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E-CHAPTER FROM THIS BOOK

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Improving cultivation of cowpea in West Africa

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1 Introduction

Cowpea [*Vigna unguiculata* (L.) Walp.] is a legume crop of vital importance to the livelihoods of millions of people in West and Central Africa (WCA). It provides a nutritious grain and a less expensive source of protein for both rural and urban poor consumers (Inaizumi et al., 1999). It can be grown and harvested in as little as 60–80 days. This enables households to harvest leaves and grains for consumption or sale during the 'hungry season' when grain reserves from the previous cereal harvests have been depleted and current crops are not ready for harvest. Most of the world's cowpea (>90) is grown in sub-Saharan Africa, most of which is in West Africa particularly in Nigeria and Burkina Faso. Over 12.61 million ha are grown to cowpea worldwide, with an annual grain production of about 5.59 million tons (FAO, 2014). Of this amount, Africa accounts for 94% of grain production. Nigeria is the largest cowpea producer in the world and accounts for over 2.5 million tons grain production from an estimated 4.9 million ha (FAO, 2014). Other major producers in West Africa are Mali, Niger and Senegal. Cowpea cultivation is mainly under traditional systems and cowpea grain yields in farmers' fields are low especially in the West African sub-region (0.025–0.3 t ha^{-1}). This is caused by severe attacks of pest complexes, diseases, low soil fertility, drought, inadequate planting systems, inappropriate cultivars and lack of inputs (Ajeigbe et al., 2010a). In addition

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to biotic and abiotic stresses, existing planting practices limit crop yields. Despite the availability of *Striga* and disease-resistant cowpea cultivars, grain yields on farmers' fields are still low. However, on-station and researcher-managed plot yields are high and encouraging. Grain yields ranging from 0.5 to 2.76 t ha^{-1} have been reported in sole crop (Ajeigbe et al., 2005, 2008), whereas grain yields ranging from 0.37 to 1.27 t ha^{-1} have been reported in intercrop in the savannahs of Africa (Ajeigbe et al., 2005, 2010b). Yield potential assumes unconstrained crop growth and adequate management that avoids limitations from nutrient deficiencies; inadequate planting systems and water stress and reductions from weeds, pests and diseases (Evans and Fisher, 1999). Considering the large differences between farmers' yields (0.3 t ha^{-1}) and experimental station yields (1.5–2.5 t ha^{-1}), potential for on-farm yield increase in the region is high. This has stimulated interest in agronomic practices that could enhance crop yields. Some of the agronomic practices that may increase cowpea productivity are optimal plant population, appropriate planting date, nutrient management, integrated pest management and suitable cropping system.

2 Optimal plant population

Cowpea is generally cultivated on rows of ridges in the cowpea growing region of West Africa. The ridges are spaced 75 cm apart because equipment used in the region for ridging is the same as for the other grain crops such as maize, soybean, sorghum and millet. This general row spacing does not consider individual crop and varietal requirements. The use of ridges spaced 75 cm apart with the recommended plant spacing of 20 cm corresponds to plant population of 133 333 plants ha^{-1}, which may not be sufficient for optimal cowpea yield. The low plant density resulting from wide row spacing usually leads to low yields in some grain legume crops, such as cowpea (Kamara et al., 2016). Grain yields of the widely available stress-tolerant cowpea cultivars hardly go above 1.7 t ha^{-1} on farmers' fields, despite the enormous gain in genetic improvement over the past three decades (Kamara et al., 2010). In Nigeria, cowpea planting density recommendations ranged from 33 000 plants ha^{-1} in the more spreading and traditional variety to 66 000 plants ha^{-1} in the improved erect varieties (Dugje et al., 2009; Utoh et al., 2008). Plant density is an important component of yield in grain crops such as cowpea and soybean. Adjusting planting density is an important method to optimize crop growth and the time required for canopy closure and to achieve maximum biomass and grain yield (Liu et al., 2008). Crop cultivars respond differently to high plant density because of differences in growth habit. Some cultivars record high grain yield when grown at high densities (Liu et al., 2008). High plant density increases light interception, radiation use efficiency, dry matter and yield components (pods and seeds) by both decreasing row spacing and increasing plant density (Bruns, 2011). Ezedinma (1974) reported that close spacing between and within rows increased biological and grain yields of cowpea, while Jallow and Fergusson (1985) reported a linear response of grain yield to plant density between 40 000 and 250 000 plants ha^{-1}. The response of cowpeas to changes in density depends on the morphology of the cultivars and the growing environment. Kwapata and Hall (1990) found that cowpea grain yield for some cultivars was significantly greater at 400 000 plants ha^{-1} than at 100 000 plants ha^{-1} under irrigated conditions in California. Semi-dwarf lines produce relatively greater yield than standard lines at narrower row spacing (Ismaila and Hall, 2000). Breeders in West Africa have produced several cowpea varieties with varying growth habits. While some

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are erect and early maturing, others are semi-erect and have a prostrate growth habit which allows them to spread and close canopy faster. These varieties are usually spaced 30 cm apart to avoid overcrowding stress, while the erect types are spaced 20 cm apart to compensate for lower branching habit. To ensure that the optimum population is achieved on the widely spaced ridges, Kamara et al. (2016) recommended planting two rows of cowpeas placed equidistant on the ridges. In an experiment in northern Nigeria, they planted four cowpea varieties with contrasting maturity duration in single, double and triple rows on ridges spaced 75 cm apart to achieve corresponding densities of 133 333, 266 666 and 400 000 plants ha^{-1}, respectively. Plant densities of 266 666 and 400 000 plants ha^{-1} gave higher crop performance in terms of light interception, biomass production, yield and yield components for all cowpea varieties. Yield increases were related largely to increased pod number and grain production, but the effect of grain size on yield was relatively minor. Their results provide evidence that the current density of 133 333 plants ha^{-1} used by farmers is not optimum for cowpea production. Smallholder farmers can increase cowpea grain and fodder yields if they use a density of 266 666 plants ha^{-1} in cowpea cultivation. Further yield increases when cowpea is planted at 400 000 plants ha^{-1} may not be sufficient to offset the cost of seed.

3 Plant configuration in intercropping systems in West Africa

In West Africa, cowpea is traditionally intercropped with other food crops such as maize, pearl millet, sorghum and cassava. Although sole cropping of cowpea is profitable, farmers continue to grow cowpea as an intercrop with these crops. This is because it fits well into the low input labour-intensive tradition of growing crops in the region. Several advantages are accruable when crops are intercropped. Lithourgidis et al. (2011) have summarized these advantages to include: the production of greater yield on a given piece of land by making more efficient use of the available growth resources; using a mixture of crops of different rooting ability, canopy structure, height and nutrient requirements based on the complementary utilization of growth resources by the component crops; improving soil fertility through biological nitrogen fixation with the use of legumes and increasing soil conservation with greater ground cover than sole cropping as well as providing better lodging resistance for crops that are susceptible to lodging when grown as sole crops. Others include reduction in pest incidence, improvement in forage quality by increasing crude protein yield of forage, provision of insurance against crop failure or against unstable market prices for a given commodity. This provide greater financial stability than sole cropping which makes the system particularly suitable for labour-intensive small farms and allows for lower inputs use through reduced fertilizer and pesticide requirements.

However, intercropping cowpea with maize has a major weakness of very low cowpea yield (Olufajo and Singh, 2002). Cowpea farmers in the dry savannah areas of sub-Saharan Africa obtain low yields, estimated at about 350 kg ha^{-1} (Olufajo and Singh, 2002; IITA, 2009). A major reason for the low productivity of cowpea in intercropping systems is shading from the taller cereal plants (Olufajo and Singh, 2002). Performance of cowpea intercropped with cereals is dependent on the growth habit of the cowpea crop. Indeterminate cowpea varieties with spreading growth habit normally performed

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better than the erect cowpea varieties because they are tolerant to shade (Ewansiha et al., 2014a). Ecological studies carried out by Terao et al. (1997) showed that at least 40% of incident light is necessary to grow healthy cowpea plants. In the traditional system, intercropped cowpea receives from <30 to >75% of incident light. In these light-limited conditions, cowpea varieties with a spreading growth habit get more light than those with an erect growth habit by producing more leaves as well as expanding their leaf area. N'tare and Williams (1992) and Terao et al. (1997) concluded that spreading cowpea type with a well-developed root system and high transpiration efficiency is best adapted to intercropping. However, intercropping would become more productive if the effect of shading were reduced.

Improved intercropping systems may be achieved by the plant configuration adopted by the farmer. Plant configuration refers to the spatial arrangement of the component crops as the intimacy of the crop mixture has important effects on the interactions between the crop species. Three plant configurations may be described: same (within) row intercropping – where the component crops are planted within the same row (Fig. 1); alternate row intercropping – where two different crops are cultivated in separate alternate rows (Fig. 2) and strip intercropping – where few–several rows of a crop are alternated with few–several rows of another crop (Fig. 3). The success of intercropping systems depends much on the interactions between the adapted crop cultivars that form the component crops, available management practices which include plant population and planting date of component crops, and the environmental conditions (Lithourgidis et al., 2011; Ewansiha et al., 2014a,b, 2015a,b). The practice of a given plant configuration or intercropping system is related to one or more cultural practices.

In a same row intercropping system trial that involved adapted and improved cultivars of cowpea and maize in the northern Guinea savannah (NGS) of Nigeria, indeterminate cowpea cultivar intercepted more light and produced higher fodder and grain yields compared to semi-determinate and erect cowpea (Ewansiha et al., 2014a). Light interception and fodder and grain production by cowpea was higher when intercropped

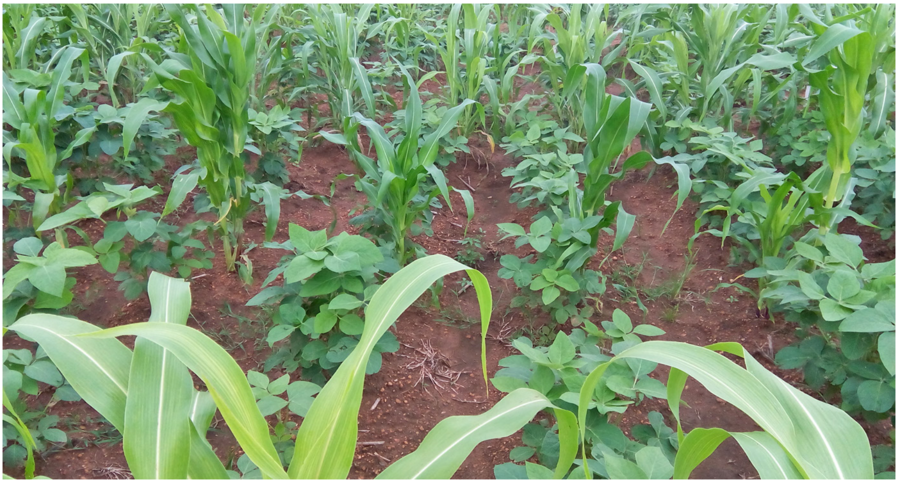

Figure 1 Same row intercropping system.

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Figure 2 Alternate row intercropping system.

Figure 3 Strip intercropping system.

with extra early and early maize cultivars than with late-maturing cultivar. The late-maturing and indeterminate cowpea was able to grow and use more light to produce higher fodder and grain yields after harvesting of the earlier maturing maize cultivars. On the other hand, the medium-maturing and semi-determinate cowpea completed its life

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cycle soon after harvesting of maize, making it unable to compensate for the reduced growth suffered when growing in the companion maize crop. In a same row intercropping system which involved intercropping of semi-determinate and indeterminate cowpea cultivars with early-maturing maize having populations of 17 777, 26 666 and 53 333 plants ha^{-1}, cowpea grain and fodder yields decreased with increase in maize population (Ewansiha et al., 2013, 2015a). The combined mean fodder yield of cowpea and maize was 6.3, 4.9 and 5.1 t ha^{-1} when cowpea was intercropped with maize having populations of 53 333, 26 666 and 17 777 plants ha^{-1}, respectively. Similarly, at these plant populations, the combined mean grain yield of cowpea and maize intercrop was 5.8, 4.5 and 3.8 t ha^{-1}, respectively. However, maize population of 0–26 666 plants ha^{-1} favoured better cowpea performance compared with 53 333 plants ha^{-1} because at these lower plant populations, maize plants had lower leaf area indices which allowed maize canopy to transmit more light into the understorey cowpea. However, in this system, the negative effects of shade were more pronounced in the semi-determinate cowpea than in the indeterminate at full maize population. Therefore, in high maize populations, indeterminate spreading cowpeas should be grown, while semi-determinate cowpeas should be planted in low to moderate maize populations because of their intolerance to severe shade. For same row intercropping systems, interactions among maize cultivar, cowpea cultivar and planting date were studied in the Sudan savannahs (SS) of Nigeria by Kamara et al. (2011) and Ewansiha et al. (2014b). The authors reported higher fodder and grain yield of cowpea intercropped with extra early maize cultivar compared with early maize cultivar. Fodder and grain yields were also higher for cowpea intercropped at four weeks after sowing maize than for cowpea intercropped at six weeks after sowing maize. Also, intercropping cowpea at six weeks after sowing maize gave a higher yield than intercropping at eight weeks after maize was sown. Furthermore, indeterminate cowpea cultivars produced higher yields than semi-determinate cowpea cultivars when intercropped early with maize (four weeks > six weeks > eight weeks). In another study comprising interactions among cowpea cultivar, plant population and planting date in the SS of Nigeria (Ewansiha et al., 2015b), the best grain yield potential for intercropped cowpea was achieved by sowing early in low to moderate maize plant populations, whereas indeterminate cowpea had higher grain yield at full maize population. Fodder yields were always higher for indeterminate cowpea across maize populations. Early sowing was more conducive to achieving a higher number of branches, higher number of peduncles, higher number of pods and higher fodder and grain yields. Cowpea performance reduced progressively with increase in maize plant population because of increased shading from maize plants. Growing cowpea under high maize population was more favourable for indeterminate cowpea cultivar, whereas growing under zero to moderate maize populations favoured semi-determinate cowpea cultivar in terms of grain production. Thus, when planning to grow cowpea with maize at full maize crop, farmers may need to sow indeterminate cowpea cultivars early under earlier maturing maize cultivars. However, at reduced maize plant populations, growing maize with semi-determinate cowpea cultivar will be preferable. The choice of maize plant population to use may depend on the income, food nutrition and feed needs of the farmer.

Studies have shown that by intercropping millet with cowpea in the semi-arid zone, millet yield is only reduced if cowpea is planted simultaneously with millet (N'tare and Williams, 1992). The relative planting dates of component crops can contribute significantly to the yield of intercrop systems as it modifies the relative periods of complementarity and competitiveness of component crops (Midmore, 1993). Terao et al. (1997) stated that cowpea planted 2–3 weeks later than millet grew to only 20% of sole-cropped cowpea

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planted at the same time, but millet yields are reduced when millet and cowpea are simultaneously intercropped, especially in the arid zones. It is therefore very important to strike a balance where there would be minimal reductions in yield of intercrops. This is especially important in the arid and semi-arid zones where root competition for moisture is more severe. Planting cowpea later than millet is one way to reduce millet yield loss. However, planting cowpea late will drastically reduce cowpea yield. Therefore, modifying the planting arrangement and the development of a cropping system that use the root zone complementarily is important.

There are several reports on the effect of spatial arrangement on the productivity of millet-cowpea intercrop in the Sudan savannah. The influence of component crop densities and manipulation of spacing between component crops, such as row arrangement and inter-row spacing on yield and production efficiency of intercrops, were evaluated by Ofori and Stern (1987). They suggested that the cereal components were less affected by these manipulations, whereas the legume yield usually decreased significantly depending on proximity of the cereal, perhaps due to the top of the legume canopy being shaded. Planting arrangement is an important determinant of how effectively the available resources are used, especially soil moisture. Clark and Myers (1994) also noted that cowpea in narrow strips (2:2) yielded average of 46% less than in wide strips (2:4) or in sole crop. They attributed the reduction in yield to the narrow strips; both of the cowpea rows were bordered by non-legume, and therefore, competition was greater than in the wide strips. Strip intercropping is advantageous in terms of ease of crop management, fertilizer and insecticide application, weeding and reduction of the shading effect of cereal on cowpea (Olufajo and Singh, 2002). Therefore, to boost cowpea productivity under intercropping, a 2cereal:4cowpea row to row planting pattern was recommended (Ajeigbe et al., 2005, 2006, 2010b). Singh and Ajeigbe (2002) noted that this system might also be more suitable and help maintain soil fertility because two-thirds of the area is legume and only one-third is cereal. In a similar trial involving different row to row arrangements, Mohammed et al. (2008) reported that 2:4 row arrangement relative to other arrangements had highest gross monetary return. Odion et al. (1994) observed that intercropping two rows of millet with four rows of cowpea was superior to intercropping both crops in alternate stands in the same row. Singh et al. (1997) reported superior yield of cowpea and higher intercrop productivity at 1:4 and 2:4 compared with 1:1cereal:cowpea row arrangement, but millet yield in 1:1 row arrangement was lower than in 1:4 and 2:4 row arrangements. These authors reported that strip cropping with two rows cereal:four rows cowpea offers an opportunity for selective input application and better economic advantage than the traditional one row cereal:one row cowpea spatial arrangement. Furthermore, alternating three rows of cowpea with two or three rows of sorghum plus one to two insecticide applications gave a yield advantage of 58–69%.

4 Manipulating planting dates to improve cowpea productivity

Despite the potential of cowpea in the dry savannahs of WCA, its production and productivity is constrained by several biotic and abiotic factors. The major yield-limiting factors of cowpea in the regions are insect pests and diseases, drought stress and parasitic weeds. Rainfall in the region has also been so variable and droughts have been so extreme

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that local cowpea cultivars and some modern cultivars that had evolved over the years in the Sahel hardly produce significant quantities of grain and fodder in recent times due to climate change. Furthermore, poor cultural practices such as inappropriate planting dates and plant population contribute to low productivity of cowpea (Singh et al., 2002; Ishiyaku et al., 2005).

Habitually, farmers in Northern Nigeria take the risk of planting their crops with the first rains in order to achieve early food security and also capture the flush of soil N that comes with the first rains (Jagtap and Abamu, 2003). Early planting with the first rain will not only make the crop mature during the rains but also predispose the crop to insect pests and disease pressure. On the other hand, planting too late may risk the danger of an early cessation of rains which may affect the quantity and quality of cowpea seed produced (Isubikalu et al., 1999). The important criteria in planting cowpea, therefore, is to determine the onset and duration of the rains and, more importantly, the maturity period of the cowpea variety. Kamara and Godfrey-Sam-Aggrey (1979) reported that high yields of good quality seeds are obtained when cowpeas are planted late so that the crop matures in dry weather. Studies by Mbong et al. (2010) showed that the grain yield of cowpea planted early in the Guinea savannah ecology was of poor quality due to disease infection, while those from late planting were of good quality. In an earlier study in Nigeria by IITA (1982), grain yield of cowpea planted early in the season was reported to be higher than those from the late planted crops. The increased yield was attributed to low pest population levels.

Planting date also affects the use of insecticide for controlling insect pests in cowpea. Farmers in the dry savannahs manipulate cowpea planting dates to avoid insect pest and disease attack. Kamara et al. (2010) reported the most effective combination of planting dates with insecticide spraying regimes for the management of insect pests of cowpea. In their study, they found that delaying planting beyond mid-August reduced cowpea grain yield by 12.3%, while the yield of the medium-maturing variety was significantly higher when planted in mid-August and sprayed twice than when planted earlier or on later dates in the savannahs of northeastern Nigeria. In that study, they also found that the yields of the indeterminate late-maturing variety were higher when planted in early August and sprayed with insecticide three times. They concluded that early and medium maturing cowpea varieties should be planted in mid-August, while the late-maturing indeterminate varieties should be planted in early August and sprayed thrice.

In WCA, reproductive development of cowpea is determined primarily by their response to photoperiod (Craufurd et al., 1996). Some cowpea genotypes are photoperiod-sensitive, while others are photoperiod-insensitive. Photoperiod which is determined by daylength is a critical factor in determining the appropriate planting time to establish cowpea. Among all the legumes, cowpea has the maximum diversity for plant type, growth habit, maturity and seed type. Breeders in West Africa have developed a range of cowpea varieties differing in growth habits (Singh and Sharma, 1996). These varieties respond differently to different photoperiods and growing environments. Some varieties of cowpeas, such as the local and indeterminate improved varieties, are photoperiod-sensitive. Planting these varieties at the onset of the rainy season (June or early July) will delay flowering and promote excessive vegetative growth leading to low yield (Kamara et al., 2010). These varieties should, therefore, be planted in mid-July to mid-August. However, planting these varieties later than mid-August in the dry savannahs will risk crop failure because of early cessation of rain in October (Kamara et al., 2016). On the other hand, the erect, early and medium maturing varieties that are photoperiod-insensitive can

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be planted anytime in the year provided there is sufficient rainfall or irrigation facilities. Ewansiha and Tofa (2016) reported that photosensitive cowpea varieties planted at the end of July produced significantly higher number of pods, number of seeds and grain yield compared with other planting dates, whereas the medium maturing erect cowpea varieties such as IT99K-573-1-1 (photoperiod-insensitive) produced higher pods, number of seeds and grain yield at all sowing dates in the Sudan savannah. They concluded that for optimum yield, indeterminate and prostrate cowpea varieties should be sown at the end of July, while the erect, medium or early maturing photoperiod-insensitive varieties could be planted at any time. In another study, Asante et al. (2001) reported that photoperiod-insensitive elite cowpea lines performed better in terms of grain yield when planted between mid-June and mid-July without insecticide protection, whereas the local varieties, which are mostly photoperiod-sensitive, produced higher grain yield when planted between late July and early August. This suggests that an important strategy to maximize cowpea yield is the ability to fit the cowpea varieties into their different planting dates for optimum performance. This makes the choice of planting date very important management decision in cowpea production. Table 1 highlights the planting dates recommended in some locality in WCA. The growing evidence from scientific and local observations suggests that the rainy season no longer comes at the same time as it did in the past. Farmers reported shifts in the onset of the rainy season, which used to start in April, toward May (Sanfo et al., 2014). With the effects of climate change, prediction of planting dates of cowpea in the savannahs from climate alone is becoming more difficult. Thus, planting dates may be chosen based on the plant maturity by ensuring that the critical growth stage, such as flowering, is synchronized with the availability of sufficient moisture during the cropping period.

As one moves from the Sahelian and Sudan to the Derived savannah, rainfall increases and the date to plant cowpea is further delayed. Distinct variations have been observed in the growth and reproduction of cowpea planted at different times in this ecology. Some authors have argued that early planting (before August) will make the plant flower when

Table 1 Rainfall distribution and planting dates of cowpea in WCA

Commencement of rains	Duration	Cowpea growth habit	When to plant
May	May–October	Erect (early and extra-early maturity)	August, week 2
		Semi-erect (medium maturity)	August, week 1
		Prostrate (late)	August, week 2
June	June–October	Erect (early and extra-early maturity)	August, week 3
		Semi-erect (medium maturity)	August, week 1
		Prostrate (late)	August, week 3
June/July	July–October	Erect (early and extra-early maturity)	End of July
		Semi-erect (medium maturity)	End of July
		Prostrate (late)	August, week 1

Source Dugje et al. (2009)

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rainfall is heavy and then require frequent spraying, while others argued for late planting. Studies have shown that for the medium/late maturing cowpea varieties, planting should commence from mid-August to early September in the Guinea savannahs, depending on the onset of late season rains. Akande et al. (2012) reported that cowpea planted in August and September matured early and produced significantly higher grain yield than cowpea planted in June and July in the Derived savannah of West Africa. Higher incidence of diseases was also reported for early planting in June and July. However, Ezeaku et al. (2015) reported that some cowpea varieties planted early (mid-July) produced significantly higher yield and yield components than those planted late (mid-September). They found that the mean grain yield of early planting ranged from 921 to 1220 kg ha^{-1} compared to late planting dates that produced grain yields that ranges from 326 to 723 kg ha^{-1}.

It is clear that planting date is a very critical factor in determining cowpea performance in the savannahs of WCA. Therefore, for optimization of yield, planting cowpea at the appropriate time is an important agronomic requirement for obtaining higher yield.

5 Nutrient management for increased cowpea productivity

Despite the importance of cowpea particularly in the dry savannahs of West Africa, its yields are very low due to several constraints including poor soil, insect pests and drought. One striking feature of the soils is their inherent low fertility expressed in low levels of organic carbon (generally less than 0.3%), total and available phosphorus and nitrogen and effective cation exchange capacity (ECEC) (Bationo et al., 2002). Total and available P levels are very low and P deficiency is the most limiting soil fertility factor for cowpea production. Apart from low P stocks, the low-activity nature of these soils results in a relatively low capacity to fix added phosphorus (Bationo et al., 1995). Soil, water and nutrient management practices are inadequate to sustain food production and to meet the food requirements of the fast-growing population. Although organic amendments such as crop residue, manure or compost are essential in the sustainability of the cropping systems, they are often not sufficient to prevent nutrient depletion. As a result, the use of external inputs such as inorganic plant nutrients or local sources of P such as phosphate rock is an essential requirement for soil productivity (Batieno et al., 2002). Significant cowpea responses to nitrogen applied as urea have been obtained in different agroecological zones of the West African savannahs (Batieno et al., 2002) suggesting that the crop does not fix enough nitrogen because of limitations in other crop nutrients. Cowpea has a high P requirement. P is essential for growth, pod formation and N fixation in legumes (Abaidoo et al., 2007). According to Adu-Gyamfi et al. (2009), legumes generally need a high P requirement for adequate growth, nodulation and N fixation. However, the available P content of soils in West Africa (averaging 8 mg kg^{-1}) is seldom adequate for optimal plant growth (Manu et al., 1991). Consequently, production of cowpea in West Africa and many parts of sub-Saharan Africa is hindered by low soil-available P, which is also a characteristic of about 5·7 billion ha of land worldwide (Bationo et al., 1985; Hinsinger, 2001). Furthermore, the soils of many sub-Saharan regions of Africa are characterized by low-activity clays with high P-fixing capacities, which render P less available to plants (Abaidoo et al., 2007). Smalberger et al. (2006) observed that soil P deficiency in sub-Saharan Africa was so severe that other technologies such as optimum

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seeding rate, improved germplasm and inoculation would not work without some form of P added as fertilizers.

One of the major benefits of cowpea production in many parts of Africa is its capacity for biological N fixation (BNF). Cowpea can fix between 20 and 100 kg N ha^{-1} with an estimated N fertilizer replacement value ranging from 10 to 80 kg N ha^{-1} (Carsky et al., 2002; Sanginga et al., 2000). The N fixed is made available to associated or succeeding cereals in the predominantly poor savannah soils. Cowpea has therefore become important in the cropping systems which allow crop rotation with cereals to supply N through BNF. However, BNF in legumes can be limited or enhanced by P availability and utilization (Vance et al., 2003; Waluyo et al., 2004). Because of its multiple effects on plant nutrition (not only on nodulation), a P fertilizer is recommended to increase yields (P_2O_5: 20–60 kg ha^{-1}). Singh et al. (2011) reported that cowpea showed a significant response to applied P on pods per plant, grain and stover yield and 100-seed weight with highest response of application to 60 kg P ha^{-1}. Despite the importance of P in the soils of cowpea growing regions in West Africa, the use of commercial P fertilizers is limited due to the high cost of imported fertilizers. Batieno et al. (2002), therefore, recommended the direct application of indigenous phosphate rocks (PR) as an alternative to the use of more expensive water-soluble phosphorus fertilizers. These phosphate rocks, however, produce variable results because of low agronomic effectiveness compared to the water-soluble fertilizers such as single super phosphate and triple super phosphate. Karikari et al. (2015) evaluated three varieties of cowpea at four P rates of 0, 20, 40 and 60 kg ha^{-1} P_2O_5 in Ghana. The rate of P fertilizer application was directly proportional to the grain yield in all three cowpea varieties. The highest grain yield of 1682 and 1476 kg ha^{-1} for major and minor seasons, respectively, was produced at 60 kg ha^{-1} P_2O_5. Ndor et al. (2012) reported significant increase in grain yield of cowpeas when P was applied at 40 kg P_2O_5 ha^{-1} in the southern Guinea savannah of Nigeria. In the predominantly cowpea growing region of the West Africa dry savannahs, the addition of some quantities of organic materials in combination with mineral fertilizers can maintain soil fertility and increase crop yields. Results from a long-term experiment at Sadore in Niger indicated that the application of small quantities of fertilizers and crop residues resulted in an increase of cowpea fodder yield from 1700 to 5300 kg ha^{-1}. In on-farm trials, pocket applications of small quantities of manure (3 t ha^{-1}) plus 4 kg ha^{-1} of P at seedling time increased cowpea yield from 180 kg ha^{-1} in the control plot to 400 kg^{-1} ha^{-1} (Batieno et al., 2002).

6 Integrated pest management (IPM) in cowpea production

Despite the importance of cowpea and its high yield potential in the West African savannahs, insect pest attack is a major constraint to production (Singh et al., 1990). Severity can vary and sometimes leads to total yield loss (Singh and Allen, 1980). Yield losses of up to 70%, from insect pests alone, have been reported (Rusoke and Rubaihayo, 1994). In some areas, the losses caused by insect pests account for a reduction in grain yield as much as 80% (ICIPE, 1980). Cowpea growers in West Africa are at risk of losing the entire crop to insect pests in most growing seasons. The most damaging of all insect pests are those that attack the crop during the flowering and podding stages (Jackai et al., 1985). Worldwide, insect pests, especially *Aphis*

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craccivora Koch, *Megalurothrips sjostedti* Trybom, *Maruca virata* Fab., and a complex of pod-feeding bugs cause the greatest yield reductions (Omongo et al., 1997). In a recent study, Kamara et al. (2007) reported that flower thrips, the legume pod-borer (Maruca) and a range of pod-feeding bugs were the major insect pests of cowpea in the dry savannahs of northeast Nigeria. Maruca larvae damage flower buds, flowers, green pods and seeds (Singh and Jackai, 1985). Thrips start to attack at flower initiation, causing flower bud abortion (Akingbohungbe, 1982). Adults and nymphs of pod bugs remove sap from green pods, causing abnormal pod and seed formation (Singh and Jackai, 1985). High levels of insect resistance are not available in current cultivars (Oghiakhe et al., 1995; H.A. Ajeigbe, pers. comm.). The development of integrated IPM strategies is the key for successful cowpea production. Insecticide application is the most widely known means of insect pest control method in cowpea (Matteson, 1982); it is not otherwise feasible to grow cowpea commercially (Jackai et al., 1985). Farmers can improve yield 10-fold if insecticides are used (Singh and Jackai, 1985).

In Nigeria, Alghali (1992) obtained yield increases of 50–200% following the application of insecticide, once each at flowering and podding stages. Spraying once at flowering stage increased grain yield by 75%; two sprays, once each at flowering and podding stages, significantly, reduced insect pest population levels and increased grain yield by 126% (Kamara et al., 2007). In Kenya, Kyamanywa (1996) obtained a 15-fold increase in grain yield after two sprays, once each at flowering and podding stages. Some farmers in Nigeria and elsewhere have resorted to the indiscriminate use of insecticides to reduce pest damage (Kamara et al., 2007), sometimes applying as many as 8–10 sprays per season. However, most Nigerian farmers are resource poor and require pest management strategies that are cost-effective and sustainable. The use of insecticides must be minimized because of high costs and harmful effects on human health and the environment (Giliomee, 1997). To increase effectiveness and reduce overuse, their application should be integrated with other cultural practices for insect pest management in cowpea (Kamara et al., 2010). In recent years, planting date has been identified as an important component of IPM practices (Kamara et al., 2010). It has been suggested that adjusting of planting dates could cause asynchrony between crops and insect pests (Pedigo, 1989). For example, in the Delmarva Region, USA, planting cowpea early in combination with an application of insecticide resulted in a much higher grain yield than planting it late (Javaid et al., 2005). Similarly, in Uganda, Karungi et al. (2000) reported that early planting reduced levels of infestation by aphids, thrips and pod-feeding bugs but increased levels of infestation by Maruca. There is usually a build-up of pests as the season progresses that causes most damage to late planted cowpea. Early sowing has also been reported to enable the crop to escape high temperatures during the flowering stages when the crop is sensitive to heat (Hall, 1992; Ismaila and Hall, 1998). Taylor (1978) and Akingbohungbe (1982) suggested that differences in planting dates could be explored as they might offer some scope in avoiding various insect pests. Cultural practices, when combined with insecticides, are probably effective against some pests and could be used as components of IPM (Javaid et al., 2005). In an earlier study in Nigeria, the grain yield of cowpea planted early in the season was higher than from the late planted crops (IITA, 1982). The increased yield was attributed to low pest population levels, and the crop was allowed to mature before the rains ceased. Some authors have argued that early planting in West Africa (before August) will allow the plant to flower in September when rainfall is heavy and cowpea flowering would usually require frequent spraying. Also, most of the cowpea varieties grown by the farmers are photosensitive and should be planted late in the season to enhance early

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flowering (H. A. Ajeigbe, pers. comm.). Farmers are therefore usually advised to plant their cowpea around late July to early August. Kamara et al. (2010) sought to establish the most effective combination of planting dates with insecticide spraying regimes for the management of insect pests of cowpea in the savannahs of northeast Nigeria. They reported that three sprays, made once each at the bud initiation, flowering and podding stages, did not differ significantly from those of two sprays, made once each at flowering and podding, in terms of reducing insect pest population and increasing grain yield. Despite the reduction in insect infestation, delaying planting beyond mid-August reduced cowpea grain yield by 12.3%, on average. The yield of the medium-maturing variety IT89KD-391 was significantly higher when planted in mid-August and sprayed twice than when planted on the earlier or later dates. The yield of the indeterminate late-maturing variety ITKD89-288 was higher when planted in early August and sprayed thrice. Early and medium maturing cowpea varieties should, therefore, be planted in mid-August and sprayed twice. Late-maturing indeterminate varieties should be planted in early August and sprayed thrice.

7 Future trends and conclusion

Cowpea production in West Africa is increasing because of the high yield of improved varieties and perhaps increases in market outlets. However, yields of cowpea in smallholders' farms are quite low due to poor crop management despite the availability of improved varieties that are tolerant to biotic and abiotic stresses. When intercropped with maize, indeterminate cowpea varieties should be sown early into extra early or early maturing maize varieties under full maize population for higher grain and fodder. IPM would increase cowpea yield by over 200%. Proper nutrients especially P fertilization would increase the productivity in Africa. Response to fertilizer is, however, dependent on good agronomic practices such as using appropriate planting systems, plant configuration, IPM and availability of water. The usage of agricultural management strategies such as tailored crop planting dates and optimal plant populations would contribute not only to reduce crop failure but also to increase cowpea production. Supplementary irrigation and deployment of *Striga* resistant, heat- and drought-tolerant cowpea varieties would help in improving cowpea productivity.

8 Where to look for further information

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