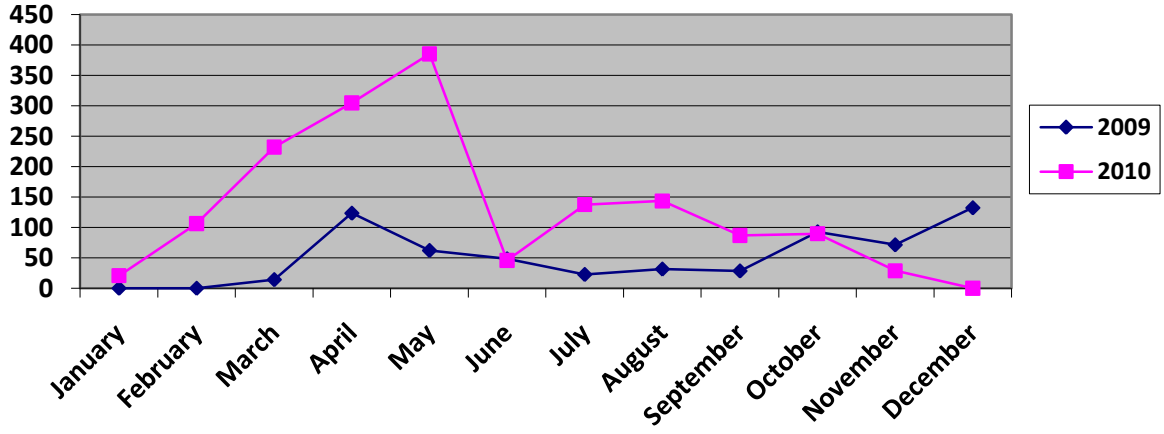

Figure 9. Monthly average rainfall (mm) in Koibatek in year 2009 and 2010

Before the year 1976 the average temperatures in Baringo were annually between 15.7^{o}C and 33.7^{o}C with an absolute minimum temperature of 10.2^{o}C (Jaetzold & Schmidt 1983, 284). Although the global warming affects our climate today, it is assumed the average temperatures are quite the same. No specific data on temperatures was found at Koibatek, but the inhabitants assume the temperature varies between 18^{o}C and 28^{o}C on average in a year, but both lower and higher temperatures can occur.

The agricultural zone in Baringo District is LM 5, meaning Lower Midland zone, and in Koibatek District UM 5, or Upper Midland zone. The characteristics of the LM 5 is the weak and very short cropping season, which is followed by another, even shorter cropping season and intermediate rains. The UM 5 characteristics are a medium to long cropping season and intermediate rains. The area in Baringo District can also be classified as a livestock-millet zone, based on which crops are most commonly grown and other sources of income in the area. Koibatek District is a livestock-sorghum zone. (Jaetzold & Schmidt 1983, 288-295).

The soil in Baringo District is a variable, shallow soil with steep slopes, which is also marked as unsuitable for cultivation. This soil is developed on undifferentiated Teritary volcanic rocks, like olivine basalts, rhyolites and andesites. This soil type is mostly well-drained, shallow, friable, rocky or stony and strongly calcareous.

The color is dark reddish brown, and the soil type clay loam, i.e. in many places it is saline. Saline means the main soils are lithisols (with rock outcrops) and xerosols (from the bouldery and saline phase). The soil in Koibatek District is classed as a soil on bottom lands, which has developed on infill from undifferentiated volcanic rocks. The soil fertility is moderate to high, but the soil is also shallow. The soil is imperfectly drained, deep, firm to very firm clay soils with varying calcareousness, salinity and sodicity, making it crack easily. The soil is undifferentiated vertisol or a solonchak, and the color of the soil is dark brown to olive grey. (Jaetzold & Schmidt 1983, 296-299).

5.3 Choice of method

To get information on the cultivation and management of the Jatropha plantations in Baringo and Koibatek Districts I decided to interview some Jatropha farmers and to visit their Jatropha plantations for making my own observations. I started by writing down topics I wanted to ask about, which resulted in a questionnaire (see Appendix 2). The education level of the interviewees is not very high and not many of them speak English. The whole interviewing process was also new to them, and as I did not want to scare them off by bringing the three page document I decided to write the topics down and to use open questions in the interviews instead. This method was also chosen to make the farmers feel more comfortable and confident enough to tell freely about their experiences and the farming, without getting locked and leaving out important information.

This interviewing method is called a half-structured interview, meaning all the interviewees are asked the same questions, and then the interviewer “controls” the substance of the question to ensure getting information on the chosen topic. In a half-structured interview the questions are “open”, i.e. the direction and character of the answer is open, like in the questions “What are your expectations on growing Jatropha?” and “How have you been weeding your Jatropha plantations?” The interviewer also has the possibility to ask follow-up questions, called exploratory questions, on something that the interview normally does not include if something interesting comes up. In this way the interviewer will most likely get

more information than when using a strict questionnaire or recording schedule, using closed questions. (Gillham 2008, 103 & 115).

Information from the Jatropha field visits was collected with the help of a form (see Appendix 3), where the average condition of the plantation was evaluated and documented. Ten plants were examined and the information was documented. The form was used to make sure the same kind of information was collected on every farm. The ten plants were chosen by me, and because the variety in plant number, plantation size and also plantation form (square, hedge, a long narrow area) was huge I did not use any strategy for choosing the plants randomly. Instead I tried to choose both from the smallest and the largest plants, and also from what looked like the average plant size, to get a good picture of the varieties in the plantations.

5.4 Choice of respondents

Farming Systems Kenya is working with all in all 61 farmers growing Jatropha in Baringo and Koibatek, and out of these I chose to interview 20 farmers: 11 from Baringo and 9 from Koibatek. Out of these 15 were women and 5 of them men, and the age of the farmers was 28 to 50 years with an average of 36 years. The percentage of participation was 33 %, which is enough to tell the average.

The choice of respondents was mainly based on the location of the Jatropha farms. This method of choosing respondents was used because of the tight time schedule: by choosing farms close to each other and farms as close as possible to the road or the center of the village I saved a lot of valuable time.

5.5 Realization

Questionnaires (see Appendix 2) for the interviews and forms for the farm visits (see Appendix 3) were made, checked and approved by Farming Systems Kenya. Together with the staff from Farming Systems Kenya a monthly schedule was made to make sure all the information would be collected during the four-month period. Other trainings were going on in the Baringo and Koibatek communities,

meaning the interviews with the Jatropha farmers and the farm visits were done at the same time as the other trainings. One or several community members were guides or translators during the interview process and the farm visits. The two teams, my “Jatropha team” and the team for other trainings, were sharing the car for the approximately two-hour drive to Baringo or Koibatek. All in all about 15 visits to Baringo and Koibatek were done between the 7th of October and the 17th of December 2010.

Figure 10. Often a translator was needed when doing the interviews

Figure 11. On a farm visit checking the plantation

The Jatropha farms I visited were owned by the farms I interviewed. One or several community members guided me to the farms, in Baringo on foot and in Koibatek by car. Because of the heavy terrain and the fact that the farms were located very far from each other, the farm visits took quite some time to do.

In the farms the average condition of the plantation was checked, including plant growth in relation to the age of the plantation, how the intercropping was done and the occurrence of weeds and pest and/or disease symptoms. Also the soil type was described as well as possible, although no soil analyses were done. The form made especially for these farm visits (see Appendix 3) was used, and ten plants were selected to fill in this form (see Figure 11). The plant height, the number of branches and branching branches were counted and the size and colour of the leaves were checked. Also the occurrence of flowering plants and pruned plants among these selected ones was observed, and if the plant already was giving fruit the number of branches with fruits were counted. Also the number of fruits per

plant, the number of fruits per branch and the number of fruits per plant were counted.

5.6 Ethics

Good ethics is important when using interviews in a research. The interviewer has responsibilities to the interviewees, and is obliged to gather and to use the information correctly and truthfully. Good ethics includes that the interviewer presents himself/herself as a researcher, and informs the interviewee about the purpose of the study in detail. It is important for the interviewee to know what is going to be asked, what kind of information the interviewer is looking for and also how the information is going to be used. (Gillham 2008, 29-31).

In ethically and legally correct interviews confidentiality, anonymity, security and publicity concerning the interviewee and the data collected are discussed with the interviewee before the interview starts. The interviewer has, of course, to show respect and courtesy concerning gender, ethnicity, social class, culture and religion of the interviewees. Protection of personal data like gender, marital status, age, occupation, number of children and source of income is important, and this data should preferably be gathered before the interview begins. (Gillham 2008, 33-37).

All the interviewees were aware of the fact that this research was going on in their villages, and agreed to participate in the research. Before the interview I presented myself, informed them about the purpose of the study and where and how the information given was to be used. They were also informed about what kind of information I was looking for, such as, for example, the cultivation and the management. The very first questions were about personal data, but before asking them these questions I assured them that this information was only to be used as average information, and that every one of them would be completely anonymous. During the interview I also tried to be as neutral as possible with regard to religion, sex and culture.

5.7 Data analysis

The data analysis is a process involving selection and interpretation. For example, the semantic properties in the human voice, like emphasis, tone and pace, cannot be seen in the text if the interviewer does not interpret these differences in the voice. Because the interviewer in one way or another selects the data for analysis and also interpret the data in his/her own way, it is important to be methodical when doing the analysis. There are different kinds of computer software for analyzing data, but the major weakness is that these programs are not able to interpret important keywords in the way we humans can. (Gillham 2008, 165-166 & 172-174).

A narrative overview and category analysis means that the data is put into different categories, but also the context is taken into account. A qualitative analysis tells what the interviewees have said in free text, while the quantitative analysis put the given data into numbers, tables or graphs, and in that way “changes” some of the data at the same time as it adds something to the analysis. (Gillham 2008, 171, 197 & 207).

For analysis of the interviews I have done both a narrative overview and a category analysis for a start, and then I analyzed the data using the qualitative analysis method. After this I used the quantitative analysis method for some of the data, and the quantitative analysis method was also used for analyzing most of the data collected in the field.

6 Results

6.1 Average information about the farmers

Most of the farmers interviewed called themselves farmers, and their main income is farming and animal keeping. Some also got their income from their salaries as teachers, from the husband’s income, from small jobs, burning charcoal, beadwork and from beekeeping. The level of education varies between finishing grade two to

eight in Baringo and no education at all to graduating from college in Koibatek. The average education level was finishing standard five.

The owned land was between one and five acres in Baringo (not including graze lands) and 5 to 60 acres in Koibatek (including grazing lands). The cultivated land varied between half an acre and five acres with the average two acres.

In Figure 12 the food crops grown in the villages are presented. Maize is most popular in Koibatek, while millet is more grown than maize in Baringo. The biggest difference between the crops grown in the two villages is that in Baringo they grow more millet and sorghum, which are very drought-resistant, and in Koibatek they grow more maize, beans, vegetables and fruits that need more water.

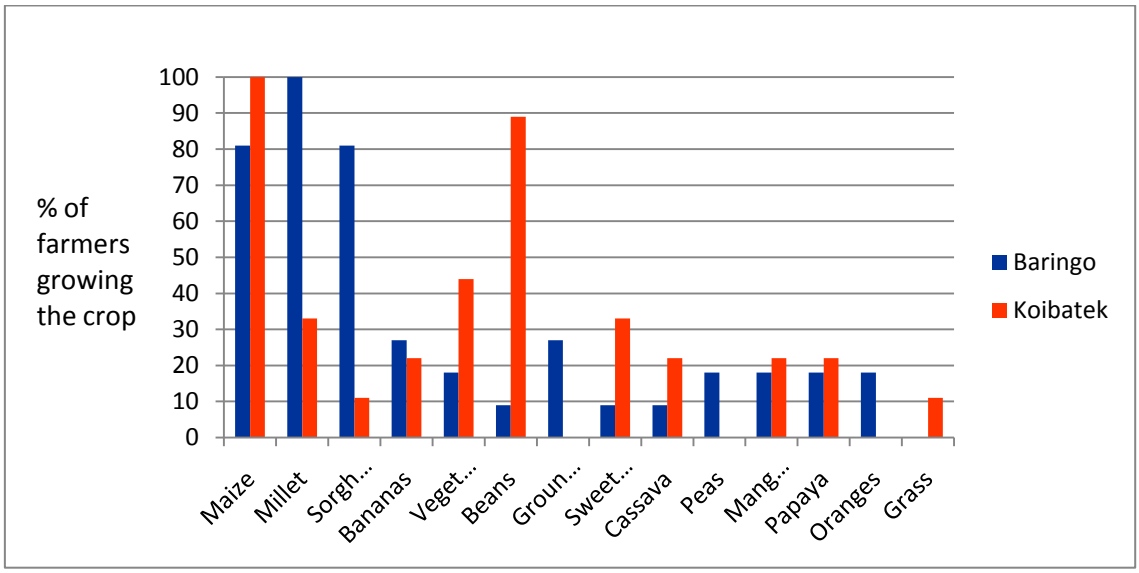

Figure 12. Percentages of different crops growing rates in Baringo (n=11) and Koibatek (n=9)

The livestock herds in Baringo and Koibatek are presented in Figure 13 and Figure 14. We can see that in Baringo they have mainly goats, and just a few cows and chicken. Where the star (*) in Figure 13 is the farmer actually has 300 goats and not only 50, but I chose to show it as only 50 in the table, because it is easier to look at in this scale. Also it is very rare for a farmer in Baringo to own 300 goats: most of the farmers have between 10 and 50 goats and the average is about 40 goats. In Koibatek it is more common to keep cows, chicken and sheep than in Baringo. The average livestock herd for a farmer in Koibatek is about 9 cows, 16 goats, 8 sheep and 14 chicken.

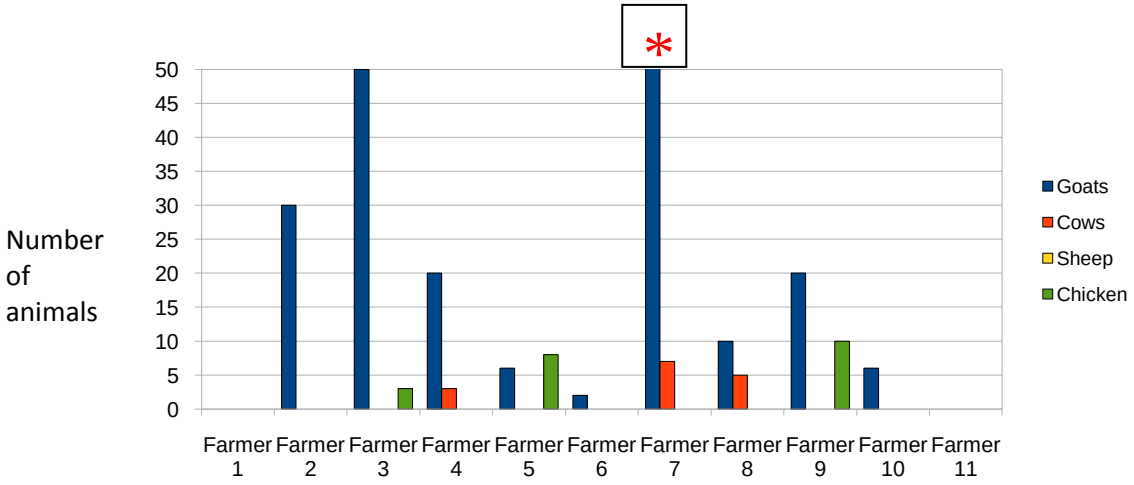

Figure 13. Livestock in Baringo, number of animals per farmer

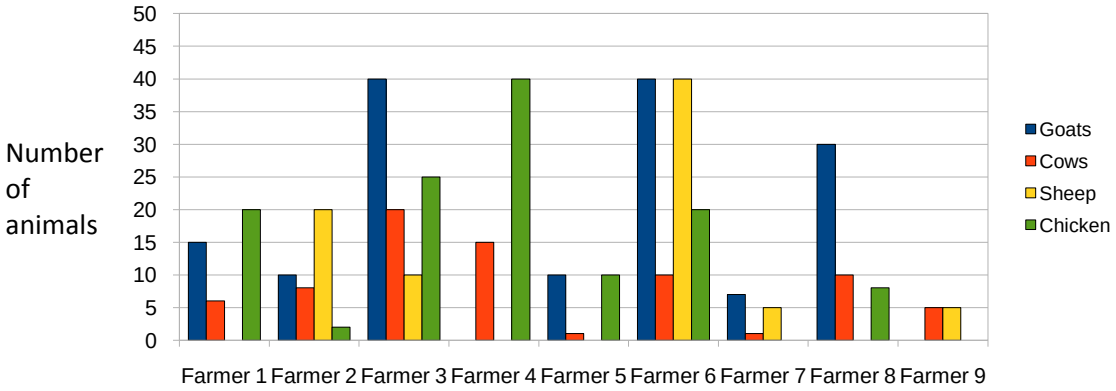

Figure 14. Livestock in Koibatek, number of animals per farmer

6.2 Introduction to and knowledge of the Jatropha plant

The Jatropha plant was new to all the farmers in both Baringo and Koibatek at the time Farming Systems Kenya introduced the plant. The farmers interviewed were not quite aware of when the plant had been introduced in their community, and everything from February 2008 to late in 2009 was among the answers. Of course, the plant was introduced in the two communities at different times, and some of the farmers might also have been away from some trainings and the time of hearing about the Jatropha plant can therefore differ very much from farmer to farmer.

Regarding the questions about what the farmers know about the Jaropha plant it came out that all of the farmers knew it is an oil producing plant. All of them also

knew you get an income from the Jatropha plants, and the different ways of getting an income mentioned by half of the group were selling the seeds, selling the oil and then saving money and time when using the oil for cooking and lighting at home instead of using paraffin, charcoal or fire wood. Half of the group knew the oil can be used for running engines. Some of the farmers also mentioned selling seedlings, soap-making, selling seed press cake and increased honey production with the help of the Jatropha flowers as a source of income. One out of 20 was not sure of exactly how the plant brings income.

Other uses mentioned besides use of the oil was the use as a living fence, that the fruit-shells can be burned, the husk can be burned or used as manure, and also the leaves are a source of manure. One comment was also that the Jatropha plant is good for the environment in several ways, for example, for preventing soil erosion, and that it will reduce poverty in the area. Some of them had noticed that the Jatropha plant needs enough water, some fertilizer and pruning to grow well, to branch and to produce flowers early. One comment was that it needs pesticides because of the problems with pests they have.

6.3 Planting

Planting of the Jatropha seedlings in the farms in Baringo started in March 2009 but most of them planted from January to April 2010. In Koibatek the planting took place from March to May 2010. All of the seedlings were taken from the nursery that was established in Baringo in 2008. The farmers planted between 50 and 1 000 plants, with an average of about 500 plants. As land preparation most of them cleared the land first – in Baringo by hand and in Koibatek some used a tractor for plowing the land – and then dug the planting holes. Some of them only dug the holes, because they were planting in an already cultivated field. The size of the planting holes varies between 20 and 70 cm deep (average 45 cm deep), and the diameter from 20 to 50 cm with the average 35 cm (see Figure 15). Two farmers had built terraces in their Jatropha fields, and three farmers out of twenty had put manure in the holes before planting. One of them also watered with 60 liters of water per planting hole before planting the seedlings.

The spacing used was everything between 1 m x 1m to 2.5 m x 2.5 m, most of them using the spacing of 2 m x 2 m (see Figure 16). One farmer used the spacing 1.5 m x 3 m, and one had also planted the Jatropha plants as a fence with the spacing of 2.5 m. One of the farmers in Koibatek planted some seeds in February 2010 when Farming Systems Kenya brought some seeds for showing the community members how they look like. He then planted seedlings when they were brought in March, and observed that the plants grown directly from seeds grew a lot faster than the seedlings did, and the plants grown from seeds also started to flower and to give fruit at a much younger age than the plants from seedlings.

Figure 15. The Jatropha seedlings were planted in holes

Figure 16. A recently planted Jatropha field with the spacing 2 x 2 meters

6.4 Intercropping

Out of 20 farmers 17 do intercropping of some sort (see Figure 17). In Baringo ten farmers out of eleven do intercropping, and the most common crops there are maize, millet and sorghum (see Figure 18). Some also intercropped with aloe, vegetables and beans. Seven farmers out of nine in Koibatek are intercropping their Jatrophas with food crops such as maize, beans, sweet potato, potato, peanuts, vegetables and cassava. The farmers said that the Jatropha does not affect the yield of the food crops, and also that the growing of food crops does not affect the growth of the Jatropha plants. Some of them mentioned that they weed more often because of the food crops.

Figure 17. Intercropping Jatropha with sweet potatoes

Figure 18. Jatropha intercropped with maize

6.5 Irrigation

In both Baringo and Koibatek the farmers water their plantations by hand (see Figure 19). In Baringo, most of the farmers watered their Jatrophas when planting with two to five liters of water. Half of the group then left the plants unwatered, because of the ongoing rain period, but the ones who planted in the drier season watered their plants for the first months. In Koibatek not a single farmer had been watering the plants before or when planting, and only one out of nine watered the plants a little during the first months. Most of the farmers there planted during the rain period, but still some say one of the problems was drought and another poor growth of the plants.

Some farmers in Baringo chose to water about 1.5 to 2 liters every day for the first months, some watered 3 to 5 liters every second to every third day. Two thirds of the farmers in Baringo said they will be watering their Jatrophas in the very dry season, and one third said that they would not water anymore, because the Jatropha is a drought-resistant plant. One farmer mentioned he will water the plants again when they are flowering and giving fruit. Five out of nine farmers in Koibatek say that they will water their plants if it gets very dry, and four will not water. The main reason why some of them would not water is that the distance for fetching water was too long, or they said that the Jatropha is drought-resistant and should not be needing irrigation.

Figure 19. The irrigation in Baringo and Koibatek is done by hand

Figure 20. A hand-full goat manure around a Jatropha plant

6.6 Plant nutrition

In Baringo, 90 % of the farmers used goat manure as fertilizer for their Jatrophas, in Koibatek only around 50 % used manure. Some said it will be enough to use manure once a year, others use fertilizers frequently, every or every second month. The amount used per fertilizing time also varies between a hand-full (see Figure 20) and three kilos. Some of the farmers said they had no manure to use, and some said they will use manure only if the growth of the plants was very poor. One of the farmers was planning to use C.A.N., which is a calcium nitrates fertilizer, when there was enough money to afford it.

6.7 Weeding

Also the weeding is done in many different ways. All of the farmers that were interviewed were weeding their Jatropha plantations. Some of the farmers weeded every week or every month, others said it is enough to weed once a year. Some weed only around the stem of the plants, and many of them said they weed their plantations more often during the rain period and less often during the dry season. Most of the farmers said that they weed when they see it is needed, but many of the Jatropha fields had quite an amount of big weeds (see Figure 21), which

seemed to affect the plant growth negatively. Also plantations with much higher weeds than the seedlings themselves were found, and the small seedlings seemed to suffer a lot from this competition with the weeds (see Figure 22).

Figure 21. Althougt the farmers said they "weed when it is needed" many Jatropha plantations were overgrown by weeds

Figure 22. Small Jatropha seedling competing with weeds for water and nutrients

6.8 Pruning

In Baringo two thirds of the farmers had been pruning their plants in some way. Most of them had been pruning only once, but three of them had already pruned even three times. In Koibatek only two farmers out of this group said they had been pruning their plants, but the plants actually had been pruned in about half of the plantations. This might be the result of goats eating the non-toxic young leaves on the young seedlings without the farmers noticing, or then the farmer did not know the wife or husband had been pruning them. That the pruning rate in Koibatek is low is because the plants are still very young and they have been growing slowly, and the farmers were not very sure of the advantages of pruning. In Baringo the knowledge of the effect of the pruning was higher, they said the purpose of pruning was to make the plant strong, make it branch and to make the plant give flowers early and a lot of fruits.

The method of pruning varies between breaking the top of the plant with their hand (see Figure 23) to cutting the top of the plant vertically with a sharp knife or cutting

the tops of the plants with a *panga* (see Figure 24). Most of the farmers cut off about 5 to 20 cm of the plants when they reach a height of about one meter, and some farmers say it is enough to prune the plants only once. Those farmers who had been pruning their plants several times had been having another strategy: to cut off half a meter when the plant reaches two meters, and then about 20 to 30 cm after a couple of months again, or cut off 10 to 20 cm when the plant is about one to one and a half meters. One of the farmers cut off some side branches after the first pruning, leaving four of these side branches to grow. The second time he pruned, he also pruned the side branches, which now have started to branch. This farmer was planning to prune six times, but most of the farmers were planning to prune about three times or less, and after that only cut the plant to keep it at about two meters height. One of the farmers is cutting away all the side branches for the plant to grow tall first, and then let it branch.

Figure 23. Some farmers pruned by breaking the top of their plants with their hand

Figure 24. Cutting the top of Jatropha plants with a panga

All twenty farms in Baringo and Koibatek had problems with pests, some more, some less. In some plantations all the plants had shed their leaves, according to the farmers because of the pest attack, but in other farms the pests did not seem to affect the growth of the plant. The pest that affected the plants most, found in almost all the plantations, is most likely the red-brown flea beetle, *Aphthona sp. n.*

dilutipes (see Figure 25). This red-brown flea beetle eats the leaves and leaves them with small holes (see Figure 26). In Baringo this pest made much more damage than in Koibatek.

Figure 25. The red-brown flea beetle, Aphthona sp. n. dilutipes*, was found in almost all Jatropha plantations visited*

Figure 26. Holes in Jatropha leave made by the red-brown flea beetle

Another very common pest in the plantations was a pupa or a green larva inside a small, whitish web on the leaves (see Figure 27 and 28). According to descriptions in the literature, this should be the blister miner or leaf miner, *Stomphastis thraustica Meyerick*, which is characterized by cocoons on leaf veins and brown leaf scars.

Figure 27. White web on Jatropha leaf

Figure 28. Green larvae in cocoon

There were many other symptoms of pests and/or diseases on the Jatropha plants in Baringo and Koibatek that have not yet been identified. These symptoms are very wrinkled upper leaves, "scattered" leaves, red small mite-like animals on the leaves, grey and moldy leaf-stems, the green young stem turning brown with dark sap drops on it and the fruits turning grey with dark drops of sap on them. The pest

seen that might be related to the moldy leaf stems, the moldy fruits and the dark sap drops is an about one cm long, black and yellow insect. Pictures of these symptoms are found in Appendix 4.

Only one of the farmers in Baringo had been using pesticides to get rid of the red-brown flea beetles affecting the plants. He had experimented with using a pesticide used on vegetables, Cyclone, on one of the plants, showing good results. By spraying the plant with a mixture of 5 ml of this pesticide per half liter of water once the red-brown flea beetle was kept away for about three months. After three months when it came back he sprayed again. After this he was about to do a test with another pesticide, Morpholy. All the other farmers had done nothing to get rid of the pests, saying that they were waiting for Farming Systems Kenya to tell them what to do, although the training on pest management had already been held.

6.10 Growth

The Jatropha plants showed a huge difference in growth on the different farms. The Jatrophas planted in the dry year of 2009 showed very poor growth in the first season, and therefore the size of these plants as quite similar to those Jatrophas planted one year later. The plant height on the different farms is showed in Figure 29, where we can see that the plant height differs from 10 cm to 3 m. The total average of plant height for the Jatrophas is about 95 cm. Also the number of branches on the plants differed very much, from no side branches at all on very small plants and plants that had not yet been pruned to around 15 side branches. On some well growing, pruned plants even the side branches had started to branch. Also very tall plants (1.5-3 m) with no branches occurred, some of them had started flowering. These plants were not pruned.

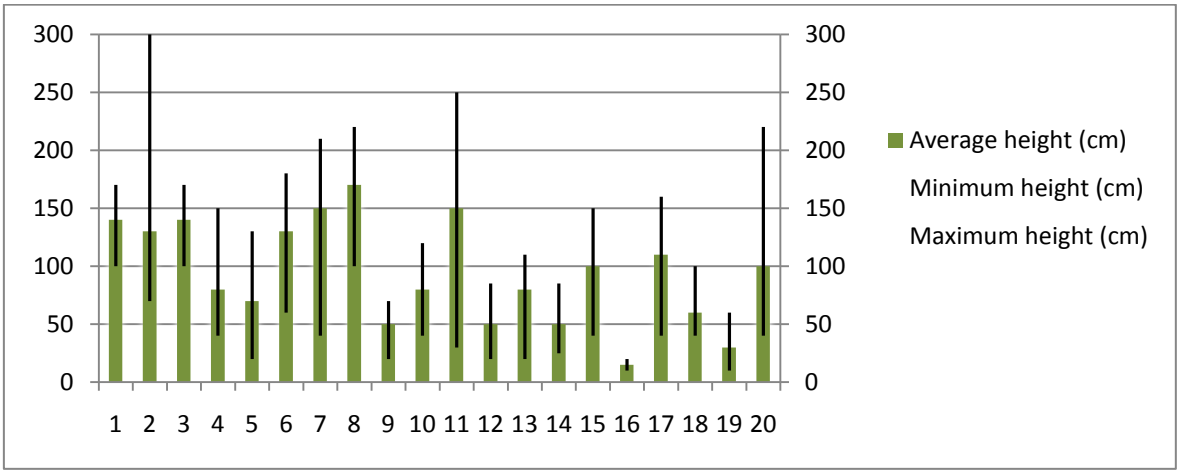

Figure 29. Plant growth in the 20 Jatropha farms in Baringo and Koibatek

6.11 Flowering and yields

The first flowering occurred at very different plant age on the different Jatropha plantations. Some of the plants started flowering already after four to five months, but most of the plants started to flower at an age of about half a year or more (see Figure 30). One third of the farms had still no flowering plants in December 2010, when the plants were one to one and a half years old.

One farmer in Koibatek had experienced that the plants directly sown from seeds grow faster, flower and give fruits faster than the planted seedlings. The plants from seeds were only seven months old when flowering for the first time, and the first fruits were harvested when the plant was only nine months old. Some of the seedlings planted at the same farm have now started to flower at an age of nine months. The difference in time for first flowering between seeds and seedlings is still bigger than it sounds, because the seedlings, when they are planted on the farms, already have reached an age of half a year to one year.

The first harvest some of them got after six to ten months, but one third of the farmers had not yet harvested in December 2010. The harvest before December 2010 was everything between 18 seeds only - where only one of the plants had been giving fruit - to about two kilograms of seeds. It takes about 2.5 to 3 months for the fruits to get ripe (see Figure 31), and most of the farmers pick the fruits when the fruit has turned from green to yellow to brown or black, when it dries and opens. One of the farmers collected the fruits already when they were yellow. After

picking the fruits they removed the fruit shell and put the seeds in the sun to dry for about one day. The one farmer picking the yellow fruits first dried them in the sun until they dry, turn brown and opens, when he removed the fruit shell and put the seed to dry for a day in the sun.

For the time being the farmers only store the seeds, waiting for more fruits and seeds to press when Farming Systems Kenya will come there with the oil press. One of the farmers mentioned that you can burn the seeds to get light. You should first remove the shell of the seed, and then burn only the white kernel for best burning results. One seed burns about five minutes, and gives the children a chance to study also after it gets dark in the evening. The fruit shells are for now used as manure and for burning. Some of the farmers do not seem to be aware of the fact that also the fruit shell can be used, so they just go to waste.

Figure 30. Jatropha flowers on farm in Baringo

Figure 31. Ripe Jatropha fruits on farm in Baringo

6.12 Expectations and challenges

The main expectations from growing Jatropha are to use the oil at home instead of paraffin and firewood, and to get an income. When using the oil instead of paraffin they will save about 500 Kshs (about 5 €) per month on average, and the time they would save from fetching firewood would be around 14 hours per week. Some of the farmers also want to use the oil for running machines and motors.

The way of getting an income from the Jatrophas would be selling the seeds and selling the oil, and some also mention selling of their own produced seedlings as well as soap production. With the income they get from growing Jatropha they want to educate their children. The Jatropha is also expected to serve as a fence and to increase the honey production with its flowers. The yields two of the farmers said they expected were 2.5 kg seeds per plant when the plant is about 10 months old, and the other expected as much as 40 kg seeds per plant every year. About half of the farmers said they want to plant more.

All of the farmers saw the pests as a big challenge, and thought that it would affect the plant growth, the flowering and the fruit yields. The small amount of rain and drought was the second biggest problem, because it affects the growth and also the yields in such a negative way. Some farmers mentioned the clay soil as a big problem, others that the field might be too dry because of the large number of weeds. One said a big challenge, when the plants are young, is that the goats were eating the young leaves, and that you therefore need a good fence around the plantation. Another mentioned that the goats were disturbing the plants through pushing them down, and that the fence therefore was needed. Lack of time fetching water for the plants was another issue.

7 Discussion

7.1 Introduction

The Jatropha plantations in Baringo and Koibatek have shown poorer growth, later flowering and lower yields than many literature sources say Jatropha should give in these conditions. The restrictions the Kenyan Government gave in 2008 (ref. Muok & Källbäck 2008, 12) included an annual rainfall of 300-1500 mm, 0-1500 m altitude, 20°C to 32°C, low fertility and alkaline soils. In Baringo and Koibatek the climate fits these restrictions, and most of the plants are alive. The question is if the yields will ever be high enough for giving the expected profit. The findings of my research seem to be consistent with the research findings done by GTZ (2009,

10 & 131), showing the Jatropha yields in smallholder farms in Kenya are much lower than reported elsewhere in the world.

7.2 Propagation and planting

Franken (2010, 13-14) points out the importance of using high quality seed material for propagation. The seeds used in the Baringo nursery are of unknown quality, which, of course, may affect the plant growth and the yields. The seeds used for germination should not either be older than six months, while the growth rate of older seeds is affected negatively (Franken 2010, 13-16). The propagation method chosen, the nursery with seedbeds is according to the literature a good choice because of the easily controlled conditions, the method is cheap, and the seeds develop a tap root that the cuttings do not develop. Compared to direct seeding in the field this propagation method is also more safe (Benge 2006, 4-5; Franken 2010, 13-16). In this way they also avoid the clones, as when using cuttings or micro-propagated plants, which are more susceptible to diseases and pests (Benge 2006, 4). The literature recommends propagating in seedbeds and then transplanting into polybags or germinating directly in polybags and transplanting them into the field after about one month after germinating, because the root development starts suffering if the seedlings are kept in the polybags longer (Franken 2010, 14-16). The seedlings in Baringo nursery are kept in the seedbeds for quite many months, which can affect the root developments of the plants because of lack of space, water and nutrients. The transportation of the bare-rooted seedlings might also affect the plant growth in the field, if the roots, for example, dry a bit during transport.

The recommended land preparation before planting is to clear the land from weeds and to dig planting holes with the minimum depth of 45 cm and width of 30 cm, and to add organic matter and fertilizers in the planting holes (Franken 2010, 11). In Baringo and Koibatek all the farmers cleared the land, and all of them also dug planting holes with a depth of 20-70 cm and a width of 20-50 cm. No significant differences were noticed in plant growth depending on the different sizes of the plant holes, but where manure and/or water was poured into the plant holes before or when planting, the plants showed a somewhat better growth.

7.3 Water

The minimum rainfall for the plant to survive is according to Ouwens *et al.* (2007, 4) 300 mm, the amount needed for producing fruits 600 mm and the optimal rainfall would be 1000-1500 mm annually. In the districts of Baringo and Koibatek the annual rainfall is between 600-900 mm annually, but the plant growth has been quite poor until now, showing the plants survive, but they show poor growth and probably also give poor yields. Some of the plants in Baringo and Koibatek shed their leaves, partly because of the lack of water, and as van der Putten (2010, 4) says, this means the plant stays in a stage of rest and also no flowering can occur either.

The farmers who planted already in 2009 lost many of their plants because of the drought, and also the plant growth was much affected by the lack of rain. Franken (2010, 12) says that the Jatropha plant needs water for at least three months after planting, which is consistent with my results: enough rainfall or irrigation, is important just after planting in the establishment phase. One of the farmers cut the leaves of the plants to help them coping with the lack of water, while the plants shed their leaves during the dry period (Brittaine & Lutaladio 2010, 27). The seedlings planted during the rains from March to May 2010 grew faster, and the survival rate was significantly higher.

Watering the Jatropha plants in the establishment phase is recommended, and irrigation can increase yield (Franken 2010, 20-21). It is said that the second rainy season is too short to give good yields, i.e. irrigation is needed. The lack of water and money makes it almost impossible, and very uneconomical and unprofitable, to introduce an irrigation system in Baringo or Koibatek. According to GTZ (2009, 39-40) most of the small-scale farmers in Kenya use a free water source and water their plantations by hand. They also state that Jatropha intercropped with food crops had the highest irrigation rate, followed by monoculture and fence. This is also the case in Baringo, where most of the farmers water their intercropped plantations. In Koibatek the irrigation rate was zero, which is explained by planting at the beginning of the rains and great water shortage in the village. In Baringo the farmers watered their plantations at least during the plants' establishment phase,

so the poor plant growth and the late flowering in Koibatek seems to be the result of lack of irrigation.

An animal had dug a hole in a clay Jatropha field in Koibatek, and the plants close to this hole were taller and had more and bigger leaves than the other plants, which could have been the result of the hole gathering water when raining. This could mean that if deeper planting holes were dug on this soil type and the plants would be planted lower than the soil surface, it would benefit the plants in terms of collecting the water. Of course, further research on this is to be done before any conclusions can be drawn.

7.4 Plant nutrition

The most suitable soil for Jatropha production is according to Ouwens *et al*. (2007, 3) a well drained soil with a well aerated structure. Clay soils and other heavy soils are unsuitable for growing Jatropha (Franken 2010, 9), and this can be the problem in some farms in Baringo and especially in Koibatek, where plants in some plantations on heavy clay soils have shown extremely poor growth. Also plantations on very rocky and stony places have shown poor growth, which can be the result of the low organic matter content in the soil, that according to Franken (2010, 9) is needed on dry soils that dry fast.

The fertilizing rate is very low in both Baringo and in Koibatek. Only 50% of the farmers have used fertilizers in their plantations, and the amount of goat manure given varies from a handful (about 50-100 grams) to about 3 kg per plant for the first to the second year. When looking at the nutrient rates in goat manure and the recommended nutrient input during the first two years (Franken 2010, 18; Murphy 2006, 3) the plants should receive about 2 kg of goat manure during the first year and almost 3 kg during the second year. According to Franken (2010, 17) and Mc Lea (2009, 20) the Jatropha plant needs nutrients, especially nitrogen for growing to full size and especially potassium for flowering and producing seeds, and it is important to build up the plant structure during the first four years. The low amount of nutrients occurring in both Baringo, but especially in Koibatek, is an important factor when looking at the poor growth, late flowering and the low yields they face.

7.5 Plant spacing, intercropping and weeding

The spacing used in Baringo and Koibatek was mostly 2 x 2 m, but also spacings of 1 x 1 m, 2.5 x 2.5 m and 1.5 x 3 m occur. According to the literature a spacing of 3 x 2.5 m makes intercropping possible for the first years, wider spacing gives larger and taller trees while shorter spacing requires more nutrients and water plus more intensive pruning (Franken 2010, 11-12). The most common spacings in Kenya are according to GTZ (2009, 38) 2 x 2 m and 3 x 3 m. In Baringo one farmer had planted the Jatrophas as a fence with the spacing of 2.5 m, while Franken (2010, 11-12) recommends 0.25 m of spacing in a living fence. It seems like most of the farmers, especially those using a shorter spacing than 2.5 x 2.5 m, are not quite aware of the extra effort needed for good growth and a good yield.

Intercropping requires sufficient water and nutrients both for the Jatrophas and the food crops (Franken 2010, 21). This would mean even more fertilizing and irrigation for the farmers if they want a good growth and good yields - especially if they use a shorter spacing than 2.5 x 2.5 m - which most of them do not seem to be aware of. Almost 90 % of the farmers intercrop Jatropha with food crops like maize, millet, sorghum, vegetables and low crops like beans and peanuts are practiced in both Baringo and Koibatek. One farmer intercrop Jatropha with cassava, which is not recommended by Franken (2010, 21) because the risk of Jatropha hosting several cassava diseases.

Some of the farmers have planted their Jatrophas in their fields for food production, i.e. these fields will in a couple of years be used only for Jatropha production or for Jatropha intercropped with shade-loving annuals like tomatoes, grasses or peppers (Francis *et al.* 2005, 19). This could be a threat to the food production in the area, which is not matching the restrictions given by the Kenyan Government (ref. Muok & Källbäck 2008, 12) on the fact that growing Jatropha in Kenya should not compete with food crops or threat food production. On the other hand, most of the farmers have cleared new land for their Jatropha plantations, which helps in controlling land degradation, reversing deforestation and sequestering carbon in the arid and semiarid lands, which is very positive (Muok & Källbäck 2008, 6-9). Naturally the plantations visited are still very young, and while there is no information collected on exactly how the intercropping with Jatropha is

done in those areas when the plants are adult, it is quite impossible to say how the Jatropha plant growth will affect the intercropping or the food production later on.

All the farmers in both Baringo and Koibatek weed their Jatropha plantations, but in some plantations the Jatrophas were still overgrown by weeds. According to GTZ (2009, 41) weeding is important to ensure that the Jatropha gets sufficient supplies of water and nutrients, and that they do not have to compete with weeds. Nielsen says (ref. Franken 2010, 17) that Jatrophas can survive overgrown by weeds, but that the growth and the seed production will be minimal in that case. This seems to be true as the farms with a lot of weeds really showed poor growth. On some farms, where the weeds were higher than the small Jatropha seedlings, or when the taller plants were almost overgrown by weeds, this seemed to affect the plant growth negatively. Although all the farmers weeded sometimes, it seemed not to be enough on some of the farms. Nielsen (ref. Franken 2010, 17) also talks about the importance of regular weeding, which does not seem to be practiced on all farms in Baringo and Koibatek.

7.6 Growth

The establishment phases of the planted seedlings are assumed to have been different in length because of different water and nutrient availability during this phase. Also the fact that the seedlings had been in the seedbeds in the nursery for quite some time, i.e. they suffered from lack of space, nutrients and water and most probably were in a state of stress, it took a bit longer for them to establish and start the vegetative growth. One farmer had sown some seeds, which grew much faster than most of the seedlings. This might be the result of the seeds germinating and growing in the same conditions all the time, while the seedlings first were in a state of stress, then transported where the roots possibly dried a bit, and then planted in a different soil with different climate conditions, i.e. they first had to recover a bit.

Franken (2010, 19-20) says, that the Jatropha in 4-5 years should have about 200-250 lateral branches after good pruning and good growth. He also recommends pruning three times during the three to four first years, and then the plant will branch by itself. In Baringo most of the farmers have pruned at least some of their

plants while only a couple of the farmers in Koibatek have done pruning. About 50 % of the farmers had pruned their plants, while the rest waited for their plants to grow big enough to be pruned, or simply did not know how to prune or even the advantages of pruning the plants.

The pruning is done by hand or with a *panga*, resulting in horizontal and big wounds that heal slowly. Franken (2010, 19-20) says that big and slowly healing wounds should be avoided, because they are gateways for many diseases. The most common method used was to cut the plants when they had reached a height of one meter, and cut 5-20 cm of the top. According to Franken (2010, 19-20) the first pruning should be done when the plants are at least 70 cm high, and with a vertical cut with a sharp knife. The pruning usually resulted in branching. A few farmers did a little more advanced pruning and also cut side branches, and one had already started pruning the side branches.

Many of the plants, in Baringo especially, were not pruned and had already reached a height of 2-3 meters. Pruning is done to remove the apical dominance and to stimulate lateral bud dominance (Mc Lea 2009, 23), so that a plant with lots of branches that can bear fruit is achieved, but the farmers did not seem to be aware of the advantages of the pruning, and they were not either sure about how it should be done or what the plant should look like when well pruned: bushy with lots of branches.

7.7 Pests and diseases

All the plantations in both Baringo and Koibatek had problems with pests, mostly the red- brown flea beetle, *Aphthona sp. n. dilutipes*, which also has been reported in other Kenyan Jatropha farms (Nielsen 2009, 72). GTZ (2009, 28) reports that many Jatropha farms in Kenya have very heavily infested plants that have stopped producing leaves, flowers and fruits and are in a state of stress. Some plantations in Baringo also were heavily infected by this red-brown flea beetle (Nielsen 2009, 72), which seems to have been a component leading to the plants shedding their leaves. In other plantations where the red-brown flea beetle also occurred, the plants did not seem to be very affected at all. Also the web, that most likely is the leaf miner, *Stomphastis thraustica Meyrick* (Shanker & Dhyani 2006, 162-163;

Gagnaux 2009, 31-32), was found in most of the plantations, but the damage of this pest is not yet documented.

A connection between good supply of water and nutrients and good weeding leading to strong, well growing plants, and the grade of the pests affecting the plantations was noticed. This would mean that good management resulting in strong and well growing plants would be a good preventive method against this pest, which matches what Ribeiro and Matavel (2009, 40) say about the weaker plants having more problems with pests and diseases. This preventive method against pests would be worth considering, while chemical pesticides are both hard to obtain and very expensive (Nielsen 2009, 72) plus have a negative impact on the environment. Only one farmer had used pesticides to get rid of the red-brown flea beetle, and this pesticide seemed to work well. The other farmers did not know how to get rid of the pests, and were waiting for Farming Systems Kenya to help them, although the training on pest management was already over. Most of the farmers said the pests were the biggest challenge they had faced when growing Jatropha.

According to Gagnaux (2009, 34) the plants planted at the end of the rainy season would face more problems with pests and diseases, but this cannot be confirmed based on my research results for the plantations in Baringo and Koibatek. The plantations are still so young that it might not show yet, and maybe the amount of rain is generally so small, that it does not affect the plants in these semi-arid regions very much. On the pests and diseases there still needs to be a lot of research done to be able to identify the symptoms and the pests, in order to advise the farmers on how to best get rid of these pests and/or diseases.

7.8 Flowering and yields

The flowering and the first harvest were delayed most likely because of the lack of water during the year 2009. In Baringo it seems impossible to tell at which age the Jatropha plant starts to flower because of factors like the climate when planting - some were planted during the rains and some during the dry season - and very different conditions and soil types in the plantations from farm to farm. Also the management, which includes irrigation, weeding, fertilization and pruning, are

factors that affect the plant growth and the flowering a lot. On many farms, where the plants were not pruned, the Jatrophas had grown tall and started to flower. This can be the result of nutrient and water deficiencies, when the plant's survival strategy is to produce flowers as fast as possible. The one farmer that had sown some seeds experienced much faster development than for the seedlings, i.e. they also started flowering and gave fruit much earlier. This would mean that direct sowing of seeds gives a faster growth, and earlier flowering and fruit production than when planting the seedlings.

The yields received by two thirds of the farmers so far in Baringo are between 18 seeds and 2 kg of seeds. In Koibatek only the plants directly sown from seeds by one farmer have started giving fruit. Still the plantations are very young, and a full yield is not expected until after four or five years. Ouwens *et al.* (2007, 2) says the yields increase with age, and Franken (2010, 22-23) says the most normal yield is assumed to be between 500 and 3 500 kg of seeds per hectare per year, depending on water supply and soil fertility. One farmer expects 2.5 kg seeds per plant per year, while another has high expectations on the Jatropha plantation: 40 kg/plant/year, which would give an income of 48,000 Kshs (about 480 €) per year. In Zimbabwe about 400 g/plant/harvest is achieved (Tigere *et al.* 2006, 7-8), showing these high expectations most probably will never come true. Patolia *et al.* (2007, 7-8) says that Jatropha yields are significantly influenced by N and P_2O_5 fertilization, showing the irrigation and fertilization are issues that need to be highly considered in Baringo and Koibatek, if high yields giving profit are desired.

The harvesting, de-hulling of the fruit and the drying of the seeds are done by hand in both Baringo and Koibatek, which is also recommended for small-scale production (Rijssenbeek 2010, 29-32; Galema 2010, 32-37). At the time of the research the farmers stored their seeds, waiting for better yields so that they could start selling the seeds or sow them. It seems that the farmers are not aware of the fact that storage of seeds for longer than eight months affects both the oil quality and oil quantity, especially if stored in a tropical climate with no cooling system, i.e. the seeds cannot be sold for biodiesel production and this also gives less profit when pressing oil for their own use. If the seeds are stored longer than 15 months the viability goes down to below 50 % (Galema 2010, 35-37). Some farmers said they use the seeds for light in the evenings so that the children can study, which

also alone is a good achievement. The candle nuts burn for about five minutes each, and Benge (2006, 5) says this method is used also in other tropical areas.

7.9 Method

Because the client of this thesis, Farming Systems Kenya, from the very beginning had areas they wanted me to do research on in their two Jatropha groups the choice of respondents was very simple. Both interviews and farm visits were done, because if choosing only one of these methods, a lot of valuable information would have been lost. For example, sometimes when doing these farm visits it came up that some information the farmers had given during the interviews, especially concerning spacing between plants, occurrence of pests and height of where the pruning was done and how the pruning had been done, was quite different from what could be observed in the field, showing both methods were necessary.

The variable levels of education among the farmers, and, of course, the fact that all of us humans think in different ways, the information given to the farmers by Farming Systems Kenya was interpreted differently from farmer to farmer. The different rates of adopting the information given explain the varieties in the farmers' managing of their Jatropha plantations. Due to this it would be essential to do further research on the farmer's adopting rates during the trainings done by Farming Systems Kenya. Another improvement would be for Farming Systems Kenya to in some way make the training program and the information given during the trainings easier to adopt.

The method used, the half-structured interview, is according to the literature (Gillham 2008, 103 & 115) a good way to get information, and I agree. Using closed questions I would most likely not have got this much valuable information. The interviewing process I did in an ethically correct way according to Gillham (2008, 29-37), and also the material from the interviews was treated and used in an ethically correct way.

This research is quite broad, covering everything from propagation to harvest and utilization, with focus on cultivation and management. For specific results in for example pest and disease management I would say a separate survey on

specifically that issue would be necessary. This research was done at a very early stage of the Jatropha cultivation, when the plants were one and a half years at the most. Therefore, I would suggest that a research similar to this one would be done in a couple of years when the plants have grown bigger. By doing research repetitions a lot of valuable data could be collected and compared to the results of this research.

7.10 Recommendations and suggestions for further research

For the Jatropha farmers it would be important to plant the seedlings on the right time, at the beginning of the rain season, to avoid problems with drought, poor growth and possibly problems with pests and diseases. Enough water supplies for the first months of growth is very important for the development of the plant and also for the yields. I would also suggest the farmers to put goat manure around the plants more frequently, especially during the first years. More regular weeding and proper pruning would also most likely make the plant stronger and increase yields.

Based on the results of this research I suggest that more specific research on the Jatropha plant's needs concerning water and nutrients should be done, while it is obvious that these factors play an important role for the plant growth, flowering and later the yields, the question is only to what extent. Also research on pest management and preventative methods is needed, because a number of pests and diseases are affecting both plant growth, flowering and probably also the yields. I would also suggest repeating this research after a couple of years for gathering new information and comparing the new data with the results from this research. In this way more specific results on cultivation and management can be reached, that could be of great importance for the Jatropha cultivation in Baringo and Koibatek in the future. For Farming Systems Kenya research on the farmers' adoption rates of the information given about the Jatropha plant and how to improve the rate of adoption amongst the farmers would be helpful when proceeding with the project.

7.11 Conclusions

The Jatropha plant needs sufficient water and nutrients to grow to full size and to give good yields. In conclusion, it seems to be like many literature sources state, that the Jatropha plant will not be giving optimal yields in Kenya. Looking at the results of this research quite a lot of factors, like watering, fertilization and pruning, on the plantations would have to be changed before the small-scale plantations in Baringo and Koibatek would give optimal yields. However, it is important to remember that the plantations are still very young, and therefore, of course, only assumptions can be made.

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Appendices

Appendix 1 Pests and diseases on *Jatropha curcas L*.

Scientific name	English name	Damage	Control	Source
Achaea janata	Semi looper			GTZ 2009, 29-30; Shanker & Dhyani 2006, 162-163
Alternaria		Permature leaf fall		GTZ 2009, 29-30
Aphthona spp.	Flea beetle	Eat leaves. stem & new shoots, larvae damage roots	Chloropyrifos, Cyphenothrin	Nielsen 2009, 72; 2010, 24
Aphthona sp. n. dilutipes	Red-brown flea beetle	Eat leaves, stem & new shoots (adult), larvae damage roots	Deep plowing (larvae), Actara, Imidacloprid	Gagnaux 2009, 28-31 & 34; Mc Lea 2009, 28; Nielsen 2009, 72
Cercospora jatrophae-curcas/ Helminthosporium tetramera/ Pestalotiopsis spp.	Leaf spot			Ouwens *et al*. 2007, 23
Clitocybe tabescens/ Fusarium moniliforme	Root rot			GTZ 2009, 29-30; Ouwens *et al*. 2007, 23
Colletotrichum gloeosporioides	Leaf spot			GTZ 2009, 29-30
Inrabela sp.	Bark eater		Endosulfan 3 ml/liter of water, or a mixture of vitex, neem, aloe, Calatropis or Rogor	Paramathma ref. Nielsen 2010, 24
Macropphomina phaseolina/ Rhizoctonia bataticola	Collar rot		Copper Oxy Chloride (COC) 0,2% solution or Bordeaux drenching 1% solution	Nielsen 2010, 24; Ouwens *et al*. 2007, 23
Oxycetonia versicolor	Flower beetle			GTZ 2009, 29-30; Shanker & Dhyani 2006, 162-163
Pachycoris klugii	Shield bug	Feeds on fruits & flowers	Endosulphan Dimethoate	Mc Lea 2009, 28
Pampelia morsalis	Fruit/inflorescence/capsule borer/leaf webber	Bores into capsules, webs & feeds on flowers	Stegodyphus godyphus, Endosulphan Dimethoate, Endosulfan 3 ml/liter of water, or a mixture of vitex, neem, aloe, Calatropis or Rogor	GTZ 2009, 29-30; Mc Lea 2009, 27; Paramathma ref. Nielsen 2010, 24; Shanker & Dhyani 2006, 162-163
Phakopsora jatrophicola	Rust			GTZ 2009, 29-30
Phytophtora spp.	Damping off			Ouwens *et al*. 2007, 23
	Powdery mildew	Damages leaves and flowers		GTZ 2009, 29-30
Scutellaria nobilis	Scutellarid bug	Flower fall, fruit abortion & malformation of seeds		GTZ 2009, 29-30; Shanker & Dhyani 2006, 162-163
Sphaceloma manihoticola/ Elsinoe Brasilinensis	Cassava superlongation disease			GTZ 2009, 29-30
Stomphastis thraustica Meyerick	Blister miner/ Leaf miner on J. curcas	Brown leaf scars, cocoons on leaf veins	Imidacloprid	Gagnaux 2009, 31-32; GTZ 2009, 29-30; Mc Lea 2009, 27; Shanker & Dhyani 2006, 162-163
	Termites	Eat stems on overage trees		GTZ 2009, 29-30
	Super elongation disease on cassava cuttings		Captafol, 3000 ppm	Lozano ref. Nielsen 2010, 24

Appendix 2 Questionnaire for interviewing the Jatropha farmers

JATROPHA QUESTIONNAIRE

Personal information

Date and place:_____
Name:_____ Age:_____ Gender:_____
Tribe:_____ District:_____
Region:_____ Number of children:_____
Distance to nearest town:_____
Education:_____ Occupation:_____
Source of income:_____
Workers on the farm: Family members_____ Others:_____
Livestock:_____

Geographical information

Annual temperatures between (^{o}C):_____
Annual rainfall between (mm):_____
Type of soil: _____
Size of farm:_____ Size of cultivated land:_____
Other crops than Jatropha you are growing:_____
_____ Acres:_____

Average information about Jatropha

What do you know about *Jatropha curcas*? _____
_____
_____
_____
When did you for the first time hear about *Jatropha curcas*? _____
_____
How did you hear about Jatropha?_____
How many in this community are growing Jatropha?_____

The Jatropha-plantation

When did you plant your first Jatropha-plants?_____
Size of the seedlings:_____
Size of Jatropha-field now:_____ Number of plants:_____
Where did you get your seeds or seedlings for planting?_____
_____
What kind of land preparation did you do before planting? _____
_____
_____
What spacing do you use in your plantation?_____
Size of plants now and their condition:_____
_____
Are you planning to plant more Jatropha plants?_____
When and how much?_____

Management

Weed control.
Before planting?_____ Methods and tools:_____
First months?_____ Methods and tools:_____
First year?_____ Regularly after the first year?_____

How often?_____

Irrigation.

When planting, how much water per plant?_____
First month, how much and how often?_____
Irrigation system for continuous irrigation?_____
_____

Intercropping.

Intercropping or monoculture?_____
If intercropping, which crops? In the first years: _____
_____After a couple of years:_____
_____

Fertilization.

Fertilizers used when planting:_____ Amount (kg/ha):_____
Fertilizers used during growt:_____
_____
Amount (kg/ha):_____ Application: how often?_____

Machines and tools.

What kind of machines and tools were used during:
Land preparation?_____
Planting?_____
Irrigation?_____
Application of fertilizer?_____
Weeding?_____

Pruning.

Have you been pruning your Jatrophas?_____ How?_____
_____
_____
Tools used:_____
Effect on the plants?_____
_____

Pests and diseases.

Description of plant symptoms or damage:_____
_____
_____
_____
_____
Pests and diseases observed only on young seedlings:_____
_____
Pest and disease control: which methods used?_____
Which substances used, when and how much?_____
_____
_____

Harvest.

When did you Jatrophas flower for the first time?_____
In which month(s) does Jatropha flower?_____
How long does it take from flowering until the seeds are ripe?_____
How many harvests do you get per year?_____
Criterions for harvesting: Size of fruit, colour, softness/hardiness?_____
_____

Utilization.

How do you dry the seeds?_____
_____ For how long?_____
How many kilograms dried seeds per tree per year? _____
Weight of 1 liter dried seeds?_____ Differences in weight?_____
What do you do with the seeds?_____
_____
What do you do with the fruit-shells?_____
_____
Pressing of oil?_____ How?_____
_____

What do you do with the husk?_____
_____
Other uses of the plant?_____
_____

The weather

Weather this season: normal or exceptionally cold/warm/dry/wet/any storms?_____
_____
_____
How much has this abnormal weather affected the plants?_____
_____
_____

Challenges

What challenges have you been facing?_____
_____
Your actions to solve these problems?_____
_____
If you have questions, who do you turn to?_____
_____

Expectations

What are your expectations with growing Jatropha?_____
_____
_____
How are you getting income from your Jatrophas?_____
_____
Who are your customers?_____
_____
Plans on value addition?_____
_____

Thank you!

Appendix 3 Table used for collecting data doing the Jatropha farm visits

Jatropha-farm observations

Date and place:_____
Name of farmer:_____

	Plant 1.	Plant 2.	Plant 3.	Plant 4.	Plant 5.	Plant 6.	Plant 7.	Plant 8.	Plant 9.	Plant 10.
Height of plant (cm)										
Pruned (x = yes, - = no)										
Number of branches										
Number of branching branches										
Number of branches with fruits										
Number of fruits per branch (average)										
Number of fruits per plant										
Flowering (x = yes, - = no)										
Size of leaves Ø cm										
Colour of leaves G=green Y=yellow B=brow										
Pest (x = yes, - = no)										

Soil observations:_____
_____
_____

Description of pest(s):_____
_____
_____
_____

Other observations:_____
_____
_____
_____

Appendix 4 Pest and disease symptoms in the Jatropha plantations

Figure 1. The red-brown flea beetle (Aphthona sp. n. dilutipes) in a Jatropha plantation

Figure 2. Three red-brown flea beetles (Aphthona sp. n. dilutipes) on a new Jatropha-shoot

Figure 3. Wrinkeled leaves on Jatropha

Figure 4. Backside on wrinkled Jatropha leaf

Figure 5. Grey, moldy leaf-stems and fruits on Jatropha

Figure 6. Moldy leaf stem

Figure 7. Next stage after moldy leaf-stem and fruits: dark sap drops

Figure 8. Dark sap drops

Figure 9. A black and yellow insect appeared on the plants with the moldy stems and sap drops on the fruits

Figure 10. The black and yellow insect on Jatropha stem

Figure 11. Red small insects on Jatropha leaf

Figure 12. Scattered Jatropha leaf