IJAAR 6 (2018) 59-68 ISSN 2053-1265

International Journal of Advance Agricultural Research
www.bluepenjournals.org/ijaar

Status of weed control in coffee farms in Nigeria: A need for improved technologies

Adeleke S. A.*, Idrisu M. and Abdul-karim I. F.

Cocoa Research Institute of Nigeria (CRIN), P. M. B. 5244, Ibadan, Nigeria.

Article History
Received 15 December, 2017
Received in revised form 01 April, 2018
Accepted 05 April, 2018

Keywords:
Coffee farmers, Weed management, Mechanical weeding, Herbicides.

Article Type:
Review

ABSTRACT

Weed management in coffee plantations in Nigeria is currently mostly through manual methods which need to be improved to ensure better production. This research examined various safe weed control methods; it was observed that there is no weeding method that is singularly perfect to handle all the varied situations in the fields. The application or adaptability of a particular method is affected by such factors as environment, cost and farmers' production level and tradition. Mechanical weeding has been identified as the most appropriate method for weed control by coffee farmers in Nigeria because of its effectiveness, immediate results, drudgery reduction and improved soil conditions, provided it is developed within the context of their production level and complemented with one or more relevant alternative weeding techniques. Successful and sustainable adoption also requires good research work and strategic information dissemination. Proper implementation of the right weed control methods, correct timing and planning, involving appropriate production philosophies, such as organic agriculture will make coffee production in Nigeria significant and sustainable, with improvement in quantity, quality and international market acceptability.

INTRODUCTION

Weeds are generally plants that grow in places where they are not desired. They are found everywhere causing several billions of dollars' worth of crop losses annually, with the global cost of control running into many billions of dollars (Abouziena and Haggag, 2016). It was further stated that losses due to weeds exceed losses from the many categories of agricultural pests such as insects, diseases and rodents. The reduction in crop yields has a direct correlation with weed competition: annual world wide losses are estimated to be approximately 10–15% attainable production of principal food sources. Weeds are one of the most important biological constraints to crop production with yield reductions ranging from 28–54% for transplanted lowland rice (Sylvestre et al., 2014).

*Corresponding author. E-mail: akinyoadefem66@gmail.com. Tel: +234 8067958098.

Weed competition in coffee agroforestry causes reduction in stem diameter and primary branch growth while reduction in yield may reach 60% (Ramos et al., 2014). The gravity of losses caused by wrong timing of weeding operations is indicated in Table 1. Early weeding is advisable to prevent weeds from setting seeds. One year seeding means seven years weeding (Thierfelder and Wall, 2008). Weeds are characterized by being prolific, high genetic diversity, seeds remaining dormant in soil for as long as 20 years and reproducing even under unfavourable conditions (Mutua et al., 2014). The longer the weeds are left uncontrolled the harder their control becomes, leading to higher cost of production and yield reduction as further stated. Controlling weeds and correct timing of weeding are, therefore necessary to ensure good yield and quality by minimizing great losses in crop production caused by weed–crop competition. Systematic approach based on a good understanding of weed biology and ecology, is vital for increased food production

Table 1. Estimated reduction in yields of some crops caused by delayed weeding.

Crop	Percentage yield reduction (%)
Coffee	62
Cotton	73
Wheat	35
Barley	18
Soyabean	50
Maize	40
Sorghum	30

Source: Kebede (2000).

(Akobundu, 1979). Weed management decisions vary according to plant life cycles, infestation level, environmental factors, operation timing and weeding objectives (FiBL, 2011b; FAO, 2015; Larimer County, 2016). In addition, success of weed management depends on proper plant identification, selection of effective methods and adequate monitoring of effects. In an attempt to find easier ways of weed control, most farmers worldwide resulted into the use of herbicides to the extent that herbicides consumption soared up to 47.5% of the 2 million of all pesticides consumed annually worldwide (Abouziena and Haggag, 2016). However, the heavy use of herbicides has led to serious environmental and public health problems as further reported. High cost, specific conditions, technicality and selectiveness are other challenges identified for herbicides use by Fongod et al. (2010), Mutua et al. (2014) and Kebede (2000). High input arising from herbicides has pushed many small-scale farmers out of production (Angelina, 2015). The potential problems associated with herbicides as further stated include: (a) injury to non-target plants, (b) crop injury, (c) residues in soil and water, (d) toxicity to other organisms such as beneficial ants, (e) human health and safety and (f) herbicide resistant weeds (Fongod et al., 2010; Abouziena and Haggag, 2016; Graham, 2017). Graham (2017) noted that herbicides are less effective than many other methods; even, blanket application cannot reverse a heavy weed infestation. These problems, mostly life-threatening, have called for safe agricultural practices such as organic agriculture. Organic agriculture is a production system that sustains the health of soils, ecosystems and people (FiBL, 2011a). But, identification of weeds as the most important pest in organic agriculture has led to further challenges of control (Ramos et al., 2014; Abouziena and Haggag, 2016), particularly in terms of avoiding herbicide residues in soil, food and ground water – atmosphere. Repeated use of herbicides, especially selective, could also lead to survival of another weed(s) that may be more difficult to control. Many nations and international bodies have initiated laws on the acceptable chemical residues on food products such as EU's maximum residue level (MRL) (Bateman, 2015) and U. S (Angelina, 2015). Generally, management practices employed to tackle the menace of weeds include manual methods, cultural methods, biological methods, chemical methods, mechanical and electrical methods. According to Abouziena and Haggag (2016), some effective and safe methods of weed control include mulching, natural herbicides (allelopathy), cultural practices, hot water treatment, soil solarization, microwave, flaming, infrared radiation (IR), electrical, ultra sonic, electrical and fresnel lens. Some of these methods are relatively new, going through further development, and require huge investment.

COFFEE PRODUCTION IN NIGERIA

Coffee is one of the major economic commodities and one of the most widely consumed beverages in the world, with about 102 million bags production in a year. Coffee cultivation in Nigeria dated back to early nineteenth century but its production was on a less significant commercial level. Coffee was reported to be the second major traded commodity to oil, thus plays a vital role in the balance of trade between developed and developing countries (Adeleke et al., 2017a and Aderolu et al., 2014), with Nigeria having better comparative advantage in its production than some similar crops (CBN, 2007). Coffee production spans through the South and North of Nigeria with Arabica and Robusta being the most widely cultivated species, with total farm holding of 25,102 Ha between 1964 and 1980 and total export of 30,780 metric ton beans valued at 22.64 million of Naira during 1970-1982 (FGN, 1985). Arabica was believed to originate from Ethiopia while Robusta came from Central Africa. Arabica is cultivated in the high humid altitude of Northern part while Robusta is grown in the forests of Southern Nigeria. According to Worldatlas (2016), Nigeria is currently regarded as the thirteenth top coffee producing country in Africa in 2016 with production of 2,400 metric tons valued at 5,291 pounds. This is certainly not the true reflection of the country's potential; poor farm management has been identified as one the major factors affecting coffee production in Nigeria (Orisajo et al., 2008; Aderolu et al., 2014) stated that although Nigeria supplies less than 2% of world coffee, yet in terms of the national economy, its contribution in the non-oil is significant. About 33 million people derived their livelihoods from growing coffee on subsistence level according to Mohammed et al. (2013). It was also added that coffee contributes a large percentage of income generation, employment and raw materials in Nigeria. Consumption of coffee beverages in Nigeria has also

increased, especially among office workers to remain alert in stressful work environments. Accordingly, coffee may be one of the best agricultural commodities for the current need for economic diversification as an important foreign exchange earner of many producing countries (Orisajo et al., 2008).

The cultivation of coffee involves removing trees from the desired plantation while some big trees are left to provide shade particularly at the young crop stage. The seedlings are then transplanted in rows of 3 m × 3 m spacing using appropriate planting patterns. Site selection is determined by the types of coffee which is highly influenced by altitude among other factors (Opeke, 2012). Weed management is one of the major post–planting operations in coffee production and it is one of the main challenges of coffee farmers in Nigeria. ICO (2001) reported that weeding is one of the most costly parts of coffee production, and it can take up to 20% of total cost under light shade. Farmers in Nigeria use cultural method, involving manual tools, or herbicides, with cultural being more popular, while none uses mechanical according to Mohammed et al. (2013). This trend is apparently against large production of safe organic coffee. Manual weeding, which has very low field capacity of 0.00206 ha/hr, accounts for about 80% of crop production in Nigeria. Most of the drudgery in subsistence farming in the tropics is associated with manual weeding requiring over 60% of the farmer's time (Labrada, 1992) with attendant low productivity. The situation is complicated by tree crops planted under clear-felled condition which are subjected to serious weed competition and tremendous production of the prevalent annuals requiring frequent weeding for successful establishment of young seedlings (Komolafe, 1976). The use of herbicides introduced into agriculture around 1896 (McGraw-Hill, 1977) is playing an increasing role in Nigerian agriculture due to increasing cost and widespread unavailability of the labour required to carry out traditional practices (Akobundu, 1979). Chemical weed control will automatically affect the quality and acceptability of agricultural produce in international markets due to contamination, considering the setting up of product residue limits (MRL). Various philosophies and trends, which discourage conventional agriculture and contain certain rules such as the ban of toxic inputs to avoid negative of agricultural production to the environment and humans, to promote 'sustainable agriculture' exist. For instance, organic agriculture rejects the use of synthetic chemicals among this family of sustainable agriculture (FiBL, 2011a). High quality/certified coffee and organic coffee currently attracts high premium in the world market (Willer and Lucas, 2010; Julio et al., 2014; Ramos et al., 2014). Organic coffee sales are increasing with 32% annual average growth rate, compared to the steady 1.5% growth of conventional coffee in North America (Ramos et al., 2014). The use of synthetic chemicals such as herbicides and fertilizers should therefore be discouraged by nations who want to remain relevant in coffee production in the nearest future.

The objective of this work is to provide an effective, efficient, labour-saving and safe approach of controlling weeds, in view of sustainable agriculture, adoptable by coffee farmers in Nigeria to ensure improved production.

PROSPECTS OF SOME SAFE WEED MANAGEMENT TECHNIQUES FOR ADOPTION IN COFFEE PLANTATIONS IN NIGERIA

The current campaign for clean agriculture in line with the prohibition of the use of synthetic herbicides necessitates the introduction of "safety methods" (Abouziena and Haggag, 2016). These methods are generally regarded as eco-friendly, though they are not without their limitations. They include mechanical weeding, mulching, natural herbicides, cultural control and solarization. Integration of two or more methods further stated for more successful results is corroborated by (FAO, 2015; Queensland Government, 2016; Larimer County, 2016). The requirement for traceability of certified coffees and aggregation of value to the marketed product reflected a new scenery in Brazilian coffee growing, in which reduction of industrialized inputs and the conservation of the environmental resources should be prioritized (Julio et al., 2014). Moreover, conventional and repetitive methods of weed control compromised the sustainability of coffee. In order to develop sustainable weed control strategies research efforts must consider the effectiveness of various weed management practices in the region, the compliance of practices with International Standards, the effect of weed management practices on the natural resource base and farmers' perceptions of weed management practices, according to Ramos et al. (2014). The relevance of a particular technique for application by concerned farmers is believed to depend on how appropriate it is with the existing cultural practices or cropping pattern of such farmers. Particularly, local farmers usually found it difficult to adopt new technologies due to low level of education and technical know- how (Mohammed et al., 2013).

Mechanical weeding

According to Akobundu (1987), mechanical weeding includes all weed control practices where a mechanical device or powered tools and machinery are used with fossil fuel or animal as a source of energy. Mechanical weeding was introduced into agriculture around 100B.C as a source of power outside that of the farmer to increase his efficiency (Adeleke, 2005). It was claimed to

Table 2. Performance characteristics of some mechanical weeders.

Type	Weeding efficiency (%)	Field capacity (Ha/Hr)	Source
Engine powered oscillatory blade	81.34	0.036	Silas and Abu (2015)
Engine powered rotary hoe	73.4	0.079	Olaoye and Adekanye (2013)
Engine powered rotary brush	97.5	0.108	Olukunle and Oguntunde (2006)
Engine powered rotary hoe,	90.5	0.06	Viren and Ajay (2003)
Manually pushed, straddle-furrow rotary hoe	80	0.0237	Adebayo and Oni (1999)
Engine powered rotary hoe	93	0.04	Rangasamy et al. (1993)
Ox-drawn straddle-row rotary hoe	64	111 (man-h/ha)	Oni (1985)
Engine powered rotary hoe	80	0.022	Ambujam et al. (1984)

be simple, easily understood by farmers and very effective with immediate result. The Operation Feed the Nation (OFN) sponsored seminar of October, 1978 challenged Nigerian Agricultural Engineers to develop different profiles of weeders for Nigerian farmers. Many mechanical weeders have been fabricated locally by these engineers, but Olukunle and Oguntunde (2006) stated that the use of mechanical weeders in agriculture in Nigeria was not yet popular; this necessitates the formulation and implementation of appropriate policies for their development and adoption. Among the factors required in designing mechanical weeders are crop type, cropping pattern, prevailing soil condition, weeding objectives and performance indices, economy and weed density, age and type. Mechanical weeding is similar to manual weeding currently commonly practiced by local farmers in term of result, except the low work rate. Olaoye and Adekanye (2013) estimated N2, 700/Ha for mechanical weeding as against N12, 000 for manual.

Mechanical weeding has been reported by FiBL (2011b) and Queensland Government (2016) as the most widely preferred direct method and certainly the most immediately applicable method for weed management when using herbicides is not desirable (Chicouene, 2007), and it is suitable for larger infestations because it reduces weed bulk with less manual effort (Queensland Government, 2016). Fully grown weeds with deep roots can only be controlled through this method, but weeds are much easier controlled when they are small. Nevertheless, care should be taken to minimize soil disturbance, not to bring weed seeds to germination zone or injure the roots of desirable plant. Mechanical weeding is also not selective and do not expose crops to partial competition with weeds like most other control methods. It was reported that most organic crop growers rely on mechanical weeding as a safe and available method for controlling weeds. Adeleke et al. (2017b) reported that mechanical weed control is the best, the simplest and widely used because of its effectiveness with little or no limitations. Sylvestre et al. (2014) believed that introduction of mechanical weeder may be cost effective and safe approach to weed management, especially for resource poor farmers. But, only good handling in terms of machine operation and maintenance can ensure best results. Various studies indicated that application of mechanical weeders would increase field capacity (Table 2), decrease time and cost of weeding (Adeleke et al., 2017b). It was added that the weeders range from hand-held tools to sophisticated tractor-driven devices. Reported most effective mechanical method of controlling weed is complete burying of weed seedling to 1 cm depth or to cut them at or just below the soil surface. Operator-carried motorized mowers (such as in Figure 1) are also becoming alternative to using the machete/cutlass in some countries (TECA, 2014). Mowing is a method in which the foliage of plants cut or shred at a specified/desired height, depending on the objectives, to suppress weeds and prevent weed seed dispersal. This practice is the most effective to reduce weed seed populations as well as to restrict weed growth, particularly when it is performed before seeds are set. It is also very successful for annual broadleaf and tall growing weeds while some weed species, especially perennials, may sprout with increased vigour which may require integrating it with another method. The understanding of the biology of weeds is therefore necessary for its successful application. Repeated removal of weed biomass through mowing reduces vigour and may totally kill weeds as it depletes plant food reserves (TECA, 2014).

Mechanical method requires planning crop arrangement from the outset to accommodate the kind of equipment that will be used for weeding. The adaptability of mechanical weeders depends on the type of weeds and crops, stages of crop and weed growth and soil condition. Weather and soil conditions have a major influence on the efficacy of this method. Many of the weeds in tree crop plantations are annuals (Komolafe, 1976) which can be killed by cutting below ground level, burying completely or dragged out to expose to dry on the soil surface or cutting as close to soil surface as possible as commonly done in post-planting control

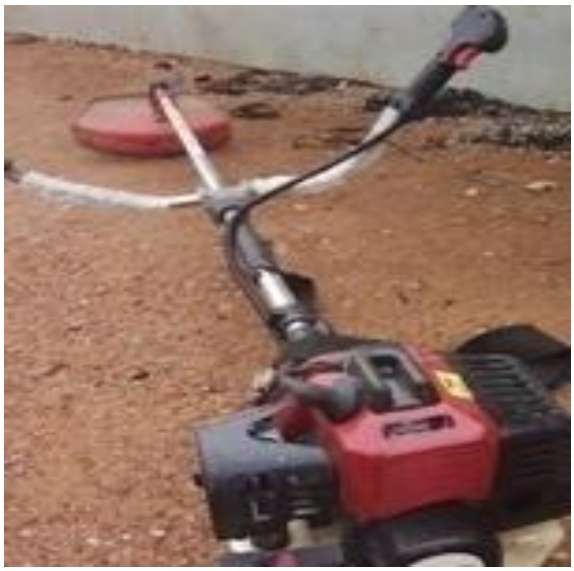

Figure 1. Carried motorized mower.

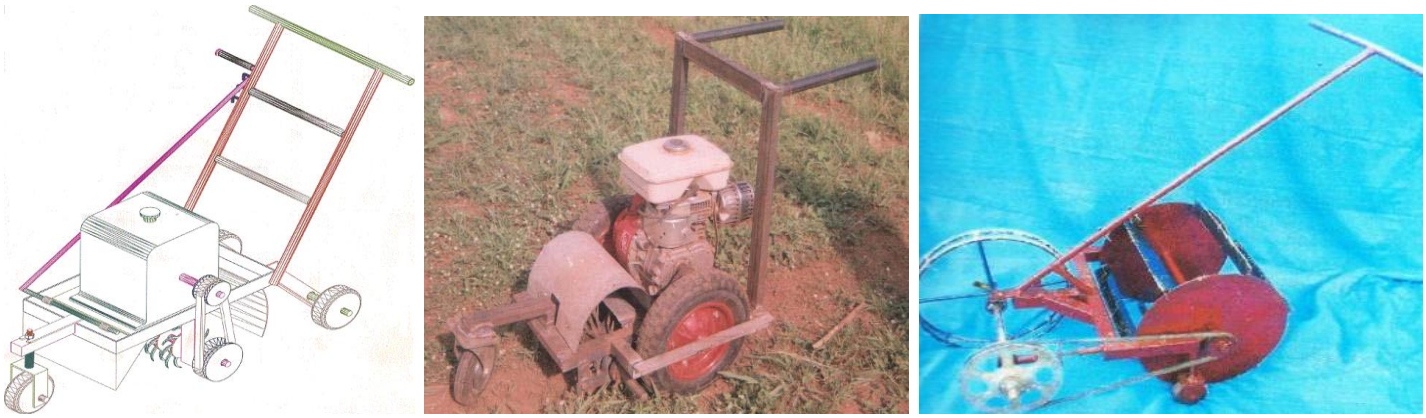

Figure 2. Some locally developed weeders.
Source: Olaoye and Adekanye (2013), Olukunle and Oguntunde (2006) and Adeleke (2005).

(Adeleke et al., 2017b). Annual weeds are also easily destroyed at the seedling stage while perennials which are also found among tree crops are more difficult to eradicate (Komolafe, 1976; Graham, 2017) as they multiply through cutting by weeding or tillage equipment. Larimer County (2016) recommended that biennial weeds should be cut at least 2 - 4 inches (2.5 - 5.0 cm) below soil surface. It is advisable to use implements such as ploughs, harrows and cultivators for weeding at early crop establishment on large scale farms where mono-cropping is usually practiced, and handy weeders for subsistence level where intercropping is common among coffee farmers. The additional advantages include improved soil condition which may result in increased yield.

Various designs of handy weeders and improved similar implements would be appropriate for weed management when the crops are relatively well established (Figure 2). The crop base can then be handled manually to avoid damage to crops. High cost of investment which is one of the major challenges of mechanical weeding can be addressed by the development of intermediate technology by local engineers and fabricators. Kebede (2000) has recommended the use of simple tools/implements and promotion of animal-drawn equipment for weeding in Ethiopia. Farm input subsidies and hiring services by government and farmers' co-operatives may also be

some of the effective approaches to address this problem. According to Delate et al. (1999), the apparent inadequacies of mechanical weeding method could be balanced by high yield and quality caused by stimulation of nutrients and consequent high premium placed on organic crops. Combining mechanical with preventive methods as commonly practiced in organic and conservative agriculture may be more effective and efficient. The development or modification of the existing mechanical weeders, including the right choice of power source, to meet the requirements of local coffee farmers is also very vital and need to be encouraged for profitable, efficient and sustainable coffee production in Nigeria. Adoption of suitable implements/tools which has been used successfully in regions with similar soil and climatic conditions should also be explored and improved.

Preventive methods

These are practices which discourage or reduce the spread of weeds to level that does not result in economic or quality loss of the crop, rather than completely eradicate the weeds. They include good soil management, balanced fertilization, and avoiding seed dissemination as practiced in organic and conservative agriculture.

Maintaining good soil quality promotes the growth of crops to compete better than weeds or at least provide a level playing ground. Healthy, fertile, well aerated and drained soil is required in this regard. According to FiBL (2011b) and FAO (2015), the likelihood of weed problems is reduced with the establishment and maintenance of healthy soil. Balanced fertilization, as stated, will support an ideal growth of the crop which promotes the growth of the desirable crop over weeds. But blindly applying fertilizers can be counterproductive: necessary soil tests are required by specialists to determine the optimal fertilization plan (Graham, 2017). Keeping unwanted plants from getting deeply established and spreading seeds will automatically reduce weeds infestation. For many species, few days or weeks are enough before weeds flower and disseminate reasonable amount of seeds which may survive for many years (Graham, 2017). Very few years of vigilant pre-flower weeding, therefore, have long-term advantages. Specifically, preventing weeds from growing into seeds for a few years will deplete the seed bank and minimize energy dissipated in weed control in the future.

Mulching

Mulching involves covering the soil with organic or synthetic materials to control weeds. It is most important in preventing weed growth (Graham, 2017) and widely used in production of such plants as crops, fruits and nursery. Organic mulches include straw, perennial grasses, residues of perennial crops like banana, sugarcane straw or bagasse, sawdust or newspaper while synthetic mulches include polyethylene sheets or film, plastics and natural fibres (Abouziena and Haggag, 2016; Graham, 2017). Plastics or natural fibres are made with or without holes, and thin plastics with holes are usually combined with thicker materials for better results. Plastic mulches are also of various colours. The black plastic which conserves heat most warms the soil more and is beneficial for some crop species while the clear type permits germination of some weed and excessive heating. Reports from most research work have indicated that opaque plastic mulches are more effective than other mulch materials. Some plastic colours (such as yellow and green) have also been reported to have little or no effects on weed control in most cases, but their combinations with some other colours could be more effective (Abouziena and Haggag, 2016). Moreover, they can be designed for effective control of insect pests and weeds simultaneously. However, the performance of soil mulching is mostly determined by the types of crops and weeds, mulch materials and number of layers, purpose of mulching, and field condition and location. Properties of a good mulch material include: being opaque and thick enough to exclude light, ability to be applied efficiently and being inexpensive enough relative to expected income (Angela, 2015). Soil mulching increased grain yield by 17%, soil water storage by 41% and reduced water loss from 0 – 30 cm depth (Hegazi, 2000; Unger et al., 2010). It increases water retention, improving Water Use Efficiency (WUE) which ensure even moisture distribution throughout the soil profile (Awodoyin et al., 2007) while the water holding capacity of the soil by the added humus from organic mulch after decomposition also increases. Water saving under plastic mulching was above 50% compared to herbicides or hoeing with benefits to crop performance under water stress increased (Abouziena and Haggag, 2016). This characteristic favours the use of plastic mulching in Northern part of Nigeria where the largest percentage of coffee is grown. The inhibitory effect of organic mulch on weeds may be due to both physical, through reduced passage of solar radiation, and temperature on soil superficial layer, emergence suppression and allelochemicals released by straw (Oliveria et al., 2014). The introduction of synthetic mulches, the mechanization of their application to meet large and small-scale agriculture at reasonably low costs, and favourable effects on yield and early crop growth favoured the use of synthetic mulch according to Abouziena and Haggag (2016). Organic mulch which is readily available to the farmers and relatively cheaper will be easily adoptable by them. Other benefits of mulching reported include

maintaining soil structure, erosion reduction and increasing soil nutrients. Its limitations include difficulty in controlling established weeds, frequent replacement in case of breakdown, availability, difficulty in handling some weeds and high cost, including extra cost for disposal. Graham (2017) believed that mulches are more effective for small annual weeds than perennials. There is also the tendency of germination of seeds from crop residues which also becomes a nuisance to crop production. This method could also be used in this case, if well developed, at the stage when coffee is relatively established.

Cultural control methods

These methods include any husbandry or management practice that enhances a crop ability to compete with weeds. They include critical weed period competition; intercropping, plant density, cover cropping, stale seedbed, crop rotation, fertilizer manipulation and selection of competitive cultivars. Intercropping, cover cropping and selection of competitive cultivars are more relevant to coffee farmers in Nigeria. In fact, coffee farmers are well used to cover cropping and intercropping; improvement may be required to be more beneficial and effective according to modern trend and compatibility of these crops as to their effects on the main crop. Intercropping may be for the purpose of harvesting crop for profit or just to provide cover for weed suppression. Various definitions of cover crops commonly stated that they are planted for the purpose of benefiting the soil and the main crop, and not for harvesting (Fongod et al., 2010). Crop residues reduce weed seed viability due to increased biological activities (Thierfelder and Wall, 2008). Intercropping in coffee plantation should be done to reduce space between coffee rows, and safe energy and time that must have been used in weeding the original relatively wide inter-rows of coffee. Weeds in the inter-rows of the intercrop or cover crop are then controlled by appropriate and safe techniques such as mechanical, mulching and solarization. Moreover, cover crop can be used at both the early and established stages of coffee. But planting of cover crop at early should be done at the correct interval after the main crop was planted to reduce undue competition. Mutua et al. (2014) recommended interval of 2 – 3 weeks. The use of cover crops has been a viable alternative commonly employed for weed control in plantations, it was further stated. Cover crops exhibit various properties, and selection is affected by instinct factors such as ability of rapid establishment, reduced competition with the main crop, good foliage cover, even during critical periods, climbing nature and efficient production of rapidly recycling biomass (Fongod et al., 2010; Julio et al., 2014). Several legume species reportedly suitable for weed control in coffee plantations include Labe-Labe (*Dolichos lablab)*, forage peanut (*Arachis pintoi*), Leucaena (*Leucaena leucocephalla*), Cassia (*Cassia mangeum*) and perennial Soybean (*Glycine wightii*). Some species of Commelinacae which cover the soil extensively have also proved effective in weed suppression in coffee plantation (Fongod et al., 2010). Rye (*Secale cereale*) provided excellent weed suppression by producing dense canopy while its residues reduce germination and growth. *Nelsona canescens*, a non-leguminous prostrate plant, had shown significant ability to control many weeds and prevent pests and diseases as 9 out of 73 weed species were found growing, showing 60 – 100% reduction in abundance and noticeable reduction in vigour in a survey at Tiko, Cameroon, while number of snails on and around pseudo-stems of banana was also significantly affected. *A. pintoi* and *Heterotis rotundifolia* as cover crops in agro-forestry are more effective in suppressing weeds than mechanical and natural herbicides according to experiments conducted on established coffee farms (Ramos et al., 2014). Plants with such characteristics need to be identified for proper utilization. Cover crops can be combined with shade trees when they are growing while only shade trees can be used when cover crops have fully established according to the report. Success of perennial legumes such as Centrosema, Mucuna and Pueraria as cover crops has also been established (Fongod et al., 2010; Mutua et al., 2014; Thierfelder and Wall, 2008). According to FiBL (2011b), Melons, Cowpeas and Pumpkins have yielded good results in Africa, but intercropping should be well-planned with fast-growing weed suppressive “smoother crops” to achieve better results. Additional advantages of cover crops include soil erosion prevention, soil fertility improvement and pest and disease control.

Tall crop varieties with broad leaves will compete better with late occurring weeds than small varieties with narrow leaves. Some crop varieties also inhibit and suppress weeds: there are witch weed (*Striga*) resistant maize and cowpea cultivars in many African countries (FiBL, 2011b). The development of high yielding coffee cultivars with higher overleaf area, resistance to loss of tiller and greater heights which are the attributes of cultivars competitive ability (Seavers and Wrigh, 1999) will yield good results in this respect. One of the disadvantages of competitive cultivars is that high yielding varieties may not effectively control weeds, vice versa. Efforts should be directed at identifying the intercrops that will give best results with coffee grown in different ecological zones of the country.

Natural herbicides

These are products made of chemicals that are not nasty

extracted from plants or animal products (Graham, 2017) that are as good as or even better, and are much safer than synthetic herbicides. It was added that organic soaps, plant oil blends and common household products are also useful in this regard. Citric acid and vinegar have shown promises for controlling weeds (Abouziena et al., 2009). Concentrated vinegar is perhaps the most common natural herbicide, though it does not kill root systems or some larger weeds according to a weed management specialist (Graham, 2017). Cinmenthylin produced from species of sage, control many annual grasses and suppressed some broad-leaved weeds (Grossman et al., 2012). Neem strongly inhibits germination and growth of several weeds as indicated by Xuan et al. (2004). It was further stated that various classes of compounds had been known for their potential use as natural herbicides. This may be the cheapest method of weed control, even pests and diseases, since these plants exist naturally. Farmers are surrounded with abundant plants which may possess this property that will make this approach the most easily adopted technique, or at least to complement another. Fongod et al. (2010) has reported identification of weed specie that effectively suppressed most other weed growth as well as preventing a pest infestation through survey of local farmers' plantations. Research work should be seriously directed in this direction to identity and utilize the allelopathic properties of many plants that are easily accessible by this group of farmers in their localities, including their farms.

Biological control

This involves the utilization of living organisms or biological agents such as insects, larvae, moths and pathogens to destroy weeds. According to Adebayo and Uyi (2010) and Labrada (1992), this is a promising solution to many tropical weeds including perennial grasses that are more difficult to control by other methods due to their subterranean organs. It was also added that biocontrol is not only self-perpetuating but sustainable, economical at long run, feasible and environment friendly. Soil-borne fungus *Fusarium oxysporum* and some other *Fusarium* spp. have been found very effective in Africa such as Mali, Burkina Faso, Sudan and Ghana in reducing witch weed (FiBL, 2011b; FAO, 2015). *Pseudomonas fluorescens putida* isolates significantly inhibited germination of *Striga hermonthica* seeds as added. Rhizobacteria capable of suppressing or actually destroying germination of witch weed seeds are promising since they can be cheaply formulated into seed inoculants. South Africa has recorded reasonable level of success using this approach, but there is not much success recorded on this method in Nigeria but some attempts have been made, especially in the early 1970s (Adebayo and Uyi, 2010).

There is need for the development of the potential of this approach which prospects has been reported to be of limitless opportunities, provided all stakeholders seriously pursue the course as further stated. Applied research, extension of research outcomes for implementation, training of specialists and education at small-scale farming level are necessary for the adoption and promotion of this technique (Labrada, 1992). Similarly, pasturing is another possible approach to weed control. It involves grazing animals such as cattle, goats and sheep's on crop plantations. It is reported to be a successful method of weed control in coffee, mangoes and avocadoes plantations (FiBL, 2011b; FAO, 2015). This practice will be very suitable to Northern Nigeria where grasses are the common weeds and coincidentally farmers keep animals such as cattle, sheep and goats. One of its limitations is the difference in the preference of these ruminants for different types of weed, such that each type of these animals has to be rotated with the others to achieve effective weed control. Grazing requires planning to suit the stage when the plants are tender enough and have not borne flowers or seeds.

Challenges against the development of biocontrol in Nigeria have been observed to range from inadequate fund, lack of government will to implement suitable policies and inadequate skilled scientists. One of the limitations of biological control noted here is that crops are still exposed to weed competition for air, water and nutrients because these weeds are rarely totally eliminated, but only partially destroyed by reducing the vigour or size (Queensland Government, 2016), as it may take some time before they are completely eradicated. The method may require combining it with another suitable method(s) for best result. Perennial weeds can alternatively be handled by exposure and desiccation or burning of their subterranean organs during land preparation before the establishment of plantations, or planting smoother crops such as sweet potato to suppress them, especially *Imperata cylindrical.*

Solarization

Solarization involves the use of transparent polyethylene sheets to trap the heat from solar radiation to raise soil temperature, with greatest effect within top 4 – 6 inches of soil, to levels that lethal to weed seeds and seedlings (Angela, 2015; Abouziena and Haggag, 2016). Extended period of full sun of 4 - 8 weeks required makes it most suitable for tropics and semitropical regions where air temperature naturally exceeds 40°C (Angela, 2015). It has been used successfully in many countries to control weeds, soil borne pathogens and mites. Mechanisms for weed control are thermal killing of seeds, thermal killing of seeds induced to germinate and biological control

through weakening. Average lettuce yield was significantly higher in solarized soil (Candido et al., 2011). It can also be beneficial in terms of improving soil conditions including temperature and nutrients, and reducing soil-borne diseases and pests such as nematode according to reports. However, effective weed control was limited by such factors as solar radiation, soil and atmospheric conditions and cost of materials and bulk handling, especially in large scale agriculture. This may be the most appropriate method to complement other methods especially in the North and Savannah where solar radiation is better accessible and coffee is, coincidentally, more grown. But the willingness of adoption by low income coffee farmers in Nigeria may be the major constraint of this method. There is need to identify materials which are relatively cheap and will perform best in this regard through research.

Flaming or thermal method is related to solarization because of heat involved, and may be appropriate to replace the use of herbicides which most farmers are used to as the two methods are similar in action. It involves touching weeds with small landscape flamers which are hooked to standard propane tanks (Graham, 2017). Plants are heated briefly to 100°C or higher to provoke proteins in the leaves and bursting their cell walls or rupturing the cytoplasm. The weeds, consequently dry out, and suppressed or die. Its success depends on the susceptibility of weeds to heat; most effective for annual weeds in crops that are tall with woody stems or have the meristem below ground (Angela, 2015). Although, it is reported to be quite expensive because of gas and machinery, formulation of the right policies including support may help adoption.

CONCLUSION

It was observed that no method can singularly and perfectly handle weeding due to variation in weed characteristics among other factors. Mechanical weeding is considered the most appropriate method for coffee farmers in Nigeria if necessary factors and right timing are adequately addressed, considering its similarity to the existing practice among farmers, effectiveness with drudgery reduction and immediate result. The limitations of mechanical weed control can be handled properly by similar readily available, effective and relatively low cost methods, such as cultural practices, organic agriculture and natural herbicides, according to the farmer's environment and traditions. Appropriate useful weeding techniques which are relatively undeveloped should be promoted for effective coffee production. Intensive research, including those on successful methods used in other regions, and strategic extension services and supportive policies, are necessary to identify and disseminate the best weed control methods for different coffee producing areas in order to boost production and ensure safe product that is acceptable internationally.

REFERENCES

Abouziena H. F. & Haggag W. M. (2016). Weed control in clean agriculture. A review. Planta Daninha. Vicosa-MG. Vol.. 34, No 2:377-392.

Hussein F. H., Abouziena Ahmad A. M., Omar Shiv D., Sharma & Megh Singh. (2009). Comparison of some new natural product herbicides for weed control at two growth stages. Weed Technol. 23(3):431-437. doi.org/10.1614/WT-08-185.1

Adebayo A. A. & Oni K. C. (1999). Local manufacture and management of agricultural equipment. In: Proceeding of the Annual Conference of the Nigerian Institution of Agricultural Engineers, Vol. 2. Pp.180–183.

Adebayo R. A. & Uyi U. O. (2010). Biological control of invasive weed species: Nigerian experience. Int. J. Agric. Res. 5 (12):1100-1106.

Adeleke S. A. (2005). Design and construction of a manual rotary weeder for row crops. PGD thesis, Agric. Engineering Dept., Federal University of Technology (FUTA), Nigeria.

Adeleke S. A., Oloyede A. A., Idrisu M. & Famuyiwa B. S. (2017b). Adapting mechanical weeder to tea (*Camellia sinensis*) plantations in Nigeria. In: Proceeding of the 51st annual conference of Agricultural Society of Nigeria (ASN), Abuja, Nigeria. Pp. 1053-1057.

Adeleke S. A., Olukunle O. J., Olaniran J. A. & Famuyiwa B. S. (2017a). Design of a small-scale hulling machine for improved wet-processed coffee. Int. J. Sci. Technol. Res. 6(08):392-397.

Aderolu I. A., Babalola F. D., Ugioro O., Anagbogu C. F., Ndagi I., Mokwunye F. C., Mokwunye I. U., Idrisu M. & Asogwa E. U. (2014). Production and marketing of coffee (*Coffea robusta*) in Kogi State, Nigeria: challenges and recommendation for intervention. J. Soc. Sci. Res. 3(2):207-215.

Angela R. P. (2015). Methods of weed control. Retrieved 14/02/2018 Available at weedscience.okstate.edu/Lecture%25206%2520Methods%2520of%2520Weed%2520Control.pdf

Angelina S. B. (2015). Weed control practices on Costa Rican coffee farms: Is herbicide use necessary for small-scale producers? Retrieved 14/02/2018 Available at https://www.researchgate.net/publication/225547398_Weed_control_practices_on_Costa_Rican_coffee_farms_Is_herbicide_use_necessary_for_small-scale_producers.

Akobundu I. O. (1987). Weed science in the tropics: principles and practices. John Wiley and Sons Ltd.

Akobundu I. O. (1979). PANS. Vol. 25, Issue 3: 287-298. Retrieved 12/11/2017. Available at www.tandfonline.com/doi/abs/10.1080/09670877909412098?src=recsys.

Ambujam J., Doger J. W. & Kersten M. (1984). Design and development of a rotary paddy weeder. AMA, 17, 2.

Awodoyin R. O., Ogbeide F. I. & Oluwole O. (2007). Effects of three mulch types on the growth and yield of tomato (*Lycopersicon esculentum* Mill.) and weed suppression in Ibadan, rainforest-savanna transition zone of Nigeria. Trop. Agric. Res. Ext. 10(1):53-60.

Bateman R. (2015). Pesticide use in cocoa. A guide for training administrative and research staff, 3rd edition: 1 111

Vincenzo C., Trifone D'Addabbo, Vito M. & Donato C. (2011). Weed control and yield response of soil solarization with different plastic films in lettuce. Sci. Hort. (130)3:491-497.

CBN, Central Bank of Nigeria (2007). Domestic, production, consumption and prices. Stat. Bull. 18:131-15.

Chicouene D. (2007). Mechanical destruction of weeds. A review. Agron. Sustain. Dev. 27(1):19-27.

Kathleen D., Andrea McKern, Daniel R. Cynthia C. & Bob B. (1999). Comparison of organic and convention rotations at the Neely Kinyon Long Term Agroecol. Res. (LTAR) site: First year results. Loepold

Center for Sustainable Agriculture Annual report. Ames: Iowa State University.
FAO (2015). Weed management in organic agriculture. Training manual for organic agriculture. Retrieved 16/02/2018 Available at teca.fao.org/read/8375.
FGN, Federal Government of Nigeria (1985). Toward increased production of coffee 'cash' crops in Nigeria. Report of the study group on the rehabilitation of 'cash' crops. Pp. 1-48.
FiBL (2011a). Definition and benefit. African Organic Agriculture Training Manual. Version 1.0 June 2011. Edited by Gilles Weidmann and Lukas Kilcher. Research Institute of Organic Agriculture FiBL, Frick. Retrieved 16/02/2018 Available at teca.fao.org/read/8359.
FiBL (2011b). Pests, diseases and weeds. African Organic Agriculture Training Manual. Version 1.0 June 2011. Edited by Gilles Weidmann and Lukas Kilcher. Research Institute of Organic Agriculture FiBL, Frick. Retrieved 16/02/2018. Available at www.organic-africa.net.
Fongod A. G. N., Focho D. A., Mih A. M., Fonge B. A. & Lang P. S. (2010). Weed management in banana production. The use of Nelsona canescens (Lam.) Spreng as a non-leguminous cover crop. Afr. J. Environ. Sci. Technol 4(3):167-173.
Graham S. (2017). 11 ways to control weeds without chemicals. Accessed 14/02/2018 Available at https://www.networx.com/article/11-ways-to-control-weeds-without-chemica .
Grossmann K, Hutzler J, Tresch S, Christiansen N, Looser R & Ehrhardt T. (2012). On the mode of action of the herbicides cinmethylin and 5-benzyloxymethyl-1,2-isoxazolines: putative inhibitors of plant tyrosine amino transferase. Pest Manag. Sci., Vol. 68(3):482-491.
ICO, International Coffee Organization (2001). Sustainable coffee. In: Baker, P.S Eds. Coffee futures: a source book of some critical issues confronting the coffee industry, The Commodities Press, pp. 56-65.
Julio C. F. S., Aquiles J. C. & Benjamin M. (2014). Soil cover and weed control on coffee intercropping perennial legume. Int. J. Appl. Technol. 4(4):149-157.
Kebede D (2000). Weed control methods used in Ethiopia. Retrieved 14/02/2018. Available at http://www.atnesa.org/weeding/weeding-kebede-methods-ET.pdf.
Komolafe D. A. (1976). Weed problems in tree crops in Nigeria. PANS. 22(2):250-256. Retrieved 12/11/2017 Available at www.tandfonline.com/doi/pdf/10.1080/09670877609412373.
Labrada R. (1992). Tropical weeds: Status and trends for their control. In: Proceedings of the 1st International Weed Control Congress, Feb. 17-21, Melbourne, Australia, pp. 263-276.
Larimer County (2016). Methods of weed control. Retrieved 14/02/2018 Available at https://www.larimer.org/naturalresources/weeds/control.
McGraw-Hill Inco. (1977). McGraw-Hill encyclopedia of Science and Technology, 6, pp. 471.
Mohammed A. B., Ayanlere A. F. & Ekenta K. M. (2013). Profitability of coffee in Kabba/Bunu LGA of Kogi State. Afr. J. Agric. Res. 8(23):2897-2902. Retrieved 30/11/2017. Available at http: //www.academicjournals.org/AJAR.
Mutua J., Muriuki J., Gachie P, Bourne M. & Capis J. (2014). Conservation Agriculture with trees: principles and practice. A simplified guide for extension staff and farmers. Technical manual No. 21. World agroforestry centre, Nairobi, Kenya. pp 100. Retrieved 19/03/2018 Available at http://www.worldagroforestry.org/downloads/publications/PDS/TM17693.pdf.
Olaoye J. O. & Adekanye T. A. (2013). Development and evaluation of a rotary power weeder. In: tillage for agricultural productivity and environmental sustainability conference held in Ilorin, Nigeria, pp. 129-141.
Oliveira Jr R. S., Rios F. A., Constantin J., Ishii-Iwamoto E. L., Gemelli A. & Martini P. E. (2014). Grass straw mulching to suppress emergence and early growth of weeks. Planta Daninha 32(I):11-17.
Olukunle O. J. & Oguntunde P. (2006). Design of row crop weeder. Conference on International Agricultural Research for Development, Tronaky, Oct. 11-13, 2006, University of Bonn.
Oni K. C. (1985). An ox-drawn straddle-row rotary weeder. Samaru J. Agric. Res. 3(1&2):96-104.
Opeke L. K. (2012). Tropical commodity tree crops. Spectrum Books Ltd, Ibadan. Second edition. Pp. 226.
Orisajo S. B., Fademi O. A., Okeniyi, M. O. & Dongo L. N. (2008). Frequency of occurrence and geographical distribution of plant-parasitic nematodes on coffee in Nigeria. Annual Report, ISSN 2384-8022, Cocoa Research Institute of Nigeria, Ibadan. Pp. 107-110.
Queensland Govt. (2016). Weed control methods. Department of Agriculture and Fisheries. Retrieved 12/02/2018 Available at https://www.daf.qld.gov.au/plants/weeds-pests-animals-ants/weeds/control-methods.
Ramos M., Alvarado E., Davila M., Rodriquez O. R. & Sanchez Y. (2014). Weed management alternatives for organic coffee agroforestry systems of Puerto Rico. Retrieved 12/02/2018 Available at htpps://projects.sare.org/project-reports/Is10-231/".
Rangasamy K., Balasubramanian M. & Swanninuthen K. R. (1993). Evaluation of power weeder performance. AMA. 24(4):16–18.
Seavers G. P. & Wright K. J. (1999). Crop canopy development and structure influence weed suppression. Weed Res. 39(4):319-328.
Silas O. N. & Abu H. (2015). Development and evaluation of wheeled long-handle weeder. The West Indian of Engineering, vol. 37, No. 2:37-44.
Sylvestre G., Ibnou D., Kokou A., Jean-Martial J., Amakoe D. A., Atsuko T., Sanoussi A. & Kazuki S. (2014). Participatory evaluation of mechanical weeders in lowland rice production systems in Benin. Crop Protect. 61:32-37.
TECA (2014). Weed management in conservation agriculture. Retrieved 16/02/2018 Available at https://tech.fao.org/technology/weed-management-conservation-agriculture.
Thierfelder C. & Wall P. C. (2018). Weed control in smallholder Conservative Agriculture. Technical Bulletin. CIMMTYs BMZ and IFAD-funded projects on Fascilating and Adoption of Conservation Agriculture in Eastern and Southern Africa. Retrieved 16/02/2018 Available at http://www.fao/ag/ca/Training Materials/Leaflet weedcontrol.pdf
Unger P. W., Kirkham M. B. & Nielsen D. C. (2010). Water conservation for agriculture, soil and water conservation advances in the United States. New York; Soil Science Society America. (Special Publication. 60).
Viren M. V. & Ajay V. (2003). Design and development of powered-operated rotary weeder for wetland paddy. AMA 34(4):27-29.
Willer H. & Lucas K. (Eds) (2010). The World of Organic Agriculture Statistics and Emerging Trends 2010. IFOAM, Bonn and FiBL Frick. pp: 244. Retrieved 14/02/2018 available at www.ifoam.org.
Worldatlas (2016). Top coffee producing countries. Accessed 6/12/2017. Available at www.worldatlas.com/articles/top-coffee-producing-countries.html.
Tran D. X. Tsuzuki E., Terao H., Matsuo M., Tran D. K. & Ill-Min C. (2004). Evaluation on phytotoxicity of neem (*Azadirachia indica* A. Juss) to crops and weeds. Crop Protect. 23(4):335–345.