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Research Article

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Pb Uptake in Roadside Grown Wheat (*Triticum aestivum L.*) in the Sudan Savanna, Kano State

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Abstract

Cereal crops grown under irrigation in a semi-arid ecological habitat can be used to assess food quality and safety of agricultural systems at proximity to highways in the Sudan savannah of Northern Nigeria. This study focussed on the risk assessments of Pb transfer, translocation and uptake at selected growth stages (15-, 30-, 45-, 60-, 75- and 90-days representing seedling or germination, tillering, shooting/booting, earing, flowering and ripening stages respectively of two cultivars of *Triticum aestivum* L. The experimental (SU 1) and control (SU 2) sites were selected based on distances (345 m and 1936 m) from the Kano-Zaria Highway. Pb levels in soils and the two cultivars of *Triticum aestivum* L. was measured using the double-beam AAS and plant uptake factors (PUF), soil-plant transfer coefficients (TC) and translocation factors (TF) were worked out. Result reveals differences in metal levels of the cultivars of wheat according to growth stages and plant parts. Pb levels was highly significant (P=0.05 and 0.01) in the stems of Siettecerros at the control site indicating selective ability of cultivar to Pb. Pb levels were highest in both cultivars at the 30-days growth stage indicating sensitivity of tillering stage to Pb uptake. A greater than unity value indicate anthropogenic source of Pb. Siettecerros had the highest TF indicating incorporation of higher levels of Pb in the edible plant parts. A higher PUF (45), TC (6.32) and TF (7.66) for Pb in Pavon-76 and Siettecerros respectively, indicates their suitability for bioremediation particularly, phytoextraction of polluted soils from atmospheric pollutants.

Keywords: Agricultural systems; Lead; Plant uptake factor; Soil-plant transfer coefficient; Sudan savannah; Translocation factor; Wheat; Zaria-Kano highway

Introduction

A substantial amount of pollutants is released into highway ecosystems as a result of automobile traffic [1,2]. The rate of release of heavy metals from vehicular emissions into the atmosphere and subsequent uptake by plant could also result in phytotoxicity and/or bioaccumulation. The increasing concern of ecotoxicity and the contamination of our agricultural systems are their sources, food safety issues and potential health risks [3] and this requires constant global monitoring. The main sources of heavy metals to vegetables and/or crops are their growth media (soil, air, nutrient solutions) from which these heavy metals are taken up by the roots or foliage [4].

Bioaccumulation, mobility and transfer of atmospheric pollutants could also result to food chain contamination. Studies reveal that the presence of toxic heavy metals like Fe, Pb and Hg reduce soil fertility and agricultural output [5] which have the potential to contaminate crops growing under such irrigation. Among all irrigated crops, wheat tends to be the most profitable enterprise in the wheat growing zones of Nigeria [6,7]. Siettecerros (Samwhit 5) and Pavon-76 (Samwhit 6) are the recommended varieties [7] presently cultivated by Nigerian farmers. Siettecerros is an old wheat cultivar that is high yielding but of relatively poorer quality while Pavon-76, a new cultivar is high yielding, possess a wide adaptability in the Sahel and Sudan savannah zones of Nigeria and has a high industrial and nutritional quality [7].

Although several eco-toxicity studies of both agricultural crops and medicinal plants and trees have been carried out in other parts of the world, there is no empirical data on ecotoxicity in Nigeria particularly on the widely cultivated cultivars of wheat grown on roadside soils in the Sudan Savanna of Nigeria.

The aim of this present study is to investigate the probable risks for humans and livestock and food chain contamination using three selected risk assessment techniques; plant uptake factor (PUF), soil-plant transfer coefficient (TC) and translocation factor (TF) of Pb and to identify the relationships among the PUF, TC and TF of Pb at the six selected growth stages in two cultivars of the commonly grown wheat.

Material and Methods

Sampling

In ecotoxicity study, the selection of sampling sites and sampling units were by principle to represent the level of pollution in regions and towns with highest level of pollution, and also determined by possible pollutants at specific regions of interest [8]. This study being an ecotoxicological research, all sampling points were selected by principle to represent the level of pollution near major traffic routs and are reference sampling points [8]. The global positioning system (GPS) was used in recording the coordinates of the sampling units and geographical information system (GIS) was used to locate the map of the investigated sites.

Determination of physico-chemical properties of soil

Prior to sowing of the two cultivars of wheat, soil samples were

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collected in duplicates at a vertical depth of 0-25 cm prior to sowing and physico-chemical parameters were determined [9-13].

Soil and plant sampling and analyses

A total of 108 plant samples and 36 corresponding soil samples were collected from two sampling sites. Two cultivars of wheat namely, *Triticum aestivum* L., var., Pavon-76 and Siettecerros, were collected in a randomised block design setup. Both the soil and plant samples were collected fortnightly at the 15 days, 30 days, 45 days, 60 days, 75 days and 90 days which represent the germination or seedling, tillering, jointing/booting, earing, flowering and ripening stages respectively. Soil and plants samples were collected in triplicates, carefully packed into polyethene bags and transported to the laboratory. In the laboratory, the roots of each variety were carefully separated from the soil particles and samples were divided into root, stem and leaf and then air-dried at room temperature. The dried plant samples were ground, using a grinding mill model Foss Cyclotec™ 1093 based on Tecator™ technology and then kept in clean polyethylene bags for Pb analysis. The soil samples were air dried at room temperature, ground in an agate mortar, sieved through 22 mm mesh sieve, and then kept in clean polyethylene bags for Pb analysis. Pb levels was determined by the double beam AAS. The PUF, TC and TF were worked out using the results of the Pb analysis.

Determination of plant uptake factor (PUF), soil-plant transfer coefficient (TC) and translocation factor (TF)

The PUF, TC and TF were worked out as followed; $PUF=C_p/C_{so}$, where, C_p and C_{so} are metal concentrations in aerial parts of the plant (μg g^{-1}) and in soil (μg g^{-1}), respectively [14,15].

$$TC = \frac{\text{Content of heavy metal in plant}\left(mg \cdot kg^{-1}\right)}{\text{Content of heavy metal in soil}\left(mg \cdot kg^{-1}\right)}$$

$TF=C_s/C_r$, where C_s and C_r are metal concentrations (μg g^{-1}) in the shoot and root, respectively.

In all cases, a ratio greater than one indicates anthropogenic sources, while a ratio close to unity or less than one indicates natural sources [15-19].

Results and Discussion

Physico-chemical analysis

Table 1 shows the physic-chemical parameters of the soils. Soil pH ranged from 4.66 to 6.21 being moderately or slightly acidic.

Soil properties such as soil pH, soil texture may have influenced the soil-plant transfer coefficient of Pb [20]. The moderately acidic nature of the soils from SU 1 and SU 2 may have increased the availability of Pb for uptake. Transfer coefficient could also be influenced by soil properties like soil texture. The sandy clay loam soil as well as the moderate organic content, organic matter and CEC observed on SU 1 shows that the higher transfer coefficient and uptake of Pb, could possibly be due to the higher availability of Pb for plant uptake at the early stages of growth. This is in agreement to the findings of [21].

ANOVA and t-test analyses

Pb was highly significant (P=0.05 and 0.01) in Siettecerros only (Tables 2 and 3). The paired student's t-test revealed that the mean increase of Pb between Pavon-76 and Siettecerros at SU 1 and SU 2 respectively was highly significant for stem and significant for leaf and root (Table 3).

Risk assessment techniques

The risk assessment techniques for plant uptake factor (PUF), soil-plant transfer coefficient (TC) and translocation factor (TF) at the selected growth stages of wheat are shown in Table 3.

Uptake and accumulation of elements by plants may follow two different paths i.e., through the roots and foliar surface [22] including deposition of particulate matter on the plant leaves [3,22]. According to Momani et al. [18], values of PUF, TF and TC greater than unity indicate anthropogenic source possibly vehicular emissions, while less than unity indicate natural source Tiller et al. [23] reported that soil could be contaminated with heavy metals by aerial deposition for up to hundreds of kilometers away from the source.

Transfer coefficient (TC): TC signifies the amount of metals in the soil that ended up in the test crop [15,19]. TC is used for the prediction of relative risks for humans. Among the two sampling units investigated in this study, it was noted that SU 1 has the highest TC (6.32) value for Pb than at (3.97) SU 2 (Table 3). The transfer coefficient for Pb in the sandy clay loam soil were much higher than the sandy loam soil and seem to decrease as the growth progresses.

SU 1 had the highest TC (6.32) at the 30 days growth stages than at SU 2 and at all the other growth stages due to varying distances. The 30 days (tillering) growth stage is one of the vegetative stage where there is increased meristematic activities resulting to the growth of shoots from the base of the main stem. However, SU 2 had the highest TC at all the growth stages as compared to SU 1.The high transfer coefficient for Pb in Pavon-76 therefore indicates atmospheric depositions on both the aerial plant parts and the soil.

Plant uptake factor (PUF): PUF signifies the ability of the test crop to accumulate metals in their above biomass [15,19]. The best Pb accumulator was pavon-76 at the tillering (30 days) stage. The highest PUF for Pb was evident at SU 1 than at SU2 (Table 3). Although, soil Pb was not detected at some of the growth stages for computing the PUF (Table 3), SU 1 at the 30 and 60 days growth stages recorded the highest PUF of 45 and 23 respectively. The PUF for Pb was only observable at the 45 (25.5) and 75 (16) days growth stages at SU 2.

Pavon-76 had the highest PUF (45) than in Siettecerros. The variations in the PUF among the two sampling sites might be due to the differing soil properties of the sampling sites. The variations might also be related to the different physical, chemical and biological properties of the soils at the two sampling sites and probably the genetic composition of each of the species and/or variety of the wheat indicate their selective ability in accumulating Pb. Particulate deposition represents the major pathway of contamination by the dry deposition of suspended particles with subsequent permeation into the cuticle [21].

Translocation factor (TF): TF signifies the ability of the test crop to translocate metals into the plant. TF indicates the fraction of the total deposition on the plant surfaces that is incorporated in the edible parts. *Triticum aestivum* L. var. Siettecerros had the highest and lowest TF for Pb (7.666 and 0.363) on SU 2 at the 45 days growth stage (Table 3).

Siettecerros had the highest TF value at the 45 days growth stage which suggests that the levels of Pb in Siettecerros might be through translocation mechanism and also indicating its capability for phytoextraction. The variations in the Pb levels among the selected growth stages in both varieties, of which Pavon-76 had the highest PUF and TC values at the tillering stage while Siettecerros had the highest TF at the shooting/booting stage indicates that the Pb levels originated

					pH				
Site	% Sand	% Silt	% Clay	Textural Class	H_2O 1:1	HCL 1:1	% OC	% OM	CEC
SU 1	62. 9	15. 2	21. 9	Sandy Clay loam	6. 41	5. 77	0. 88	1. 50	7. 25
SU 2	75. 5	12. 4	12. 1	Sandy loam	5. 48	4. 66	0. 65	1. 12	5. 9

Key: SU 1=Wheat (Pavon-76) on Doruwa Salau at close proximity to the Kano-Zaria Highway; SU 2=Wheat (Siettecerros) at the Control Site (Irrigation Research Station-IRS), Kadawa.

Table 1: Physicochemical Parameters of Soils from Doruwa Salau at close proximity to the Kano-Zaria Highway and from the Irrigation Research Station before sowing.

Source of Variation	DF	Sampling Sites	SS	MS	F-Ratio
Plant Parts (P–1)	2	SU 1	5200	2600	0. 0447^{NS}
	2	SU 2	408933.33	204466.66	8. 4770**
Growth stage (G-1)	5	SU 1	934400	186880	3. 2154 ^{NS}
	5	SU 2	326866.66	65373.33	2. 7103 ^{NS}
t-test analysis	5	Leaf	-	-	2. 5586*
		Stem	-	-	4. 1059**
		Root	-	-	2. 3297*

Key: SU 1=Wheat (Pavon-76) on Doruwa Salau at close proximity to the Kano-Zaria Highway; SU 2=Wheat (Siettecerros) at the Control Site (Irrigation Research Station-IRS), Kadawa; **=significant at 0.01; *=significant at 0.05; NS=Non-Significant.

Table 2: ANOVA and t-test Analyses.

Sampling Units	Factor	Growth Stages (days)					
		15	30	45	60	75	90
SU 1	TC	3.25	6.32	1.01	2.67	2.04	1.27
	PUF	ND	45	3.5	23	6.12	5.75
	TF	0.62	1.16	0.36	3.5	0.75	2
SU 2	TC	1.53	3.97	2.28	3.74	2.09	2.15
	PUF	ND	ND	25.5	ND	16	ND
	TF	0.52	5.33	7.66	5	2	2.5

Key: SU 1=Wheat (Pavon-76) on DoruwaSalau at close proximity to the Kano-Zaria road; SU 2=Wheat (Siettecerros) at the Control Site (Irrigation Research Station-IRS), Kadawa; TC=Soil-plant Transfer Coefficient; PUF=Plant Uptake Factor; TF=Translocation Factor; ND=Not Detected.

Table 3: PUF, TC and TF among the two sampling sites at the selected growth stages.

from both the atmosphere and the soil through the leaves and roots respectively.

Conclusion

Siettecerros was identified as a good material for bioremediation of polluted soils due to high traffic density. The greater than unity values for PUF, TC and TF in Pavon-76 and Siettecerros reflects anthropogenic source possibly, vehicular emissions. Therefore, agricultural produce from these sites could pose potential health risks to livestock and humans. Tree-planting strategy of plants which have no edible, industrial, medicinal/pharmaceutical and economic benefits except ornamental or aesthetic values should be employed. Tree-planting strategy should be done at certain distances to serve as screen or windbreaks where these cereal crops are cultivated.

Competing Interests

Authors have declared that no competing interests exist.

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