Phytotoxicity and mode of application of crude cassava water extract as a natural herbicide on weeds of cowpea (*Vigna unguiculata* (L.) Walp).

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ABSTRACT

Two field trials were conducted in 2007 and 2008 to evaluate the toxicity and mode of action of Crude Cassava Water Extract (CCWE) as a natural post - emergence herbicide on cowpea weeds. The study was a factorial trial laid out in split plot design with three replications. The main plot comprised of mode of application: foliage spray (F), soil drench (SD) and foliage+ soil drench (F+SD), sub and sub sub plots were: CCWE at the rates of 50 and 100 % and CCWE herbicide of Bulk source, MS (*Manihot* Selection),TMS (Tropical *Manihot* Selection) while weedy check and handweeded served as controls. The results showed contact and systemic action as the phytotoxicity of CCWE. The phytotoxic effects from Bulk and MS at 100% on F and F+SD recorded over 50% on weeds of cowpea. About 77% and 82 % for Bulk and MS on F and F+SD reached herbicidal efficacies of weed biomass and density respectively with significant differences ($p<0.05$). All herbicidal treatments showed statistical differences ($p<0.05$) in Cowpea Plant Height (CPH) and Leaf Area (LA).The highest CPH and LA were recorded from handweeded, Bulk and MS at 100% on F+SD in the trials. The yield parameters revealed all herbicidal treatments achieved similar high values with statistical differences ($p<0.05$). The cowpea grain yield recorded in 2007 and 2008 from CCWE were MS (520-600 kg/ha^{-1}) and Bulk (520-590kg/ha^{-1}) at 50 and 100% on F and F+SD which compared favourably with handweeded (530-600kg/ha^{-1}) while TMS was (360-470kg/ha^{-1}). Although, TMS CCWE could not compared favourably with MS and

Bulk in most parameters, but it was significantly higher than weedy check. Significantly reduced growth and yield parameters with cowpea grain yield of 160-200kg/ha^{-1} were recorded from weedy check in the trials. It is concluded that, hydrogen cyanide (HCN) from CCWE is a causative factor in the herbicidal actions in different mode of application which produced contact and systemic mode of action on weeds of cowpea.

Key words: Cowpea, Crude cassava water extract, Phytotoxicity, Mode of application, Weed control

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INTRODUCTION

Cowpea *Vigna unguiculata* (L) Walp is an important crop for farmers in the West African region. It is an ancient crop grown for its green pods, ripened seeds and green leaves which are cheap sources of high quality protein in the daily diet of rural and urban populations. Its haulms are also important source of nutritious fodder for the livestock in the dry savannas (Dugje *et al*., 2009).

Weed interference is a major production constraint in legumes worldwide and especially throughout the production areas of Nigeria (Dugje *et al*., 2009). Cowpea yields are however, low in most farms in Nigeria due to unchecked weed growth which has reduced cowpea yield by as much as 68-81% (Akobundu, 1979). Ayeni *et al.,* (1996) however, reported that the first 4-6 weeks after planting are the critical period of weed competition in cowpea. Since complete eradication of all weeds is not possible, it becomes imperative that their infestation be managed in a sustainable manner that will not cause economic damage (Okereke, 2000).

However, several approaches exist for the control of the weeds and these include use of chemicals (Adeosun and Lagoke, 2005), cultural, mechanical and biological methods, land management, use of resistant crop varieties, crop rotation, following use of botanicals (Jha and Dhaka, 1990) and allelochemicals (Rice, 1984). The use of chemicals in cowpea has been hampered by injury from herbicides. Mode of action of herbicides which might be contact or systemic also results into phytotoxicity from the chemicals. Contact herbicides affect the photosystem (photosynthesis) which involves electron transport with cellular membrane disruptions (Dropdata 2010). Systemic mode of action of herbicides inhibits photosynthesis (photosystem), essential chloroplasts and causes slow chlolorosis (Dropdata 2010)

Moletti *et al*., (1991) had earlier observed that because of phytotoxicity of these chemicals, highest yield does not always come from the field with the most complete control of weeds. The long term hazardous effects on humans, wildlife, pollution of water, soils, air and the environment resulted due to the use of larger doses of herbicides thereby increasing cost to farmers and the society Adesiyan (2005). The development of natural herbicides is one method of addressing cost, impact of weed management and toxic effect of herbicides on our community.

Cassava processing is one of the major occupations in Nigeria where cassava is processed into gari, fufu (akpu) and cassava flour after fermentation. However, a cursory look shows that vegetation scarcely grows at the cassava processing sites, where the crude cassava water (effluents) is discharged. The phytotoxic and herbicidal effects on the weed flora are caused by hydrocyanic acid (HCN) according to the work of Fayinminnu (1999; 2010) and Fayinminnu *et al*., (2013). Hydrogen cyanide had been absorbed into a carrier for use as a pesticide (Dwork and Robert Jan 1996). Isom and Way (1974), reported the mode of action of cyanide to inhibit electron transport (photosystem). Toxicity of cyanide ion halts cellular respiration by inhibiting an enzyme cytochrome c oxidase in mitochondria (Dwork and Robert Jan 1996). Cyanide toxicity may be due to inhibition of many enzymes as reported by USEPA (1990) and ATSDR (1997). Therefore, this study was executed to evaluate the toxicity and mode of action of crude cassava water extract as a natural herbicide to control weeds in cowpea.

MATERIALS AND METHODS

The study was conducted in September, 2007 and April, 2008 at Ijako – Owode in Sango Ota, Ado –Odo Otta Local Government Area in Ogun State, Nigeria. The study site lies at $6^0\ 35^1$N - $6^0\ 45^1$N and longitudes $2^0\ 55^1$E - $3^0 15^1$E with an elevation of 100m above sea level. It lies within the rain forest agro-ecological in south western Nigeria. It has an average annual rainfall between 116.18mm – 154.03mm while the average daily temperature was 29^0C. The annual relative humidity at 9 hours had the range of 60-88% while 56-77% at 15hours. The annual sunshine ranged from 2.7- 6.9 hours (Source: Nigerian Metrological Agency, NIMA 2005).

At land preparation, pre planting soil samples were collected randomly per replication at a depth of 0-15cm for physical and chemical analysis. Samples were bulked to form a composite sample. The samples were air dried, crushed and sieved through 2 and 0.5mm sterilised meshes to determine pH, total N, organic carbon (OC), available phosphorous (P), iron (Fe), copper (Cu), zinc (Zn) and exchangeable cations following the methods of IITA (1982). Similarly, chemical and physical analysis was carried out for post planting and the results as shown in Table 2.

Extraction of Crude Cassava Water Extract (CCWE) from the cassava tubers were carried out according to the method of Fayinminnu *et al*, (2013).

The experimental design used for the experiments was a split plot arrangement in a randomised complete block design (RCBD) replicated three times. The main plots were three levels of mode of application: foliage spray (F), soil drench (SD) and foliage + soil drench (F+SD), the sub plots were two rates of CCWE at 50, 100 % and sub sub plots were five levels herbicide treatments of: Bulk, MS, TMS (CCWE), handweeded and weedy check (controls). The area of land used for the trials was 15m x 49 m (735m^2) respectively. The foliage application (F) of herbicides on the weeds was done with a comfortable pace and maintaining constant nozzle height as reported by Akobundu (1987). The soil drenching (SD) application of herbicides (CCWE) on weeds was by drilling holes into the soil which was 8cm (depth) by 5cm away from the rhizosphere of the weeds. The combination of foliage (F) and soil drench (SD) mode of application was applied simultaneously as F+SD application.

Three seeds of Ife brown cowpea were sown per stand at a spacing of 0.6m x 0.3m, missing stands were supplied at one week after sowing (WAS), while seedlings were thinned to one stand at 2WAS. Insect pests were controlled with regular spray of Cypermethrin at 1 L/ha. Application of CCWE on the cowpea weeds from 3 - 7 WAS weekly was carried out according to Fayinminnu (1999;2010) using Knapsack sprayer CP 15 while hand weeding was done at 3 and 5 WAS.

Data collection commenced at three weeks after sowing (WAS) and was carried out fortnightly until 12WAS. These sampling periods covered the active vegetative development in cowpea. Data were collected on growth, yield and weed control parameters as described below.

Six plants from the middle row were tagged in order to prevent boarder line effects from which data on growth parameters were obtained. The growth parameters taken at 6WAS were plant height (cm), number of leaves produced and leaf area (LA) (cm^2). Yield parameters included numbers of pods, pod weight (g), seeds per pod and seed grain yield (kg/ha) taken at harvest 12WAS.

Weed control parameters showed samples of weeds within a 1.0 m^2 quadrant which were collected, identified and classified based on floral morphology (broad and narrow) prior to CCWE treatments. Phytotoxicity on weeds was a visual toxicity rating which was determined using a scale of 0 -10, (Clay and Davison 1978) where \`0\` indicates no toxicity on weeds and \`10\` indicates full toxicity of weeds at 4,6 and 8WAS. The weed biomass (WB) fresh and dry matter production of the weeds and weed density (WD) were determined at 3, 6, 9 and 12 WAS. The weeds were uprooted and washed thoroughly with clean water and air dried for 2 hours. Fresh weights (g/m^2) of the weeds were taken and were packed in paper envelope and oven-dried for dry weight at 70^0C for 48 hours until constant weight was attained. Weed density was determined by counting the number of weeds (no/m^2) in $1.0m^2$ quadrant.

The data collected were analyzed using analysis of variance (ANOVA). Test of significance of the means was by Duncan Multiple Range Test (DMRT), $p<0.05$ was the criterion for significance.

RESULTS AND DISCUSSION

The results from the experiments showed a total of 12 weed species from 8 families associated with cowpea crop (Table 1) at the experimental site in 2007 and 2008. About 70% of these weeds were broad leaves (mostly herbs) while 30% were perennial and grasses. The physico chemical properties of pre- and post- cropping soil analyses (Table 2) indicated that, the soil from the experimental site was slightly acidic with pH of 5.92. The total Nitrogen increased from initial 1.96 g kg^{-1} to 2.10g kg^{-1} while exchangeable cations (Mn, Fe, Cu and Zn) and cyanide (0.040 mg/kg) were available at the post cropping.

The increment of Nitrogen level may be as a result of cowpea, a nutrient fixing crop planted on the same experimental site used for the experiments. This has been demonstrated in various experimental findings as attested to by Quin (1997) and Dugje *et al*., (2009). Other essential minerals and cyanide detected in the soil may be due to the application of CCWE (Fayinminnu *et al*., 2013). The cyanide in the soil analysis may be due to the free neglible HCN residue which is within the recommended level 0.05mg/kg of United State Development Agriculture (USDA) as reported by Delange *et al*., (1982).

Phytotoxicity effects of CCWE on weeds were higher between 12-15 hours in the experiments; this may be due to the reduction in annual relative humidity and higher sunshine intensity. The results from the trials showed that phytotoxicity on weeds of cowpea were significantly ($p<0.05$) affected by different mode of application (A), herbicides (H) and rates (Table 3). Crude cassava water extract from Bulk and MS CCWE at 100% on F and F+SD application significantly recorded over 50% phytotoxicity than soil drench (SD) treated plots. It was also revealed from the results that phytotoxicity on weeds was slightly high in 2007 when compared with 2008. The least phytotoxic effects were observed from the TMS CCWE treated plots. The phytotoxic effects from foliar application (F) showed the symptoms in turning the green colour of the weeds to yellowish (decoloration) colour within 24 hours. This resulted to acute cyanide poisoning (acute phytotoxicity) on the photosystem (photosynthesis), thereby showing a contact mode of action (Dropdata 2010). This observation may be due to the herbicidal ingredient in CCWE which resulted into considerable amount of injury in tissues thereby resulting in the onset signs. This is in conformity with the report by Marrs and Ballantyne (1987) and work of Fayinminnu (2010), that CCWE decolorised chlorophyll pigment after application. Wolfsie and Shaffer (1959) also reported that hydrogen cyanide and cyanides are true protoplasmic poisons.

Phytotoxic effects of CCWE on the F+SD application were observed within 24 and 72 hours. The symptoms shown were light to dark brown patches formed on the leaves in form of chlorosis, resulting to drying and wilting of the weeds showing contact and systemic mode of action. This may be due to the accumulation of free cyanide (CN) in tissues especially at the rate of 100%. This was reported by Ballantyne (1987) that CN complex in the mitochondria produces a blockage of energy transfer which causes cessation of cellular respiration, thereby causing phytotoxicity. This work is also in conformity with the herbicide mode of action reported by Dropdata (2010). Mode of application of the SD application also showed acute cyanide poisoning (phytotoxicity) which was observed within 96hours (4 days) and above thereby showing systemic mode of action; with dried black rot observed on the roots. This may be due to the high mobility of HCN in the experimental sub surface soil with pH of 5.92-6.06 (Table 1). This value was lower than sub soil surface with pH of 9.2 pH as reported by ATSDR (1995) that HCN is expected to be highly mobile in sub soil surface with pH less than 9.2. The soil texture of the experimental site which was sandy clay (Table 1) would also determine the adsorption of the herbicide to the soil and the amount of pesticide that will leave the sprayed area as reported by Kellogg *et al*., (2000). However, due to the high mobility of HCN in the soil it may be observed that, adsorption of HCN by clay is fairly weak and decreased as reported by Callaham *et al*., (1979) hence HCN would probably biodegrade.

Acute cyanide poisoning (phytotoxicity) on weeds was frequently observed in the trials. This was due to the relatively massive overdose of CCWE at 100% as against 50% which was applied as post emergence herbicide on weeds especially between 3 – 7WAS as confirmed by the work of Fayinminnu (2010). This also resulted because, the amount of cyanide (100%) greatly exceeded the minimal concentration, whereby many enzymes and biological systems are disrupted, thereby causing wilting which usually led to death of the weeds. Also, higher sunlight intensity and low relative humidity especially at 12- 15 hours (12.00 -3.00pm) enhanced the herbicidal action of CCWE on weeds in this study. When the sunlight intensity was higher, the phytotoxic action of crude cassava water extract on weeds was rapid and more effective. This work confirmed the report of Callahan *et al*. (1995) that HCN is resistant to photolysis. This is also in agreement with Ogundola and Liasu (2007) that cassava effluents on growth inhibition of *C. odorata* weed was more effective during dry season.

The results of WB from the experiments (Table 3) showed Bulk, MS and TMS CCWE at different rates and application recording significant reduction of weeds in cowpea. There were statistical differences ($p<0.05$) pronounced in WB of broadleaves and grasses as shown in 2007 and 2008. Plots that received Bulk and MS at the rates 50 and 100% on F and F+SD recorded significant reduction comparable with the handweeded. This probably may be due to the high toxins of hydrocyanic acid (probable herbicide) content in CCWE of Bulk and MS (Fayinminnu, 2010) and higher rate of CCWE at 100%. It may also be due to the increased cyanide accumulation via the vascular system within the tissues, accompanied by reduction in shoot weight as reported by Grossmann (1996).

The WB of broad leaved weeds which included *Spigelia anthelmia*, *Portulaca oleracea* showed reduction through F+SD application at 50 and 100% while it could not reduce *Triangulare fruticosurp* weed biomass effectively. *Euphorbia heterophylla*, *Phyllatus amarus, Chromolaena odorata, and Scwenkia americana* WB were reduced through F, F+SD or SD application at the rates of 50 and 100%. The WB of grasses from Bulk and MS CCWE at 100% on F and F+SD plots also compared favourably with handweeded with no significant difference ($p>0.05$) in recording significant reduction. The CCWE reduced WB of grass *Cyperus rotundus* to a moderate extent through F+SD or SD application at 100%.

However, the effectiveness of CCWE on WB of *Talinium fruitcosurp* and *Commelina benghalensis* broad leaves through SD and F+SD application at 50 and 100% was to a moderate effect. This may be due to the ability to give rise to new plants and re establishment quickly from chopped stem segments. This is also in agreement with Akobundu (1980) that these weeds have the ease to produce new vegetative shoots and complicate chemical control and therefore needs constant application of the herbicide. The WB recorded for *Panicum* spp showed that it could not be controlled effectively by CCWE even at the rate of 100%. The CCWE showed only burning effect on the leaves of *Panicum* spp when applied as foliage treatment. The weedy check recorded the highest WB.

The results of WD from Bulk, MS and TMS CCWE at different rates and application recorded significant differences ($p<0.05$) in this study (Table 3). The handweeded in both trials (2007 and 2008) recorded significant reduction over other treatments. Crude cassava water extract from Bulk, MS and TMS at 100% on F and F +SD showed similar reduction on WD as observed in 2007 and 2008. Reduction in WD by all sources of CCWE may be due to an increase in CN levels in the tissues from the application, thereby leading to concentration (rate) – dependent which may eventually led to WD reduction as reported by Grossmann (1996). This result may also be attributed to the mode of application; foliage spray (F) produced decolouration, F+SD application may have produced combined toxicity effects on the vascular system and the accumulation of CN in root (SD application). However, handweeding (control) recorded the least WD while the weedy check recorded the highest WD.

Results from the experimental trials in 2007 and 2008 (Table 4) showed similar values in cowpea plant height with significant differences ($p<0.05$)

amongst the treatments. Handweeded recorded the highest plant height with a significant difference ($p<0.05$) over other treatments in 2007. Crude cassava water extract of MS at 100% on F +SD recorded the highest cowpea plant height with a significant difference ($p<0.05$) over other treated plots in 2008 (Table 4). However, Bulk CCWE at 50% on F+SD recorded highest cowpea leaf area with a significant difference ($p<0.05$). This may be due to the reduction of weeds which allowed more incidents light during the early growing season of cowpea crop hence high leaf area was produced (West Gate *et al*., 1997; Johnson *et al*., 1998). The vegetative growth parameters revealed that the reduction in weed biomass and density resulted in significantly higher growth parameters of cowpea crop.

Cowpea yield parameters (Table 5) in this study revealed similar results among all the plots treated with CCWE but with statistical differences ($p<0.05$) in the trials. The highest number of pods was produced from CCWE of Bulk and MS at 50 and 100% on F, SD and F+SD application over other treatments. Handweeded recorded the highest seeds/pod ($p<0.05$) over other treatments in 2007 while in 2008, all CCWE treatments at 50 and 100% on F, SD and F+SD compared favourably ($p>0.05$) with handweeded. However, higher values of seeds/pod were recorded in 2008

The cowpea grain yield recorded from CCWE of Bulk at 50% on F application and MS at 50% on F and F+FD application showed comparable high yield to handweeding. The grain yield recorded from the plots of TMS CCWE at 100% on SD application compared favourably with Bulk and MS at 100% on F+SD application. Weedy check recorded significant reduced cowpea grain yield in the trials.

The high growth and yield parameters recorded by the different sources of crude cassava water extracts especially Bulk and MS; at different rates and application at 3-7WAS may be due to the toxicity of hydrocyanic acid on the weeds. The HCN could have acted as a post emergence herbicide potential (Fayinminnu, 2010; Fayinminnu *et al.*, 2013) which suppressed and markedly reduce the weeds of cowpea at the critical growing period (Ayeni *et al*., 1996). Therefore, this could have led to a higher yield as reported by Olofintoye and Adesiyun (1989).

Table 1: The Weed Species at the Experimental Site in Experiments 2007 and 2008

Experiment 1 (2007)				Experiment 2 (2008)			
	Weed Species	Morphology	Life Cycle	Family	Weed Species	Morphorlogy	Life Cycle
Amaranthaceae	*N/A*	N/A	N/A	Amaranthaceae	*Amaranthus spinosus* L.	Broadleaf	Annual
	Agerantum conyzoides L	Broadleaf	Annual	Asteraceae	*Agerantum conyzoides* L	Broadleaf	Annual
	Tridax procumbens L	Broadleaf	Annual		*Chromolaena odorata L*	Broadleaf	Perrenial
Commelinaceae	*Commelina benghalensis*L	Broadleaf	Annual	Commelinaceae	*Commelina benghalensis*L	Broadleaf	Annual
	Cyperus rotundus L	Grass	Perrenial	Cyperus	N/A	N/A	N/A
Euphorbiaceae	*Euphorbia heterophylla L*	Broadleaf	Annual	Euphorbiaceae	*Euphorbia heterophylla L*	Broadleaf	Annual
	Cyanodon dactylon L	Grass	Perrenial	Poacea	*Cyanodon dactylon* L	Grass	Perrenial
	Paniculum maximum Jacq	Grass	Perrenial		*Paniculum maximum* Jacq	Grass	Perrenial
Portulacaceae	*Talinum Pfruticosurp*(Jacq)Willd	Broadleaf	Annual	Portulacaceae	*Portulaca oleracea* L	Broadleaf	Annual
	Schwenkia americana L	Broadleaf	Annual	Solanaceae	*Schwenkia americana* L	Broadleaf	Annual
	Phyllantus amarus *(Schum& Thomm)*	Broadleaf	Annual		*Phyllantus amarus (Schum& Thomm)*	Broadleaf	Annual

N/A= Not Available

Table 2: Physicochemical Properties of Pre and Post Planting of the soil at the experimental site

Characteristics	Pre-planting	Post cropping
pH2O	5.92	6.06
pH KCl	0	5.05
Total Nitrogen (N)g/kg-1	1.96	2.2
Organic Carbon (OC)g/kg-1	24.7	19.01
Avail. Phosphorous (P)g/kg-1	161.88	160.24
Exchangeable Cations (Cmolkg-1)		
Calcium (Ca) Cmolkg-1	3.98	4.9
Magnessium (Mg) Cmol kg-1	3.39	4.01
Potassium(K) Cmol kg-1	1.01	0.07
Sodium (Na) Cmol kg-1	1.13	0.063
Manganese (Mn) mg/kg-1	0	330.97
Iron (Fe) mg/kg-1	0	210.9
Copper (Cu)mg/kg-1	0	18.49
Zinc (Zn) mg/kg-1	0	93.59
Cyanide (CN)mg/kg	0	0.04
Micronutrients (mg/kg-1)		
Sand	72.2	79
Clay	7.4	15.8
Silt	13.4	5.2
Exchange Acidity (molkg-1)	0.2	0.2
ECEC Cmol kg-1	0	7.92
Bulk Density g/cm3	1.095	1.282

ECEC = Exchangeable Cation Exchange Capacity

Table 3: Herbicide rates and phytotoxicity levels

Herbicide Treatments	Rates %	Application	Phytotoxicity 2007	Phytotoxicity 2008	WB Broad (g/m2)2007	WB Grass (g/m2)2008	WB Grass (g/m2)2007	WB Grass (g/m2)2008	WD No/m^2 2007	WD No/m^2 2008
Bulk CCWE	50	F	4.96ab	4.29c	3.82ab	3.00a	2.50ab	2.00ab	19.17c	18.81d
	100		5.66a	5.00a	2.61a	2.8a	1.17a	1.33a	12.15b	9.75b
	50	SD	3.16ef	3.16f	4.75ab	5.17ab	4.25bc	2.50ab	18.86c	19.85d
	100		4.16d	4.29c	4.35ab	5.00ab	2.92ab	2.00ab	14.29bc	12.83bc
	50	F+ SD	4.29c	3.66e	3.31ab	4.20ab	2.59ab	2.50ab	20.75c	20.13de
	100		5.33ab	5.12a	2.69a	3.61a	1.25ab	1.17a	11.30b	11.30b
MS CCWE	50	F	4.88b	2.62g	3.72ab	4.38ab	2.16ab	2.25ab	20.75c	18.15d
	100		5.33ab	4.08cd	2.68a	2.60a	2.15ab	1.00a	13.00bc	10.58b
	50	SD	3.10e	2.27h	3.57ab	4.38ab	2.63ab	3.00ab	18.38c	18.95d
	100		4.16d	3.16f	3.49ab	2.75a	2.00ab	2.25ab	12.00c	12.83bc
	50	F +SD	4.08d	4.78b	3.57ab	2.75a	2.06ab	3.30b	19.86c	18.10d
	100		5.30ab	5.33a	2.79a	2.61a	1.20a	1.67ab	11.40b	11.17b
TMS CCWE	50	F	3.10f	2.27h	5.09ab	5.00ab	2.75ab	3.50b	18.86c	19.17d
	100		4.00d	3.54e	4.69ab	4.20ab	2.23ab	2.45ab	13.15bc	14.33c
	50	SD	4.16d	4.16c	3.21ab	5.00ab	3.25abc	3.50b	18.25c	20.34de
	100		4.42c	4.42c	3.69ab	4.20ab	2.73ab	3.00ab	12.65b	12.65bc
	50	F +SD	3.54e	3.83cde	4.59ab	4.50ab	3.25abc	3.00ab	20.00c	20.35de
	100		4.42c	4.08cd	4.19ab	4.20ab	2.73ab	2.00ab	10.15b	17.00d
HDW	0		0g	0i	0.60a	1.00a	0.25a	0.20a	2.00a	2.00a
Unweeded	0		0g	0i	56.35c	56.67c	29.00c	29.00c	67.67d	67.67e
Mean			4.4	3.5	6.13	6.31	3.54	3.58	17.76	17.8
SE±			0.4	0.33	2.6	2.66	1.36	1.35	2.84	2.86

Means in the same column followed by the same letter(s) are not significantly different at $p< 0.05$

SE± = Mean Standard Error CCWE: Crude Cassava Water Extract

HDW: Handweeding

Table 4:Toxicity Effect of Rates and Mode of Application of different CCWE as post emergence herbicide on growth parameters of cowpea

Herbicide Treatments	Rates %	Application	PH (cm) 2007	PH (cm) 2008	LA (cm2) 2007	LA (cm2) 2008
Bulk CCWE	50	F	19.94bcd	19.02e	37.95de	37.75d
	100		20.33b	22.00b	41.57c	40.75c
	50	SD	20.78b	18.21f	43.18b	37.48d
	100		20.67b	21.00c	36.25de	39.71cd
	50	F+ SD	20.17bc	21.01c	44.88b	39.76c
	100		20.94b	23.00a	40.72c	42.80ab
MS CCWE	50	F	20.83b	19.00e	40.30c	40.63c
	100		20.11bc	21.02c	44.03b	42.16b
	50	SD	19.72bcd	20.00d	39.34cd	37.75d
	100		20.22bc	21.00c	40.83c	40.08c
	50	F +SD	21.31b	21.11c	40.72c	38.55d
	100		20.39bc	23.00a	38.59d	39.66cd
TMS CCWE	50	F	20.00bc	19.12e	31.45g	32.33ef
	100		20.06bc	19.01e	33.26f	32.36ef
	50	SD	19.67bcd	20.00d	31.56g	38.14d
	100		19.56bcd	22.00d	35.50def	38.55d
	50	F +SD	19.00cd	18.01f	31.49g	31.13f
	100		19.33bcd	20.00d	31.77g	33.53e
HDW	0		27.56a	21.03c	47.97a	43.64a
Unweeded	0		10.60d	15.01g	22.63g	20.64g
Mean			20.05	20.15	37.7	37.37
SE±			0.63	0.42	1.34	1.18

Means in the same column followed by the same letter(s) are not significantly different at p(<0.05)

WAS = Weeks After Sowing

PH= Plant Height, LA= Leaf Area CCWE= Crude Cassava Water Extract SE± = Mean Standard Error

Table 5:Toxicity Effect of Rates and Mode of Application of different CCWE as post emergence on cowpea yield parameters

Herbicide Treatments	Rates %	Application	NOP 2007	NOP 2008	GY(kg/ha-^{1}) 2007	2008
Bulk CCWE	50	F	41.56a	29.00fg	9.67c	400.00e
	100		22.78g	38.01d	9.56c	590.00a
	50	SD	40.33a	25.00h	9.93c	300.03g
	100		39.28ab	27.02g	8.28e	330.10fg
	50	F+ SD	29.67e	30.00f	8.22e	450.00d
	100		22.83g	38.01d	7.28f	460.12cd
MS CCWE	50	F	36.61c	43.11b	9.17d	600.02a
	100		33.17d	48.00a	9.52c	500.00b
	50	SD	38.22c	28.02g	9.33d	370.00f
	100		39.11ab	35.13e	9.00d	420.00e
	50	F +SD	39.89a	35.10e	8.33e	580.00a
	100		39.50ab	40.12cd	11.20b	470.02c
TMS CCWE	50	F	28.33e	18.24i	8.07e	370.11f
	100		28.28e	20.10i	8.22e	390.00ef
	50	SD	24.67f	22.23h	8.11e	450.00d
	100		22.78g	24.00h	8.36e	470.03c
	50	F +SD	24.67f	20.03i	8.77de	300.00g
	100		22.78g	22.11hi	8.65de	350.01fg
HDW	0		38.24c	40.21c	16.78a	600.00a
Unweeded	0		13.39h	13.00j	4.05g	200.01h
Mean			31.39	29.82	9.02	430.1
SE±			1.83	2.12	0.51	25.36

Means in the same column followed by the same letter(s) are not sign different at p(<0.05), NOP= Number of Pods, GY=Grain Yield

CONCLUSION

This study revealed that crude cassava water extract of the Bulk, MS and TMS, their mode of application Foliage, Soil drench and Foliage + Soil drench and rates 50 and 100% could suppress and markedly reduce weeds of cowpea during the early critical period of 3 – 7 WAS. This may due to the hydro cyanide from CCWE which is a causative factor in the phytotoxic and herbicidal effects observed on weeds, hence higher cowpea growth and grain yield. The mode of action of CCWE in this study revealed contact and systemic actions. This study also revealed that higher sunlight intensity and low relative humidity especially at 12 - 15 hours (12.00-3.00pm) enhanced the herbicidal action of crude cassava water extract in this study; since HCN is resistant to photolysis. High mobility of HCN in the soil reduced its adsorption to soil texture thereby makes it to biodegrade easily.

Although, all the three sources of CCWE with their mode of application and different rates performed well, CCWE of Bulk and MS on foliage and foliage + soil drench at 50% and 100% are recommended to the peasant farmers as a natural post emergence herbicide in order to promote organic agriculture. Hence, crude cassava water extract could serve as biocide for its quick biodegradation activity, easily available and an environmental friendly herbicide.

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