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Research Paper

Influence of a Mixture of Spent Engine Oil, Fresh Diesel and Gasoline on Nerica Rice (Tox, Mecux and Wita.4) Tiller and Panicle Parameters

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***Abstract** - Rice provides a staple food for more than half of the world's population. Therefore, in order to improve rice production, it is imperative to elucidate how rice physiological parameters will respond to anticipated unfavorable changes in soil as a result of petroleum products contamination. The results of this work showed that leaf elongation rate was unaffected most especially in Tox variety compared with the control plants ($P > 0.05$). Whereas, progressive decrease in leaf area index and shoot growth dynamics of the three varieties ($P<0.05$, $P < 0.01$ and $P < 0.001$) were recorded for plants seeded in 2–5% pollutants mixture. Statistical analysis shows that no significant reduction was observed in main–culm leaf number of the three NERICA rice varieties ($P > 0.05$).Although, the number of tillers and number of productive tillers produced by the plants were reduced at 3–5% treated soils ($P < 0.05$, $P < 0.01$ and $P < 0.001$), except Tox variety ($P > 0.05$).The results indicated that percentage tillering efficiency of the three NERICA rice varieties was unaffected by the pollutant ($P > 0.05$). However, 2–5% concentrations of the pollutant mixtures significantly reduced the rate of panicle extrusion and panicle weight ($P < 0.05$, $P < 0.01$ and $P < 0.001$), while panicle length and panicle number were unaffected ($P > 0.05$). The results of this study suggest that knowledge of stress and disturbance physiology can contribute to rice production programmes in oil polluted environments.*

Keywords: Rice, Panicle, Petroleum, Main-Culm Leaf, Tillers.

Introduction

Rice is one of the most important food crops cultivated in the world today. It provides a staple food for more than half of the world's population [1]. Out of 662 million tonnes produced in 2008, 432 million tonnes were consumed worldwide and approximately 5 million tonnes were consumed in Nigeria (USDA, 2011)[2]. Akinwale*et al*. (2011)[3] quoting Khush and Brar (2002) wrote "The world population is expected to reach 8 billion by 2030 and rice production must be increased by 50% in order to meet the growing demand". Nigeria the second largest producer of rice in Africa (USDA, 2011)[2] is expected to contribute towards this proposed increase in production.

Based on FAO (2010) [4] forecast, rice production in Nigeria is expected to rise to 4.5 million tonnes in 2010 (2.7 million tonnes, milled basis), 5% more than in 2009, presuming average growing conditions. With the launching of National Rice Development Strategy in Nigeria in 2010, rice production is aimed to reach 12.85 million tonnes by the year 2018. Thisgreater production is expected to be achieved through the introduction of NERICA (New Rice for Africa) rice varieties in rainfed and irrigated lowlands in north-central producing regions of the country (FAO, 2010)[4].The increase in soil contamination by petroleum products presents a challenge to meeting the more than 50% improvement in rice production in Nigeria.

Although, plants respond differently to chemical exposure [5], research reports has shown that crude oil and petroleum products, such as spent engine oil, diesel and gasoline has adverse effects on plants [6,7,8]. Therefore, as concerted efforts are been made to reduce the amount of petroleum products contamination of the environment and arable lands, there is need for identification and improvement of rice varieties able to withstand the stress and penalty of a mixture of organic xenobiotics.

In order to improve rice production, it is increasingly important to elucidate how rice physiological parameters will respond to anticipated unfavorable changes in soil as a result of petroleum products contamination. In line with this, the present study was designed to evaluate the effect of different concentrations of a mixture of spent engine oil, fresh diesel and gasoline on development of productive tillers, panicles, plant height and other physiological parameters of three varieties of NERICA rice (Tox, Mecux and WitA.4).

According to Semagn*et al*. (2006)[9], NERICA varieties inherited the characteristic high yield and ability to thrive in harsh environments from its Asian parent (*Oryza sativa*L.) and the African parent (*Oryzaglaberrima*Steud.) respectively.

Material and Methods

Experimental Design

Seeds of three varieties of NERICA rice used for this study were kindly supplied by Dr. Oyekanmi of College of Plant Science, University of Agriculture, AbeokutaOgun State Nigeria. The diesel and gasoline used were sourced from filling station in Akoka Lagos, while the spent engine oil was procured from automobile mechanic workshops in Akoka Lagos. The soil used was obtained from the Biological Garden of the University of Lagos, Akoka Lagos.

Fifty-four (30 x 20 cm)Bagco bags containing 15 Kg of soil were used. The fifty-four bags were divided into three equal parts that is, eighteen bags for each of the three NERICA rice varieties. Gasoline, diesel, spent engine oil were thoroughly mixed together in ratio 1:1:1. The amounts of the mixture added to the soil in different concentration were 1%, 2%, 3%, 4%, and 5% weight per weight (w/w, oil/soil).The added petroleum product mixtures were mixed thoroughly with the soil in each bag using hand trowel and each treatment was replicated three times. The treatments with the control were left for five days to allow for proper settling of the mixture of gasoline, diesel fuel and spent engine oil in the soil.

The three varieties of the NERICA rice were sown at a depth of 2-4cm according to WARDA, (2008)[10] procedure. Each bag of the control and treated had ten seeds sown in it, but later thinned to four seedlings per bag and this was replicated three times. All the seedlings were manually watered regularly in order to keep them moist.

Measurements

The growth rate of the test crops in the polluted soil was determined by measuring the shoot length, leaf length and leaf breadth of the crops in different treatments in order to determine the leaf elongation growth rate, shoot growth rate and leaf area index(LAI) using a calibrated meter rule. This was done 20days after sowing (DAS) at three leaf stage of the crops and onward at an interval of twenty days. These growth parameters were taken at this stage because at three-leaf stage, the rice plants become autotrophic, manufacturing their own food through the process of photosynthesis [11].

The shoot length of each test crop plant was measured from the base of the plant to the apex of the longest leaf, the leaf length from the stalk to the apex of the longest leaf and leaf breadth, the widest portion of the leaf [11].Main-Culm leaf number was determined by manual counting. All measurements were in centimeter (cm).

The effect of the mixture of petroleum hydrocarbon products on the growth and development of the 3 NERICA rice varieties was determined by comparing the heights of the crops sown in soils contaminated with different concentrations of the pollutant with those from the control treatment.

The leaf area of the three varieties of NERICA rice from contaminated soil and the control plants was determined according to Fageria, (2007)[11]and Yoshida, (1976)[12]using the formula:

Leaf Area (LA) = L x B x K

Where: L = leaf length

B = leaf breadth

K = adjustment factor (0.75) for rice at vegetative growth stage

K = adjustment factor (0.67) for rice at maturity growth stage

The Leaf Area Index (LAI) of the three NERICA varieties in polluted and control was determined based on the method by Fageria, (2007)[11] using the formula:

$$LAI\ (cm^2\ m^{-2}) = \frac{\text{leaf Area } (cm^2) \times \text{Number of Tillers/Number of plants } (m^{-2})}{10{,}000}$$

Manual method was used to measure total number of tillers, tillers carrying panicles were taken as productive tillers while tillers without panicles unproductive tillers, and the percentage tillering efficiency calculated [13].The effects of the pollutants on panicle extrusion were elucidated by manual observation. Numbers of panicles in each replicate were counted and at harvest panicles weight were determined in grammes by air drying to a constant weight; also panicle length was measured [12].

A two-way ANOVA followed by bonferonniposthoc test using the graphpad prism version 5.00 for windows software was employed in analyzing results obtained from this study.

Results

As shown in Table 1,2 and 3, 1% mixture of spent engine oil, fresh diesel and gasoline had no significant effect on leaf elongation growth rate (P > 0.05) of the three varieties of NERICA rice compare with the control, except in Tox variety which was significantly affected 60 days after sowing (DAS) i.e. P < 0.05. However, Mecux and WitA.4 varieties of NERICA rice were significantly reduced by the pollutants mixture (P < 0.05, P <0.01, P <0.001) at 2–5% concentrations. In contrast, Tox variety seems to respond better to the stress and disturbance occasioned by the pollutants mixture. For example, at 20 DAS 5% of the pollutants mixture had no significant effect on the leaf elongation growth rate (P > 0.05), although there was a relapse in 40 and 60 DAS (P < 0.05), picking up again in 80 and 100 DAS (P > 0.05).

In non-stressed plants (0%), leaf area index was higher and no significant difference was recorded among the three cultivars. But the plants grown in soils treated with the pollutants mixture of spent engine oil, fresh diesel and gasoline concentrations (2-5%) induced a progressive decrease in leaf area index of the three varieties (P < 0.05, P < 0.01, P < 0.001), this is shown in Table 4, 5 and 6.

Table 7 presents the comparison between shoot growth dynamics of the control and treated Mecux rice seedlings. On the average 1% concentration of pollutants mixture somehow reduced the shoot growth rate, but it did not reach significant level (P > 0.05), while statistically significant reduction in shoot growth rate were recorded in Mecux rice seedlings grown in 2 – 5% concentrations of the organic pollutants (P < 0.05, P < 0.01, P < 0.001). Table 8 indicates statistically significant reduction in shoot growth rate of WitA.4 NERICA rice seedlings grown in 1 – 5% concentrations of the pollutant ($P < 0.05$, $P < 0.01$, $P < 0.001$), although increase in maximum values of the shoot length was observed throughout the growing duration, same applicable to Mecux and Tox NERICA rice varieties (Table 7,8 and 9). The response of shoot growth dynamics in Tox NERICA rice seedling during the growing period (20–100 DAS) is shown in Table 9. Statistical analysis showed that at 1% concentration no statistically significant reduction was recorded throughout the growing duration in shoot growth rate of Tox rice seedlings compared with the control, whereas 2–4% concentrations significantly reduced the shoot length ($P < 0.05$, $P < 0.01$). At 5% concentration, shoot growth of Tox seedlings was statistically unaffected throughout the growth duration except on 20 DAS ($P < 0.05$).

A summary of the effect of the pollutants mixture on main–culm leaf number is shown in Figure 1. At 95% confidence interval no statistically significant difference was observed in plants grown in 1-5% concentrations of the pollutants mixture compared with the control in all the three varieties of NERICA rice seedlings ($P > 0.05$), except in WitA.4 seedlings grown in 4% of the pollutants mixture ($P < 0.05$).

There were no marked differences in the number of tillers produced by therice seedlings (Mecuxand WitA.4) grown in 1-2% treated soils compared with the control ($P > 0.05$) (Figure 1). In contrast, 3–5% treated soils impacted negatively on the tiller production of Mecux and witA.4 ($P < 0.05$, $P < 0.01$ and $P < 0.001$), whereas at 95% confidence interval no significant difference was recorded for Tox rice seedlings grown in 1–5% concentrations of the pollutants mixture compared with the control ($P > 0.05$) (Figure 1).For number of productive tillers, similar results as described above were observed (Figure 1). Furthermore, the P values derived from this study suggested that unproductive tillers produced by the rice seedlings grown in treated soils are not significantly different from the ones produced by the control plants ($P > 0.05$).

When values on percentage tillering efficiency of the three NERICA rice varieties grown in 1-5% concentrations of the pollutant mixture were calculated relative to the control plants (Table 10), no statistically significant difference was demonstrated ($P > 0.05$) compared with the control plants, except in WitA.4 seedlings sown in 4-5% concentrations of the pollutant mixture ($P < 0.05$).

The data obtained (with the use of all the three test plants) on panicle extrusion are in good agreement. As is evident in Figure 1, 1% concentration of the pollutant mixture had no significant toxic effect on panicle extrusion of the plants ($P > 0.05$) compared with the control. However, analysis revealed that 2–5% concentrations had toxic effects on the plants panicle extrusion compared with the untreated plants ($P < 0.05$, $P < 0.01$ and $P < 0.001$) with little exception recorded in Tox seedlings grown in 3 and 5% concentrations which extruded its panicle better than the other varieties grown in the same concentrations ($P>0.05$).

Overall, treatment with organic pollutants induced no reduction in panicle length of all the three NERICA rice varieties ($P > 0.05$) (Figure 1). Whereas panicle weight was remarkably depressed in Mecux seedlings grown in 4-5% pollutants treated soils ($P < 0.001$, $P < 0.01$) respectively, WitA.4 and Tox were equally reduced at these concentrations ($P < 0.05$), ($P < 0.01$). Panicle weight of all the seedlings were unaffected compared with the control plants at 1–3% concentrations ($P > 0.05$), except in Mecux and WitA.4 which were slightly reduced ($P < 0.05$) (Figure 1).

The P values from the analysis suggested that Tox NERICA rice seedlings panicle numbers were unaffected by the polluted soils, as there were no statistically significant reduction in panicle numbers of the seedlings sown in 1–5% pollutants treated soils compared with plants grown in 0% treated soils ($P > 0.05$) (Figure 1). 2–5% concentrations remarkably depressed panicle number in WitA.4 ($P < 0.01$, $P < 0.001$), while Mecux's panicle numbers were reduced by 4% concentrations of the pollutant mixture ($P < 0.001$).

Discussion

The reduction in leaf elongation growth rate, shoot growth dynamics and its attendant reduced values of leaf area index (LAI) of the NERICA rice seedlings is not unconnected with the mixture of spent engine oil, fresh diesel and gasoline. This finding is corroborated by the work done by Njoku *et. al*. (2009) on Maize, Ogbo, (2009) – *Vignaunguiculata* and Falodun *et al*. on NERICA rice plants (unpublished data). The complex mixture of these organic pollutants results in compounds with different water solubilities and biodegradabilities [14]. Auffret *et. al*., (2009) deposited that, mixture of diesel oil and gasoline can interact to produce detrimental or beneficial effects as the case may be, such as enhanced mobility of dissolved Benzene, Toluene, Ethylbenzene and Xylenes (BTEXs), therefore increased dispersion of the pollutant mixture. This dispersion increases rate of toxic gas emission, resulting in depressed growth of plant and/or death.

According to Leahy and Colwell (1990), petroleum spilled or applied to soil is largely adsorbed to particulate matter, decreasing its toxicity but at the same time contributing to its persistence in the environment. In view of this, high rate of survival of the three NERICA rice varieties may be due to enhanced dispersion of toxic chemicals and adsorption of the organic pollutants to soil particles. Meanwhile, some studies has shown that petroleum and its products causes clogging and coating of soil, reducing nutrients availability to growing plants[7,16,17]. These observations may explain the poor leaf elongation, shoot growth dynamics and reduced leaf area index values recorded in the rice seedlings.

Fageria (2007), in his review of Yield Physiology of Rice stated that; plant height is an important trait that determines lodging resistance of rice plant and grain yields. Intermediate stature (100–130 cm) is considered desirable over short or long stature. Therefore, the reduced shoot growth rate recorded in this study could be beneficial to the rice seedlings yields [12], since the analysis of results shows that panicle extrusion, panicle number, panicle weight were unaffected mainly in the rice seedlings grown in 1–2% and some in 3–5% treated soils, the variation may be due to genetic differences in rice varieties used [10,18]. Also, age of plants could impact efficient partitioning of synthesized carbohydrates to the panicle development during reproductive growth stage of the rice seedlings because the numbers of petroleum degrading microorganisms increase with age of plant [19].

According to Ao *et. al.*, (2010), ability of rice plants to produce tillers which is one of the most important traits determining rice yield depends partially on environmental factors such as radiation, temperature, soil moisture, soil nutrients and varietal characteristics. Therefore, it is noteworthy that drought condition and other adverse environmental conditions caused by the pollutant mixture had no significant effect on percentage tillering efficiency (Figure 2) this may be as a result of increased tillering occasioned by low density of plants as tillering dynamics of rice plants usually respond to the level of resources available, that is, high density of rice plant may incurred low tillering ability [20].

Fageria (2007) quoting Yoshida, (1981) stated that total panicle number per square meter depends more on the main culm than on tillers. This could explain why there is significant correlation between the main culm leaf number and number of panicles of the rice seedlings grown in the polluted soils (Figure 3), that is, low main culm leaf number is correlated with low panicle number in each of the replicates studied while high main culm leaf correlates with high panicle number of the seedlings.

Conclusion

The patterns of development of rice plants under oil-pollution stress in this study suggests that knowledge of stress and disturbance physiology can contribute to rice planting programmes which aim to increase yield in oil polluted environments. Even though land pollution is to be discouraged, that in itself does not make the land unusable for rice production, provided time is allowed between period of pollution and cultivation of the crops. This time lag allows the emission of toxic gas and increase in number of petroleum degrading microorganisms.

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Table 1: Descriptive Statistics of the Influence of a Mixture of Spent Engine Oil, Fresh Diesel and Gasoline on the Leaf Elongation Rate of Nerica Rice Variety (MECUX)

DAY	CONC.	VARIETY	MEAN	S.D	S.E	MIN	MAX
DAY 20	**MECUX**	**0%**	33.20	1.93	1.11	31.00	34.60
		1%	27.50	1.32	0.76	26.50	29.00
		2%	14.87**	4.61	2.66	10.40	19.60
		3%	17.47**	4.89	2.82	13.20	22.80
		4%	8.47***	7.48	4.32	0.00	14.20
		5%	13.20***	3.98	2.30	8.60	15.50
DAY 40	**MECUX**	**0%**	41.33	1.53	0.88	40.00	43.00
		1%	34.33	2.08	1.20	32.00	36.00
		2%	22.00**	4.36	2.52	17.00	25.00
		3%	18.67***	4.65	2.57	13.50	22.50
		4%	8.50***	7.57	4.37	0.00	14.50
		5%	17.33***	2.02	1.17	15.00	18.50
DAY 60	**MECUX**	**0%**	51.67	1.53	0.88	50.00	53.00
		1%	44.00	2.00	1.15	42.00	46.00
		2%	27.00**	2.00	1.16	25.00	29.00
		3%	23.80***	6.35	3.67	19.00	31.00
		4%	12.00***	10.82	6.25	0.00	21.00
		5%	21.67***	4.73	2.73	18.00	27.00
DAY 80	**MECUX**	**0%**	56.67	0.58	0.33	56.00	57.00
		1%	51.00	1.00	0.58	50.00	52.00
		2%	32.33*	2.89	1.67	29.00	34.00
		3%	34.00*	10.44	6.02	27.00	46.00
		4%	15.00***	13.23	7.64	0.00	25.00
		5%	26.33**	6.66	3.84	22.00	34.00
DAY 100	**MECUX**	**0%**	61.00	5.57	3.22	55.00	66.00
		1%	51.67	3.79	2.19	49.00	56.00
		2%	36.67*	4.51	2.60	32.00	41.00
		3%	38.67	8.62	4.98	31.00	48.00
		4%	18.33***	16.26	9.39	0.00	31.00
		5%	32.00**	6.00	3.46	26.00	38.00

Key: S.D = Standard deviation**, S.E** = Standard error, **MIN** = Minimum percentage tillering efficiency, **MAX** = Maximum percentage tillering efficiency, * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$

Table 2: Descriptive Statistics of the Influence of a Mixture of Spent Engine Oil, Fresh Diesel and Gasoline on the Leaf Elongation Rate of Nerica Rice Variety (Wita.4)

DAY	CONC.	VARIETY	MEAN	S.D	S.E	MIN	MAX
DAY 20	**WITA.4**	**0%**	30.00	1.78	1.03	28.60	32.00
		1%	20.50	3.92	2.27	16.00	23.20
		2%	8.80***	2.43	1.41	6.00	10.40
		3%	7.07***	6.28	3.63	0.00	12.00
		4%	9.43***	2.27	1.31	7.00	11.50
		5%	6.50***	5.63	3.25	0.00	10.00
DAY 40	**WITA.4**	**0%**	38.33	1.16	0.67	37.00	39.00
		1%	29.00	7.21	4.16	23.00	37.00
		2%	13.50***	4.77	2.75	10.50	19.00
		3%	8.83***	7.97	4.60	0.00	15.50
		4%	11.17***	4.65	2.68	8.00	16.50
		5%	10.00***	8.79	5.08	0.00	16.50
DAY 60	**WITA.4**	**0%**	48.00	5.29	3.06	42.00	52.00
		1%	34.83	9.17	5.29	24.50	42.00
		2%	16.00***	10.39	6.00	10.00	28.00
		3%	9.00***	7.94	4.58	0.00	15.00
		4%	10.67***	8.33	4.81	4.00	20.00
		5%	10.33***	9.07	5.24	0.00	17.00
DAY 80	**WITA.4**	**0%**	54.67	1.16	0.67	54.00	56.00
		1%	42.33	11.02	6.36	31.00	53.00
		2%	20.67***	16.07	9.28	9.00	39.00
		3%	9.67***	8.74	5.04	0.00	17.00
		4%	13.33***	8.08	4.67	6.00	22.00
		5%	11.33***	9.87	5.70	0.00	18.00
DAY 100	**WITA.4**	**0%**	59.00	2.00	1.16	57.00	61.00
		1%	45.67	11.50	6.64	34.00	57.00
		2%	23.00***	17.58	10.15	10.00	43.00
		3%	12.33***	10.79	6.23	0.00	20.00
		4%	17.00***	11.53	6.66	6.00	29.00
		5%	14.67***	12.74	7.36	0.00	23.00

Key: S.D = Standard deviation**, S.E** = Standard error, **MIN** = Minimum percentage tillering efficiency, **MAX** = Maximum percentage tillering efficiency, * = P < 0.05, ** = P < 0.01, *** = P < 0.001

Table 3: Descriptive Statistics of the Influence of A Mixture of Spent Engine Oil, Fresh Diesel and Gasoline on the Leaf Elongation Rate of Nerica Rice Variety (TOX)

DAY	CONC.	VARIETY	MEAN	S.D	S.E	MIN	MAX
DAY 20	**TOX**	**0%**	23.33	9.07	5.24	13.00	30.00
		1%	12.33	13.65	7.88	3.00	28.00
		2%	10.17*	10.52	6.07	0.00	21.00
		3%	10.00*	1.73	1.00	8.00	11.00
		4%	10.70*	4.25	2.45	8.00	15.60
		5%	11.13	5.01	2.89	6.00	16.00
DAY 40	**TOX**	**0%**	29.17	5.01	2.90	24.00	34.00
		1%	18.67	11.72	6.77	10.00	32.00
		2%	11.00**	10.54	6.08	0.00	21.00
		3%	14.00*	4.36	2.52	9.00	17.00
		4%	13.17**	4.73	2.73	9.50	18.50
		5%	15.67*	2.89	1.67	14.00	19.00
DAY 60	**TOX**	**0%**	37.33	7.64	4.41	29.00	44.00
		1%	20.67*	12.50	7.22	12.00	35.00
		2%	14.00**	15.10	8.72	0.00	30.00
		3%	17.33*	4.73	2.73	12.00	21.00
		4%	12.67**	5.03	2.91	8.00	18.00
		5%	20.00*	6.08	3.51	16.00	27.00
DAY 80	**TOX**	**0%**	45.67	4.04	2.33	42.00	50.00
		1%	32.00	17.09	9.87	14.00	48.00
		2%	18.00**	18.52	10.69	0.00	37.00
		3%	20.67*	5.51	3.18	15.00	26.00
		4%	19.67**	6.43	3.71	15.00	27.00
		5%	25.67	9.81	5.67	20.00	37.00
DAY 100	**TOX**	**0%**	44.33	6.03	3.48	38.00	50.00
		1%	29.67	16.80	9.70	15.00	48.00
		2%	18.33*	19.60	11.32	0.00	39.00
		3%	22.00	9.85	5.69	11.00	30.00
		4%	16.00**	4.58	2.65	12.00	21.00
		5%	24.67	6.66	3.84	19.00	32.00

Key: S.D = Standard deviation**, S.E** = Standard error, **MIN** = Minimum percentage tillering efficiency, **MAX** = Maximum percentage tillering efficiency, * = P < 0.05, ** = P < 0.01, *** = P < 0.001

Table 4: Descriptive Statistics of the Influence of a Mixture of Spent Engine Oil, Fresh Diesel and Gasoline on Leaf Area Index of Nerica Rice Plants (MECUX)

DAY	CONC.	VARIETY	MEAN	S.D	S.E	MIN	MAX
DAY 20	MECUX	0%	0.026	0.003	0.002	0.023	0.028
		1%	0.009***	0.005	0.003	0.004	0.014
		2%	0.002***	0.002	0.001	0.001	0.004
		3%	0.002***	0.001	0.000	0.001	0.002
		4%	0.001***	0.001	0.001	0.000	0.002
		5%	0.002***	0.002	0.001	0.001	0.005
DAY 40	MECUX	0%	0.048	0.004	0.002	0.044	0.051
		1%	0.016***	0.012	0.001	0.004	0.028
		2%	0.003***	0.002	0.001	0.002	0.005
		3%	0.002***	0.001	0.000	0.001	0.002
		4%	0.001***	0.001	0.001	0.000	0.002
		5%	0.004***	0.004	0.002	0.001	0.008
DAY 60	MECUX	0%	0.072	0.003	0.002	0.068	0.074
		1%	0.029***	0.018	0.010	0.010	0.044
		2%	0.006***	0.003	0.002	0.003	0.008
		3%	0.003***	0.002	0.001	0.002	0.005
		4%	0.002***	0.003	0.001	0.000	0.005
		5%	0.006***	0.007	0.004	0.002	0.014
DAY 80	MECUX	0%	0.086	0.005	0.003	0.081	0.091
		1%	0.036***	0.023	0.013	0.014	0.060
		2%	0.009***	0.004	0.003	0.005	0.013
		3%	0.006***	0.002	0.001	0.003	0.007
		4%	0.003***	0.004	0.002	0.000	0.007
		5%	0.011***	0.012	0.007	0.004	0.024
DAY 100	MECUX	0%	0.400	0.033	0.019	0.374	0.437
		1%	0.142***	0.122	0.071	0.029	0.272
		2%	0.048***	0.050	0.029	0.015	0.105
		3%	0.022***	0.011	0.007	0.012	0.034
		4%	0.010***	0.016	0.010	0.000	0.029
		5%	0.080***	0.061	0.035	0.009	0.118

Key: S.D = Standard deviation**, S.E** = Standard error, **MIN** = Minimum percentage tillering efficiency, **MAX** = Maximum percentage tillering efficiency, ***** = P < 0.05, ****** = P < 0.01, ******* = P < 0.001

Table 5: Descriptive Statistics of the Influence of a Mixture of Spent Engine Oil, Fresh Diesel and Gasoline on Leaf Area Index of Nerica Rice Plants (WITA.4)

DAY	CONC.	VARIETY	MEAN	S.D	S.E	MIN	MAX
DAY 20	**WITA.4**	**0%**	0.026	0.001	0.001	0.025	0.027
		1%	0.003***	0.001	0.001	0.002	0.005
		2%	0.001***	0.000	0.000	0.000	0.001
		3%	0.000***	0.000	0.000	0.000	0.001
		4%	0.000***	0.000	0.000	0.000	0.001
		5%	0.001***	0.001	0.001	0.000	0.003
DAY 40	**WITA.4**	**0%**	0.038	0.004	0.002	0.034	0.041
		1%	0.006***	0.001	0.000	0.005	0.007
		2%	0.001***	0.001	0.000	0.000	0.002
		3%	0.000***	0.000	0.001	0.000	0.001
		4%	0.001***	0.001	0.000	0.000	0.002
		5%	0.002***	0.003	0.002	0.000	0.005
DAY 60	**WITA.4**	**0%**	0.065	0.008	0.004	0.058	0.074
		1%	0.008***	0.003	0.002	0.005	0.010
		2%	0.001***	0.001	0.001	0.000	0.003
		3%	0.000***	0.000	0.000	0.000	0.001
		4%	0.001***	0.001	0.001	0.000	0.002
		5%	0.002***	0.003	0.002	0.000	0.005
DAY 80	**WITA.4**	**0%**	0.083	0.002	0.001	0.081	0.086
		1%	0.010***	0.004	0.003	0.005	0.014
		2%	0.002***	0.002	0.001	0.000	0.004
		3%	0.001***	0.000	0.000	0.000	0.001
		4%	0.001***	0.002	0.001	0.000	0.004
		5%	0.003***	0.004	0.002	0.000	0.007
DAY 100	**WITA.4**	**0%**	0.378	0.025	0.014	0.354	0.404
		1%	0.026***	0.015	0.009	0.009	0.036
		2%	0.005***	0.006	0.004	0.000	0.012
		3%	0.001***	0.001	0.001	0.000	0.002
		4%	0.004***	0.006	0.003	0.000	0.010
		5%	0.011***	0.019	0.011	0.000	0.034

Key: S.D = Standard deviation**, S.E** = Standard error, **MIN** = Minimum percentage tillering efficiency, **MAX** = Maximum percentage tillering efficiency, * = P < 0.05, ** = P < 0.01, *** = P < 0.001

Table 6: Descriptive Statistics of the Influence of a Mixture of Spent Engine Oil, Fresh Diesel and Gasoline on Leaf Area Index of Nerica Rice Plants (TOX)

DAY	CONC.	VARIETY	MEAN	S.D	S.E	MIN	MAX
DAY 20	**TOX**	**0%**	0.014	0.009	0.005	0.005	0.023
		1%	0.006*	0.008	0.019	0.000	0.016
		2%	0.003**	0.004	0.002	0.000	0.007
		3%	0.002***	0.001	0.001	0.001	0.002
		4%	0.000***	0.000	0.000	0.000	0.000
		5%	0.002***	0.002	0.001	0.000	0.004
DAY 40	**TOX**	**0%**	0.020	0.001	0.006	0.010	0.029
		1%	0.009*	0.013	0.007	0.001	0.024
		2%	0.004**	0.005	0.003	0.000	0.009
		3%	0.003***	0.002	0.001	0.000	0.005
		4%	0.000***	0.000	0.000	0.000	0.001
		5%	0.003**	0.004	0.002	0.000	0.008
DAY 60	**TOX**	**0%**	0.033	0.018	0.010	0.016	0.051
		1%	0.014*	0.020	0.011	0.001	0.036
		2%	0.006**	0.008	0.005	0.000	0.016
		3%	0.004***	0.004	0.003	0.000	0.009
		4%	0.001***	0.000	0.000	0.000	0.001
		5%	0.007**	0.009	0.005	0.000	0.017
DAY 80	**TOX**	**0%**	0.050	0.028	0.016	0.021	0.076
		1%	0.023*	0.027	0.016	0.000	0.053
		2%	0.010***	0.013	0.008	0.000	0.025
		3%	0.006***	0.007	0.004	0.000	0.013
		4%	0.001***	0.000	0.000	0.000	0.001
		5%	0.008***	0.010	0.006	0.001	0.019
DAY 100	**TOX**	**0%**	0.211	0.111	0.064	0.099	0.320
		1%	0.106	0.135	0.078	0.001	0.258
		2%	0.034**	0.053	0.030	0.000	0.099
		3%	0.043**	0.049	0.029	0.000	0.097
		4%	0.001***	0.001	0.000	0.000	0.001
		5%	0.038**	0.049	0.028	0.001	0.093

Key: S.D = Standard deviation**, S.E** = Standard error, **MIN** = Minimum percentage tillering efficiency, **MAX** = Maximum percentage tillering efficiency, * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$

Table 7: Descriptive Statistics of the Influence of a Mixture of Spent Engine Oil, Fresh Diesel and Gasoline on Shoot Growth Dynamics of Nerica Rice Plant (MECUX)

DAY	CONC.	VARIETY	MEAN	S.D	S.E	MIN	MAX
DAY 20	**MECUX**	**0%**	41.93	1.83	1.06	40.50	44.00
		1%	32.27	1.10	0.64	31.00	33.00
		2%	18.20**	3.39	1.96	15.50	22.00
		3%	19.23**	3.66	2.11	15.70	23.00
		4%	9.67***	8.39	4.84	0.00	15.00
		5%	16.73***	3.50	2.02	12.70	19.00
DAY 40	**MECUX**	**0%**	53.35	1.30	.749	51.90	54.40
		1%	43.17	2.17	1.26	40.70	44.80
		2%	26.03***	4.30	2.48	23.50	31.00
		3%	22.20***	2.48	1.43	20.30	25.00
		4%	10.17***	8.81	5.09	0.00	15.50
		5%	23.33***	3.21	1.86	19.70	25.80
DAY 60	**MECUX**	**0%**	64.10	2.62	1.51	61.30	66.50
		1%	54.53	4.37	2.52	49.50	57.30
		2%	32.53**	6.50	3.76	28.10	40.00
		3%	26.73***	10.26	5.92	19.70	38.50
		4%	15.90***	13.89	8.02	0.00	25.70
		5%	28.17***	5.20	3.01	24.00	34.00
DAY 80	**MECUX**	**0%**	74.77	3.66	2.11	71.00	78.30
		1%	65.43	3.88	2.24	61.30	69.00
		2%	40.33**	5.86	3.38	36.00	47.00
		3%	34.67**	10.69	6.17	28.00	47.00
		4%	19.00***	16.46	9.50	0.00	29.00
		5%	33.77**	6.82	3.94	28.00	41.30
DAY 100	**MECUX**	**0%**	79.77	4.76	2.70	74.30	83.00
		1%	68.33	4.93	3.34	65.00	74.00
		2%	48.67*	7.23	4.34	44.00	57.00
		3%	44.67*	9.87	7.76	38.00	56.00
		4%	21.83***	19.62	12.44	0.00	38.00
		5%	43.67*	7.02	3.92	37.00	51.00

Key: S.D = Standard deviation**, S.E** = Standard error, **MIN** = Minimum percentage tillering efficiency, **MAX** = Maximum percentage tillering efficiency, * = P < 0.05, ** = P < 0.01, *** = P < 0.001

Table 8: Descriptive Statistics of the Influence of a Mixture of Spent Engine Oil, Fresh Diesel and Gasoline on Shoot Growth Dynamics of Nerica Rice Plant (WITA.4)

DAY	CONC.	VARIETY	MEAN	S.D	S.E	MIN	MAX
DAY 20	WITA.4	0%	41.60	1.28	0.74	40.50	43.00
		1%	22.77*	6.44	3.72	15.80	28.50
		2%	11.67***	2.31	1.33	9.00	13.00
		3%	9.33***	8.81	5.09	0.00	17.50
		4%	14.17***	3.25	1.88	10.50	16.70
		5%	9.23***	8.03	4.64	0.00	14.60
DAY 40	WITA.4	0%	51.27	3.36	1.94	47.40	53.50
		1%	29.90**	10.39	6.00	18.00	37.20
		2%	15.10***	2.97	1.72	13.00	18.50
		3%	10.67***	10.07	5.81	0.00	20.00
		4%	14.60***	5.39	3.11	11.00	20.80
		5%	11.70***	10.14	5.86	0.00	18.00
DAY 60	WITA.4	0%	64.27	3.86	2.23	60.00	67.50
		1%	38.67*	13.58	7.84	23.00	47.00
		2%	18.33***	5.35	3.09	15.00	24.50
		3%	11.00***	10.54	6.08	0.00	21.00
		4%	14.33***	10.69	6.17	5.00	26.00
		5%	12.83***	11.12	6.42	0.00	19.50
DAY 80	WITA.4	0%	77.20	2.48	1.43	75.30	80.00
		1%	45.33*	20.23	11.68	22.00	58.00
		2%	22.50***	10.97	6.33	14.50	35.00
		3%	13.00***	12.53	7.23	0.00	25.00
		4%	18.00***	11.53	6.66	7.00	30.00
		5%	14.67***	12.70	7.33	0.00	22.00
DAY 100	WITA.4	0%	83.67	2.08	1.20	82.00	86.00
		1%	55.67	19.66	11.35	33.00	68.00
		2%	27.00***	14.18	8.19	16.00	43.00
		3%	16.00***	15.10	8.72	0.00	30.00
		4%	23.33***	16.04	9.26	8.00	40.00
		5%	18.00***	15.62	9.02	0.00	28.00

Key: S.D = Standard deviation**, S.E** = Standard error, **MIN** = Minimum percentage tillering efficiency, **MAX** = Maximum percentage tillering efficiency, * = P < 0.05, ** = P < 0.01, *** = P < 0.001

Table 9: Descriptive Statistics of the Influence of a Mixture of Spent Engine Oil, Fresh Diesel and Gasoline on Shoot Growth Dynamics of Nerica Rice Plant (Tox)

DAY	CONC.	VARIETY	MEAN	S.D	S.E	MIN	MAX
DAY 20	**TOX**	**0%**	30.27	11.68	6.74	17.00	39.00
		1%	15.33	17.37	10.03	3.70	35.30
		2%	10.93**	12.02	6.94	0.00	23.80
		3%	11.43*	2.23	1.29	10.00	14.00
		4%	13.57*	7.31	4.22	9.00	22.00
		5%	14.87*	4.79	2.77	12.00	20.40
DAY 40	**TOX**	**0%**	36.57	10.45	6.03	25.20	45.75
		1%	19.98	19.11	11.03	7.70	42.00
		2%	13.20**	14.37	8.29	0.00	28.50
		3%	16.44*	3.38	1.95	13.50	20.13
		4%	19.00*	6.61	3.82	14.00	26.50
		5%	21.13	5.52	3.19	17.00	27.40
DAY 60	**TOX**	**0%**	47.03	14.65	8.46	32.50	61.80
		1%	29.27	21.92	12.66	13.50	54.30
		2%	17.53**	19.05	10.10	0.00	37.80
		3%	21.73*	5.75	3.32	16.00	27.50
		4%	20.33*	8.51	4.91	14.00	30.00
		5%	26.60	7.12	4.11	22.00	34.80
DAY 80	**TOX**	**0%**	59.10	16.21	9.36	41.30	73.00
		1%	38.67	23.46	13.54	20.00	65.00
		2%	22.00**	23.07	13.32	0.00	46.00
		3%	27.00*	7.21	4.16	21.00	35.00
		4%	28.33*	10.12	5.84	22.00	40.00
		5%	32.67	8.15	4.70	27.00	42.00
DAY 100	**TOX**	**0%**	63.53	18.01	10.40	44.30	80.00
		1%	41.67	23.67	13.67	28.00	69.00
		2%	22.67**	23.54	13.59	0.00	47.00
		3%	29.00*	11.53	6.66	20.00	42.00
		4%	28.33*	8.51	4.91	22.00	38.00
		5%	34.87	10.85	6.33	27.30	47.30

Key: S.D = Standard deviation**, S.E** = Standard error, **MIN** = Minimum percentage tillering efficiency, **MAX** = Maximum percentage tillering efficiency, ***** = $P < 0.05$, ****** = $P < 0.01$, ******* = $P < 0.001$

Table 10: Percentage Tillering Efficiency

VARIETY	CONC	MEAN	S.D	S.E	MIN (%)	MAX (%)
MECUX	**0%**	87.67	21.36	12.33	63	100
	1%	83.33	16.50	9.53	67	100
	2%	62.67	14.98	8.65	46	75
	3%	77.67	38.68	22.33	33	100
	4%	66.67	57.74	33.33	0	100
	5%	100	0.00	0.00	100	100
WITA.4	**0%**	91.67	14.43	8.33	75	100
	1%	93.33	11.55	6.67	80	100
	2%	83.33	28.87	16.67	50	100
	3%	49	42.93	24.79	0	80
	4%	27.67*	47.92	27.67	0	83
	5%	22.33*	38.68	22.33	0	67
TOX	**0%**	100	0.00	0.00	100	100
	1%	80	26.46	15.28	50	100
	2%	66.67	57.74	33.33	0	100
	3%	100	0.00	0.00	100	100
	4%	100	0.00	0.00	100	100
	5%	83.33	28.87	16.67	50	100

Key: S.D = Standard deviation**, S.E** = Standard error, **MIN** = Minimum percentage tillering efficiency, **MAX** = Maximum percentage tillering efficiency, ***** = $P < 0.05$.

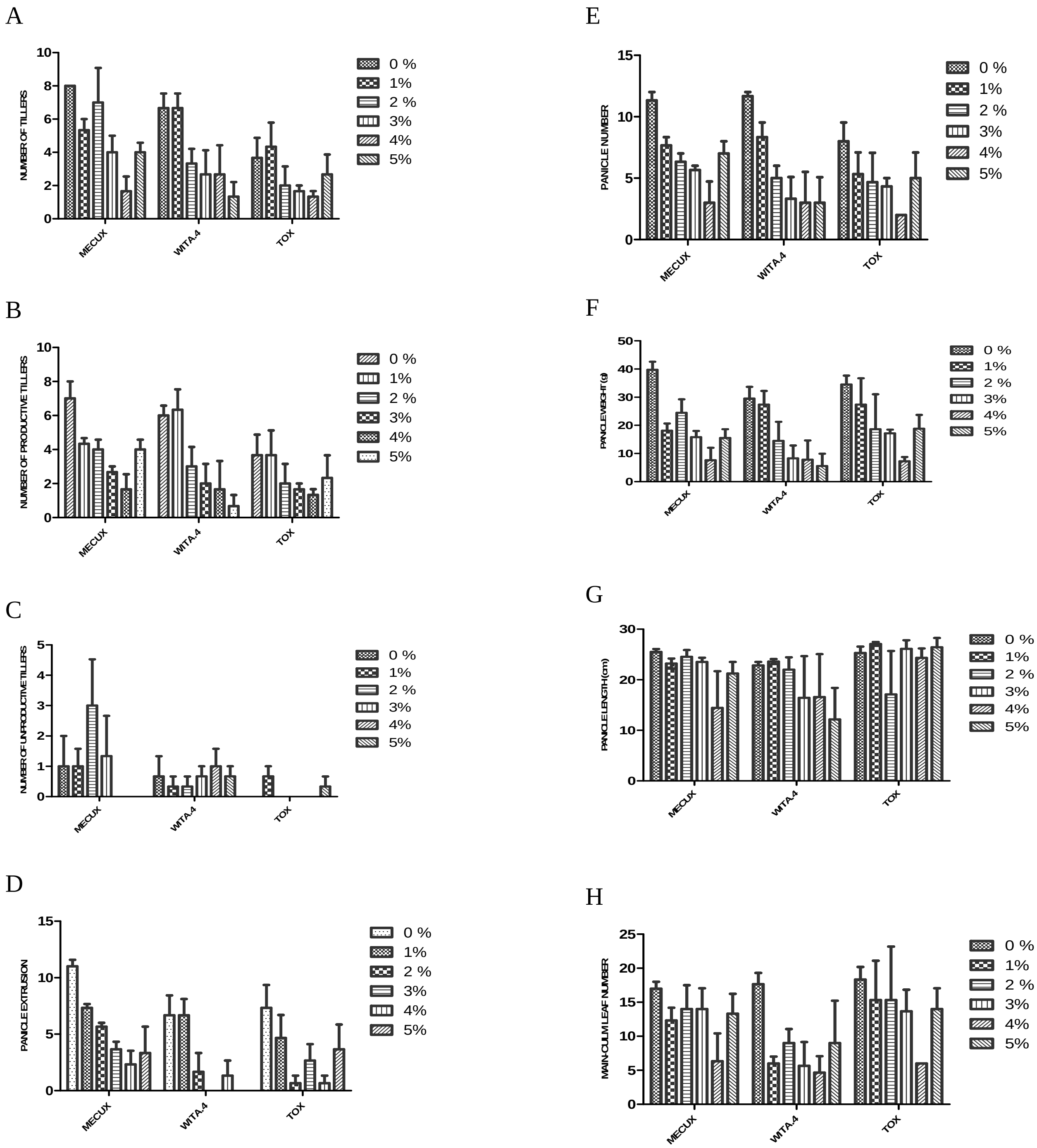

Figure 1: Graph showing the effects of the pollutants (spent engine oil, fresh diesel and gasoline) on some yield attributes of NERICA rice crop plants (Mecux, WitA.4

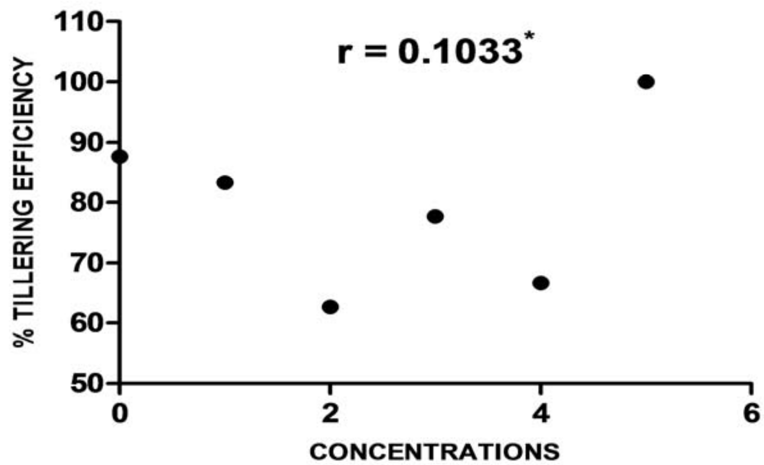

Figure 2a: Shows no correlation between concentrations of pollutants and percentage tillering efficiency of Mecux rice seedlings (* = Not significant).

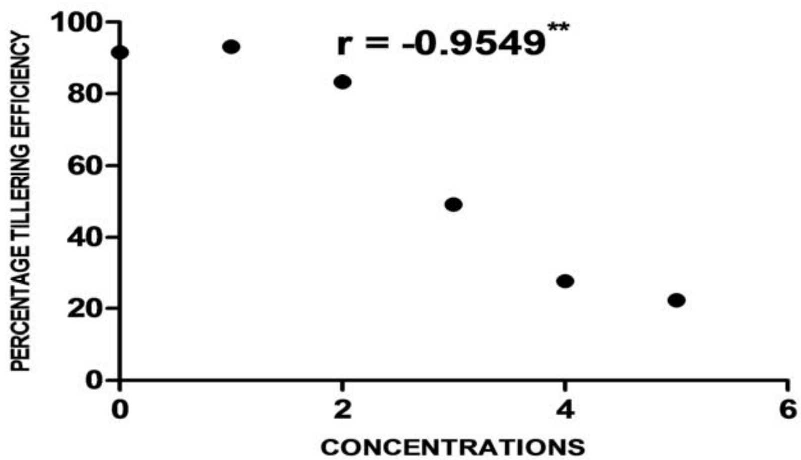

Figure 2b: Shows correlation between concentrations of pollutants and percentage tillering efficiency of WitA.4 rice seedlings (= Significant).**

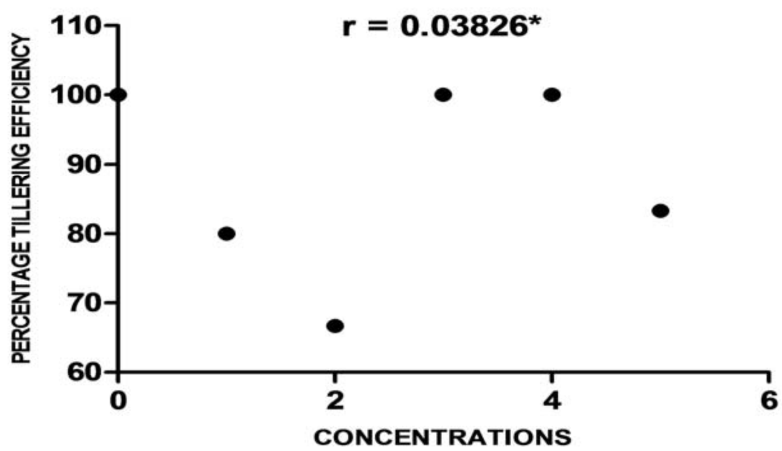

Figure 2c: Shows no correlation between concentrations of pollutants and percentage tillering efficiency of WitA.4 rice seedlings (* = Not significant).

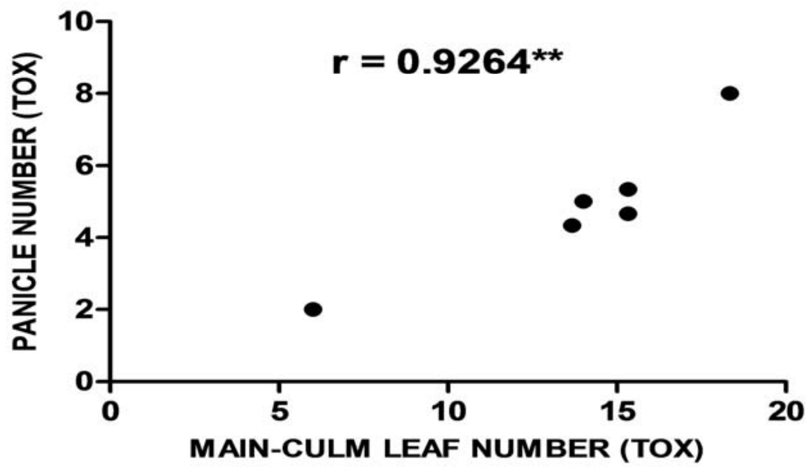

Figure 3a: Shows correlation between Main – Culm Leaf Number and Panicle Number of Tox variety at α = 0.05 (=Significant).**

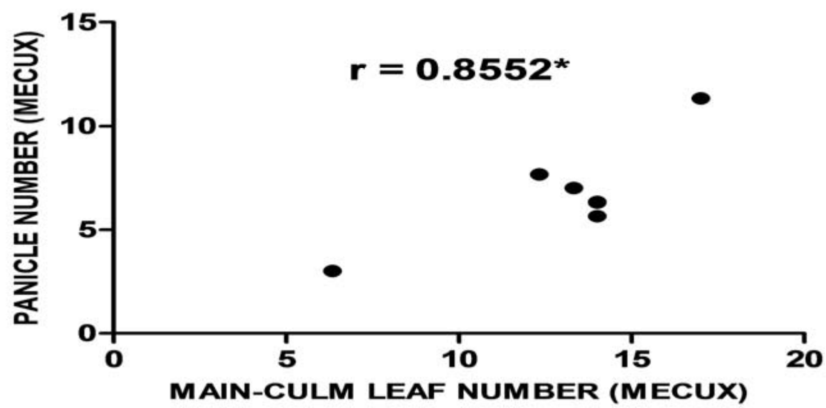

Figure 3b: Shows correlation between Main – Culm Leaf Number and Panicle Number of Mecux variety at α = 0.05 (* = Significant).

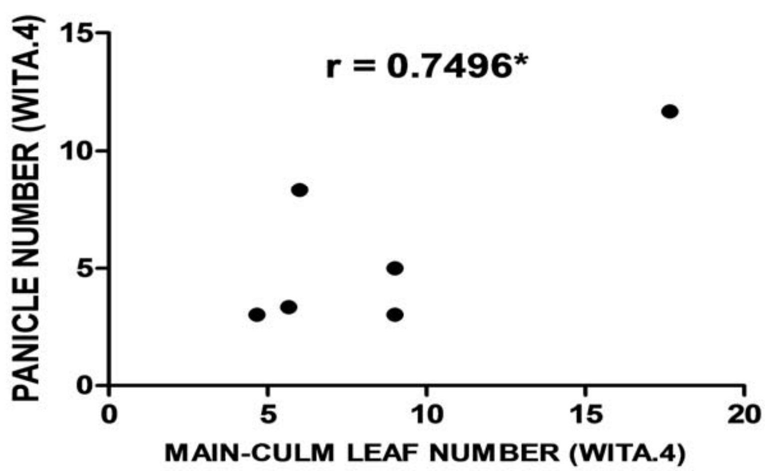

Figure 3c: Shows no correlation between Main – Culm Leaf Number and Panicle Number of Wita.4 variety at α = 0.05 (* = Not Significant).