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Original Research PaperASSESSMENT OF THE MICROBIAL POPULATIONS AND ~~PHYSICO~~^{characteristics}CHEMICAL COMPONENTS OF PARAQUAT TREATED SOIL

ABSTRACT

This study assessed the microbial population and physicochemical components of paraquat treated soils. The soil samples were treated with the low, recommended and high doses of paraquat respectively for a period of eight weeks at two weeks interval. Isolation and identification of the soil microbes as well as the determination of the physicochemical components (soil pH, organic carbon and organic matter) were carried out using standard procedures. The results of the study showed that, microbes such as *Staphylococcus* sp., *Micrococcus* sp., *Pseudomonas* sp., *Escherichia coli*, *Bacillus* sp., *Actinomycetes bovis*, *Actinomycetes Israeli*, *Streptomyces* sp., *Aspergillus fumigatus*, *Aspergillus niger*, *Aspergillus flavus*, *Absidia corymbifera* and *Rhizopus stolonifer* were found present in the paraquat treated soils of different doses ^{and} with the control soil samples having most of the fungal species isolated. The organic matter and carbon contents of the paraquat treated soils of different doses were at the 4th weeks after application (WAA) significantly ($P < 0.05$) the highest whereas the pH of the soils was at 2nd WAA the highest compared to those of the other soils at different WAA. Different doses of paraquat at different WAA affect soil microbial populations as well the ^{as} ~~physico~~ chemical components of the soil. So, the effects of paraquat on soil microbial population and ~~physico~~ chemical components depended on the concentrations used and the duration of application.

Key words: Paraquat, soil, microbial populations, ~~physico~~ chemical components

These are chemical properties

Don't repeat words in the title!

24 1.0 INTRODUCTION

25 Herbicides are chemical compounds that are used to kill unwanted plants. These are used to
 26 clear waste grounds, industrial sites, railways and farm lands (Kellogg *et al.*, 2000). Prior to
 27 the wide spread use of chemical herbicides, cultural controls such as altering soil pH and
 28 fertility levels were used to control weeds. Mechanical control (including tillage) was also
 29 (and still is) used to control weeds (Kellogg *et al.*, 2000). Today, chemical herbicides is the
 30 indispensable instruments of reliable and intensive plant production and without their help,
 31 hunger and societal tensions would be more serious than the Ecotoxicological effect which
 32 they are intended (Bandala *et al.*, 2007). Numerous experiments have been conducted that
 33 demonstrated the potential positive impacts of the use of herbicides by farmers; for instance;
 34 maize yields double and production costs fell by 61% in Nigeria (Benson, 1982). Shave and
 35 Avav, (2004) also reported in Nigeria that the cost of weed control in rice with herbicides
 36 was 50% lower than hoe weeding.

37 In achieving the optimization of agricultural resources thus satisfying human needs and at the
 38 same time maintaining the quality of the environment and sustaining natural resources, the
 39 soil microbial community composition is of great importance, because they play a crucial role
 40 in carbon flow, nutrient cycling and litter decomposition, which in turn affect soil fertility and
 41 plant growth (Chauhan *et al.*, 2006; Tripathi *et al.*, 2006; Pandey *et al.*, 2007), and hence
 42 occupy a unique position in biological cycles in terrestrial habitat. The soil microbial
 43 population is considered as active nutrient pool to plants and plays an important role in
 44 nutrient cycling and decomposition in ecosystem (De-Lorenzo *et al.*, 2001). A healthy
 45 population of soil microorganisms can stabilize the ecological system in soil (Chauhan *et al.*,
 46 2006) due to their ability to regenerate nutrients to support plant growth. Any change in their
 47 population and activity may affect nutrient cycling as well as availability of nutrients which
 48 indirectly affect productivity and other soil functions (Wang *et al.*, 2008).

? Recast

Recast!
Recast
to bring
out
clearer
meaningRepetition
false

49 However, despite the benefits of using these herbicides by farmers as noted by Bandala *et al.*
 50 (2007) and Shave and Avav (2004), the increased use of herbicides in agricultural soils
 51 causes the contamination of the soil with toxic chemicals, thus may exert certain effects on
 52 non-target organisms including soil microorganisms (Stanley *et al.*, 2013). In Nigeria,
 53 especially Mubi local government area of Adamawa State as well as most of the northern part
 54 of Nigeria where farming is the major occupation, strict observance of manufacturer's
 55 instructions on how to make use of these herbicides are not being adhered to as they are
 56 ignorant of its danger to the environment. Natural ways of controlling pests and pathogens of
 57 crops which are friendly to the environment have been forfeited by farmers for synthetic
 58 herbicides as the synthetic herbicides provide quick solutions to pests or pathogens problems
 59 as noted by Bandala *et al.* (2007). Therefore, there ^{the} is need to occasionally assess the effects
 60 of herbicides on micro flora and other soil organisms as reported by Zaid *et al.* (2014) so as
 61 to know the measures to be taken. The use of paraquat as herbicide of choice in this study
 62 was as a result of it being the most widely used herbicide to control broad-leaf weeds and
 63 grasses especially in the study area.

64 2.0 MATERIALS AND METHODS

65 2.1 Study area

66 The study was carried out at Modibbo Adama University of Technology Yola, in the
 67 Department of Plant Science Botanical garden, Girei Local Government Area of Adamawa
 68 state, Nigeria.

— Information on soil type & properties
 — Climate etc. etc.

69 2.2 Experimental design

70 Completely randomized block design (CRBD) was used to design the ^{for experiment} experimental field. For
 71 each treatment, ~~there was one block which~~ ^{it was replicated three times} was replicated three times.

72 2.3 Preparation of herbicides

73 The paraquat used was purchased from Jimeta Modern Market Yola, Adamawa State of
74 Nigeria from the recommended dealer of herbicides. The preparation/concentration of the
75 paraquat for application was prepared according to the manufacturer's recommendations.
76 One-half and double of the recommended concentration for the herbicide was prepared also
77 with a little modification for application at the rates of 0.3ml, 0.6ml, and 0.9ml (at 150 ml
78 10L) 0.6 L/ha (at 30 ml in 16 L sprayer). Each of the concentrations has three replications.

Is it
little?
rate?

79 2.4 Soil Treatment

80 The application of the herbicide with the concentrations prepared above was done at two
81 weeks interval over a period of eight weeks. The control blocks were not treated.

? Do you
control
weeds?
every 2
weeks?

82 2.5 Sample Collection

83 The top soil samples were collected at the depths of up to 0-1 cm, 1-3 cm, and 5 cm
84 respectively from each block of the field during each collection. It was then put into a
85 sterilized polythene bags and were taken to the laboratory for isolation. The soil samples
86 were then made free of large stones and plant debris using 2.0 mm mesh sieve and stored at
87 4°C. The collection was done at two weeks interval for a period of eight weeks.

spray
every
2 weeks?

The depth
should
have
been
0-15 cm

88 2.6 Isolation of Microorganisms

89 2.6.1 Isolation of Bacteria

90 Isolation of bacteria was performed by making serial dilution of the taken samples and the
91 dilution that was used for studies were 10^{-2} and 10^{-4} . The dilution was spread in freshly
92 prepared Nutrient agar medium plates. The media was weighed out and prepared according to
93 the manufacture's specification, with respect to the given instructions and directions. The
94 inoculated plates were then incubated at 37°C for 24 – 48 hrs after cooling.

95 After the incubation period, the pure cultures was obtained based on the color of colony and
96 the pure cultures of the bacterial isolates was subjected to morphological and characterization
97 tests to determine the identity of the bacteria isolates with reference to Bergey's Manual of
98 Determinative Bacteriology as described by Cheesbrough (2006).

99 2.6.2 Isolation of Fungi

100 The isolation of fungi was performed by making pour plate method using Potato Dextrose
101 Agar (PDA.) medium. 39.9 was dissolved in 39 L and topped with
102 according to the manufacture's specification, with respect to the given instructions and
103 directions. The plates were then incubated at room temperature for 5 days. After incubation
104 period, the pure cultures were obtained and the fungi were identified (firstly by staining a
105 pinch of the pure culture placed on a slide with lacto-phenol stain and secondly, observing it
106 under the microscope using 10X and 40X objective lens) through its micro and macro
107 morphological structures (Guy, 2006).

109 2.6.3 Isolation of Actinomycetes

110 About 2.0ml, 5.0ml, 15ml of glycerol yeast agar and 1.0 g of potassium hydrogen phosphate
111 (K_2HPO_4) were used for the isolation of actinomycetes and after incubation period of 7-14
112 days. The isolates were characterized based on colony.

113 2.7 Determination of soil pH

114 The pH of soil sample was determined using pH meter 3150 Jenway model according to the
115 method described by Onyeike and Osuji (2003).

116 2.8 Determination of organic matter and organic carbon

117 Organic carbon and organic matter in the soil was determined using Walkly and Black (1934)
118 method.

Use
organic
Carbon
and delete
organic
Carbon
matter

119 3.0 RESULTS ✓

120 3.1 Fungi, Bacteria and Actinomycetes species identified from paraquat treated and 121 control (untreated) soil samples at two (2) weeks after application (WAA)

122 The results of the fungi, bacteria and actinomycetes identification in paraquat treated and
123 untreated (control) soil samples at two weeks after application (WAA) showed that in
124 paraquat low dose (PLD), paraquat recommended dose (PRD), paraquat high dose (PHD) and
125 the control (CON), fungi, bacteria and actinomycetes such as *A. fumigatus*, *Pseudomonas* sp.,
126 and *A. israelis*; *A. flavus*, *E.coli* and *Streptomyces* sp.; *A. corymbifera*, *Pseudomonas* sp. and
127 *A. bovis*; *A. fumigatus*, *A. flavus*, *A. corymbifera*, *A. niger*, *R. stolonifer* and *Micrococcus* sp.
128 and *Streptomyces* sp. respectively were identified (Table 1).

129 3.2 Fungi, Bacteria and Actinomycetes identified from paraquat treated and untreated 130 (control) soil samples at four (4) weeks after application (WAA)

131 At four (4) weeks after application, the fungi, bacteria and actinomycetes identification in
132 paraquat treated and control soil samples showed that, in PLD, PRD, paraquat high PHD and
133 the CON, fungi, bacteria and actinomycetes such as *A. flavus*, *Bacillus* sp. and *A. bovis*; *A.*
134 *niger*, *E. coli* and *A. Israeli*; *R. stolonifer*, *Pseudomonas* sp. and *Streptomyces* sp.; *R.*
135 *stolonifer*, *A. flavus*, *A. niger*, *A. corymbifera*, *A. fumigatus* and *E. coli* and *A. bovis*
136 respectively were identified (Table 1).

137 3.3 Fungi, Bacteria and Actinomycetes identified from paraquat treated and control soil 138 samples at six (6) weeks after application (WAA)

139 The result of the identification revealed the presence of fungi, bacteria and actinomycetes
 140 such as *A. niger*, *Staphylococcus* sp. and *A. bovis*; *A. flavus*, *Pseudomonas* sp. and
 141 *Streptomyces* sp.; *R. stolonifer*, *E. coli* and *A. israeli*; *A. niger*, *A. flavus*, *R. stolonifer*, *A.*
 142 *corymbifera*, *A. fumigatus* and *Bacillus* sp. and *Streptomyces* sp. in PLD, PRD, PHD and
 143 CON soil samples respectively (Table 1).

144 3.3 Fungi, Bacteria and Actinomycetes identified from paraquat treated and control soil 145 samples at eight (8) weeks after application (WAA)

146 Identified from the PLD, PRD, PHD and CON soil samples were fungi such as *R. stolonifer*,
 147 *A. flavus*, *A. niger*, and *R. stolonifer*; *A. flavus*, *A. niger*, *A. corymbifera* and *A. fumigatus*
 148 respectively. *Bacillus* sp., *Pseudomonas* sp., *Bacillus* sp. and *E. coli* and *A. bovis*,
 149 *Streptomyces* sp., *A. Israeli* and *A. bovis* respectively were the bacterial and actinomycetes
 150 species identified from the four soil samples (Table 1).

151 **Table 1: Fungi, Bacteria and Actinomycetes species identified from paraquat treated**
 152 **and untreated soil samples**

* please Table 1 on one full page

Week Interval	Treated Soil	Fungal Species	Bacterial Species	Actinomyetes Species
2 nd WAA	Paraquat Low Dose	<i>Aspergillus fumigatus</i>	<i>Pseudomonas</i> sp.	<i>A. Israeli</i>
	Paraquat Recommended Dose	<i>Aspergillus flavus</i>	<i>E. coli</i>	<i>Streptomyces</i> sp.
	Paraquat High Dose	<i>Absidia corymbifera</i>	<i>Pseudomonas</i> sp.	<i>A. bovis</i>
	Control (untreated soil sample)	<i>A. fumigatus</i> <i>A. flavus</i> <i>A. corymbifera</i> <i>Aspergillus niger</i> <i>Rhizopus stolonifer</i>	<i>Micrococcus</i> sp.	<i>Streptomyces</i> sp.
4 th WAA	Paraquat Low Dose	<i>A. flavus</i>	<i>Bacillus</i> sp.	<i>A. bovis</i>
	Paraquat Recommended	<i>A. niger</i>	<i>E. coli</i>	<i>A. Israeli</i>

6th WAA	Dose			
	Paraquat High	<i>R. Stolonifer</i>	<i>Pseudomonas</i>	<i>Streptomyces</i>
	Dose		sp.	sp.
	Control	<i>R. stolonifer</i>	<i>E. coli</i>	<i>A. bovis</i>
	(untreated soil	<i>A. flavus</i>		
	sample)	<i>A. niger</i>		
		<i>A. corymbifera</i>		
		<i>A. fumigatus</i>		
	Paraquat Low	<i>A. niger</i>	<i>Staphylococcus</i>	<i>A. bovis</i>
	Dose		sp.	
	Paraquat	<i>A. flavus</i>	<i>Pseudomonas</i>	<i>Streptomyces</i>
	Recommended		sp.	sp.
	Dose			
	Paraquat High	<i>R. stolonifer</i>	<i>E. coli</i>	<i>A. Israelis</i>
8th WAA	Dose			
	Control	<i>A. niger</i>	<i>Bacillus</i> sp.	<i>Streptomyces</i>
	(untreated soil	<i>A. flavus</i>		sp.
	sample)	<i>R. stolonifer</i>		
		<i>A. corymbifera</i>		
		<i>A. fumigatus</i>		
	Paraquat Low	<i>R. stolonifer</i>	<i>Bacillus</i> sp.	<i>A. bovis</i>
	Dose			
	Paraquat	<i>A. flavus</i>	<i>Pseudomonas</i>	<i>Streptomyces</i>
	Recommended		sp.	sp.
	Dose			
	Paraquat High	<i>A. niger</i>	<i>Bacillus</i> sp.	<i>A. Israelis</i>
	Dose			
	Control	<i>R. stolonifer</i>	<i>E. coli</i>	<i>A. bovis</i>
	(untreated soil	<i>A. flavus</i>		
	sample)	<i>A. niger</i>		
		<i>A. corymbifera</i>		
		<i>A. fumigatus</i>		

153 WAA: Week After Application

154 3.4 Effect of Paraquat Treatment on Fungal Count at 2 – 8 Weeks after Application

155 (WAA)

156 At the 2nd WAA of PLD, PRD and PHD, the result showed that the fungal count was

157 significantly higher (P<0.05) compared to those of the other WAA with 4.00, 3.00 and 4.00 x

158 10⁴ cfu/mg respectively. However, that of PRD was not significantly different (P<0.05) from

159 those of 4th – 8th WAA. The CON on the other hand, showed the highest fungal count at 6th

160 and 8th WAA with 5.00 and 5.00 x 10⁴ cfu/mg respectively which were significantly different
 161 P=0.05 (P<0.05) from those of 2nd and 4th WAA (Table 2).

162 3.5 Effect of Paraquat Treatment on Soil Bacterial Population at 2–8 WAA

163 The bacterial population was significantly the highest P=0.05 (P<0.05) at the 4th – 8th WAA of PLD,
 164 PRD and PHD with 33.20, 32.00 and 32.30 x 10⁴ cfu/mg respectively. The control, however,
 165 was at 2nd and 6th WAA recorded the highest population of bacterial with 35.00 and 35.00 x
 166 10⁴ cfu/mg respectively (Table 2).

167

168 3.6 The Effect of Paraquat Treatment on Actinomycetes Population at 2 – 8 WAA

169 The population of actinomycetes at the 2nd WAA of PLD and PRD and even the CON were
 170 significantly the highest P=0.05 (P<0.05) with 2.50, 1.40 and 3.48 x 10⁸ cfu/mg respectively. The
 171 same thing was observed for PRD at 6th WAA with 6.80 x 10⁸ cfu/mg (Table 2).

172 3.7 The Effect of Paraquat Treatment on Soil Organic Carbon at 2 – 8 WAA

173 In Table 3, the application of paraquat doses recorded the most effective action on the soil
 174 organic carbon only at the 4th WAA with 1.34 %, 1.12 % and 1.12 % respectively except for
 175 its high dose at the 6th WAA which also had the highest effect (1.10) that was not
 176 significantly different P=0.05 (P<0.05) with that at the 4th WAA. The control, on the other hand,
 177 recorded the most effective action at the 6th and 8th WAA with 1.42 % and 1.43 %
 178 respectively (Table 3).

179 3.8 The Effect of Paraquat Treatments on Soil Organic Matter at 2 – 8 WAA

180 In Table 3, the application of the different doses of paraquat significantly P=0.05 (P<0.05) showed
 181 the most effective action at the 4th WAA with 1.93%, 1.93% and 1.84% respectively. The

182 control, however, was only effective on the soil organic matter only at the 8th WAA with
183 2.46%.

184 **3.9 The Effect of Paraquat Treatment on Soil pH at 2nd - 8th WAA**

185 The application of paraquat doses was at the 2nd WAA recorded the most effective action
186 with 7.39 %, 7.49 % and 7.49 % respectively. Similar action was also observed at 6th WAA
187 for PHD with 7.49 % which was significantly the same ($P < 0.05$) with that at the 2nd WAA.
188 The control, also was at the 2nd WAA had the most effective action with 7.52 % (Table 3).

189

Table 2: Effect of paraquat on soil fungi, bacteria and actinomycetes populations

Week	Fungal count (10 ⁴ cfu/mg)				Bacterial Population (10 ⁴ cfu/mg)				Actinomycetes (10 ⁸ cfu/mg)			
	PLD	PRD	PHD	CON	PLD	PRD	PHD	CON	PLD	PRD	PHD	CON
2 nd WAA	4.00 ^a	3.00 ^a	4.00 ^a	2.00 ^b	24.00 ^b	16.00 ^c	9.80 ^c	35.00 ^a	2.50 ^a	2.70 ^d	1.40 ^a	3.48 ^a
4 th WAA	3.00 ^{ac}	2.00 ^a	1.00 ^b	3.00 ^b	33.20 ^a	15.20 ^c	12.30 ^b	16.40 ^b	0.55 ^c	4.00 ^c	0.12 ^c	0.15 ^c
6 th WAA	3.00 ^{ac}	2.00 ^a	2.00 ^b	5.00 ^a	21.40 ^{bc}	32.00 ^a	32.30 ^a	35.00 ^a	1.32 ^b	6.80 ^a	0.17 ^c	2.39 ^b
8 th WAA	2.00 ^{bc}	3.00 ^a	2.00 ^b	5.00 ^a	19.00 ^c	20.30 ^b	9.00 ^c	9.50 ^c	0.82 ^c	5.30 ^b	1.23 ^b	2.76 ^b

Key: Means with the same superscript(s) along the column are not significantly different at $P < 0.05$.
 PLD: Paraquat low dose; PRD: Paraquat recommended dose; PHD: Paraquat high dose; CON: Control; WAA= Week After Application

194 Table 3: Effect of paraquat treatment on soil organic carbon, Organic matter and soil pH

Week	Organic carbon (%)				Organic matter (%)				Soil pH			
	PLD	PRD	PHD	CON	PLD	PRD	PHD	CON	PLD	PRD	PHD	CON
2 nd WAA	0.38 ^d	0.55 ^d	0.38 ^c	0.95 ^c	0.65 ^c	0.95 ^d	0.62 ^d	1.63 ^d	7.39 ^a	7.49 ^a	7.49 ^a	7.52 ^a
4 th WAA	1.34 ^a	1.12 ^a	1.12 ^a	1.07 ^b	1.93 ^a	1.93 ^a	1.84 ^a	2.33 ^c	6.49 ^b	6.81 ^{ac}	6.84 ^{ac}	6.83 ^{ac}
6 th WAA	1.01 ^b	0.99 ^c	1.10 ^a	1.42 ^a	1.62 ^b	1.89 ^b	1.57 ^c	2.44 ^b	5.73 ^{cd}	6.35 ^{bc}	7.49 ^a	6.55 ^{bc}
8 th WAA	0.95 ^c	1.06 ^b	0.94 ^b	1.43 ^a	1.63 ^b	1.82 ^c	1.62 ^b	2.46 ^a	6.23 ^{bd}	6.94 ^{ac}	6.36 ^{bc}	6.74 ^{bc}

195 **Key:** Means with the same superscript(s) along the column are not significantly different at $P < 0.05$. *P = 0.05*

196 **PLD:** Paraquat low dose; **PRD:** Paraquat recommended dose; **PHD:** Paraquat high dose; **CON:** Control; **WAA:** Week After Application

197 **4.0 DISCUSSION**

198 In this study, assessment of fungal species in ^{untreated} paraquat untreated (control) soil samples from
 199 the 2 – 8 WAA presents fungal species such as *A. fumigatus*, *A. flavus*, *A. niger*, *A.*
 200 *corymbifera* and *R. Stolonifer* which were found common in all the control soil samples.
 201 ^{Similar} Similarly observation was made by Dagze *et al.* (2016) in their control soil samples when
 202 they determined the effect of atrazine on soil microbes. This occurrence could be attributed to
 203 the fungi being well adapted to the soil conditions or probably the health status of the soil as
 204 similarly reported by Zain *et al.* (2013) who associated soil microbial activity and content to
 205 soil health. Also, the similarity in fungal species isolated in the control soil samples of
 206 paraquat (of this study) and atrazine (of Dagze *et al.*, 2016) treated soils could be as a result
 207 of these studies being carried out in the same study area with probably the same
 208 environmental conditions as such factor according to Bolter *et al.* (2006) affect soil microbes.
 209 On the other hand, fungal species such as *A. fumigatus*, *A. flavus*, *A. corymbifera*, *A. niger*
 210 and *R. stolonifer* were found present in the paraquat treated soils with *A. niger*, *A. flavus* and
 211 *R. stolonifer* being the commonest especially from the 4-8th WAA. This finding was
 212 supported by the findings of Ayansina and Oso (2006) who reported the presence of *A. niger*,
 213 *A. flavus* and *Penicillium* sp. in their herbicides treated soil. However, their findings differ in
 214 one of the fungal species identified probably as a result of the differences in the type of
 215 agrochemicals, concentrations, mode of applications, environmental conditions and
 216 herbicides combination used as these according to Subhani *et al.* (2000) and Zain *et al.*
 217 (2013) affect soil's microbes content. Apparent from the assessment of the type of fungal
 218 species present in the untreated (control) soils of this study was the fact that fungal species, *A.*
 219 *corymbifera*, was not present in the paraquat treated soils especially from 4th – 8th WAA. This
 220 could be that the paraquat had a fungicidal effect on the fungi species.

221 The results of the identification of bacteria and actinomycetes present in the treated and control
 222 (untreated) soil samples showed that, bacteria such as *Staphylococcus* sp., *Bacillus* sp., *Streptococcus*
 223 sp., *Pseudomonas* sp., *E. coli* and *Micrococcus* sp. were present in both the treated and untreated
 224 (control) soil samples with *Pseudomonas* sp. and *E. coli* being the most common in occurrence in the
 225 soil samples from the 2nd – 8th WAA. On the other hand, actinomycetes such as *A. bovis*, *A. israelis*,
 226 *Streptomyces* sp. were identified and even the commonest in all the WAA.

227 These bacteria and actinomycetes species identified, differ across the number of WAA of the
 228 treatments as well as the doses probably as a result of the effect of the chemicals on them. This was so
 229 because herbicides could adversely affect soil microbes depending upon the application rate/dose and
 230 the type of herbicide used (Ayansina and Oso, 2006; Sebiomo *et al.*, 2011). The bacterial species
 231 identified in the treated and control soil samples of this study were similarly reported by Stanley *et al.*
 232 (2013) in the control and paraquat treated soils. However, some of the bacterial species identified in
 233 this study such as *Staphylococcus* sp., *Streptococcus* sp., and *E. coli* were not reported in their
 234 findings probably as a result of the differences in concentration used, period of application and
 235 collection of samples for assessment and the depth at which the soil samples were collected.

236 The effect of paraquat treatments on soil fungal count at the 2nd WAA of PLD, PRD and PHD showed
 237 a higher fungal count compared to those of other WAA. Similar report was given by Stanley *et al.*
 238 (2013) who reported a decrease in the fungal count of the soil treated with butachlor, pyrazosulfuron
 239 and paraquat with passage of time from 7th to 28th day after treatment. The decrease of the fungal
 240 count observed in this study could be due to the adverse effect of the herbicide on the fungal
 241 component of the soil. This was proven by the fungal count of the control as the fungal count was
 242 higher especially at 6th and 8th WAA.

243 Bacterial population was low for most of the paraquat doses at the 2nd WAA, but increased at other
 244 WAA. Ayansina and Oso (2006) discovered that higher concentrations of herbicide treatments
 245 resulted in much lower microbial counts when compared to soils treated with recommended doses.
 246 This study somehow agrees with the above statement because the bacterial population of the control
 247 soil samples had the highest compared with those of paraquat treated soils.

248 Actinomycetes population was high at 2nd WAA of PLD, PRD and the control as well as at the 6th
249 WAA of PHD. This could be influenced by the factors such as temperature, pH, organic carbon
250 content, aeration and moisture content of the soils as reported by Arifuzzaman *et al.* (2010). Similar
251 result was published by Stanley *et al.* (2013) who reported a significant increase in actinomycetes
252 population from 7th to 28th day as a result of herbicide application.

253 The behavior of most herbicides is generally influenced by the content of organic carbon (Torrents
254 and Jayasunda, 1997). The phenomenon of herbicide leaching was primarily related to the adsorption
255 of herbicides in the different soils, mainly due to their contents of fulvic-acids, humus in the organic
256 fraction of the soils, followed by parameters such as the cat-ion exchange capacity, acid dissociation
257 constant (Alister *et al.*, 2011). Variation in the effect of paraquat treated soils on organic carbon
258 content was observed with respect to the doses of the herbicides and the weeks after application. Same
259 was observed for the effect of paraquat on the soil organic matter content as well as pH of the soils.
260 This could be due to vigorous microbial activities in the soil (Greaves *et al.*, 1976).

261 5.0 CONCLUSION

262 Different doses of paraquat at different WAA affect soil microbial populations as well the
263 physicochemical components of the soil. So, the effects of paraquat on soil microbial populations and
264 physicochemical components depended on the concentrations used and the duration of application. It
265 also determines the type of microbes present in the soil by getting rid of those that cannot withstand
266 its effects, in this way allowing only the resistible species.

267

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