## CHAPTER 2

## LITERATURE REVIEW

### 2.1 Cassava agronomy

Even though cassava can be cultivated with annual rainfall ranging from 1 000−3 000 mm, the ideal range is from 1 500−2 000 mm year$^{-1}$. Cassava growth is favourable under temperatures ranging from 25ºC to 29ºC, but it can tolerate lower and higher temperatures, ranging from 12ºC to 40ºC (Alves 2002). Cassava is generally considered to be well adapted to poor and degraded soil because of its tolerance to low pH, high exchangeable aluminium (Al) and low phosphorus (P) in the soil solution (Howeler 1996). However, yield may range from very low to very high according to soil fertility. The characteristics and level of nutrients and soil chemical properties have been classified to identify their capacity to meet cassava requirements (Table 1).

***Planting time and land preparation***

Generally, in tropical regions, cassava is planted when there is enough soil moisture to support germination of planted stakes. Over the past 25 years in Southeast Asia, higher yields were achieved when cassava was planted early in the rainy season (Howeler 2001). However, the best time to plant cassava may also depend on other climatic and marketing conditions at the time of expected harvest (Howeler 2007).

Like other crops, cassava needs good land preparation, which is important for crop establishment as it allows the roots to penetrate the soil and produce yield via root thickening (Leihner 2002). The use of specific land preparation methods, e.g. mounds, ridges, flat-tilled or not-tilled, depends on climate, soil type, topography and cropping system (Lebot 2009). Land preparation may be done with manually (using hoe, sharp spades or knives), with animal-drawn or mechanized equipment. In remote areas, such as the mountainous region of northern Lao PDR, smallholders grow cassava on steep slopes using manual equipment on no-till soil. The soil is opened and stakes are inserted in vertical, inclined or horizontal positions. However, commercial production in Thailand, Malaysia, India and Vietnam presently uses tractors for land preparation. Tongglum et al. (2001) reported that one pass with a seven-disc harrow mounted on a four-wheeled tractor was cheaper while having the same effect on root yield as ridge, flat, flat + earthing methods. Onwueme and Charles (1994) reported that cassava seemed to like deep, loose and well-drained soils. Therefore, it is likely that soil physical properties will determine the type of land preparation that is suitable.

***Cassava planting method and appropriate density***

Cassava stakes are planted in vertical, inclined or horizontal positions (Leihner 2002; Howeler 2007). Generally farmers use 20−30-cm-long stakes for planting. When planted vertically or inclined, stakes are pushed into the soil to about two-thirds of their length. In horizontal planting, stakes are placed horizontally in a hole or trough and covered with soil to 5−7 cm depth. With well-prepared soil, vertical or inclined planting is faster than horizontal planting, but care needs to be taken to ensure that the buds (eyes) on the stake face upward. A few studies have reported that the planting method may affect root yield. For example, cassava grown at the beginning of the dry season in Rayong, Thailand produced higher yield when stakes were planted vertically or inclined as opposed to horizontally (Tongglum et al. 2001). In China inclined planting produced higher yield than horizontal planting (Zhang et al. 1998).

Planting density depends on cultivars and growing conditions. Generally, cassava density varies from 10 000 to 15 000 plants $ha^{-1}$. Cultivars that branch less should be planted closer than those that branch more. Again with high soil fertility and rainfall, spacing could be wider because plants tend to be very abundant.

**Table 1** Approximate classification of soil chemical characteristics according to the nutritional requirements of cassava.

| Soil parameter | Ability to meet cassava requirements | | | | |
|---|---|---|---|---|---|
| | **Very low** | **Low** | **Medium** | **High** | **Very high** |
| pH[a] | < 3.5 | 3.5-4.5 | 4.5-7 | 7-8 | > 8 |
| Organic matter [b] (%) | < 1.0 | 1.0-2.0 | 2.0-4.0 | > 4.0 | |
| Al saturation [c] | | | < 75 | 75-85 | > 85 |
| Salinity (mS $cm^{-1}$) | | | < 0.5 | 0.5-1.0 | > 1.0 |
| Na saturation (%) | | | < 2 | 2-10 | > 10 |
| P [d] (µg $g^{-1}$) | < 2 | 2-4 | 4-15 | > 15 | |
| K [d] (meq 100 $g^{-1}$) | < 0.10 | 0.10-0.15 | 0.15-0.25 | > 0.25 | |
| Ca [d] (meq 100 $g^{-1}$) | < 0.25 | 0.25-1.0 | 1.0-5.0 | > 5.0 | |
| Mg [d] (meq 100 $g^{-1}$) | < 0.2 | 0.2-0.4 | 0.4-1.0 | > 1.0 | |
| S [d] (µg $g^{-1}$) | < 20 | 20-40 | 40-70 | > 70 | |
| B [e] (µg $g^{-1}$) | < 0.2 | 0.2-0.5 | 0.5-1.0 | 1-2 | > 2 |
| Cu [e] (µg $g^{-1}$) | < 0.1 | 0.1-0.3 | 0.3-1.0 | 1-5 | > 5 |
| Mn[e] (µg $g^{-1}$) | < 5 | 5-10 | 10-100 | 100-250 | > 250 |
| Fe [e] (µg $g^{-1}$) | < 1 | 1-10 | 10-100 | > 100 | |
| Zn [e] (µg $g^{-1}$) | < 0.5 | 0.5-1.0 | 1.0-5.0 | 5-50 | > 50 |

[a]pH in $H_2O$.

[b]OM = Walkley and Black method.

[c]Al saturation = 100 x Al (Al + Ca+ Mg + K) in meq 100 $g^{-1}$.

[d]P in Bray II; K, Ca, Mg and Na in 1N $N_4H$-acetate; S in Ca phosphate.

[e]B in hot water; and Cu, Mn, Fe and Zn in 0.05 N HCl + 0.025 N $H_2SO_4$.

**Source:** Howeler (1996).

***Cassava fertilization***

Cassava is a popular crop among poor farmers who live in marginal areas with unfavourable climatic and soil conditions. In such cases, it becomes a 'scavenger crop' because the crop is considered more tolerant to drought, soil acidity and infertility than many other food crops. On the other hand, since cassava is highly efficient in nutrient absorption from infertile soils, it is often blamed for rapid depletion and decline of soil fertility (Howeler 2002). However, it has been demonstrated that N and P removal per tonne of dry matter in cassava roots was much lower than other crops, while K removal was not different from other crops (Howeler 1991; Putthacharoen et al. 1998). It is most likely that soil fertility decline under cassava is the result of repeated cropping with cassava on the same land year after year by farmers with limited land who also lack the economic means to replenish soil fertility with fertilizer. Cassava nevertheless appears to be especially sensitive to K deficiency. Howeler (1991) reported that cassava yield declined after several years of annual application of N and P, with yield decline attributed to declining K content in the soil; yield decline was reversed by adequate K application. Similar long-term cassava fertilizer trials conducted in India and Thailand (for more than 30 years) reported that without K application yield continuously decreased year by year, but with moderate rate of annual N, P and K application higher yield could be maintained. Previous reports indicated that K plays an important role in increasing root and starch content as well (Howeler 1998; Nguyen et al. 1998). In almost all long-term cassava fertilizer trials, root yield responds strongly to the application of K follow by N and P (Howeler 2007). It has been recommended that to maintain 15 tonnes $ha^{-1}$ of yield and prevent soil fertility depletion, all stems and leaves should be returned to the soil and incorporated with fertilizer at the rate of about 60 kg N, 12−20 kg $P_2O_5$ and 50 kg $K_2O$ $ha^{-1}$ (Howeler 2002).

**2.2 Factors affecting germination and establishment of cassava stakes**

Cassava can be propagated via seeds, stakes or stem cuttings. However cassava plants are generally grown from true seed in breeding programmes only. In commercial cassava production, stakes are normally used as propagation units (Leihner 2002). The germination process of most crop plants generally depends on environmental factors and the quality of the propagule unit. Soil moisture is an environmental factor affecting germination of many plant species. Soil moisture content varies in different regions and seasons. Optimal moisture content for germination depends on plant species. In rainfed areas, the cassava planting date is determined by rainfall and soil moisture content. It is generally grown early in the wet season when there is enough soil moisture to allow adequate germination (Howeler 2001).

Seed also needs optimum temperature for germination. Optimum temperature increases the permeability of the seed coat membrane, which allows more entry of oxygen to the seed interior, thereby stimulating growth of the embryo or breaking dormancy of the buds. The optimal of temperature for seed germination varies with species. Temperate plants germinate better at 10−20˚C, tropical plants germinate better at 25−30˚C (Sinha 2005). The optimal temperature range for cassava germination is 25−30˚C. At low temperature (16˚C) sprouting of the stake is delayed (Akparobi et al. 2003) and is inhibited at temperatures greater than 37˚C (Keating and Evenson 1979; Lebot 2009).

Rapid germination and good establishment not only need suitable environments but also high quality stakes. Lozano et al. (1984) and Cock (1985) stated that good quality stakes should be 20−30 cm long and 2−3 cm in diameter, with 5−7 nodes, taken from 8−18-month-old mother plants. Stakes taken from the middle and lower part of the stem survive better than those from the upper part (Howeler 2007). Stakes from the middle and lower parts had survival rates of 73.7 to 92.8% compared with those from upper parts at 49.9% (Tongglum et al. 2001). This is because the stakes from the upper part have higher water content, so they tend to dehydrate rapidly after planting (Leihner 2002). Sprouting capacity of stakes produced from young stakes is lower than those from older parts of the stem (Wargiono and Ispandi 2007). However, Eze and Ugwuoke, (2010) suggested that belowground cassava stem portions can be a good source of planting material. Stakes 15−20 cm long had 73.7 to 95.0% germination while those that were 5-cm long had only 59.9% germination (Tongglum et al. 2001). It is unlikely that stake quality is associated with their length per stem, but more likely to be dependent on the number of buds that can be regenerated. Okeke (1994) and Eke-Okoro et al. (2001), on the other hand, reported that stake quality is determined by weight. A heavy stake has higher quality than a light stake because the heavy stake has more food reserves.

In most cassava-growing areas, climatic conditions do not allow the stakes to be planted immediately after harvest. Cassava stems have to be stored for some length of time. Germination of the stake is also affected by the condition and length of stem storage after harvest. During storage, the stem which is still alive continues with its respiration and dehydration, resulting in the loss of soluble carbohydrates (Leihner 2002), which are essential reserves for regeneration (Cock 1985). The general recommendation is that stems should be stored upright in the shade for no longer than 1.5−2 months to obtain at least 80% germination (Howeler 2007). However, from previous literature about selection of agronomic characterization of stakes such as stake size, stem portion, age stem storage and length of storage seem to be important. Moreover, other aspects of stake quality that should be considered are food reserves and nutrient content of the stakes.

**2.3 Nutrition of the planting material**

Cassava germination, shoot and root development depend on food reserves and nutrient content in stakes until 30 days after planting (Alves 2002; Lebot, 2009). Sufficient carbohydrate reserves and mineral element content are important for this initial phase (El-Sharkawy 2003). The sprouting rate and root formation are strongly influenced by N, P and K, especially K, contents in the stakes; a low sprouting rate and small rootlets occur in stakes from the mother plant receiving no K in soil that is very low in K (Molina and El-Sharkawy 1995). Many studies have found that germination and growth of plants are influenced by the nutrient content of seed. Rerkasem et al. (1997) reported that soybean (*Glycine max*) seed with low B (7 mg B $kg^{-1}$) performed poorly, with 70 to 80% failing to germinate or establish in the field. Wheat seed with high zinc (Zn) also grew better than seed with low Zn in soil with limited Zn (Rengel and Graham 1995). In the same way, plants grown from high-Zn oilseed rape seed (160 mg per seed) had better seedling vigour and improved root growth and higher Zn content in the shoots compared to those grown from low Zn seed (80 mg per seed). Therefore, applying fertilizer to the mother plant can increase nutrient content of the seed which will improve germination and subsequent plant growth and yield (Molina and El-Sharkawy 1995).

## 2.4 Priming

Priming stakes or seed before planting improves germination and early growth that can result in increased yield. The priming can increase speed and uniformity of germination (Ghiyasi et al. 2008b). Seed priming treatments can lead to better germination and establishment in many crops such as maize, rice, wheat and canola (Basra et al. 2005; Ghiyasi et al. 2008a; Ghiyasi et al. 2008b). Bajehbaj (2010) found that the germination percentage of primed seed was greater than that of unprimed seeds. Methods and solutions used differ depending on the crop plant. Maximum total germination (%) was obtained under 24 hours for tomato seeds soaked in water (Sabongari and Aliero 2004). Priming with water, also called osmopriming, improved germination and seedling vigour of wheat (Salehzade et al. 2009). Takrattanasaran et al. (no date) found that maize seeds soaked for 15 hours in a $ZnSO_4$ solution, resulted in better germination and seedling growth. Watanaonta et al. (2004) found that cassava stakes soaked with 2% $ZnSO_4$. $7H_2O$ for 15 minutes gave higher root yield and starch content. Similarly Wargiono and Ispandi (2007) found that priming stakes with 1% $ZnSO_4$ or 2% $FeSO_4$ for 15 minutes before planting increased cassava root yield. In the same way, Lozano et al. (1981), Cock (1985) and Howeler (2002) suggested that Zn and Fe deficiency can be solved by soaking stakes in solutions of $ZnSO_4$ and $FeSO_4$ for 15 minutes before planting.