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RESEARCH ARTICLE

SCREENING OF RICE VARIETIES TOLERANT AND SUSCEPTIBLE TO IRON TOXICITY IN INLAND VALLEY SWAMPS (IVS) IN SIERRA LEONE

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Abstract

Iron toxicity is a nutrient disorder, which is brought about by the uptake of Fe (II) in amounts that disrupt or over-expressseveral metabolic processes, resulting in damage to the rice plant. A pot experiment was conducted in a greenhouse at Sierra Leone Agricultural Business Initiatives (SABI) Center Newton to enable the screening of many different varieties thereby resulting in the identification of both tolerant and susceptible varieties that could be used as breeding materials for rice improvement programs in the tropics. The hot spot iron toxic soils used in the pot were weighed at a uniform rate The parameters or items of measurement to be looked at could be; the dry weight of root, dry weight of stem, dry weight of filled grain, dry weight of unfilled grains, plant height (cm) of the genotypes, tiller number of the genotypes, leaf area (cm^2)of the genotypes, phenotypic acceptability of the genotypes, Iron-toxicity score of the genotypes Based on their performance in terms of toxicity scores, dry root weight, stem weight, leaf area, unfilled grains, filled grains, tiller count, plant height, and phenotypic acceptability the following varieties have been identified as iron toxicity tolerant with high yield potential; Gbassay, Rok-24, Chim, kiamp.

Introduction:-

Rice (Oryza sativa) is the most important food crop for more than half of the world's population living in the tropics and sub-tropics. Rice has become a commodity of strategic importance across much of Africa. Projection by the FAO suggests rice consumption in West Africa to remain high and continue to increase at 4.5% through the year 2000 and beyond (WARDA 2000).

West African rice production however has not been able to meet the growing demand due to several production constraints. The increasing gap between regional supply and demand is being filled by rising imports at a growth rate of 8.4% per annum since 1997.

In Sierra Leone approximately 75% of the total land area is arable (that is 5.4 million hectares out of the 7.32 million hectares). The upland accounts for about 4.3 million hectares (80% of the total arable land) while the swamps account for 1.06 million hectares (20%) swamp land is classified according to the following categories. Inland valley swamps 640000 hectares (12.1%), mangrove swamps 200000 (3.8%), Bolilands 120000 (2.3%), and Riverrain grassland comprising 100000 hectares (1.8%) (MAFFS and FAO, 2005).

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The Inland Valley Swamp rice ranks second in importance to the upland in terms of ecology for rice culture. Paramount among the constraints of rice production in the rain-fed lowland and irrigated systems is the problem of iron toxicity. Lowland rice is being cultivated on approximately 128 million hectares of irrigated and rain-fed land (Maclean et al., 2002). As many as 100 million hectares show some sort of nutritional constraint to rice growth caused by either deficiencies or toxicities (Brady, 1982). Among toxicities, iron toxicity is well recognized as the most widely distributed nutritional disorder in lowland rice production (Dobermann and Fairhurst, 2000).

A wide range of soil types can be iron-toxic, including acid sulfate soil (Tinh, 1999), acid clay soils (Alaily, 1998), peat soils (Deturck, 1994), and valley-bottom soils receiving interflow water from adjacent slopes (Sahrawat and Diatta, 1995).

Iron toxicity is a nutrient disorder, that is brought about by the uptake of Fe (II) in amounts that disrupt or expressseveral metabolic processes, resulting in damage of the rice plant.

The purpose of the study was to screen some rice cultivars from the Sierra Leone Agricultural Research Institute (SLARI) to identify their varying degree of sensitivity or tolerance to iron toxicity and also assess the performance of upland and lowland rice varieties under iron toxicity in pot conditions.

This study will enable the screening of many different varieties thereby resulting in the identification of both tolerant and susceptible varieties that could be used as breeding materials for rice improvement programs in the tropics.

Material and Methods:-

The soil from the known toxic site (iron toxic hotspot) was collected thoroughly mixed, dried, sieved, and weighed 4.5kg, placed in 6-litre plastic buckets. The soil showing Fe toxicity symptoms (substances that look like oil spills in the flood water and reddish stains in the soil) was collected with a spade within 0-15cm depth. The soil was air-dried under shade before analysis.

Growing Conditions

Pot experiments were conducted under climate-controlled conditions in the Green House, at Sierra Leone Agric. Business Initiative Centre, Newton developing a standard screening tool for iron toxicity in lowland rice.

Plant Materials

Seeds of lowland rice cultivars (Oryza Sativa L), varying in their reported degree of sensitivity towards reduced iron, were obtained from the Sierra Leone Agricultural Research Institute (SLARI). Five of these cultivars originated from breeding programs of the Rokupr Agricultural Research Centre (RARC) and three as local cultivars respectively. (Rok – 24, Nerica -19, Pa kiamp, Pa chaim,YaGbassay, Sandnicu, Gbuipu and Kowihun).

Growth Media and Nutrition Composition of Liquid Culture Medium

The rice seedlings were cultivated in Hoagland medium a culture nutrition solution. It contained solution one 48.2g/L(NH_4CL), 65.9g/L ($MgSo_4$). Solution two contained 15.9g/L (K_2So_4). Solution three contained 18.5g/L (KNo_3), 59.9g/L ($CaCl_2$), 24.8g/L (KH_2Po_4). Solution four contained 9g/L ($MnCl_2.4H_2O$), 1.1g/L ($ZnSo_4.7H_2O$), 0.4g/L ($CuSo_4.5H_2O$), 29g/L (H_3Bo_4) and 0.1g/L [$(NH_4)_6Mo_7O_{24}.4H_2O$]

Treatment and Experimental Design

Rice seeds were soaked with water incubated and pre-germinated on filter paper in petri dishes until the seeds were sprouting (72 hours). Sprouted seeds were transferred into a sand nursery for two – weeks. There were 24 treatments derived from a combination of eight lowland rice cultivars. The 24 treatments were arranged in a completely randomized design (CRD) and replicated eight times. The Hoagland solution 1 of 5mls/plot added and 3mls/plot of solution two, three, and four respectively. The setup is shown in Figure.

Sowing and Pot Management

Four seedlings were transplanted per pot. The pots were watered with water from the field of the hot spot. Each pot was kept weed-free as weeds were removed regularly.

Data Collection

Growth Data

Data were collected on several leaves and tillers formed by visual counting at 21, 42, 63 and 84 days (DAT), plant height was determined by measuring from the base to the tip of the tallest leaf at the middle of the plant. Leaf Area (LA) was measured by measuring the length and maximum width of each leaf in the middle tiller and computing the area of each leaf base on the length width method; LA = KxLxW.

Where LA = Leaf Area, K= 0.75 at the vegetative stage and 0.67 at the maturity stage. L = Length of leaf and W= Maximum with of leaf (Gomez, 1983).

Iron toxicity score (ITS)

The iron toxicity score was based on the Standard Evaluation System for Rice (SES) Score of the International Rice Research Institute (IRRI 1996) on a 9-point scale. Where 1 =Growth and tillering nearly normal 2=Growth and tillering nearly normal, reddish-brown spots or orange discolouration on tips of older leaves 3= Growth and tillering nearly normal, old leaves reddish-brown, purple or orange yellow 5=Growth and tillering retarded; many leaves discoloured 7=Growth and tillering ceases, most leaves discoloured or dead 9=Almost all plants dead or dying.

The phenotypic acceptability indicates the breeding objectives for each location vary. The score should reflect the overall acceptability of the variety in the location where it is being grown on also a 9-point scale. Where 1=Excellent 3=Good 5=Fair 7=Poor 9=Unacceptable.

Dry matter

At physiological maturity when 90% of the panicles have turned yellow, each plant was uprooted per pot. The root portion was washed under a flowing tap to remove all soil particles. The plants were separated into shoot and root portions and spread on the workbench to air dry. The air-dried plant samples were oven-dried at 70 degrees centigrade to a constant weight.

Yield data.

Data were collected on the number of panicles, number of tillers, number of productive tillers and grain yield (g/plant/pot).

Statistical analysis

Analysis of variance (ANOVA) was used to analyse the data and differences in means were separated with the least significant difference (LSD) P <_ 0.05 using statistical analysis system software version 9. (SAS,2002).

Correlation and simple regression analysis were made by relating grain yield to growth and SES parameters. The model expression of the relationship between grain yield (Y) and independent variables was as given below;

Y = f(x_1, x2, x3, x4, x5, e1), where; Y = grain yield, X_1 = Number of leaves with iron toxicity symptoms,
X_2 = Plant height, X_3 = Number of productive tillers, X_4 = Number of tillers, X_5 = Iron toxicity score and
e_1 = Error term.

Results:-

Effect of iron toxicity on dry weight of root (g) of the genotypes tested in pots using iron-toxic soil

The root dry weight measurement of varieties tested under iron toxicity conditions are given in (table 2) there was a wide variation in root dry weight (0.2-16.9) as they grew from 3WAP (Week After Planting) to 12WAP.

Analysis of Anova indicates that there was a significant difference (p=0.05) in the mean dry weight of the root. The highest root weight was recorded for Gbassay (12.9), followed by Nerica-19 (11.2). The lowest root weight (1.8) was recorded for Gbuipuwa

Table 1:- Mean dry weight of root of the genotypes tested in pots using hot sport iron-toxic soil.

Variety	Mean dry weight of root
Rok – 24	9.6
Nirica – 19	11.2
Kiamp	6.2
Chaim	9.4

Gbassay	12.9
Sandaicu	3.3
Gbuipu	1.8
Kowihun	2.6

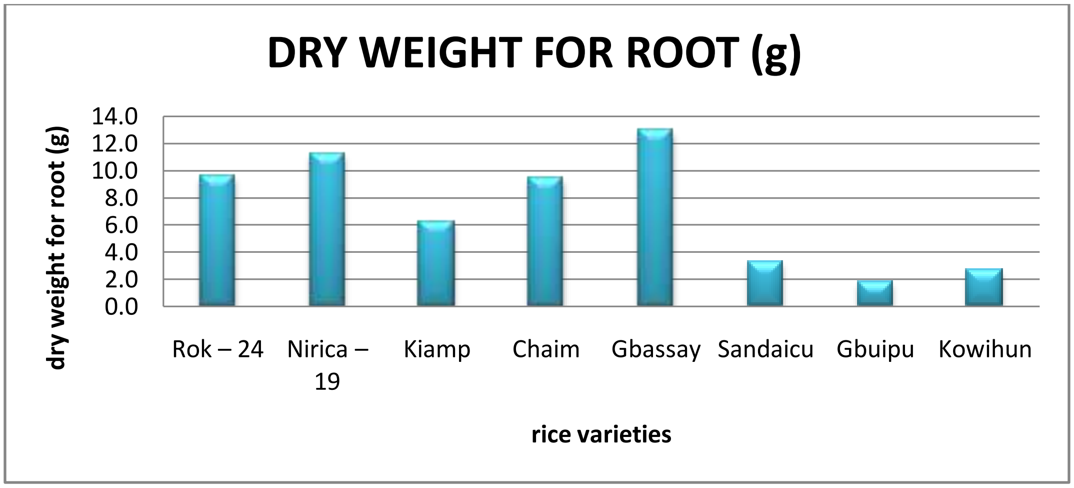

Figure1:-

Effect of iron toxicity on dry stem weight (g) of the genotypes tested in pots using iron-toxic soil.
The stem dry weight measurement of varieties tested under iron toxicity conditions are given in Table (2) there was a wide variation in stem dry weight (12.0-81.0) as theygrew from 3WAP to 12WAP.

Analysis of Anova indicates there was a significant difference (p=0.05) in the mean dry weight of the stem. The highest stem weight was recorded for Rock -24 (23.9), followed by Gbassay (23.7). The lowest stem weight (6.3) was recorded for Gbuipu

Table 2:- Mean of the dry weight of a stem of the genotypes tested in pots using hot sport iron-toxic soil.

Variety	**Mean of dry weight of stem**
Rok – 24	23.9
Nirica – 19	21.8
Kiamp	13.7
Chaim	19.4
Gbassay	23.7
Sandaicu	9.2
Gbuipu	6.3
Kowihun	7.3

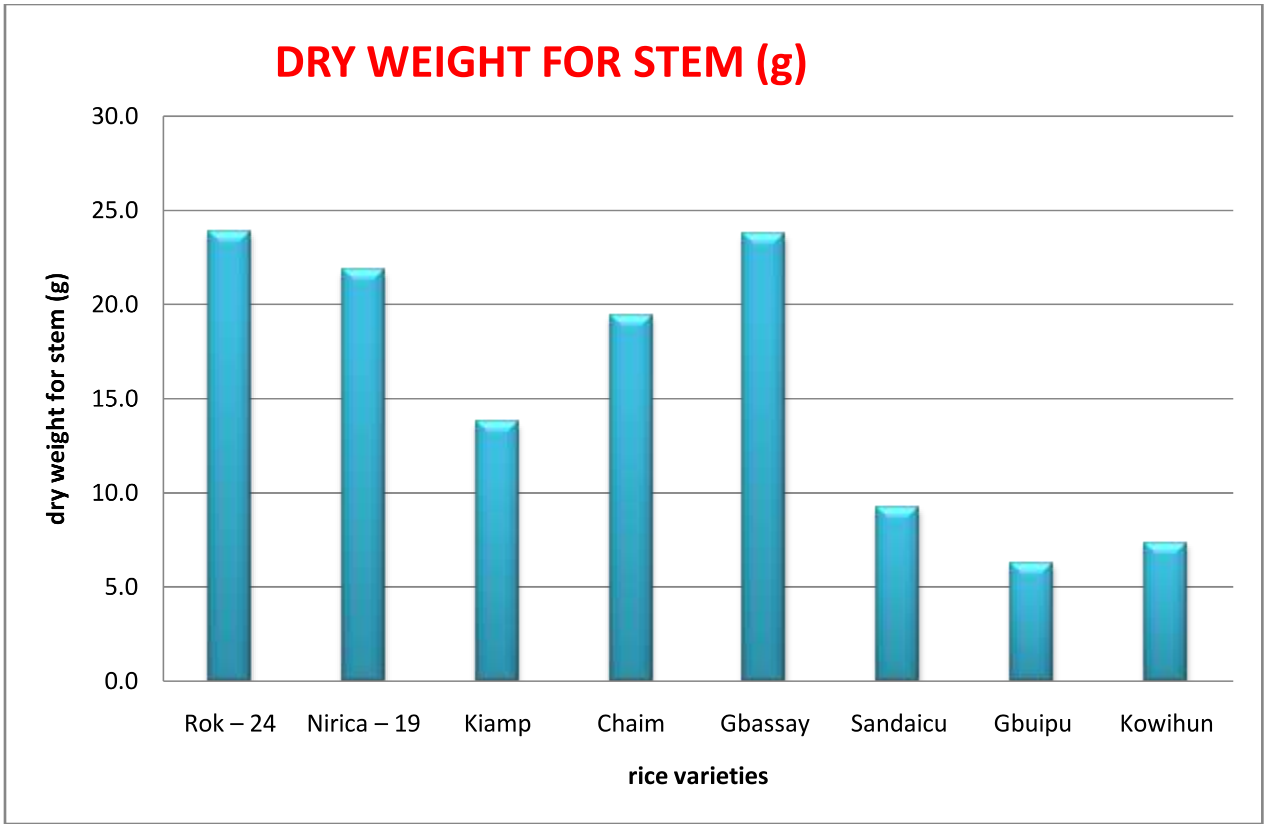

Figure 2:-

Effect of iron toxicity on dry weight (g) of filled grains of the genotypes tested in pots using hot sport iron-toxic soil.

The dry weight measurement for filled grains of varieties tested under iron toxicity conditions is given in Table (2). There was a wide variation in mean dry weight for filled grains (0.21-0.52) after harvest.

Analysis of Anova indicates there was a significant difference (p=0.05) in the mean dry weight of the filled grains. The highest filled grain weight was recorded for Gbassay (8.0) followed by Rock -24 (6.7), and the lowest filled grain weight (1.0) was recorded for Gbuipu.

Table3:- Mean of dry weight of filled grain of the genotypes tested in pots using hot sport iron-toxic soil.

Variety	**Mean dry weight of filled grain(g)**
Rok – 24	6.7b
Nirica – 19	3.9e
Kiamp	5.3c
Chaim	4.7d
Gbassay	8.0a
Sandaicu	2.5f
Gbuipu	1.0h
Kowihun	2.1g

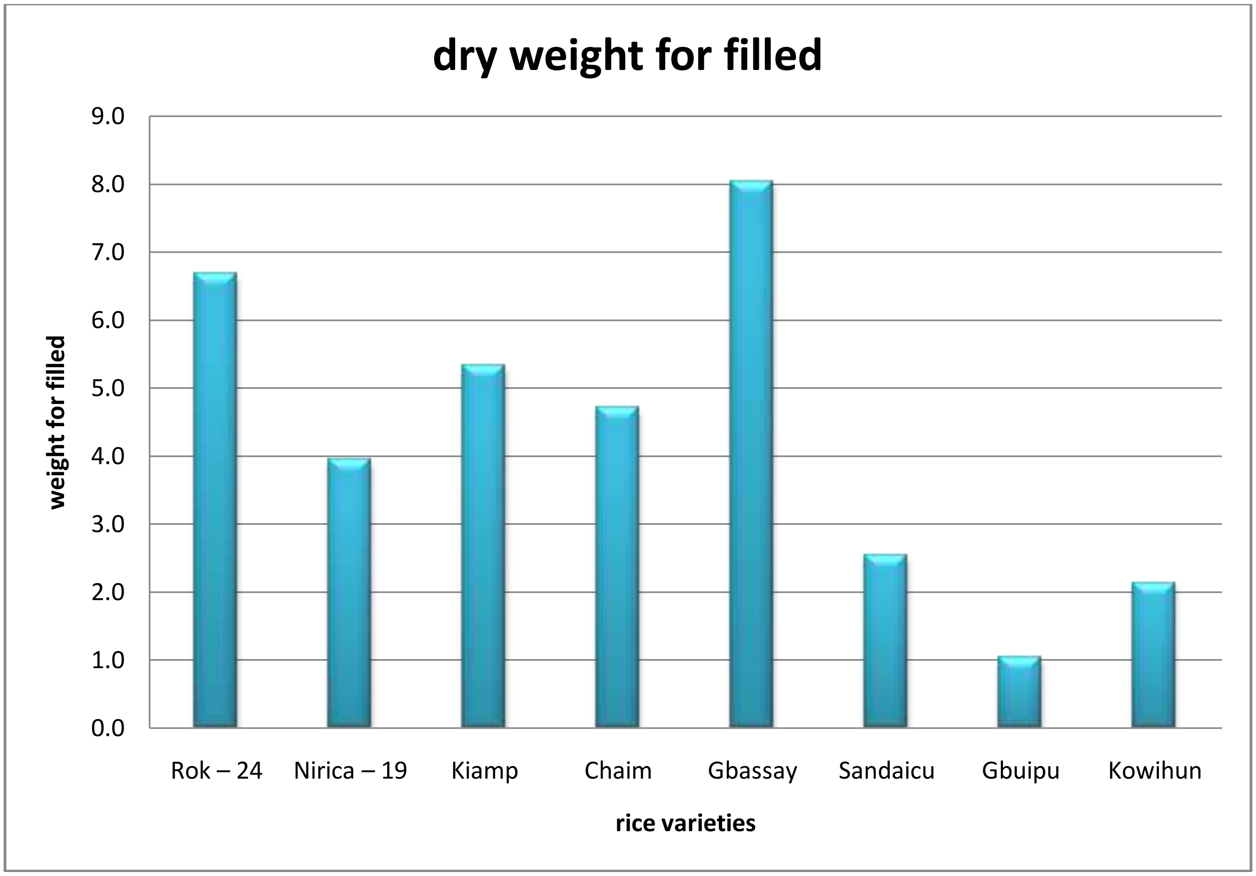

Figure 3:-

Effect of iron toxicity on dry weight (g) of unfilled grains of the genotypes tested in pots using iron-toxic soil.
The dry weight for unfilled grain measurement tested under iron toxicity conditionsis given in Table (2) There was a wide variation in plant height with a mean of (43.1) (64.9) (69.8) and (77.2) as the grows from 3WAP to 12WAP.

Analysis of ANOVA indicates there was a significant difference (p=0.05) in the mean dry weight of the unfilled grains. The highest unfilled grain weight was recorded for Neric -19 (1.9) followed by Chain (1.2). The lowest unfilled grain weight (0.1) was recorded for Gbuipu.

Table 4:- Means dry weight of unfilled grains of the genotypes tested in pots using hot sport iron-toxic soil.

Variety	**Means dry weight of unfilled grains(g)**
Rok – 24	0.6
Nirica – 19	1.9
Kiamp	0.1
Chaim	1.2
Gbassay	0.3
Sandaicu	0.4
Gbuipu	0.2
Kowihun	0.1

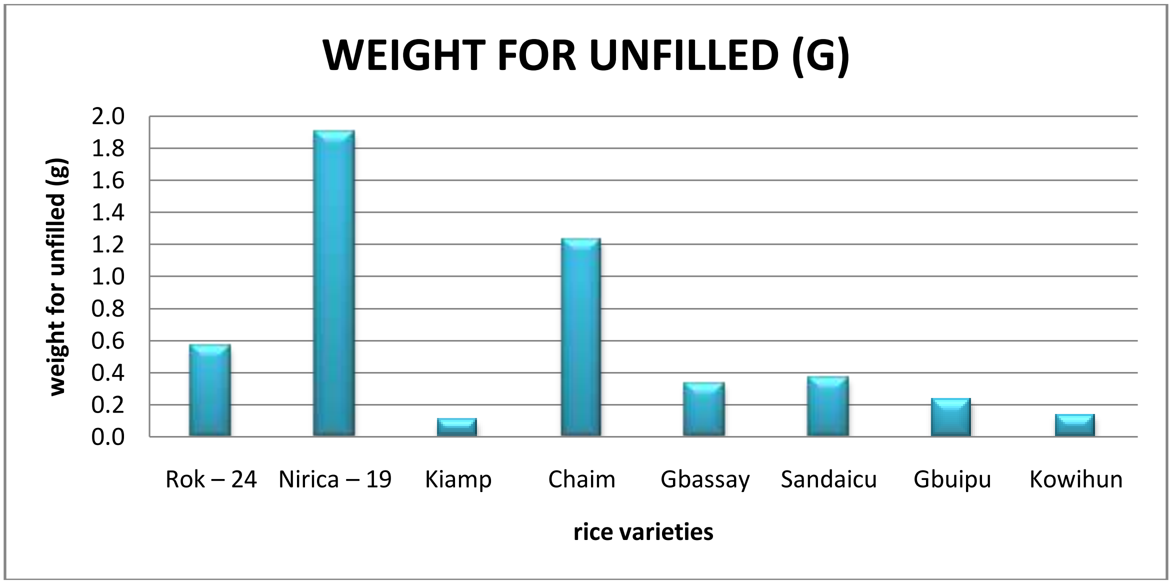

Figure 4:-

Effect of iron toxicity on plant height (cm) of the genotypes tested in pots using iron-toxic soil

The plant height measurements tested under iron toxicity conditions are given in Table (2) There was a wide variation in plant height with a mean of (43.1) (64.9) (69.8) and (77.2) as the plant grew from 3WAP to 12WAP. The differences in mean plant height between the varieties were significant (p=0.05).

At 3WAP the tallest plant height (51.1cm) was recorded for Rok – 24 which was statistically at par with Gbassay, followed by Kiamp (48.4cm). Nirica – 19 has the shortest plant height (29.1cm). Other varieties with short plant height wereGbuipu (35.4) and Kowihun(38.9) and intermediate heights were recorded for the following varieties, Sandaicu (42.8), Chaim (47.9), and Kiamp (48.4)

At 6WAP the tallest plant height (75.3cm) was recorded for Kowihun, followed byGbuipu(68.7cm) which was statistically at par with kiamp (68.6cm).Nerica–19has the shortest plant height (55.1cm). Other varieties with short plant heightswere Rock-24 (58.6cm) and intermediate plant heights were recorded for the following varieties,sanndaicu (67.9cm), Gbassay (65.3cm). and Chaim(60.1)

At 9WAP the tallest plant height (80.3) was recorded forSandaicu, followed byKowihun(79.8cm). Nirica – 19 has the shortest plant height (66.3cm). Other varieties with short plant height were Rock-24 (66.4cm) and intermediate heights were recorded for the following varieties,Gbuipu(73.5cm), Kiamp (72.8cm). Gbassay (70.2cm), and Chaim (65.7cm),

At 12WAP the tallest plant height (85.6) was recorded forSandaicu which was statistically at par withKowihun(84.7cm). these were followed byKiamp (79.3cm). Nirica – 19 has the shortest plant height (70.7cm). Other varieties with short plant height were Rock-24 (72.0cm) and Chaim (72.6cm. Intermediate heights were recorded for the following varieties,Gbuipu(77.7cm), and Gbassay (75.4cm).

Table5:-Mean of plant height (cm) of the genotypes tested in pots using hot sport iron-toxic soil.

Variety	Mean plant height (cm)			
	3WAS	6WAS	9WAS	12WAS
Rok – 24	51.1	58.6f	66.4f	72.0f
Nirica – 19	29.1	55.1g	65.7h	70.7g
Kiamp	48.4	68.6b	72.8d	79.3b
Chaim	47.9	60.1e	66.3g	72.6e
Gbassay	51.1	65.3d	70.2e	75.4d
Sandaicu	42.8	67.9c	80.3a	85.6a
Gbuipu	35.4	68.7b	73.5c	77.7c
Kowihun	38.9	75.3a	79.8b	84.7a

mean	43.1	64.9	69.8	77.2

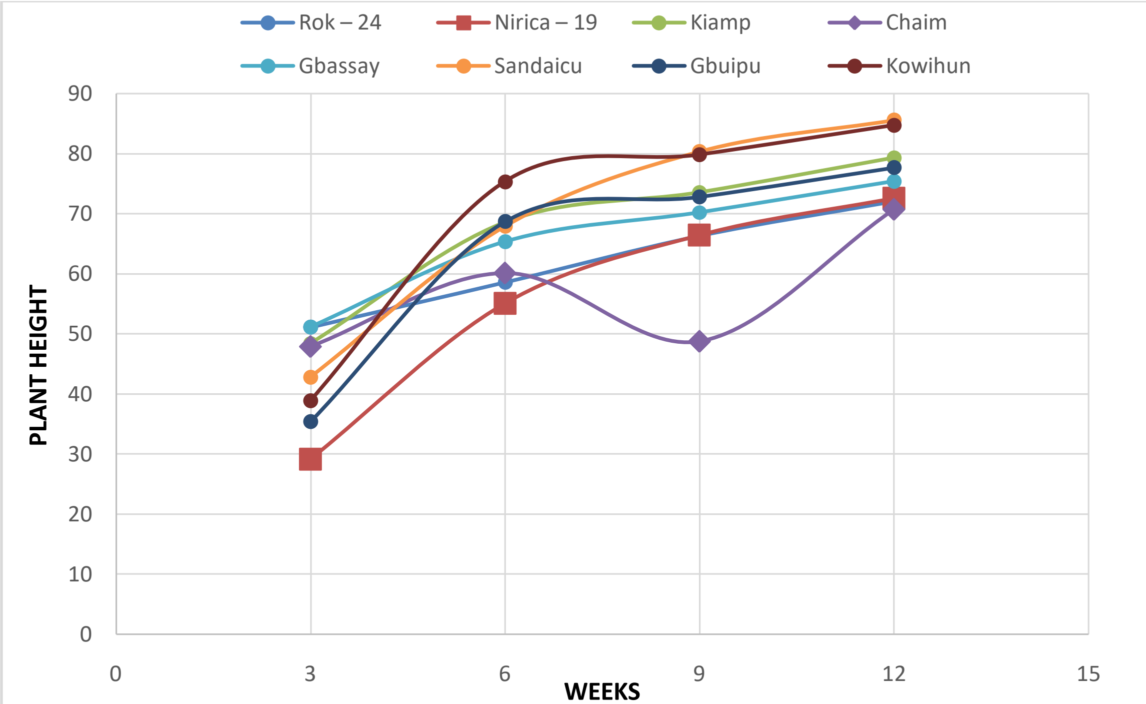

Figure 5:-

Effect of iron toxicity on tiller count of the genotypes tested in pots using iron-toxic soil.
Table (4) shows the number of tillerscounted per plant of the varieties screened for iron toxicity tolerance. There was a wide variation in tiller count (0.6 – 1.2) with a mean of (1.9), (3.5), and (3.5) as the plant grew from 3WAP to 9WAP. The differences in tiller count between the varieties were significant (p=0.05).

At 3WAP, the highest number of the tiller (3.0) was recorded for Rok – 24, followed by Gbassay(2.7) which was statistically at par with Chaim (2.7)). Nirica – 19 has the lowest tiller count (1.0). Other varieties with the lowest tiller count arekowihun(1.2) and sandiaku(1.3) which is at par with Gbuipu (1.3). Other variety with an intermediate tiller count iskiamp (2.7)

At 6WAP, the highest number of tiller (4.8) was recorded for Gbassay, followed by Chaim (4.6),Rok – 24 (4.2) and kiamp (4.0). sandiaku and kowihun are at par with the lowest tiller count (2.0). Other varieties with intermediate tiller count wereNirica – 19 (3.9), andGbuipu (2.8)

At 9WAP, the highest number of tiller (4.8) was recorded for Gbassay, followed by Chaim (4.6),Rok – 24 (4.2) and kiamp (4.0). sandiaku and kowihun are at par with the lowest tiller count (2.0). Other varieties with intermediate tiller count wereNirica – 19 (3.9), andGbuipu (2.8)

Table 6:- Mean dry weight of root of the genotypes tested in pots using hot sport iron-toxic soil .

VARIETY	**Mean dry weight of root** (g)		
	3WKS	**6WKS**	**9WKS**
Rok – 24	3.0a	4.2c	4.2c
Nirica – 19	1.0e	3.7e	3.9
Kiamp	2.3c	4.0d	4.0d
Chaim	2.7b	4.6b	4.6b
Gbassay	2.7b	4.8a	4.8a
Sandaicu	1.3d	2.0g	2.0
Gbuipu	1.3d	2.8f	2.8
Kowihun	1.2	2.0g	2.0

mean	1.9	3.5	3.5

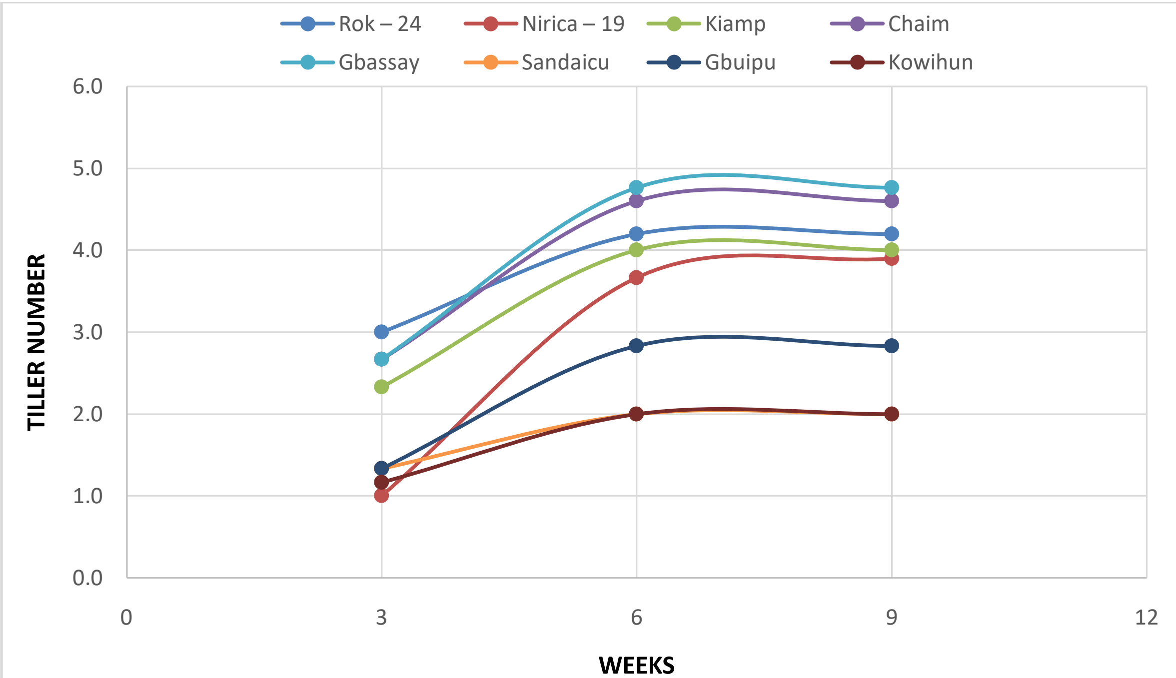

Figure 6:-

Effect of iron toxicity on leaf area (cm^2) of the genotypes tested in pots using iron-toxic soil

Table (4) shows the leaf area of the varieties screened for iron toxicity tolerance. There was a wide variation in the leaf area with a mean of (16.22) (45.89) (66.57) and (110.43) as they grew from 3WAP to 9WAP. The differences in leaf area between the varieties were significant (p=0.05)

At 3WAP the highest leaf area was recorded for Rok- 24 (26.04),followed byKiamp (18.80). kowihun (14.60) recorded the intermediate value. The smallest leaf area was recorded for Nerica-19 (9.44), other varieties with intermediate leaf area includeChaim (16.89) which was at par with sandiacu (16.84) and Gbuipu (13.99) which was also at par with Gbassay (13.16)

At 6WAP the highest leaf area was recorded for kowihun (69.80) followed bysandiacu (65.98)and Gbuipu (58.55),and the smallest leaf area (30.20) was recorded for Nerica-19 (9.44).Rok- 24 (38.34),Kiamp (35.57), Chaim(32.16), and Gbassay (36.51) all recorded an intermediate value for leaf area.

At 9WAP the highest leaf area was recorded for kowihun (91.37) followed bysandiacu (90.41) andGbuipu (76.62), the smallest leaf area (51.45) was recorded for Chaim. Nerica-19 was another variety with the smallest leaf area (51.94).Rok- 24 (58.76),Kiamp (55.53), and Gbassay (56.45) all recorded an intermediate value for leaf area.

At 12WAP, the highest leaf area was recorded for Rok- 24 (303.58), followed by kowihun (106.56), and smallest leaf area was recorded for Nerica-19 (65.28)

Table7:- Mean leaf area (cm2)of the genotypes tested in pots using hot sport iron-toxic soil.

VARIETY	Mean leaf area (cm^2)			
	3WKS	6WKS	9WKS	12WKS
Rok – 24	26.04a	38.34d	58.76d	303.58
Nirica – 19	9.44f	30.24h	51.94g	65.28
Kiamp	18.80b	35.57f	55.53f	70.88
Chaim	16.89c	32.16g	51.45h	66.16
Gbassay	13.16e	36.51e	56.45e	69.8
Sandaicu	16.84c	65.98b	90.41b	105.17
Gbuipu	13.99e	58.55c	76.62c	95.97
Kowihun	14.60d	69.8a	91.37a	106.56
mean	16.22	45.89	66.57	110.43

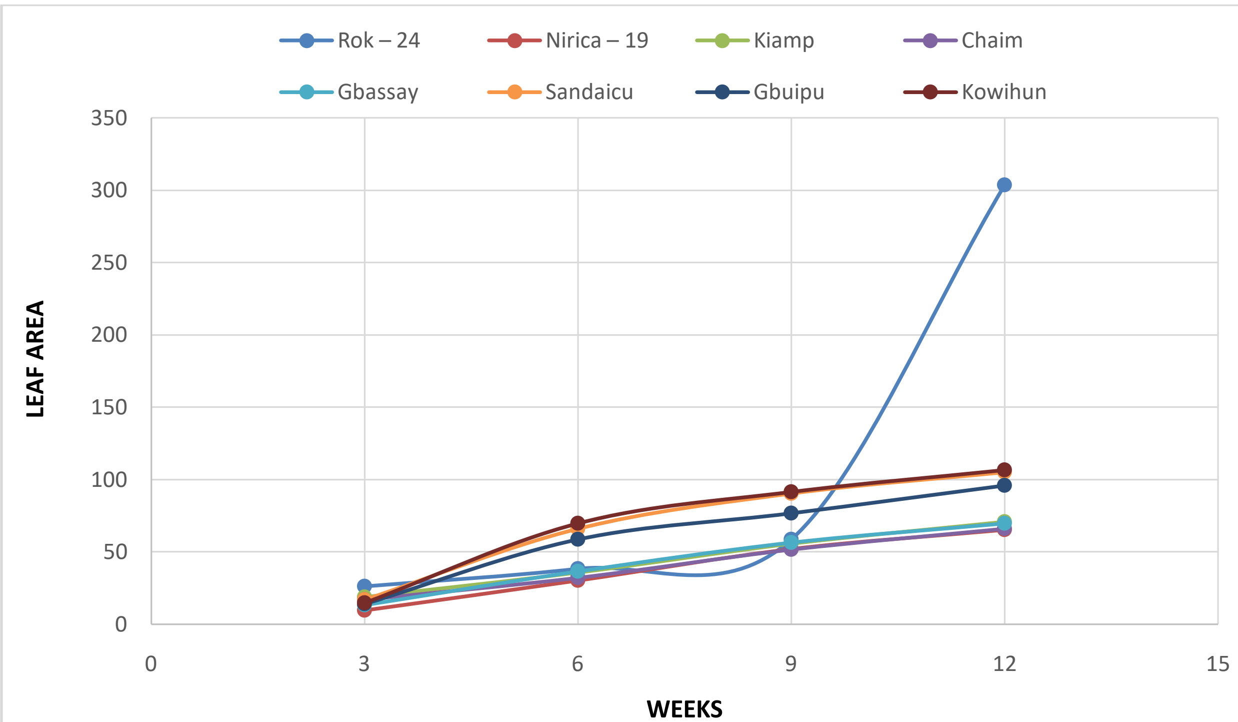

Figure 7:-

Effect of iron toxicity on phenotypic acceptability of the genotypes tested in pots using iron-toxic soil

Table (4) shows the phenotypic acceptability of the varieties screened for iron toxicity tolerance. There was a wide variation in the phenotypic acceptability with a mean of (1.0), (2.6), (2.8) and (2.9) as they grew from 3WAP to 12WAP. The differences in phenotypic acceptability between the varieties were significant (p=0.05)

At 3WAP the highest phenotypic acceptability recorded was one (1) which was statistically at par for all varieties

At 6WAP the highest phenotypic acceptability (3) was recorded for Kiamp, Chaim,Gbassay,Sandaicu,GbuipuandKowihun, followed by Nerica – 19 (2), and the least phenotypic acceptability was recorded for Rok- 24 (1)

At 9WAP the phenotypic acceptability increases to (3) for Nerica-19 and all the other varieties maintaining their later values at 6WAP.

At 12WAP Rok- 24 maintained the phenotypic acceptability score of (1), whilst Nirica – 19, Kiamp, Chaim, and Gbassay reduced their score to (1), phenotypic acceptability scores increased to (7) for Gbuipu, (6) for Sandaicu, and (5) forkowihun.

Table8:- Mean of phenotypic acceptability of the genotypes tested in pots using iron-toxic soil.

VARIETY	Mean of phenotypic acceptability			
	3WKS	6WKS	9WKS	12WKS
Rok – 24	1	1	1	1
Nirica – 19	1	2	3	1
Kiamp	1	3	3	1
Chaim	1	3	3	1
Gbassay	1	3	3	1
Sandaicu	1	3	3	6
Gbuipu	1	3	3	7
Kowihun	1	3	3	5
Mean	1.0	2.6	2.8	2.9

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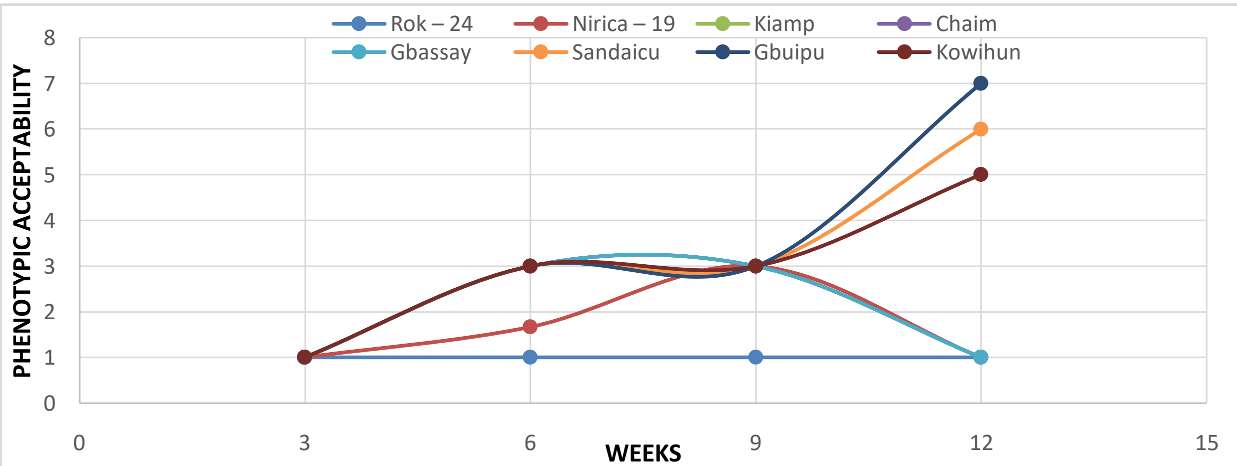

Figure 8:-

Iron-toxicity score of the genotypes tested in pots using iron-toxic soil

The field experiments showed that the iron-toxicity tolerant level is different from one variety to another. There was a wide variation in the iron toxicity tolerance level with a mean of (1.8), (2.6), (2.5), and (4.4) as they grew from 3WAP to 12WAP.

The reaction of 8 varieties to iron toxicity tolerance as they grow from 3WAP–12WAP is shown in table (8). the iron toxicity scores range from 1 to 9 with a mean of 4.50.

At 3WAP two varieties Rok – 24 and Nerica – 19 scored 1, and six varietiesKiamp,Chaim,Gbassay,Sandaicu, Gbuipu, andKowihun scored 2

At 6WAP two varieties Rok – 24 and Nerica – 19 increased their scores to (2), three varieties; Kiamp, Chaim, and Gbassay maintained their scores to (2) at 3WAP, and two varieties, Gbuipu, andKowihun scored 3 and one variety;Sandaicu scored 5

At 9WAP one variety; Rok – 24reduced it score back to 1, while Nerica – 19, Kiamp, Chaim, and Gbassay still maintained a score of 2, two varieties, Gbuipu, andKowihunincreased their scores to 3, and one varietySandaicuincreased it score to 5

At 12WAP one variety, Rok – 24increasedits score to 2 andGbassaymaintained its score of 2, both recorded as the least, this was followed by Nerica – 19, Kiamp, and Chaim which have a score of 3.Sandaicuincreased its score to 6, Kowihunincreased it score to 7,andGbuipuincreased it score to 9

Table9: - Mean of Iron-toxicity score of the genotypes tested in pots using iron-toxic soil .

VARIETY	Mean of Iron-toxicity score			
	3WKS	6WKS	9WKS	12WKS
Rok – 24	1	2	1	2
Nirica – 19	1	2	2	3
Kiamp	2	2	2	3
Chaim	2	2	2	3
Gbassay	2	2	2	2
Sandaicu	2	5	5	6
Gbuipu	2	3	3	9
Kowihun	2	3	3	7
mean	1.8	2.6	2.5	4.4

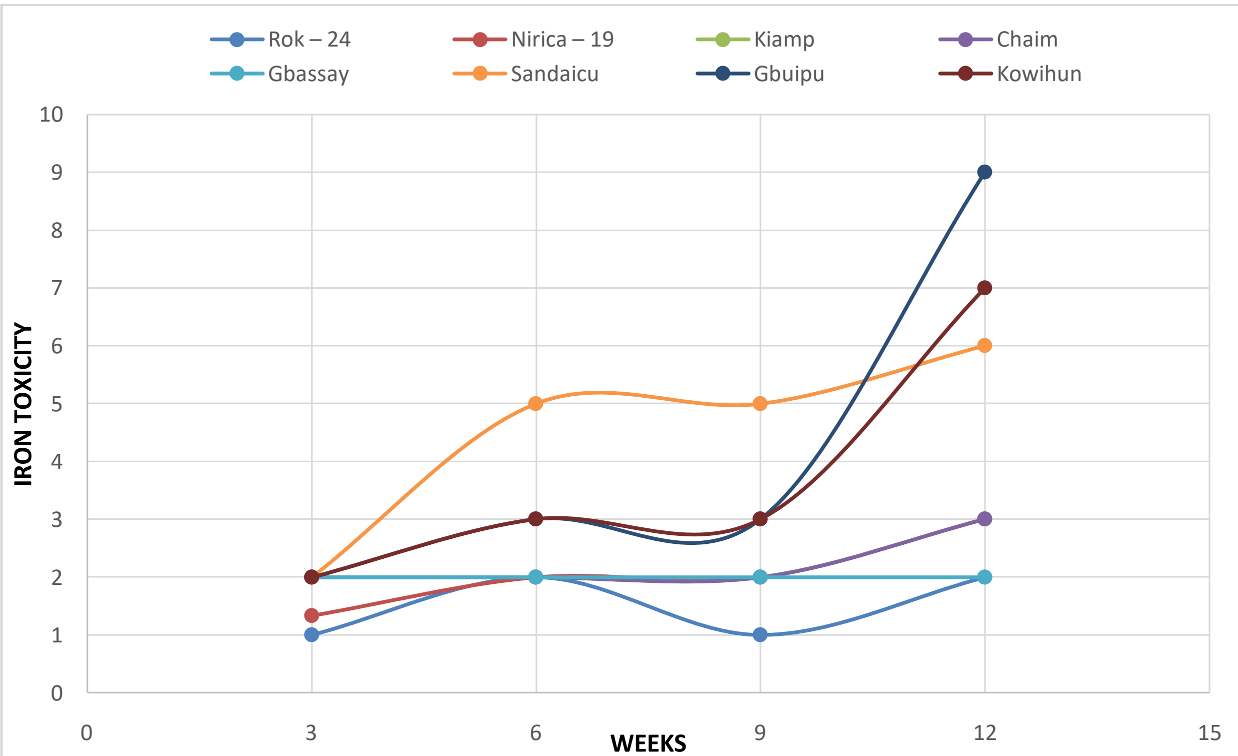

Figure 9:-

Discussion:-

Eight rice varieties were used in this study. The eight varieties were evaluated for their tolerance for iron toxicity during the wet season. Iron toxicity is more severe in the wet season than in the dry season due to strong acidification before the wet season crop and increased upwelling and groundwater seepage from higher land (ponnamperuma and Soliva 1982a,b; ponnamperuma, 1958).

The root dry weight measurements of varieties tested under iron toxicity conditions are given in (table 2) there was a wide variation in root dry weight (0.2-16.9) as they grew from 3WAP to 12WAP. Analysis of ANOVA indicates that there was a significant difference (p=0.05) in the mean dry weight of the root. The highest root weight was recorded for Gbassay (12.9), followed by Nerica-19 (11.2). The lowest root weight (1.8) was recorded for Gbuipuwa.

These differences suggested that the varieties reacted differently to the effect of iron toxicity.

The stem dry weight measurement of varieties tested under iron toxicity conditionsis given in Table (2) there was a wide variation in stem dry weight (12.0-81.0) as theygrew from 3WAP to 12WAP. Analysis of ANOVA indicates that there was a significant difference (p=0.05) in the mean dry weight of the stem. The highest stem weight was recorded for Rock -24 (23.9), followed by Gbassay (23.7). The lowest stem weight (6.3) was recorded for Gbuipu. These results confirm the susceptibility of Gbuipu to stress.

However, root dry weights of varieties were significantly affected by the iron stress in this experiment. This showed an organ-specific response of the varieties towards iron stress. The relative decrease of root dry weights was not calculated because there were no significant differences in root dry weights in any variety under stress and control conditions.

The dry weight measurement for filled grains of varieties tested under iron toxicity conditions is given in Table (2). There was a wide variation in mean dry weight for filled grains (0.21-0.52) after harvest.Analysis of ANOVA indicates there was a significant difference (p=0.05) in the mean dry weight of the filled grains. The highest filled grain weight was recorded for Gbassay (8.0) followed by Rock -24 (6.7), and the lowest filled grain weight (1.0) was recorded for Gbuipu.

The possible reason for the low-filled grains observed could be attributed to a combination of factors of which low tiller count, low panicle number, and reduced plant height due to iron toxicity may be key factors. The low grain yield obtained in the different varieties has a direct bearing on the tiller number, panicle number, and plant height observed in this study. This is in agreement with other researchers who reported that a decrease in tiller count, panicle number, height, and high percentage of unfilled grains attributed to grain yield reduction (Virmani 1979; van breemannad Moorman 1978; Bada 1958)

The dry weight for unfilled grain measurement tested under iron toxicity conditions is given in Table (2). There was a wide variation in plant height with a mean of (43.1) (64.9) (69.8) and (77.2) as they grew from 3WAP to 12WAP. Analysis of ANOVA indicates there was a significant difference (p=0.05) in the mean dry weight of the unfilled grains. The highest unfilled grain weight was recorded for Nerica -19 (1.9) followed by Chain (1.2). The lowest unfilled grain weight (0.1) was recorded for Gbuipu.

The plant height measurement tested under iron toxicity conditions is given in Table (2). There was a wide variation in plant height with a mean of (43.1) (64.9) (69.8) and (77.2) as the plant grew from 3WAP to 12WAP. The differences in mean plant height between the varieties were significant (p=0.05). At 3WAP the tallest plant height (51.1cm) was recorded for Rok – 24which was statistically at par with Gbassay, followed by Kiamp (48.4cm). Nirica – 19 has the shortest plant height (29.1cm). Other varieties with short plant height wereGbuipu (35.4) and Kowihun(38.9) and intermediate heights were recorded for the following varieties, Sandaicu (42.8), Chaim (47.9), and Kiamp (48.4). At 6WAP the tallest plant height (75.3cm) was recorded for Kowihun, followed by Gbuipu (68.7cm) which was statistically at par with kiamp (68.6cm). Nirica – 19 has the shortest plant height (55.1cm). Other varieties with short plant height were Rock-24 (58.6cm) and intermediate plant heights were recorded for the following varieties,sandaicu (67.9cm), Gbassay (65.3cm). And Chaim (60.1). At 9WAP the tallest plant height (80.3) was recorded for Sandaicu, followed byKowihun(79.8cm). Nirica – 19 has the shortest plant height (66.3cm). Other varieties with short plant height were Rock-24 (66.4cm) and intermediate heights were recorded for the following varieties,Gbuipu (73.5cm), Kiamp (72.8cm). Gbassay (70.2cm), and Chaim (65.7cm).At 12WAP the tallest plant height (85.6) was recorded for Sandaicu which was statistically at par with Kowihun(84.7cm). These were followed by Kiamp (79.3cm). Nerica–19 has the shortest plant height (70.7cm). Other varieties with short plant height were Rock-24 (72.0cm) and Chaim (72.6cm. Intermediate heights were recorded for the following varieties, Gbuipu (77.7cm), and Gbassay (75.4cm).

Table (4) shows the number of tiller counts per plant of the varieties screened for iron toxicity tolerance. There was a wide variation in tiller count (0.6 – 1.2) with a mean of (1.9), (3.5), and (3.5) as the plant grew from 3WAP to 9WAP. The differences in tiller count between the varieties were significant (p=0.05). At 3WAP, the highest number of the tiller (3.0) was recorded for Rok – 24,followed by Gbassay (2.7) which was statistically at par with Chaim (2.7). Nirica – 19 has the lowest tiller count (1.0). Other varieties with the lowest tiller count are kowihun (1.2) and sandiaku (1.3) which is at par with Gbuipu (1.3). Another variety with an intermediate tiller count iskiamp (2.7). At 6WAP, the highest number of the tiller (4.8) was recorded for Gbassay, followed by Chaim (4.6), Rok – 24 (4.2), and kiamp (4.0). sandiaku and kowihun are at par with the lowest tiller count (2.0). Other varieties with intermediate tiller count wereNerica – 19 (3.9), and Gbuipu (2.8). At 9WAP, the highest number of tiller (4.8) was recorded for Gbassay, followed by Chaim (4.6), Rok – 24 (4.2) and kiamp (4.0). sandiaku and kowihun are at par with the lowest tiller count (2.0). Other varieties with intermediate tiller count were Nerica – 19 (3.9), and Gbuipu (2.8)

The low and medium tiller counts recorded by the varieties could be due to the effects of iron toxicity and other undermined soil problems. Ottow et al. (1983) made similar observations on other varieties.
Table (4) shows the leaf area of the varieties screened for iron toxicity tolerance. There was a wide variation in the leaf area with a mean of (16.22) (45.89) (66.57) and (110.43) as they grew from 3WAP to 9WAP. The differences in leaf area between the varieties were significant (p=0.05). At 3WAP the highest leaf area was recorded for Rok- 24 (26.04), followed byKiamp (18.80). kowihun (14.60) recorded the intermediate value. The smallest leaf area was recorded for Nerica-19 (9.44) Other varieties with intermediate leaf area include Chaim (16.89) which was at par with sandiacu (16.84) and Gbuipu (13.99) which was also at par with Gbassay (13.16).At 6WAP the highest leaf area was recorded for kowihun (69.80) followed bysandiacu (65.98) and Gbuipu (58.55), and the smallest leaf area (30.20) was recorded for Nerica-19 (9.44).Rok- 24 (38.34),Kiamp (35.57), Chaim(32.16), and Gbassay (36.51) all recorded an intermediate value for leaf area.At 9WAP the highest leaf area was recorded for kowihun (91.37) followed bysandiacu (90.41) and Gbuipu (76.62), the smallest leaf area(51.45) was recorded for Chaim. Nerica-19 was another variety with the smallest leaf area (51.94).Rok- 24 (58.76),Kiamp (55.53), and Gbassay (56.45) all recorded an intermediate value for leaf area. At 12WAP the highest leaf area was recorded for Rok- 24 (303.58), followed by kowihun (106.56), and the smallest leaf area was recorded for Nerica-19 (65.28)

Table (4) shows the phenotypic acceptability of the varieties screened for iron toxicity tolerance. There was a wide variation in the phenotypic acceptability with a mean of (1.0), (2.6), (2.8), and (2.9) as they grew from 3WAP to 12WAP. The differences in phenotypic acceptability between the varieties were significant (p=0.05)**.** At 3WAP the highest phenotypic acceptability recorded was one (1) which was statistically at par for all varieties. At 6WAP the highest phenotypic acceptability (3) was recorded for Kiamp Chaim, Gbassay, Sandaicu, Gbuipu and Kowihun, followed by Nerica – 19 (2), and the least phenotypic acceptability was recorded for Rok- 24 (1). At 9WAP the phenotypic acceptability increases to (3) for Nerica-19 and all the other varieties maintaining their later values at 6WAP. At 12WAP Rok- 24 maintained the phenotypic acceptability score of (1), whilst Nerica – 19, Kiamp, Chaim, and Gbassay reduced their score to (1), phenotypic acceptability scores increased to (7) for Gbuipu, (6) for Sandaicu, and (5) for kowihun.

The field experiments showed that the iron-toxicity tolerant level is different from one variety to another. There was a wide variation in the iron toxicity tolerance level with a mean of (1.8), (2.6), (2.5) and (4.4) as they grew from 3WAP to 12WAP. The reaction of 8 varieties to iron toxicity tolerance as they grow from 3WAP–12WAP is shown in table (8). The iron toxicity scores range from 1 to 9 with a mean of 4.50. At 3WAP two varieties Rok – 24 and Nirica – 19scored 1, and six varietiesKiamp,Chaim,Gbassay,Sandaicu, Gbuipu, andKowihun scored 2

At 6WAP two varieties Rok – 24 and Nerica – 19 increased their scores to (2), three varieties; Kiamp, Chaim, and Gbassay maintained their scores (2) at 3WAP, two varieties, Gbuipu, and Kowihun scored 3 and one variety;Sandaicu scored 5. At 9WAP one variety,Rok – 24reduceditsscore back to 1, while Nerica – 19, Kiamp, Chaim, and Gbassay still maintained ascore of 2, two varieties, Gbuipu, andKowihu increased their scores to 3 and one varietySandaicuincreased it score to 5. At 12WAP one variety, Rok – 24increased it score to 2 andGbassaymaintained it score of 2, both recorded the least, this was followed by Nerica – 19, Kiamp, and Chaim which had a score of 3.Sandaicuincreased it score to 6, Kowihunincreased its score to 7, andGbuipuincreased it score to 9.

Nearly all the varieties tested were tolerant except for Kowihun, Gbuipu and Sandaicu which were sensitive. The degree of susceptibility in varieties varies according to growth stage and also varies greatly between varieties (Bacha, 1984). The pot experiment using hot-spot soil showed that iron toxicity was more severe in the Gbuipu and Sandaicuvarieties.

Conclusion:-

Nearly six varieties tested were tolerant to iron toxicity. However, two varieties including Rok–24 and Gbassay were more tolerant.

The highest root weight was recorded for Gbassay and Nerica-19. The lowest root weight was recorded for Gbuipu

The highest stem weight was recorded for Rock -24 and Gbassay. The lowest stem weight was recorded for Gbuipu.

The highest filled grain weight was recorded for Gbassay and Rock -24, and the lowest filled grain weight was recorded for Gbuipu.

The highest unfilled grain weight was recorded for Nerica -19 and Chain. The lowest unfilled grain weight was recorded for Gbuipu.

Varieties with tall plant height included Sandaicu,Kowihun and Kiamp. Nerica–19has the shortest plant height. Other varieties with short plant height included Rock-24 and Chaim. Intermediate heights were recorded for the following varieties,Gbuipu, and Gbassay.

Varieties with a high number of tillers included Gbassay,Chaim,Rok – 24, and kiamp. sandiaku and kowihun are at par with the lowest tiller count (2.0). Other varieties with intermediate tiller count wereNerica – 19, andGbuipu.

The highest leaf area was recorded for Rok- 24, followed by Kowihun, and the smallest leaf area was recorded for Nerica-19.Rok- 24 maintained the phenotypic acceptability score of (1), whilst Nirica – 19, Kiamp, Chaim, and Gbassay reduced their score to (1), phenotypic acceptability scoresincreased to (7) for Gbuipu, (6) for Sandaicu, and (5) for k At 12WAP one variety, Rok – 24 increasing it score to 2 andGbassaymaintaining its score of 2, bothrecorded as the least, this was followed by Nerica – 19, Kiamp, and Chaim which have a score of 3.Sandaicuincreased its score to 6, Kowihunincreased its score to 7, andGbuipuincreased it score to 9

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