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Influence of Imazaquin Seed Treatment on Control of Striga gesnerioides and its Consequence on Yield and Yield Components of Selected Cowpea Genotypes

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Abstract

The effect of Imazaquin seed treatment on *Striga* control, yield, and yield components of cowpea were investigated in Nigeria, in 2010 and 2011 rainy seasons. Imazaquin at 0.00, 0.06, and 0.24 kg a.i. ha^{-1} was the main plot treatment; cowpea genotypes (Achishiru, IT97K-1263, IT97K-390-2, IT98K-133-1-1, TVU-1283, TVU-1542 and TVU-1908) were the subplots. The untreated control recorded the highest number of *Striga* m^{-2} which was 2.8 times higher than seed treatment with imazaquin at 0.06 kg a.i. ha^{-1}, and 6.8 times higher than treatment at 0.24 kg a.i. ha^{-1}. Achishiru had the most *Striga* infestation (4.29 m^{-2}) in 2010 and TVU-1283 (5.61 m^{-2}) in 2011; genotype IT97K-1263 had no *Striga* in 2010 and 2011. TVU-1542 and IT97K-390-2 recorded the highest grain yield in 2010 and 2011. Treating IT97K-390-2, IT98K-133-1-1 and TVU-1542 with imazaquin at 0.06 and 0.24 kg a.i. ha^{-1} reduced *Striga* parasitism in the field and increased grain yield and yield component of these genotypes. These treatment combinations are therefore recommended for *Striga* control.

Keywords: genotypes, cowpea, imazaquin, *Striga* control, seed treatment

1. Introduction

Cowpea **(***Vigna unguiculata* (L.) Walp**)** is a preferred staple food in many regions of Africa and elsewhere since the leaves, immature pods, fresh seeds, and dry grains can be eaten. Some varieties have short growing cycles and tend to mature early; thus they are able to provide food during the hungry period (middle of the wet season) when foods can become extremely scarce in semi-arid regions of sub-Saharan Africa. With early maturing varieties, two or more crops can possibly be grown in one season. This multiple cropping cycle gives the farmer the advantages of improving food-and-cash flows, minimizing on-farm storage and consequent losses, and making good quality seeds available on a timely basis (Ashraf, 1985).

Cowpea production is faced with many constraints. In addition to insect pests it is attacked by obligate parasitic weeds, especially *Striga gesnerioide*s (Willd.) Vatke and *Alectra vogelii* Benth. A very serious parasite *S. gesnerioides* requires a living host for survival and causes considerable yield losses in more than 29 sub-Saharan African countries (Emechebe *et al*. 1991), including the Savanna grasslands and arid zones of Nigeria (Gworgwor *et al*., 2000, 2001). It exerts potent phytotoxic effects on its host by inducing changes in enzymes and plant hormones, disrupting the host-water relation, and reducing carbon fixation below that expected purely from competition for water, nutrients, and light (Kanampiu *et al*., 2002). Massawe *et al*. (2001) noted that *S. gesnerioides* reduces the potentials for flowering and pod production, and consequently the capacity to produce seeds. Yield reductions of up to 100% caused by *Striga* infestation of susceptible cultivars have been reported (Emechebe *et al.*,1991). Similarly Berner *et al*. (1994) reported yield reductions of 41-90% from infestation on farmer’s fields in *Striga* prone areas. Average yield losses of 40-90% are common (Massawe *et al.* 2001). Weight of seeds pod^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, and pod weight were significantly reduced as a result of *Striga* infestation (Alonge *et al.,* 2005; Munir and Muktar, 2008).

Most cultural or agronomic practices fail to provide a lasting solution to *Striga* problems. Because of the obligate nature of the relationship between *Striga* and its hosts, the use of herbicide with a sufficient margin of selectivity may be the best option to control it (Tuinstra *et al*., 2009). Herbicides capable of destroying *Striga* but allowing cowpea growth and development will be helpful in alleviating this problem thereby increasing yield and productivity. Berner *et al*. (1994) had successfully control *Striga gesnerioides* in cowpea using seed treatment with imazaquin, but his finding resulted on high mortality rate on the genotype because of insufficient margin of selectivity. His work was also restricted to screen house condition and therefore needs further evaluation to ascertain the effect of this treatment on yield and yield component under field condition. With herbicide-treated seeds, farmers may not have to purchase and calibrate sprayers and this may facilitate adoption. The need for spraying is eliminated and there is an ecological advantage that no herbicide is applied off-target and considerably lower amounts of herbicide ha^{-1} will be required for *Striga* control. This novel approach will use genotypes that are tolerant to the herbicide (Tuinstra *et al*., 2009).This method might control *Striga* early in its growing cycle, reduce yield loss, and deplete the *Striga* seed bank in the soil as being cost-effective and compatible with existing cropping systems and technologies. Field experiments were undertaken to assess the potential of treating seeds with the herbicide imazaquin for *Striga* control in cowpeas. This paper reports on the effects of imazaquin on *Striga* infestation, yield, and yield components of cowpea genotypes.

2. Materials and Methods

2.1 Experimental Site

These trials were conducted in the rainy seasons 2010 and 2011 at the Teaching and Research Farm of the Faculty of Agriculture, Bayero University Kano (12^0 03'N, 8^0 32' E, 481 m above sea level) in the Sudan savanna ecological zone of Nigeria. Total annual rainfall at the experimental sites was 990 mm in 2010 and 839.1 mm in 2011. The physico-chemical properties of the experimental soils are presented (Table 1).

2.2 Treatments and Experimental Design

The treatments consisted of seven genotypes (Achishiru, IT97K-1263, IT97K-390-2, IT98K-133-1-1, TVU-1283, TVU-1542, and TVU-1908) and imazaquin herbicide treatment at 0.00, 0.06 and 0.24 kg a.i. ha^{-1}. These genotypes and imazaquin rates were selected through a series of evaluations conducted in the laboratory and screen house. The genotypes were sourced from International Institute of Tropical Agriculture (IITA), Kano Station. Seeds were treated with imazaquin by injecting the required dose of the herbicide in a test tube containing the seeds and shaking it vigorously until the seeds absorbed all the herbicide. The control seeds were treated with distilled water. The seeds were air dried under shade before planting. The experiments were laid out in a split-plot design with three replications. The herbicide rate was assigned to the main plot; cowpea genotypes constituted the subplot treatment.

The field was harrowed and ridged at 0.75 m inter-row distance and marked out into appropriate plots while cowpea was planted on the ridges with planting distance of 0.25 m. The field was artificially infested with 2000 germinable *Striga* seeds $stand^{-1}$ from 0.94 g of *Striga*-sand seed inoculum to ensure uniform infestation. *Striga*-sand mixture was sprinkled into each of the planting hills and the dispersed mixture was lightly covered with a thin layer of soil. The objective was to cover the mixture but still leave a depression that could be seen and planted into at a later date. The sprinkled *Striga*-sand mixtures were allowed to condition for a week before planting the cowpea seeds. Two seeds of each of the treated cowpea genotypes were planted in holes 4 cm deep, and about 1 cm on top of the sprinkled *Striga* seed-sand mixture. Weeds other than *Striga* were controlled by manual hoe weeding at 3 and 6 weeks after sowing (WAS). Fertilizer was applied at the rate of 20 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 20 kg K_2O ha^{-1} using NPK (15-15-15) and Single Superphosphate (18% P_2O_5) at two WAS by band placement. Muncozep was used to control fungal diseases. Insect pest control was achieved by spraying the cowpea plants with the insecticide BEST ACTION (cypermethrin 30 gm l^{-1} plus dimethoate 25 gm l^{-1}) at the rate of 1L ha^{-1} at flowering and podding using CP 20 knapsack sprayer. Harvesting was done by hand picking mature dry pods from each net plot.

2.3 Data Collection

Data were collected on *Striga* m^{-2} by counting the number from a quadrant 1 m^2 and transformed using square root transformation. Number of pods $plant^{-1}$ was determined by counting the number of pods from each net plot and dividing it by the number of plants per net plot. Number of grains was determined from each net plot by manually hand threshing 20 randomly selected pods from each net plot and recording the average number of grains. One hundred seed weight was determined by counting and weighing 100 seeds from each net plot area. Grain yield was obtained from 4.5 m^2 (at 10% moisture content) after threshing, winnowing, and weighing the output with a weighing balance (Camry model: Sp, capacity 20 kg) and extrapolated to kg ha^{-1}.

2.4 Data Analysis

Combined analysis of variance (ANOVA) was performed using the PROC Mixed procedure of SAS (SAS, 2011). Block was treated as a random effect whereas year; genotypes, and imazaquin rates and their interactions were considered as fixed effects in determining the expected mean square and appropriate F-test. Means were separated using LSMEANS statement of PROC Mixed code of SAS with option pdiff at $P \leq 0.05$. The statement calculates the difference between two means and the standard error of the difference (SED). The option calculates the P value for the comparison of the difference between two means according to $LSD_{0.05.}$

3.0 Results and Discussion

Probability of F values for imazaquin rates and genotypes on number of *Striga* m^{-2}, numbers of pods $plant^{-1}$ and grains pod^{-1}, 100-seed weight and grain yield is shown in Table 2. Year, genotypes, and imazaquin rates, as well as their interaction significantly influenced numbers of *Striga* m^{-2}, numbers of pods $plant^{-1}$ and grains pod^{-1}, 100-seed weight and grain yield. However the effect of year on grain yield and the interaction between year and genotypes on grain yield were not significant. Similarly, interactions among year, genotype, and imazaquin rate on grain yield were also not significant. The interaction between year and genotype on number of pods $plant^{-1}$

and number of grains pod^{-1} was also not significant.

3.1 Effect of Imazaquin Seed Treatments and Cowpea Genotypes on Number of *Striga* M^{-2}

Numbers of *Striga* m^{-2} varied with year, genotype, and imazaquin rate (Table 3). Application of imazaquin significantly reduced numbers of *Striga* m^{-2} in both years. The untreated control recorded the highest number of *Striga* in both years; seeds treated at a rate 0.24 kg a.i. ha^{-1} supported the lowest number. Increasing imazaquin rate from 0.00 to 0.06 kg a.i. ha^{-1} significantly reduced numbers of *Striga* by 39.72% in 2010 and by 23.88% in 2011. Further increase of imazaquin rate to 0.24 kg a.i. ha^{-1} reduced the numbers of *Striga* by 51.59% in 2010 and 42.16% in 2011. This suggests that imazaquin is effective for seed treatment of cowpea to control *Striga*. The result is in agreement with the earlier report by Berner *et al.* (1994) that imazaquin significantly reduced *Striga* numbers on cowpea. The results of this study further corroborate the report of Berner *et al.* (1997) that seed treatment with imazaquin controlled the parasitic *Striga hermonthica* in ALS-modified corn. A related herbicide (Imazapyr) has also been reported to control *S. hermonthica* in maize. For example, Kabambe *et al.* (2008) reported more emerged *Striga* in untreated plots than in imazapyr-treated maize.

Genotype had significant effect on rates of *Striga* parasitism. Achishiru (5.08 m^{-2}) recorded the highest number of *Striga* and IT97K-1263 (0.26 m^{-2}) the lowest. This reflected the difference in terms of tolerance to *Striga* between the genotypes. IT97K-1263 had few *Striga* indicating that it may be partially resistant to the strain of *Striga* in the locality; Achishiru, IT97K-390-2, and TVU-1283 among others were highly susceptible. Several *Striga* resistant and susceptible cowpea cultivars had been reported by Parker and Polniaszek (1990), Singh (2005), as well as Sawadogo *et al.* (2010).

Significant interaction between imazaquin rate and cowpea genotype was observed on number of *Striga* m^{-2} in both years. In 2010, untreated Achishiru supported the highest number of *Striga;* IT97K-1263 supported the lowest (Table 3). In 2011, IT97K-390-2 supported the highest number of *Striga* and IT97K-1263 supported the lowest. In 2010, as the imazaquin rate was increased to 0.06 kg a.i. ha^{-1}, Achishiru supported the highest number of *Striga*; IT97K-390-2 supported significantly the lowest number of *Striga*. In 2011, TVU-1283 supported the highest number of *Striga;* IT97K-1263 supported the lowest. In 2010, at 0.24 kg a.i. ha^{-1}, TVU-1283 supported more than one *Striga* m^{2} while other genotypes had only one *Striga* m^{2}. In 2011 Achishiru supported more *Striga* than the other genotypes; IT97K-1263 supported the lowest number. Across imazaquin rates, when no herbicide was applied *Striga* numbers were highest for Achishiru and lowest for IT97K-1263. This suggested that IT97K-1263 has some resistance to *Striga* and may not need seed treatment with the herbicide. This genotype may be used in breeding program as parent for the development of *Striga*-resistant cowpea and also be recommended for cultivation in areas prone to *Striga* infestation. Untreated Achishiru recorded the highest number of *Striga,* suggesting that it is susceptible to *Striga*. Application of imazaquin at 0.06 and 0.24 kg a.i. ha^{-1} reduced the number of *Striga* in other genotypes, such as such as IT97K-390-2, IT98K-133-1-1, TVU-1283, TVU 1542, and TVU-1908, suggesting that these genotypes are susceptible to *Striga* but tolerant to imazaquin. At 0.24 kg a.i. ha^{-1} of imazaquin, IT97K-390-2 produced less *Striga* than other treatment combinations, suggesting that this genotype can tolerate higher rates of imazaquin than the others with a significant decrease in *Striga.* This could be attributed to the fact that the herbicide might have remained within the vicinity of the host and caused post-attachment mortality of any germinating *Striga* which might otherwise have reduced the growth and development of the crop. The genotype might have also retained some herbicide within its system which retarded the growth and development of attaching *Striga* as evidenced by the significant reduction of *Striga* numbers on this genotype at this rate. All these might have helped in controlling *Striga,* thereby making more nutrients and photosynthates available to support grain development and more grain yield. Our findings are supported by reports of Tuinstra *et al*. (2009) on sorghum and of Kwaga (2010) on groundnut. Citaden *et al*. (2013) similarly reported cowpea line 59 to be imazapyr-tolerant to 400 g ha^{-1}. This is encouraging to farmers because the combination of herbicide seed treatment with herbicide-tolerant genotypes could be useful in Africa. In time, as the gene for herbicide tolerance is identified from this genotype, it could be introgressed into other susceptible genotypes to control *Striga* as was done with ALS-resistant maize.

3.2 Effect of Imazaquin Seed Treatments and Cowpea Genotypes on Number of Pods Plant^{-1}

Imazaquin rate, genotype, and interactions between genotype and imazaquin rates significantly affected numbers of pods plant^{-1} in both years (Table 4). The numbers of pods plant^{-1} were lower when no herbicide was applied than when the seeds were treated. When imazaquin was applied at 0.24 kg a.i. ha^{-1} the number of pods plant^{-1} was 19.31% higher than in the untreated control in 2010 and 68.55% higher in 2011. When imazaquin was applied at 0.06 kg a.i. ha^{-1} the number of pods plant^{-1} was increased by 2.54% in 2010, and 19.01% in 2011.This translates to more pods plant^{-1} in imazaquin treated than from the untreated controls. This could be attributed to effective control of *Striga* by imazaquin which reduced damage to the host. The result contradicted an earlier report (Shinggu, 1999) that herbicide seed treatment had no effect on number of pods plant^{-1}.

The genotypes responded differently to imazaquin application in both seasons. When untreated in 2010, IT97K-1263 produced the highest number of pods plant^{-1} and Achishiru produced the lowest (Table 4). When the rate was increased to 0.06 kg a.i. ha^{-1}, IT98K-133-1-1 produced the highest number of pods plant^{-1}; Achishiru produced the lowest. At 0.24 kg a.i. ha^{-1}, Achishiru produced the highest number of pods plant^{-1} and TVU-1908 produced the lowest. In 2011, when untreated with herbicides TVU-1283 produced the highest number of pods plant^{-1} and Achishiru produced the lowest number. When the herbicide was applied at 0.06 kg a.i.ha^{-1}, IT97K-390-2 produced the highest number of pods plant^{-1}; IT98K-133-1-1 produced the lowest number. At a higher rate of 0.24 kg a.i.ha^{-1}, IT98K-133-1-1 produced the highest number of pods plant^{-1}; TVU-1542 produced the lowest. Good performance of IT97K-390-2 and IT98K-133-1-1 at higher rate of imazaquin may be related to the fact that these genotypes are tolerant to imazaquin which effectively control *Striga* thereby making more photosynthate available to support higher number of pods plant^{-1}. The result is consistent with earlier report of Shingu (1999) that treating Sampeas 6 and 7 with cinosulfuron at 0.1g/l produced higher number of pods than IT81D-985.

3.3 Effect of Imazaquin Seed Treatment and Cowpea Genotypes on Number of Grains pod^{-1}

Imazaquin application and genotypes significantly affected numbers of grains pod^{-1} in both years (Table 5). Imazaquin application increased numbers of grains pod^{-1} in both years. The lowest number was produced by untreated cowpea. Application of imazaquin at 0.24 kg a.i. ha^{-1} produced the highest number of grains pod^{-1}. Increasing imazaquin rate from 0.00 to 0.06 kg a.i. ha^{-1} increased the number of grains pod^{-1} by 7.75% in 2010 and 5.76% in 2011. When the rate was further increased to 0.24 kg a.i. ha^{-1}, the number of grains pod^{-1} was increased by 26.53% in 2010 and by 8.62% in 2011. Effective *Striga* control by imazaquin seed treatment might have explained the reason of higher number of grains pod^{-1} than the control. This is because the higher number of *Striga* in untreated control plots may have reduced the productivity of cowpea as reported by Kamara *et al*.(2008).

Genotype had significant influence on number of grains pod^{-1} in both seasons (Table 5). Genotypes IT97K-1263 produced the highest number of grains pod^{-1} in 2010; TVU-1908 produced the lowest number of grains pod^{-1}. In 2011, IT98K-133-1-1 produced the highest number of grains pod^{-1}; TVU-1908 produced the lowest. This could be attributed to the variation on pod length within these genotypes. The interaction between Imazaquin rate and cowpea genotype for number of grains pod^{-1} was not significant in both years.

3.4 Effect of Imazaquin Seed Treatments and Cowpea Genotypes on 100-seed Weight

Imazaquin application and cowpea genotype significantly affected 100-seed weight in both years (Table 6). The lowest seed weight was produced in both seasons when no herbicide was applied. Application of imazaquin at 0.24 kg a.i ha^{-1} produced the highest seed weight in both seasons. Increasing the rate from 0.00 to 0.06 kg a.i. ha^{-1} significantly increased seed weight by 31.36% in 2010 and by 8.52% in 2011. As the rate was further increased to 0.24 kg a.i. ha^{-1}, seed weight was significantly increased by 37.81% in 2010 and by 3.23% in 2011. Effective *Striga* control by imazaquin seed treatment reduced competition between the crop and *Striga* thereby making more photosynthate and environmental resources available to support growth. This increased leaf number, leaf size and generally increased the capacity of the crop to assimilate production which made the seed to be bigger and heavier hence higher seed weight than control.

Genotype had significant influence on 100-seed weight in both years (Table 6); IT97K-1263 produced the highest seed weight; TVU-1908 produced the lowest in 2010. This could be attributed to the seed size of IT97K-1263 which made it heavier and therefore higher seed weight than other genotypes with smaller and lighter seeds. The result was in line with earlier findings of Futuless and Bake (2010) who reported that cowpea genotype CH14 had higher seeds weight than other genotypes. Increasing imazaquin rate significantly increased 100-seeds weight of most genotypes. This could be as a result of a significant reduction in number of *Striga* m^{-2} which limit amount of photosynthate translocated to the sink. However, increasing imazaquin rate from 0.06 to 0.24 kg a.i. ha^{-1} significantly reduced seeds weight of Achishiru and TVU-1542. This is possibly due to the fact that higher rate of the herbicide may be injuries to these genotypes. This corresponds with Beck *et al*. (1989) that cinosulfuron was slightly toxic to rice at higher rate of 40-80 g a.i.ha^{-1}.

4.0 Conclusion and Recommendations

Results from our study show that treatment of cowpea with imazaquin reduced *Striga* parasitism but was dependent on genotype. Treating IT97K-390-2, IT98K-133-1-1, and TVU-1542 with imazaquin at 0.06 and 0.24 kg a.i. ha^{-1} reduced *Striga* parasitism in the field and increased grain yields and yield components. These treatment combinations are therefore recommended for *Striga* control. With or without herbicide treatment, IT97K-1263 recorded the lowest number of *Striga,* suggesting that it is partially resistant and could be used as parent in breeding programs for developing varieties that are resistant to *Striga*. Since IT97K-390-2 and TVU-1542 showed tolerance to imazaquin, further research should be conducted to determine the effect of post-emergence application of this herbicide on these genotypes to control other weeds in the field.

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Table I. Soil Physico-chemical properties of the soils at the experimental sites in 2010 and 2011rainy seasons (0-30 cm).

Physico-chemical properties of soils	Rainy seasons	
	2010	2011
pH (in water)	6.6	6.8
organic carbon %	0.439	0.354
Organic matter %	0.759	0.621
Total N %	0.041	0.030
Available P (ppm)	16	20
C.E.C (cmol kg^{-1})	7.33	7.26
Exchangeable K (cmol kg^{-1})	0.30	0.27
Exchangeable Na (cmol kg^{-1})	0.09	0.09
Exchangeable Ca (cmol kg^{-1})	4.56	4.39
Exchangeable Mg (cmol kg^{-1})	2.38	2.16
Sand %	76	82
Silt %	18	12
Clay %	6	6
Textural class	Loamy sand	Loamy sand

Analyzed in Laboratory of the Department of Soil Science, Bayero University, Kano.

Table 2. Probability of F values for imazaquin seed treatment and genotypes for number of S*triga* m-^{2}, grain yield, and yield attributes of cowpea

Effect	Number of Striga m^{-2}	Number of pods per plant	Number of grains per pod	100 -seed weight (g)	Grain yield kg ha^{-1}
Year (Y)	<0.0001(< 0.0001)	0.002	< 0.0001	0.0126	0.8567
Genotypes (G)	<0.0001(< 0.0001)	0.0281	< 0.0001	< 0.0001	< 0.0001
Imazaquin rate (R)	<0.0001(< 0.0001)	0.0040	0.0014	< 0.0001	0.0108
Y *G	< 0.0001(<0.0001)	0.1302	< 0.0001	< 0.0001	< 0.0001
Y* R	0.0085 (0.0025)	0.0073	0.0021	< 0.0001	0.4616
G *R	<0.0001(< 0.0001)	0.0008	0.3823	< 0.0001	0.0002
Y *G*R	<0.0001(< 0.0001)	<0.0001	0.0984	< 0.0001	0.8731

Y= year R= Imazaquin rate G= Genotype ( )= transformed value

Table 3. Effect of imazaquin seed treatment and genotypes on number of *Striga* m-^{2}

Genotypes (G)	2010 season				2011 season			
	Imazaquin rate kg a.i ha^{-1} (R)				Imazaquin rate kg a.i. ha^{-1} (R)			
	0.00	0.06	0.24	Mean	0.00	0.06	0.24	Mean
Achishiru	12.66 (3.68)	2.10 (1.70)	0.00 (1.00)	4.92 (2.13)	8.33 (2.99)	4.25 (2.29)	3.14 (2.03)	5.24(2.43)
IT97K-1263	0.11 (1.05)	1.50 (1.52)	0.00 (1.00)	0.53 (1.19)	0.0 (1.00)	0.0 (1.00)	0.00 (1.00)	0.00 (1.00)
IT97K-390-2	2.44 (1.76)	0.16 (1.07)	0.00 (1.00)	0.87 (1.28)	11.48 (3.52)	3.98 (2.23)	0.83 (1.32)	5.43(2.36)
IT98K-133-1-1	0.50 (1.21)	1.22 (1.48)	0.00 (1.00)	0.57(1.23)	5.37 (2.51)	4.07 (2.25)	2.50 (1.78)	3.98(2.18)
TVU-1283	3.60 (2.14)	0.83 (1.31)	0.38 (1.14)	1.61 (1.53)	10.74 (3.41)	5.18 (2.46)	0.90 (1.35)	5.61 (2.41)
TVU-1542	3.22 (2.04)	0.66 (1.26)	0.00 (1.00)	1.29(1.43)	7.22 (2.86)	3.14 (2.03)	1.85 (1.67)	4.07(2.18)
TVU-1908	11.00 (3.45)	0.38 (1.17)	0.00 (1.00)	3.79 (1.87)	5.09 (2.46)	3.14 (2.02)	1.94 (1.71)	3.39 (2.06)
Mean	4.79 (2.19)	0.98 (1.36)	0.14 (1.36)		6.89 (2.68)	3.39 (2.04)	1.59 (1.53)	
SED G	0.586 (0.118)				0.726 (0.142)			
SED R	0.332 (0.077)				0.475 (0.093)			
SED G*R	0.852 (0.207)				1.265 (0.130)			

G = Genotype, R = Imazaquin rate, ( )= transformed means

Table 4. Effect of Imazaquin seed treatment and genotypes on number of pods plant^{-1}

Genotypes (G)	2010 season Imazaquin rate kg a.i. ha^{-1} (R)				2011 season Imazaquin rate kg a.i. ha^{-1} (R)			
	0.00	0.06	0.24	Mean	0.00	0.06	0.24	Mean
Achishiru	10.05	14.17	36.69	20.30	10.05	48.72	59.79	39.53
IT97K-1263	31.97	9.32	26.42	22.57	34.39	16.88	48.43	33.24
IT97K-390-2	17.27	15.34	30.83	21.15	17.27	54.03	122.68	64.66
IT98K-133-1-1	17.63	52.49	22.57	30.90	21.91	11.62	166.69	66.74
TVU-1283	25.99	34.39	30.40	30.26	42.80	22.92	39.61	35.12
TVU-1542	19.66	23.74	16.48	19.96	19.66	43.88	23.74	29.09
TVU-1908	14.86	16.66	16.90	16.13	34.86	25.38	113.36	57.87
Mean	19.63	23.73	25.75		25.85	31.92	82.04	
SED G	4.559				15.641			
SED R	2.979				10.240			
SED G* R	7.858				27.093			

G = Genotype, R = Imazaquin rate

Table 5. Effects of Imazaquin seed treatment and cowpea genotype on number of grains pod^{-1} in 2010 and 2011 rainy seasons

Treatments	Seasons 2010	2011
Imazaquin rate kg a.i. ha^{-1} (R)		
0.00	11.02	13.79
0.06	12.03	13.87
0.24	15.00	13.91
SED	1.561	4.610
Genotypes (G)		
ACHISHIRU	12.57	13.37
IT97K-1263	13.81	12.03
IT97K-390-2	11.78	17.13
IT98K-133-1-1	12.49	17.40
TVU-1283	13.38	13.30
TVU-1542	13.10	12.06
TVU-1908	11.66	11.72
SED	2.382	1.570
Interaction		
Genotype* Imazaquin rate	Ns	Ns

G = Genotype, R = Imazaquin rate

Table 6. Effect of Imazaquin seed treatments and genotypes on 100-seed weight (g)

Genotypes (G)	2010 season Imazaquin rate kg a.i. ha^{-1} (R)				2011 season Imazaquin rate kg a.i. ha^{-1} (R)			
	0.00	0.06	0.24	Mean	0.00	0.06	0.24	Mean
Achishiru	8.11	8.33	11.52	9.32	8.05	8.54	8.16	8.25
IT97K-1263	8.12	16.06	17.89	14.02	15.55	17.50	17.93	16.99
IT97K-390-2	8.16	10.43	14.65	11.08	13.04	14.64	13.91	13.86
IT98K-133-1-1	8.15	16.52	11.81	12.16	13.41	14.12	13.35	13.62
TVU-1283	7.95	7.74	12.54	9.41	7.67	9.25	7.32	8.08
TVU-1542	7.90	14.72	10.24	10.95	11.67	12.02	11.75	11.81
TVU-1908	7.94	8.09	11.85	9.29	7.79	8.53	7.50	7.94
Mean	8.04	11.70	12.93		11.03	12.08	11.42	
SED G	0.647				0.520			
SED R	0.424				0.340			
SED_G* R	1.122				1.511			

G = Genotype, R = Imazaquin rate