JOURNAL OF PLANT PROTECTION RESEARCH
Vol. 48, No. 3 (2008)

DOI: 10.2478/v10045-008-0042-5

EFFECTS OF TITANIUM DIOXIDE ON THE DISEASES, DEVELOPMENT AND YIELD OF EDIBLE COWPEA

Oluwaferanmi Fortune Owolade[1]*, *David Ogundeji Ogunleti*[2]

[1] Institute of Agricultural Research and Training, Obafemi Awolowo University
Moor Plantation, Ibadan, Nigeria
[2] Federal College of Agriculture, Institute of Agricultural Research and Training
Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria

Received: April 4, 2008
Accepted: May 13, 2008

Abstract: Titanium dioxide (TiO_2) is being considered as a growth promoter that plays the function of antibiotics in cowpea (*Vigna unguiculata* Walp) production in Nigeria. Field trials were conducted at the Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria in 2006 and 2007 to evaluate the influence/effect of TiO_2 on the development yield and diseases of cowpea. Two treatments of TiO_2 at 125 cc/ha significantly improved the development and yield and reduced the severity of foliar and pod diseases of cowpea compared to a single treatment at lower concentrations. Irrespective of the number of sprays and concentrations TiO_2 increased the yield of cowpea by 8.74–36.11%, and 10.33–51.31% respectively, in both years.

Key words: Titanium dioxide (TiO_2), cowpea, disease

INTRODUCTION

Cowpea (*Vigna unguiculata* Walp) is an important food legume used for its leaves, green pods, green peas and dried peas as well as dry haulms to feed livestock (Kamara *et al*. 2007). The grains are a good source of human protein and the haulms are also a valuable source of livestock protein (Fatokun *et al*. 2002). Cowpea diseases induced by species of pathogenic groups constitute one of the most important constraints to profitable cowpea production in all agro-ecological zones where it is cultivated. Among the fungal diseases brown blotch is the most devastating which causes yield loss of about 46% in Northern Nigeria (Alabi 1994), but yield loss could reach 75% in wet years in the same area (Emechebe and Shoyinka 1985). In the forest environment the yield loss could be as high as 85% (Emechebe

*Corresponding address:
ofowolade@softhome.net

and Shoyinka 1985). Alternative methods to control diseases in this crop are needed as key pesticides are removed from market and disease resistance develops in microbial populations. Titanium dioxide (TiO_2) is a non-toxic, white pigment, for the use in manufacture of paints, plastics, paper, ink, rubber, textile, cosmetics, leather, and ceramics (Moore 1997), and as adjuvants and additives in commercial formulations (Arthurs *et al.* 2006). Photocatalytic degradation of pesticides with TiO_2 and other catalyst has shown promise as a potential water remediation method (Lee *et al*. 2003). TiO_2 is an artificial pigment allowed for using in food products in Egypt (Gain Report 2005). Barley (2003) also reported that TiO_2 is considered to be non-toxic and harmless, that is approved for the use in food up to 1% of product final weight. In order to reduce the hazard from heavy metals and improve whiteness of glass in glassmaking technology, Morse and Glover (2000) reported the use of TiO_2 to replace lead oxide and barium/zinc-based lithopone. It has been noted that TiO_2 breaks down the ethylene gas produced in storage rooms into carbon dioxide and water. It is used to treat the air in fruit, vegetable, and cut flower storage areas to prevent spoilage and increase product shelf life (Fonseca 2004). Illuminated TiO_2 photocatalysts are effective against food-borne bacteria such as *Vibrio* sp., *Salmonella* sp. and *Listeria* sp, suggesting that future use of this technique will likely target food safety issues (Fonseca 2004). Use of TiO_2 as the most suitable photocatalytic catalyst, which upon exposure to ultraviolet light mineralizes organic chemicals in solution to water and carbon dioxide, and may have potential in destruction of microorganisms (CETAC 2000; Frazier 2001). Presently TiO_2 is available in liquid form and contains nanoparticles.

The application of titanium dioxide (TiO_2) on food crops has been reported to promote plant growth, increase the photosynthetic rate, reduce disease severity and enhance yield by 30% (Chao *et al*. 2005). The application of TiO_2 had been proved beneficial to crops by increasing their photosynthetic ability. The application of TiO_2 has been found to show an excellent efficacy in rice (*Oryza sativa* L) and maize (*Zea mays* L.) by reducing the effect of *Curvularia* leaf spot and bacterial leaf blight disease incidence and severity (Chao *et al*. 2005). They also reported that the application of TiO_2 significantly reduced incidence of rice blast and tomato mould with a correspondent 20% increase in grain weight due to the growth promoting effect of TiO_2 nano-particles (NPL 2002). Bowen *et al.* (1992) demonstrated that, a combination of TiO_2, aluminum and silica was effective in controlling downy and powdery mildews of grapes (*Vitis vinifera* L) through a mechanism that may involve direct action on the hyhae, interference with recognition of plant surface, and stimulation of plant physiological defenses. Titanium dioxide does not deteriorate and it shows a long-term anti-bacterial effect. A very strong oxidizing power of TiO_2 can destroy bacterial cell membranes, causing leakage, which inhibits cellular activity and ultimately results in death and decomposition of the cell (Frazer 2001). Disinfection with titanium dioxide is 3× stronger than chlorine, and 1.5× stronger than ozone (Fujishima *et al*. 1999; Maness *et al*. 1999). It has been reported that when TiO_2 is used at rates greater than recommended, there is no damage caused to plants (Frazer 2001). It has also been reported that there is no damage caused by the consumption of farm products treated with TiO_2 in 250 cc of solution containing 7.2 g of TiO_2 (NPL 2002). The objective of this study was to evaluate the response of edible cowpea to the material.

MATERIALS AND METHODS

The experiment was conducted in 2006 and 2007 at the Institute of Agricultural Research and Training (IAR&T), Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria (Latitude 7°30′N Longitude 3°54′E). The mean annual rainfall is 1350 mm and bimodal in distribution. The soil was a light textured sandy-loam, with 1.05% organic matter and pH of 7.0. The site was plowed and disked. The design of the experiment was a randomized complete block with four replicates. Plots were 16 m^2 (4 × 4 m). Treatments included: (1) untreated plots as control, (2) one application of TiO_2 at 62 ml/ha, (3) one application of TiO_2 at 125 ml/ha, (4) two applications of TiO_2 at 62 ml/ha and (5) two applications of TiO_2 at 125 ml/ha. When two applications were used the first application of TiO_2 was at flowering and the second at the onset of pods. The manufacturer recommends two applications of TiO_2 at 125 ml/ha. Three seeds of cowpea, cv 'Ife Brown' were planted per hill, and later thinned to two, at spacing of 60 × 30 cm^2. Metobromuron plus metolachloro and 1, 1-dimethy-4,4-bipyridinium ion were used to control weeds at rates of 100 and 50 ml, respectively, per 20 l of water. The insecticide Lambolacyhalothrin [1*α* (5*), 3 *α*(z)-(±)-cyano-(3-phenoxyphenyl)methyl-3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2dimethylcyclo-propanecarboxylate] was applied at the rate of 65 ml per 20 l of water. Leaf area, number of pods/plant, pod length, seed/pod, seed weight, dry seed yield, and incidence and severity of foliar and pod diseases were determined. Disease incidence was calculated from the number of infected plants in the plant population. The severity of brown blotch disease on individual pod on each plant was determined using the following visual assessment scale:

0 – no symptoms
1 – up to 20% pods part covered with brown blotch
2 – 21–40% pods part covered with brown blotch
3 – 41–60% pods part covered with brown blotch
4 – 61–80% pods part covered with brown blotch
5 – over 80% pods part covered with brown blotch

The severity of Cercospora disease was determined using the following visual assessment scale:

0 – no symptoms
1 – up to 20% leaf part s covered with Cercospora leaf spots
2 – 21–40% leaf part s covered with Cercospora leaf spots
3 – 41–60% leaf part s covered with Cercospora leaf spots
4 – 61–80% leaf part s covered with Cercospora leaf spots
5 – over 80% leaf part s covered with Cercospora leaf spots

Data were subjected to analysis of variance (ANOVA) using the general linear model procedured in SAS (SAS, Inc., 2000). If interactions were significant means were separated with the Student-Newman-Keuls (SNK) test.

RESULTS AND DISCUSSION

The impact of year and number of applications was significant for all the yield parameters. Interactions of year × number of applications and number of applications× concentrations affected all variables (Table 1). All sources of variation significantly influenced edible cowpea yield. The application of TiO_2, irrespective of number of applications, and concentration significantly affected plant leaf area, number of pods per plant, and pod length in both years (Table 2). In 2006 and 2007 plants treated twice with TiO_2 at 125 cc/ha had the largest leaf area, the highest number of pods per plant and the longest pods which were significantly different from other treatments. This was followed by plants treated with single application of TiO_2 at 125 cc/ha two applications and a single application of TiO_2 at 62 cc/ha, and the controls. In 2007 plants treated with a single application of TiO_2 at 62.5 cc/ha had a similar leaf area to controls just as it was obtained for pod length in both years.

Table 1. ANOVA table for the effect of titanium dioxide on yield parameters of cowpea

Source	df	Leaf area	No. pod/ plant	Pod length	Seed/pod	100 seed weight	Yield [kg/ha]
Year (Y)	1	21.87**	196.90**	6.52*	8.65*	33.08*	229.64**
Application (A)	1	8.16*	73.36**	8.27*	10.23*	9.59*	123.62**
Concentration (C)	2	4.09 NS	123.51**	1.51 NS	6.07 NS	3.89 NS	262.40**
Y × C	2	4.10 NS	123.51**	8.27*	6.71 NS	3.62 NS	261.80**
Y × A	1	8.16*	73.49**	12.66**	11.36*	9.60*	208.17**
A × C	1	73.50**	112.66**	19.76**	12.41**	9.76*	378.55**
Y × A × C	2	46.82**	166.26**	13.42**	12.03**	14.09**	396.47**
Error	19	3.01	7.35	1.81	1.24	1.24	11.08

NS, *, ** not significant or significant at $p \leq 0.05$ of $p \leq 0.01$, ANOVA

Table 2. The effect of number of titanium dioxide applications and the concentration interaction on leaf area, number of pod/plant and pod length of cowpea

No. applications	Concentration [ml/ha]	Leaf area [cm^2]		No. pod/plant		Pod length [cm]	
		2006	2007	2006	2007	2006	2007
0	0	43.00 d*	44.33 d	20.33 c	14.67 d	13.00 c	9.33 c
1	62.5	49.33 c	46.33 d	24.00 c	17.00 c	14.33 c	10.00 c
	125	53.33 b	56.67 b	27.33 b	22.67 b	18.00 a	13.67 a
2	62.5	45.00 c	52.67 c	25.00 c	17.33 c	16.33 b	13.66 b
	125	59.33 a	60.00 a	33.33 a	27.33 a	18.33 a	15.00 a

*means in a column followed by the same letter are not significantly different ($p \leq 0.05$)

The number of seed per pod, 100-seed weight and the seed yield were affected by treatments (Table 3). In both years, plants treated with TiO_2 at 125 cc/ha had the highest number of seed per pod just as it was with the 100-seed weight and the grain yield. The 100-seed weight and grain yield were higher in 2006 than in 2007. This may be due to the excess rainfall in 2007 that negatively affected cowpea production. In both years, plants treated with TiO_2 at 62 cc/ha, irrespective of the number of treatments had similar numbers of seed per pod and seed weight, which were not significantly different from control plants. Yields in both years were best for plants treated with two applications of TiO_2 at 125 cc/ha. This was followed by plants treated with a single application of TiO_2 at 125 cc/ha, two applications of TiO_2 at 65.5 cc/ha, a single applications of TiO_2 at 65.5 cc/ha and controls.

The incidence and severity of foliar and pod diseases were significantly affected by the application of TiO_2 irrespective of frequency of treatments and concentration (Table 4). However, the higher the concentration and number of sprays, the lower the incidence and severity of cowpea diseases. Two applications of TiO_2 at 125 cc/ha gave the best disease control.

Table 3. The effect of number of titanium dioxide applications and the concentration interaction on yield components of cowpea

No. applications	Concentration [ml/ha]	Seed/pod		100 seed weight [g]		Yield [kg/ha]	
		2006	2007	2006	2007	2006	2007
0	0	9.33 d*	8.33 d	12.57 c	09.03 c	695.68 e	482.44 e
1	62.5	13.00 c	10.33 c	13.66 c	10.41 c	700.49 d	502.29 d
	125	15.33 b	12.67 b	16.45 b	14.64 b	847.68 b	629.52 b
2	62.5	13.00 c	11.00 c	13.46 c	10.19 c	742.90 c	553.56 c
	125	18.67 a	16.00 a	18.47 a	16.15 a	948.90 a	730.04 a

*means in a column followed by the same letter are not significantly different ($p \leq 0.05$)

Table 4. The effect of number of titanium dioxide applications and the concentration interaction on cowpea foliage and pod diseases

No. applications	Concentration [ml/ha]	Cercospora leaf spot				Brown blotch			
		Incidence		Severity		Incidence		Severity	
		2006	2007	2006	2007	2006	2007	2006	2007
0	0	89.00 a*	79.00 a	3.67 a	4.00 a	95.66 a	78.23 a	4.00 a	3.99 a
1	62.5	38.33 b	22.33 b	2.33 b	2.00 b	63.33 b	60.22 b	2.67 b	2.33 b
	125	12.33 c	14.00 c	1.00 c	1.33 b	20.00 c	18.33 c	1.66 c	1.33 c
2	62.5	22.33 b	15.23 c	1.67 c	1.00 b	22.00 c	17.67 c	1.00 c	1.00 c
	125	7.67 d	8.23 d	1.00 c	1.33 b	14.33 c	10.33 d	1.33 c	1.00 c

*means in a column followed by the same letter are not significantly different ($p \leq 0.05$)

The increase in yield observed when cowpea was treated with TiO_2 may be due to the photocatalyst ability of the material which lead to an increased photosynthetic rate. Similar yield increases were reported in rice with corresponding reduction in the incidence of *Curvularia* leaf spot and bacterial leaf blight disease (Chao *et al*. 2005). Titanium dioxide may be applicable for the use in disease control in cowpea.

REFERENCES

Alabi O. 1994. Epidemiology of cowpea brown blotch induced by *Colletotrichum capsici* and assessment of crop losses due to the disease. Ph.D. thesis. Ahmadu Bello University, Zaria, Nigeria, 95 pp.

Arthurs S.P., Lacey L.A., Bechle R.W. 2006. Evaluation of spray-dried lignin formulations and adjuvant as solar protectant for granulovirus of codling moths Cydic pomonella. J. Inverteb. Pathol. 93: 88–95.

Barley R. 2003. The Smaller the Better (Long but Interesting). Reason Newsl., 15 pp.

Bowen P., Menzies J., Ehret D., Samuel L., Glass A.D.M. 1992. Soluble silicon sprays inhibit powdery mildew development in grape leaves. J. Americ. Soc. Horticul. Sci. 117: 906–912.

Chao S-H.L., Choi H-S. 2005. Method for providing enhanced photosynthesis. Korea Research Institute of Chemical Technology, Jeonju, South Korea. Bull. 11: 1–34.

Canadian Environmental Technology Advancement Centre (CETAC). 2002. Performance report, 20 pp.

Emechembe A.M., Shoyinka S.A. 1985. Fungal and bacterial diseases of cowpeas in Africa. p. 173–192: In: "Cowpea: Research, Production and Utilization" (S.R. Singh, K.O. Rachie, eds.). John Wiley & sons, New York, USA..

Fatokun A.C. 2002. Breeding cowpea for resistance to insects pests; attempted crosses between cowpea and *Vigna vexillata*. p. 52–61: In: "Challenges and Opportunities for Enhancing Sustainable Cowpea production" (C.A. Fatokun, S.A. Tarawali, B.B. Singh, P. M. Kormawa, M. Tamo, eds.). International Institute of Tropical Agriculture (IITA), Ibadan. Nigeria..

Fonseca J. 2004. Titanium dioxide and food safety. Western Vegetable Newsletter 2 (3): 2–3.

Frazer L. 2001. Titanium dioxide: Environmental white knight. Environmental Health Perspect. 109 (4): 174–177.

Fujishima A., Hashimoto K., Watanabe T.. 1999. TiO_2 photocatalysis: Fundamentals and applications. BKC, Inc., Tokyo. Bull. 3: 1–22.

Gain Report. 2005. Food and agricultural import regulations and standards. Gain Report Number EG5018.

Kamara A.Y., Chikoye D., Omoigui L.O., Dugje I.Y. 2007. Influence of insecticide spraying regimes and cultivars on insect pests and yield of cowpea in dry savannas of north-eastern Nigeria. Food, Agricul. Environ. 5 (1): 154–158.

Lee D.S., Senseman A., Sciumbato A.S., Jung S., Krutz L.J. 2003. The effect of titanium dioxide Alumina Beads on the photocatalytic degradation of Picloram in water. J. Agricul. Food Chem. 51: 2659–2664.

Maness P.C., Smolinski S., Blake D.M., Huang Z., Wolfrum E.J., Jacoby W.A. 1999. Bactericidal activity of photocatalytic TiO_2 reaction: toward an understanding of its killing mechanism. Appl. Environ. Microbiol. 65 (9): 4094–4098.

Moore D. 1997. Key issues in medium term outlook for titanium and zircon resource. Outlook Conference, Canberra, 4–6 Feb. 1997, 23 pp.

Morse D.E., Glover A.N. 2000. Minerals and materials in the 20th century – a review. US Geological Minerals Yearbook.

Nano-Plant Technology (NPL). 2002. Method of accelerating metabolism and growth of plant using the corpuscular of Titanium Dioxide. A handbook. Sun Plus Corp., Korea.
SAS Institute. 2000. Statistical Analytical Systems SAS/STAT User's guide, ver. 8 (2). SAS Institute Inc., Cary, N.C.

POLISH SUMMARY

DZIAŁANIE DWUTLENKU TYTANU NA CHOROBY, ROZWÓJ I PLON WSPIĘGI JADALNEJ

Dwutlenek tytanu (TiO_2) jest uważany za związek pobudzający wzrost i pełniący rolę antybiotyków w spiędze (*Figna unguiculata* Walp) uprawianej w Nigerii. W latach 2006 i 2007 prowadzono w Badawczym Dydaktycznym Instytucie Rolniczym, Plantacja Moor, Ibadan, Nigeria, badania mające na celu ocenę wpływu TiO_2 na rozwój, plon oraz choroby wspięgi. Dwa zabiegi dwutlenkiem tytanu w dawce 125 cc/ha miały istotny wpływ na rozwój i plon roślin oraz ograniczały nasilenie chorób liści i strąków wspięgi, w porównaniu do jednego zabiegu w którym zastosowano niższe stężenia TiO_2. Niezależnie od liczby zabiegów i stężeń dwutlenek tytanu wpływał w obydwóch latach badań na zwiększenie plonu wspięgi odpowiednio o 8,74–36,11% i 10,33–51,31%.