

<sup>a</sup> Jamshaid Ali Junaid, <sup>a</sup> Huma Saleem, <sup>a</sup> Khazina Jamshaid, <sup>b</sup> Iram Sharif, <sup>a</sup> Muhammad Azam Khan, <sup>a</sup> Umara Sahar Rana, <sup>c</sup> Saba Akram

## <sup>a</sup> Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Punjab, Pakistan, <sup>b</sup> Cotton Research Station, Ayub Agricultural Research Institute, AARI, Faisalabad, Punjab, Pakistan, <sup>c</sup> Nuclear Institute for Agriculture and Biology (NIAB) Faisalabad, Punjab, Pakistan.

Authors Junaid, J. A., conceived the idea, performed research, H. Saleem & K. Jamshaid performed data collection, M. A. Khan, Contribution I. Sharif, U. S. Rana and S. Akram reviewed and edited the paper. **Review Process: Peer review** 

\*Corresponding Author's Email Address: Jamshaid.2574@uaf.edu.pk ABSTRACT The development and output of maize plants are impacted by heavy metals in a number of ways, and they also hinder a number of physiological processes. Humans have major health issues when heavy metals are present in their diet. This study examined the impact of several heavy metals (both singly and in combination) on maize yield and numerous yield-related parameters. A replicated totally randomized factorial design was used to analyse eight parents—five lines, three testers, and their crosses. Data were recorded on days to 50% germination, fresh root length, fresh root weight, dry root weight, dry shoot weight, dry root to shoot weight ratio, chlorophyll content, and leaf temperature at seedling stage while yield contributing parameters like cobs per plant, grain rows per ear, grain yield per plant, and 100 grain weight were recorded after harvesting. These measurements were then analysed using line × tester analysis to determine the effects of combining ability and to evaluate the variations in heavy metals uptake in maize grain. With the exception of cobs per plant, all of the attributes in the combining ability analysis produced significant results. The genotype Sulltan and hybrid (K54TMS × Agatti 84) were found to only absorb a minimal quantity of the metals (Cr and Pb) both separately and in combination. This suggests that they should be used in breeding programs going forward to increase the genotypes' resistance to heavy metal absorption. Keywords: Combining ability, heavy metals, morphological parameters, seedlings, yield, Zea mays

**INTRODUCTION:** Maize is an imposing and widely farmed crop of grass family that is a member of the Maydeae tribe. In comparison to other crops, maize, wheat, and rice are grown and produced in enormous amounts across the world; yet, maize has the highest potential for grain output per hectare. The maize is a third most important cereal after wheat and rice due to its multipurpose uses suc as cornmeal, grits, starch, flour, tortillas, snacks and breakfast cereals. Maize is a staple diet for humans and cattle alike in many nations throughout the world. It is crucial for nations like Pakistan, where a fast growing population has already depleted the existing food supply, as it is the highest yielding cereal crop in the world. In Pakistan, it is the fourth-largest crop grown crop after wheat, rice and cotton. It makes for 0.7% of the Gross domestic products and 3% of the value added. The area planted with maize for 2022–2023 was 1720 thousand hectares, and production was around 10.183 million tons (GOP, 2023). It is grown in the subtropical and temperate regions around the globe. It is a C4 plant and can endure high levels of oxidative stress and water scarcity. The leaf and seed might have greater concentrations of heavy metals (Shanker et al., 2005). There are approximately 35 different types of metal in nature, of which 23 are categorized as heavy metals. Plants experience significant effects from heavy metal poisoning at various development stages. It occurs as a result of various metal ions in the soil and irrigation water being applied to the crop. Industrial wastes and untreated municipal effluents are utilized in underdeveloped nations to grow crops in and around metropolitan centres. Heavy metals, boron, salts, and other potentially harmful organic and inorganic compounds are present in it, which might have a negative impact on consumers, plants, and the soil (Mapanda et al., 2005). Since many enzymes and proteins depend on different metals for normal plant growth and development, several of these metals are also necessary for human consumption. However, all metals can become toxic when they exceed their respective critical tissue concentrations. Humans have major health issues when heavy metals are present in their diet (Martin and Griswold, 2009). Lead and chromium have an impact on maize plants at various growth stages and reduce crop output. Chromium toxicity prevents seed germination, caused stunted seedling development, and inadequate formation of phytomass, all of which ultimately cause plant mortality. It also inhibits a number of metabolic activities (Zou et al., 2009). Lead (Pb) is thought to have a comparatively low level of phytotoxicity due to its low availability and therefore low absorption from soils and soil solutions. Due to its adsorption to root surfaces and cell walls, translocation to shoot after root absorption is constrained.

OPEN

**OBJECTIVES:** The objectives of the current study were : I) To evaluate the morphological traits of maize seedlings and yield contributing factors influenced by various heavy metals II) To assess the impacts of various heavy metal concentrations on various developmental stages of the crop.

**MATERIALS AND METHODS:** The experiment was carried out in the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan during 2021-22, located between 31.43° north and longitude 73.8° east and 184 m above sea level in central Punjab. The first step of experiment was to screen 20 inbred lines (F-219, F-216, F-289, 2P-735, T-02, F-01, F-275, EV 77, F-167, F-221, DTC-1, F-168, F-303, 2P-735, ML 22, L-5-1, 20 P2- 1, FH-735, K54TMS and 1335-2B) at seedling stage. Seeds of inbred lines were taken from the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The inbred lines were sown in triplicated completely randomized design in polythene bags (8" × 4") filled with sand in the green house. Four treatments were applied at seedling stage to screen the inbred lines. The treatments were designated as: T<sub>0</sub> (Control), T<sub>1</sub> (5 mM of Chromium as CrCl<sub>3</sub>). T<sub>2</sub> (5 mM of Lead as PbCl<sub>2</sub>) and T<sub>3</sub> (2.5 mM of Chromium as CrCl<sub>3</sub> + 2.5 mM of Lead as PbCl<sub>2</sub>). After 28 days of sowing, data were recorded for morphological parameters like Days to 50% germination, Fresh root length, Fresh root weight, Dry root weight, Dry shoot weight, Dry root to shoot weight ratio, Chlorophyll content and Leaf temperature. On the basis of recorded data, 5 tolerant inbred lines (F-167, F-168, 1335-2B, 2P-735 and K54TMS) were selected. In next season, selected lines from first phase of experiment were sown and crossed with open pollinated testers in a line × tester fashion. Each line was crossed with three testers (Agati-85, Sonneri and Sulltan) and also selfed (table 1). The seeds obtained through crossing and selfing of lines were used in the next experiment.

Sr. No.	Crosses	Sr. No.	Crosses	Parents				
1	F-167 × Agatti 84	9	1335-2B × Sulltan	F-167 (Line)				
2	F-167 × Sonneri	10	2P-735 × Agatti 84	F-168 (Line)				
3	F-167 × Sulltan	11	2P-735 × Sonneri	1335-2B (Line)				
4	F-168 × Agatti 84	12	2P-735 × Sulltan	2P-735 (Line)				
5	F-168 × Sonneri	13	K54TMS × Agatti 84	K54TMS (Line)				
6	F-168 × Sulltan	14	K54TMS × Sonneri	Agatti 84 (Tester)				
7	1335-2B × Agatti 84	15	K54TMS × Sulltan	Sonneri (Tester)				
8	1335-2B × Sonneri			Sultan (Tester)				

Table 1: Crosses of selected inbred lines with testers in line × tester fashion.

The seeds of parents and their crosses were sown in duplicated randomized completely block design (factorial) and four treatments (Control, Chromium, Lead and Chromium + Lead) at a concentration of 5 mM were applied at the time of sowing. At maturity, seeds were harvested followed by the recording of yield parameters (Cobs per plant, Grains per ear row, Grain rows per ear, Grain yield per plant (calculated by accounting all the yield contributing factors, like number of cobs per plant, number of grain rows per ear, number of grains per ear row and 100 grain weight), Grains per ear, 100 grain weight and Heavy metals concentration in grain). Heavy metal toxicity (Cr and Pb) in the prepared samples were determined by using Atomic Absorption Spectrophotometer (Hitachi Polarized Zeeman AAS, Z-8200, Japan). Calibrated standards were prepared from the commercially available stock solution (AppliChem®) in the form of an aqueous solution (1000 ppm). Highly purified de-ionized water was used for the preparation of working standards. All the glass apparatus used throughout the process of analytical work were immersed in 8N HNO<sub>3</sub> overnight and washed with several times of de-ionized water prior to use.

**Statistical analysis:** The data collected from seedlings were analysed by using Analysis of Variance (ANOVA) to assess difference among inbred lines (Steel *et al.*, 1960) and data collected from maturity experiment were subjected to Line × Tester analysis (Kempthorne, 1957) to compute the combining ability effects. The mean comparison of different genotypes for different traits was done through LSD.

**RESULTS AND DISCUSSION:** In first phase of experiment, data were recorded at seedling stage and inbred lines were evaluated for morphological parameters discussed below:

**Days to 50% germination:** The analysis of variance (ANOVA) for the days to 50% germination revealed significant variations across various genotypes. The results from the different treatments were highly significant. It was determined that the treatment and genotype interaction impact was not significant (table 2). The LSD readings showed a clear distinction between the control group and the various treatments. Under combined treatment with Cr + Pb, the greatest mean value was discovered to be 4.8000, while the lowest mean values were discovered under control, at 4.16. Non-significant differences were also found between the Cr, Pb, and combination treatments (Cr + Pb) (table 3). The time required to germinate the seed was significantly increased by the use of heavy metals. It slowed down germination by raising the content of heavy metals (Mahmood *et al.*, 2007; Datta *et al.*, 2011). Additionally, it lengthened the time it took for the seeds to sprout.

SOV	V		DG-50%	FRL	FRW	DRW	DSW	DRSWR	CC	LT	
Treatment	ent 3 14.26		14.26**	6.37** 142.75**		36.97**	18.8**	28.57**	30.79**	29.87**	
Genotype		19	2.52**	5.68**	17.04**	$1.14^{NS}$	12.48**	1.62 <sup>NS</sup>	2.01**	2.22**	
<b>Treatment*Geno</b>	type	57	1.34 <sup>NS</sup>	3.23**	15.09**	1.61**	15.43**	1.79**	2.51**	2.48** 5.928	
Error		160	0.337	61.32	0.096	0.059	0.005	0.882	13.12		
Table 2: Analysis of	f <mark>varia</mark> n	nce for va	arious traits un	der the stu	ıdy at seedling	g stage.					
Treatment	nt DG		FRL	FRW	DRW	DS	W D	DRSWR	CC	LT	
To	4.1667 <sup>в</sup>		53.655 <sup>a</sup>	2.942	3 <sup>A</sup> 0.815	0 <sup>A</sup> 0.3	445 <sup>a</sup> 2	.8333 <sup>A</sup>	25.397 <sup>A</sup>	36.765 <sup>a</sup>	
$T_1$	4.6833 <sup>A</sup>		47.865 <sup>в</sup>	2.141	8 <sup>c</sup> 0.375	7 <sup>c</sup> 0.2	662 <sup>c</sup> 1	.4358 <sup>B</sup>	25.362 <sup>A</sup>	33.728 <sup>B</sup>	
$T_2$	4.68	333 <sup>a</sup>	49.255 <sup>в</sup>	1.873	5 <sup>D</sup> 0.705	8 <sup>B</sup> 0.3	15 <sup>в</sup> 2	.4972 <sup>A</sup>	21.513 <sup>c</sup>	34.488 <sup>B</sup>	
Τ3	4.80	000 <sup>A</sup>	48.957 <sup>в</sup>	2.614	8 <sup>B</sup> 0.707	5 <sup>в</sup> 0.2	662 <sup>c</sup> 2	.7665 <sup>A</sup>	23.987 <sup>B</sup>	32.725 <sup>c</sup>	

Table 3: Mean pairwise comparisons of all treatments for various traits under the study at seedling stage. (T<sub>0</sub>= Control, T<sub>1</sub>= 5 mM Chromium chloride, T<sub>2</sub>= 5 mM Lead chloride, T<sub>3</sub>= Chromium chloride + Lead chloride 2.5 mM of each) \*= Significant at 5% probability level, \*\*= Highly significant at 1% probability level, <sup>NS</sup>= Non-significant, DG-50%= Days to 50% germination, FRL= Fresh root length, FRW= Fresh root weight, DRW= Dry root weight, DSW= Dry shoot weight, DRSWR= Dry root to shoot weight ratio, CC= Chlorophyll content, LT= Leaf temperature.

**Fresh root length:** The ANOVA for fresh root length showed quite significant variations across various genotypes. It was also found that the effects of various treatments and their interactions with genotypes were highly significant (table 2). The control group had the greatest mean value (53.65 cm), whereas the Cr treatment group had the lowest mean value (47.86 cm). Between the control group and each of the other treatments (Pb, Cr, and Cr+Pb), there were substantial mean differences. The mean differences between the Cr, Pb, and combination treatments (Cr+Pb) were not statistically significant (table 3). As heavy metals were applied, the root length shrank. Pb was shown to be more harmful than Cr when applied. By applying certain heavy metals, the root length in wheat and rice decreased by up to 50% and 40%, respectively, in comparison to the control (Mahmood *et al.*, 2007; Atta *et al.*, 2014).

**Fresh root weight:** For fresh root weight, the analysis of variance indicated a significant difference across genotypes. The results of various treatments were also very significant. Additionally, a highly significant interaction between treatment and genotypes was identified (table 2). The Control group had the greatest mean value (2.94 g), whereas the Pb treatment group had the lowest mean value (1.87 g). All of the treatments had substantial mean changes (table 3). Root length is the key for plant to take up nutrients from the soil, also for good crop stands. Length of roots facilitates nutrient and minerals uptake from the deeper soil in water deficit stress. The lead has the adverse effect on the fresh root weight as compared to all other treatments (John *et al.*, 2009; Liang ChangCong *et al.*, 2009; Ghani, 2010; Hussain *et al.*, 2010).

Dry root weight: Dry root weight ANOVA showed no statistically significant changes between genotypes. The results of various treatments were very significant. Additionally, a highly significant interaction between treatment and genotypes was found (table 2). The LSD results showed a clear distinction between the control group and the various treatments. The control group had the greatest mean value (0.81 g), whereas the Cr treatment group had the lowest mean value (0.37 g). Between the Cr, combination (Cr+Pb), and Control treatments, there were statistically significant mean differences. Between Pb treatments and combination treatments (Cr+Pb), there were no statistically significant mean differences (table 3). As various metals are used, dry weight lowers. The decrease rate rises as concentration levels rise. Compared to Cd and other metals, Pb and Cr treatment resulted in a smaller decrease in dry root weight in maize (Hussain et al., 2010; Malik et al., 2010; Mukhtar *et al.*, 2010).

Dry shoot weight: Dry shoot weight analysis of variance

demonstrated highly significant variations across genotypes. Highly significant results were observed for the impact of several treatments and the interaction between genotypes and treatments (table 2). The LSD results showed a clear distinction between the control group and the various treatments. The combined treatments (Cr+Pb) had the lowest mean value (0.26 g), whereas the control had the greatest mean value (0.34 g). The Pb, combination (Cr+Pb), and Control treatments showed the most significant mean differences. Between the Cr and combination treatments (Cr+Pb), there were no statistically significant mean differences (table 3). According to Ghani (2010) and Malik *et al.* (2010), Pb had a stronger negative impact on dry shoot weight than Cr.

**Dry root to shoot weight ratio**: The ANOVA exhibited no statistically significant variability between genotypes. Additionally, a highly significant interaction between treatment and genotypes was discovered (table 2). The LSD results showed a clear distinction between the control group and the various treatments. The control group had the greatest mean value (2.83), whereas the Cr treatment group had the lowest mean value (1.43). The Cr treatment group showed significant variation from all other treatments groups. The difference in mean between the control, Pb, and combination treatments (Cr+Pb) is not statistically significant (table 3). The standout treatment was chromium that effects the dry root to shoot weight ratio most as compared to all other treatments (Liang ChangCong *et al.*, 2009; Ghani, 2010; Hussain *et al.*, 2013).

Chlorophyll content: For Chlorophyll content, the analysis of variance showed highly significant variations among genotypes. The results of treatments were also highly significant. Additionally, a highly significant interaction between treatment and genotypes was found (table 2). The LSD results showed significant variations between the control group and the various treatments. The control group had the greatest mean value (25.39 mg/g), whereas the Pb treatment group had the lowest mean value (21.513 mg/g). Significant changes were found between the control, Pb, and combination (Cr+Pb) treatments. Between the control and Cr treatments, there were no statistically significant changes (table 3). In different treatments, Chlorophyll contents reduced as compared to control. The reduction in chlorophyll contents directly affects the performance of the maize especially photosynthetic activity. The lead treatment had more effect on chlorophyll contents but chromium did not affect the concentration of chlorophyll contents (Sengar et al., 2008; Mukhtar et al., 2010).

**Leaf temperature:** According to the ANOVA, highly significant differences were found among genotypes. It was also found that the

effects of various treatments and their interactions with genotypes were extremely significant (table 2). The LSD data showed a clear distinction between the control group and the various treatments. The combination treatment (Cr+Pb) produced the lowest mean value (32.72 °C) and the greatest mean value (36.76 °C) under control. Significant changes were discovered between the Control, Cr, and combination (Cr + Pb) treatments. The treatments for Cr and Pb did not differ significantly from one another (table 3). In general, heavy metal treatments lower the leaf temperature as compared to control but individual treatments does not have any significant differences from each other (Malik *et al.*, 2010; Mukhtar *et al.*, 2010; Aliu *et al.*, 2013; Singh *et al.*, 2015).

**Effect of heavy metals on yield and yield contributing parameters:** In pots, the parents (Lines and Testers) and seeds obtained from the crosses made in line × tester fashion in previous season were planted together, and heavy metal treatments were applied. Data were gathered after harvesting for several yield and yield contributing factors. To determine the impacts of combining ability, the data from this experiment was subjected to line × tester analysis.

Cobs per plant: Under control and chromium treatment, the analysis of variance for treatment, parents, crosses, parent's versus crosses, testers, lines, and line tester interaction was found to be non-significant. Under lead treatment, the analysis of variance showed that treatment, crosses, lines, and the interaction between lines and testers were all very significant. The parents were the ones who got the most significant results. Parents vs crosses and testers showed non-significant findings. For the treatment, crosses, testers, lines, and line tester interaction under combined treatment, ANOVA revealed extremely significant results. The parent's vs. crosses comparison produced the significant findings. For parents, the results were non-significant (table 4). General combining ability (GCA) values were highest for 1335-2B (0.10) and lowest for F-167 (-0.067) under control; however, with chromium treatment, 1335-2B displayed the highest (0.133) and F-167 the lowest (-0.033) GCA values among lines (table 5). With lead treatment, the GCA values for the K54TMS were greatest (0.40) and lowest (-0.10) for F-167, while those for the F-167 were highest (0.233) and lowest (-0.10) for 2P-735 among the lines with combination treatment (Cr + Pb) (table 5). Sonneri (0.033) and Agatti 84 (-0.067) had the greatest general combining abilities (GCA) values under control, whereas Sulltan (0.067) and Sonneri (-0.033) had the lowest GCA values with chromium treatment. When exposed to lead, the Sulltan had the highest (0.100) and Agatti 84 the lowest (-0.10) GCA values, while Sonneri displayed the highest (0.100) and Agatti 84 the lowest (-0.100) GCA values in response to combined (Cr + Pb) treatments among testers (table 6). Under control conditions, K54TMS × Sonneri had the greatest specific combining ability (SCA) value (0.30), while 1335-2B × Sonneri had the lowest (-0.20), while for chromium treatment, 1335-2B × Sulltan had the best GCA value (0.267) and  $1335-2B \times Sonneri had the lowest (-0.133)$ . With lead treatment, the K54TMS  $\times$  Sulltan exhibited the greatest (0.40) and lowest (-0.40) GCA values recorded for K54TMS × Agatti 84, whereas the F-167  $\times$  Agatti 84 demonstrated the highest (0.56) and (-0.33) GCA values for F-167 Sulltan with lowest × combined treatment (Cr+Pb) (table 7).

Grain rows per ear: For the treatment, parents, crosses, parent's versus crosses, lines, and line × tester interaction under control, the analysis of variance was extremely significant. For testers, the results were non-significant. Under chromium treatment, the ANOVA showed that the treatment, parent vs. cross, and tester were all very significant. Crosses produced the findings with significance. Results for the parent's vs. crosses and line × tester interactions were not statistically significant. Under the lead treatment, the analysis of variance showed that the treatment, parents, parent's vs. crosses, crosses, and testers were all very significant. Results for lines and the interaction between lines and testers were not statistically significant. Under combined treatment (Cr+Pb), the analysis of variance for treatment and parents vs. crosses was extremely significant. Crosses, testers, and the interaction between lines and testers produced the most significant findings. The nonsignificant results were recorded for lines and parent's (table 4). Under control conditions, the general combining ability (GCA) value was found to be highest for F-167 (0.53) and lowest for 1335-2B (-0.8), but with chromium treatment, F-168 had the highest (0.53) and K54TMS lowest recorded with lowest (-0.46) GCA values. When exposed to lead, the F-168 displayed the greatest GCA value (0.4),

while the 1335-2B displayed the lowest GCA value (-0.26), whereas the F-167 displayed the highest GCA value (0.33) and the F-168 shown the lowest GCA value (-0.33) for combined treatment (Cr+Pb) among the lines. Sulltan (0.26) and Sonneri (-0.13) had the highest and lowest general combining abilities (GCA) scores, respectively, under control conditions, whereas Agatti 84 (0.80) and Sulltan (-0.40) had the highest and lowest GCA values, respectively, with chromium treatment. The Agatti 84 recorded the highest (0.73) and Sulltan lowest (-0.66) GCA value under lead treatment while Sulltan exhibited highest (0.66) and Sonneri lowest (-0.33) GCA value under combined treatment (Cr+Pb) among testers (table 5 & 6). Pavan et al. (2011), and Haddadi et al. (2012) found the direct positive relation of grain rows per ear to yield of corn plants as our results are also in conformity with those studies. The SCA was found highest for F-167 × Sulltan (1.06) and lowest for F-168 × Sulltan (-0.60) under control conditions while F-168 × Agatti 84 exhibited highest (0.86) and F-168 × Sulltan recorded with the lowest (-0.93) GCA values under chromium treatment. The F-168 × Sulltan (1) and 2P-735 × Agatti 84 (-0.73) exbibited highest and lowest lowest GCA value respectively, for lead treatment while F-168 × Sulltan recorded highest (1.33) and F-168 × Agatti 84 lowest (-1.66) GCA value for combined treatment (Cr + Pb) (table 7). These results are according with the previous findings of Kanagarasu et al. (2010), Zare et al. (2011), Dawod et al. (2012), Ali et al. (2011) and Haddadi et al. (2012).

Grain yield per plant: The ANOVA for grain yield per plant indicated highly significant variations for treatment, parents, crosses, parent's vs crosses, lines and line × tester interaction under control. The statistically non-significant results were found for testers. For chromium, lead and combined treatment (Cr+Pb), ANOVA was found highly significant for treatment, parents, crosses, parent's vs crosses, testers, lines, and line × tester interaction (table 4). General combining ability (GCA) results presented in table 5 & 6. Under control, the lines F-167 (10.40) and 1335-2B (-7.66) recorded with highest and lowest GCA value respectively. The highest value was found for K54TMS (12.30) and 1335-2B (-13.41) showed lowest under chromium treatment. The F-168 exhibited highest (6.15) and K54TMS lowest (-3.73) GCA value for lead treatment while 2P-735 recorded highest (12.13) and K54TMS lowest (-11.58) GCA value under combined treatment (Cr+Pb). For testers, GCA value was recorded highest for Sulltan (4.38) and lowest for Sonneri (-2.43) under control while Sonneri exhibited highest (5.85) and Sulltan lowest (-4.93) for chromium treatment. The Sonneri has shown highest (4.45) and Sulltan lowest (-6.12) GCA value for lead treatment while Agatti 84 exhibited highest (2.60) and Sulltan lowest (-3.60) GCA value for combined treatment (Cr+Pb) (table 5 & 6). The cross 2P-735 × Sulltan (13.48) and K54TMS × Sulltan (-16.45) recorded with highest and lowest SCA value respectively for control while 2P-735 × Sulltan exhibited highest (12.89) and 2P-735 × Sonneri lowest (-18.73) SCA values for chromium treatment. The 2P-735 × Sulltan shown highest (9.99) and 2P-735 × Sonneri lowest (-10.28) SCA value for lead treatment while F-168 × Sulltan recorded highest (11.45) and F-168 × Sonneri lowest (-7.94) SCA value under combined treatment (Cr+Pb) (table 7).

Hundrad grain weight: For the control, chromium and lead treatment, the analysis of variance showed that the variables treatment, parents, crosses, parents vs. crosses, tester, lines, and line × tester interaction were all very significant. Under combined treatment (Cr+Pb), the ANOVA was very significant for the treatment, parents, crosses, lines, tester, and line × tester interaction. Parents vs. crosses yielded non-significant findings (table 4). The lines under control, chromium, lead, and combined treatment (Cr+Pb) showed the highest general combining ability (GCA) values at K54TMS (4.94), K54TMS (4.10), K54TMS (2.90), and F-168 (2.76) while the lines 1335-2B (-2.77), F-167 (-4.05), F-168 (-2.41), and K54TMS (-2.53) showed the lowest. Sulltan (5.59), Sulltan (2.68), Sulltan (0.46), and Agatti 84 (0.69) had the greatest general combining ability values, while Agatti 84 (-3.86) and Agatti 84 (-3.55), Agatti 84 (-0.4) and Sonneri (-0.60) had the lowest values under control, chromium, lead, and combination treatment (Cr+Pb) respectively (tables 5 and 6). The SCA value was found to be highest for F-167 × Sonneri (6.50), F-167 × Agatti 84 (4.19), F-168 × Sulltan (4.64), and F-168 × Sulltan (10.49), whereas F-167 × Sulltan (-4.68), F-167 × Sulltan (-4.60), F-168 × Agatti 84 (-3.35), and F-168 × Sonneri (-8.84) recorded lowest under control, chromium, lead and combined treatment (Cr+Pb) respectively (table 7).

Online Available at: https://www.sciplatform.com/index.php/wjb/article/view/1158

S.O.V DF		СРР				GRPE					GYP				100 GW				НМСС			
S.O.V	DF -	T0	T1	T2	Т3	Т0	T1	T2	T3	Т0	T1	T2	T3	Т0	T1	T2	Т3	T0	T1	T2	Т3	
Replications	1	0.32NS	2.10NS	2.10NS	1.00NS	0.00NS	2.41NS	1.64NS	0.07NS	2.44NS	0.01NS	0.00NS	1.07NS	0.50NS	2.18NS	1.97NS	0.06NS		0.81NS	1.12NS	0.08NS	
Treatments	22	0.88NS	1.00NS	2.90**	4.82**	7.33**	2.26**	4.07**	1.77**	34.59**	93.42**	256.09**	244.64**	43.27**	142.84**	72.56**	93.16**		31.09**	30.40**	640.89**	
Parents	7	0.93NS	1.51NS	1.51*	0.00NS	2.36**	0.91NS	3.00**	0.94NS	35.91**	39.27**	181.26**	224.18**	15.94**	31.99**	102.77**	61.16**		11.96**	18.45**	1296.33**	
Parents vs crosses	1	0.00NS	0.21NS	0.35NS	4.80*	117.91**	20.33**	42.60**	9.61**	1.01NS	320.60**	2201.17**	516.43**	25.62**	1339.96**	203.57**	3.61NS		23.54**	91.08**	2463.03**	
Crosses	14	0.92NS	0.80NS	3.79**	7.23**	1.91**	1.65*	1.85**	1.62*	36.33**	104.27**	154.56**	235.46**	58.20**	112.75**	48.10**	115.55**	· N/A	41.19**	32.04**	183.01**	
Lines Testers	4 2	0.74NS 0.50NS	0.80NS 0.80NS	7.23** 2.41NS	6.13** 4.60**	3.02** 0.73NS	0.96NS 5.33**	0.55NS 5.83**	0.57NS 2.83*	52.72** 16.18**	150.15** 89.46**	136.53** 380.81**	589.35** 95.78**	47.45** 215.59**	136.69** 260.86**	81.64** 6.05**	77.82** 9.18**		46.37** 70.92**	6.63** 87.46**	299.68** 4.06**	
Lines x	2																					
Testers	8	1.12NS	0.80NS	2.41**	8.43**	1.65*	1.07NS	1.50NS	1.84*	33.18**	85.03**	107.02**	93.43**	24.22**	63.75**	41.84**	161.01**	c	31.18**	30.88**	169.41**	
Error	22	0.067	0.042	0.042	0.022	0.727	0.901	0.846	1.178	8.957	3.319	0.790	1.084	1.142	0.395	0.310	0.467		0.010	0.016	0.010	
Table 4: Analy	sis of v	ariance (	Fcal) for y	yield and	yield relat	ted traits at	t physiolog	ical matur	ity grown i	under diffei	rent treatm	ients.										
			СРР		·	GRPE					GYP				100	GW		HMCG				
Lines -	T <sub>0</sub>	T <sub>1</sub>	,	<b>T</b> <sub>2</sub>	<b>T</b> <sub>3</sub>	T <sub>0</sub>	<b>T</b> <sub>1</sub>	<b>T</b> <sub>2</sub>	<b>T</b> <sub>3</sub>	T <sub>0</sub>	T <sub>1</sub>	<b>T</b> <sub>2</sub>	<b>T</b> <sub>3</sub>	T <sub>0</sub>	<b>T</b> <sub>1</sub>	<b>T</b> <sub>2</sub>	<b>T</b> <sub>3</sub>	T <sub>0</sub>	<b>T</b> <sub>1</sub>	<b>T</b> <sub>2</sub>	<b>T</b> <sub>3</sub>	
F-167	-0.067				0.233	0.533	0.200	0.067	0.333	10.407	0.523	-3.663	-9.847	-0.660	-4.050	0.607	2.233	0.000	-0.387	-0.057	-0.463	
F-168	-0.067				0.067	0.200	0.533	0.400	-0.333	8.690	-0.193	6.437	3.137	0.357	-0.367	-2.410	2.767	0.000	0.180	-0.123	1.053	
1335-2B	0.100				-0.100	-0.800	-0.133	-0.267	0.333	-7.660	-13.410	-0.680	6.153	-2.777	1.300	0.357	-2.267	0.000	0.163	0.043	0.187	
2P-735 K54TMS	-0.067 0.100				-0.100 -0.100	-0.467 0.533	-0.133 -0.467	-0.267 0.067	-0.333 0.000	-3.860 -7.577	0.773 12.307	1.637 -3.730	12.137 -11.580	-1.860 4.940	-0.983 4.100	-1.460 2.907	-0.200 -2.533	$0.000 \\ 0.000$	0.247 -0.203	-0.073 0.210	0.070 -0.847	
Table 5: Gener																2.907	-2.333	0.000	-0.203	0.210	-0.047	
																II: ables ai an	figent at 1	0/ much	- le : l : Le - L	al NC - Nam	ai an ifi an nt	
(T0= Control,	11 = 5 n	IM CHIOI	mum chic	oriae, 12=	= 5 mm Lea	ad chioride	13 = Cnr0	mum cmo	ride + Lead	i chioride z	.5 mixt of ea			/o nronaniii	IV IEVEL ***=	: Ητοπιν ειση	ilicani al 1	% DF0D	апни у тем	91 INNE INON		
CDD Calasses		CDDC C.										· ·		•	cy ievel,		incunt at 1	70 probe			-significant,	
CPP=Cobs per	plant, (	GRPE=Gr		per ear, (			plant, 1000	GW= 100 G			leavy meta	l concentrat		•				,0 prob			-significant,	
<u>CPP=Cobs per</u> Testers			CPP		GYP= Grain	n yield per j	plant, 1000 GRI	GW= 100 G PE	rains weig	ht, HMC= H	leavy metal G	l concentrat /P	ion in grain	l	100 G	W		•	H	IMCG		
Testers	To	T	<b>CPP</b>	T <sub>2</sub>	GYP= Grain	n yield per j	plant, 1000 GRI T1	$\frac{GW=100 G}{T_2}$	rains weig	ht, HMC= H	leavy metal GY T1	l concentrat <u>ZP</u> T <sub>2</sub>	ion in grain T <sub>3</sub>	To	100 G	W T <sub>2</sub>	<b>T</b> 3	To	н Т1	IMCG T <sub>2</sub>	T <sub>3</sub>	
Testers Agatti 84		<b>T</b> 67 -0.0	<b>CPP</b> 	<b>T</b> <sub>2</sub> 0.100	<u>GYP= Grain</u> <u>T<sub>3</sub></u> 0.100	<u>To</u> -0.133	plant, 1000 GRI T <sub>1</sub> 0.800	$\frac{\text{GW}=100 \text{ G}}{\text{PE}}$ $\frac{\text{T}_2}{0.733}$	T <sub>3</sub> -0.333	ht, HMC= H <u>T₀</u> -1.953	leavy metal GY T1 -0.920	l concentrat YP T <sub>2</sub> 1.673	ion in grain T <sub>3</sub> 2.607	T <sub>0</sub> -3.863	<b>100 G</b> T <sub>1</sub> -3.557	W T <sub>2</sub> -0.400	<b>T</b> <sub>3</sub> 0.697	<b>T</b> <sub>0</sub> 0.000	H T1 -0.297	IMCG <u>T2</u> 0.040	<u>T</u> <sub>3</sub> 0.067	
Testers	To	67 -0.0 33 -0.0	<b>CPP</b> 1 033 -( 033 0	T <sub>2</sub>	GYP= Grain	n yield per j	plant, 1000 GRI T1	$\frac{GW=100 G}{T_2}$	rains weig	ht, HMC= H	leavy metal GY T1	l concentrat <u>ZP</u> T <sub>2</sub>	ion in grain T <sub>3</sub>	To	100 G	W T <sub>2</sub>	<b>T</b> 3	To	н Т1	IMCG T <sub>2</sub>	T <sub>3</sub>	
Testers Agatti 84 Sonneri Sulltan	<b>T</b> <sub>0</sub> -0.06 0.03 0.03	<b>T</b> 67 -0.0 33 -0.0 33 0.0	CPP 033 -( 033 0 067 0	<b>T</b> <sub>2</sub> 0.100 0.000 0.100	T3           0.100           -0.100           0.000	<b>T</b> <sub>0</sub> -0.133 -0.133 0.267	plant, 1000 GRI 0.800 -0.400 -0.400	GW= 100 G PE 0.733 -0.067 -0.667	T₃ -0.333 -0.333 0.667	ht, HMC= H T <sub>0</sub> -1.953 -2.433 4.387	leavy metal GY T1 -0.920 5.850 -4.930	<b>Concentrat</b> <b>T</b> <sub>2</sub> 1.673 4.453 -6.127	tion in grain T <sub>3</sub> 2.607 0.997 -3.603	T₀ -3.863 -1.733 5.597	<b>100 G</b> <b>T</b> 1 -3.557 0.873 2.683	<b>W</b> -0.400 -0.060	<b>T</b> <sub>3</sub> 0.697 -0.603	<b>T</b> <sub>0</sub> 0.000 0.000	H T <sub>1</sub> -0.297 0.113	IMCG T <sub>2</sub> 0.040 -0.390	T <sub>3</sub> 0.067 -0.063	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene	<u>To</u> -0.06 0.03 0.03 eral com	<b>T</b> 67 -0.0 33 -0.0 33 0.0	CPP 033 -( 033 0 067 0	<b>T</b> <sub>2</sub> 0.100 0.000 0.100	T3           0.100           -0.100           0.000	<b>T</b> <sub>0</sub> -0.133 -0.133 0.267	plant, 1000 GRI 0.800 -0.400 -0.400	GW= 100 G PE 0.733 -0.067 -0.667	T₃ -0.333 -0.333 0.667	ht, HMC= H T <sub>0</sub> -1.953 -2.433 4.387	Leavy metal T1 -0.920 5.850 -4.930 comium (Cr	<b>Concentrat</b> <b>T</b> <sub>2</sub> 1.673 4.453 -6.127	tion in grain T <sub>3</sub> 2.607 0.997 -3.603	T₀ -3.863 -1.733 5.597	<b>100 G</b> <b>T</b> 1 -3.557 0.873 2.683	T2           -0.400           -0.060           0.460	<b>T</b> <sub>3</sub> 0.697 -0.603	<b>T</b> <sub>0</sub> 0.000 0.000	н Т1 -0.297 0.113 0.183	IMCG T <sub>2</sub> 0.040 -0.390	T <sub>3</sub> 0.067 -0.063	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse	<u>To</u> -0.06 0.03 0.03 eral com	<b>T</b> 67 -0.0 33 -0.0 33 0.0	CPP 033 -( 033 0 067 0	T <sub>2</sub> 0.100 0.000 0.100 A) of test CPP	GYP= Grain T <sub>3</sub> 0.100 -0.100 0.000 ers grown	<b>T</b> 0 -0.133 -0.133 0.267 <b>under diffe</b>	plant, 1000 GRI 0.800 -0.400 -0.400	GW= 100 G PE 0.733 -0.067 -0.667 y metal tree	T₃ -0.333 -0.333 0.667	ht, HMC= H T <sub>0</sub> -1.953 -2.433 4.387	Leavy metal T1 -0.920 5.850 -4.930 comium (Cr	l concentrat YP T2 1.673 4.453 -6.127 C), Lead (Pb)	tion in grain T <sub>3</sub> 2.607 0.997 -3.603	T₀ -3.863 -1.733 5.597	<b>100 G</b> <b>T</b> <sub>1</sub> -3.557 0.873 2.683 <b>b</b> ).	T2           -0.400           -0.060           0.460	<b>T</b> <sub>3</sub> 0.697 -0.603 -0.093	<b>T</b> <sub>0</sub> 0.000 0.000	н Т1 -0.297 0.113 0.183	<b>IMCG</b> 0.040 -0.390 0.350	T <sub>3</sub> 0.067 -0.063	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8	<u>To</u> -0.06 0.03 0.03 eral com es 34	<b>T</b> 67 -0.0 33 -0.0 33 0.0 bining al <b>D</b> <b>T</b> 0.067	CPP           33         -0           333         0           67         0           50         0           7         0.03	T2           0.100           0.000           0.100           A) of test           CPP           T;           3           0.10	$     GYP = Grain     T_3     0.100     -0.100     0.000     ers grown     2     T_3     00     0.563     $	To -0.133 -0.133 0.267 under diffe To 7 -0.533	plant, 1000           GRI           1           0.800           -0.400           -0.400           erent heavy           T1           3           0.200	GW= 100 G           T2           0.733           -0.067           -0.667           y metal tree           GRPE           T2           0.733	T3           -0.333           -0.333           0.667           atments (C           T3           7	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197	Ieavy meta           GY           T1           -0.920           5.850           -4.930           comium (Cr           T1           5.987	T2           1.673           4.453           -6.127           t), Lead (Pb)           GYP           T2           -3.207	tion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023	T₀ -3.863 -1.733 5.597 ned (Cr + F T₀ -1.820	100 G T1 -3.557 0.873 2.683 b). 100 G T1 4.190	Tz           -0.400           -0.060           0.460	T <sub>3</sub> 0.697 -0.603 -0.093 T <sub>3</sub> L.687	T <sub>0</sub> 0.000 0.000 0.000 T <sub>1</sub> 0.000	H T1 -0.297 0.113 0.183 HI T2 -0.703	T2           0.040           -0.390           0.350	T <sub>3</sub> 0.067           -0.063           -0.003           T4           0.083	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri	<u>To</u> -0.06 0.03 0.03 eral com es 34	<b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b>	CPP           033         -(           033         0           067         0           011ity (GCA         0           T1         0           7         0.03           3         0.03	T2           0.100           0.000           0.100           A) of test           CPP           T2           3           0.101	GYP= Grain           T <sub>3</sub> 0.100           -0.100           0.000           ers grown           2           T <sub>3</sub> 00         0.567           00         -0.23	To           -0.133           -0.133           0.267           under diffe           To           7           -0.533           3           -0.533	T1           0.800           -0.400           -0.400           erent heavy           T1           3           0.200           3           -0.600	T2           0.733           -0.067           -0.667           y metal tree           GRPE           T2           0.733           -0.067           y metal tree           0.72           0.006           0.007	T3           -0.333           -0.333           0.667           atments (C           T3           7           0.667           3           -0.333	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 3 5.583	leavy meta T1 -0.920 5.850 -4.930 romium (Cr T1 5.987 6.567	T2           1.673           4.453           -6.127           t), Lead (Pb)           GYP           T2           -3.207           1.463	ion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023 1.537	To -3.863 -1.733 5.597 ned (Cr + F To -1.820 6.500	100 G T <sub>1</sub> -3.557 0.873 2.683 b). 100 G T <sub>1</sub> 4.190 0.410	T2           -0.400           -0.060           0.460	T <sub>3</sub> 0.697           -0.603           -0.093	T <sub>0</sub> 0.000 0.000 0.000 T <sub>1</sub> 0.000 0.000	H T1 -0.297 0.113 0.183 HI T2 -0.703 0.537	$\frac{T_2}{0.040}$ -0.390 0.350 MCG T_3 0.527 -0.143	T <sub>3</sub> 0.067           -0.063           -0.003	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri F-167 × Sulltan	To -0.06 0.03 0.03 eral com es 34 i	<b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b>	CPP           033         -(           033         0           067         0           011ity (GCA         0           T1         0.03           7         0.03           3         0.03           3         -0.06	T2           0.100           0.000           0.100           A) of test           CPP           T:           3         0.10           3         0.00           57         -0.1	T3         0.100           -0.100         0.000           ers grown         2           2         T3           00         0.567           00         -0.23           00         -0.33	To           -0.133           -0.133           0.267           under diffe           7           -0.533           3           1.067	T1           0.800           -0.400           -0.400           erent heavy           T1           3         0.200           3         -0.600           7         0.400	GW= 100 G           T2           0.733           -0.067           -0.667           y metal tree           GRPE           0           -0.060           0           0           -0.666	Tains weig           T3           -0.333           -0.333           0.667           atments (C           T3           7           0.667           3           -0.333           7           -0.333           7           -0.333           -0.333	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 3 5.583 3 0.613	leavy meta T1 -0.920 5.850 -4.930 comium (Cr T1 5.987 6.567 -12.553	Concentrat           T2           1.673           4.453           -6.127           t), Lead (Pb)           GYP           T2           -3.207           1.463           1.743	ion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023 1.537 3.487	T₀ -3.863 -1.733 5.597 ned (Cr + F T₀ -1.820 6.500 -4.680	100 G T <sub>1</sub> -3.557 0.873 2.683 b). 100 G T <sub>1</sub> 4.190 0.410 -4.600	T2           -0.400           -0.060           0.460	T <sub>3</sub> 0.697           -0.603           -0.093           T <sub>3</sub> L.687         (1.413)           0.273         (1.413)	T₀ 0.000 0.000 0.000 0.000 T₁ 0.000 0.000 0.000	H T1 -0.297 0.113 0.183 HI T2 -0.703 0.537 0.167	T2           0.040           -0.390           0.350   MCG           T3           0.527           -0.143           -0.383	T3           0.067           -0.063           -0.003	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri F-167 × Sulltan F-168 × Agatti 8		<b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b>	CPP           033         -(           033         0           067         0           011ity (GCA         0           T1         0.03           7         0.03           3         -0.06           7         0.03           3         -0.06           7         0.03	T2           0.100           0.000           0.100           A) of test           CPP           T;           3         0.10           3         0.00           67         -0.1           3         0.10	T3         0.100           -0.100         0.000           ers grown         2         T3           200         0.567           00         -0.23           00         -0.33           00         -0.26	To           -0.133           -0.133           0.267           under diffe           7           -0.533           3           1.067           7           -0.533           3           -0.533	plant, 1000 GRI T1 0.800 -0.400 -0.400 erent heavy T1 3 0.200 3 -0.600 7 0.400 0 0.867	GW= 100 G           PE           0.733           -0.067           -0.667           y metal tree           GRPE           0           -0.060           0           -0.667           y metal tree           -0.066           -0.066           -0.066	Tains weig           T <sub>3</sub> -0.333           -0.333           0.667           atments (C           T <sub>3</sub> 7           0.667           3           -0.333           0.667           0.667           0.667           0.667           0.667           0.667           0.667           0.667           0.667           0           -1.667	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 3 5.583 3 0.613 7 10.170	leavy meta T1 -0.920 5.850 -4.930 omium (Cr T1 5.987 6.567 -12.553 -7.947	Concentrat           T2           1.673           4.453           -6.127           ), Lead (Pb)           GYP           -3.207           1.463           1.743           -1.057	ion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023 1.537 3.487 -3.507	To -3.863 -1.733 5.597 ned (Cr + F -1.820 6.500 -4.680 -1.087	100 G T1 -3.557 0.873 2.683 b). 100 G T1 4.190 0.410 -4.600 1.307	T2           -0.400           -0.060           0.460             W           T2           1.933           0.293           -2.227           -0.3350	T3           0.697           -0.603           -0.093           T3           1.687           1.413           0.273           1.647	T₀ 0.000 0.000 0.000 0.000 T1 0.000 0.000 0.000 0.000	H T1 -0.297 0.113 0.183 T2 -0.703 0.537 0.167 0.430	T2           0.040           -0.390           0.350         MCG       T3           0.527           -0.143           -0.383           0.293	T3           0.067           -0.063           -0.003	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri F-167 × Sulltan F-168 × Agatti 8 F-168 × Sonneri		<b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>0</b> <b>0</b> <b>0</b> <b>0</b> <b>0</b> <b>0</b> <b>0</b> <b>0</b>	CPP           033         -(           033         0           067         0           011ity (GCA         0           7         0.03           3         0.03           3         -0.06           7         0.03           3         -0.06           7         0.03           3         0.03           3         0.03	T2           0.100           0.000           0.100           A) of test           CPP           T;           3         0.10           67         -0.1           3         0.10           67         -0.1           3         0.10	GYP= Grain           T <sub>3</sub> 0.100           -0.100           0.000           ers grown           2           20           0.00           2           00           0.00           00           00           00           00           00           00           00           00           00           00           00           00           00           00           00           00           00	To           -0.133           -0.133           0.267           under diffe           7           -0.533           3           1.067           7           -0.200           7           0.201	plant, 1000 GRI T1 0.800 -0.400 -0.400 erent heavy T1 3 0.200 3 -0.600 7 0.400 0 0.867 0 0.067	GW= 100 G           PE           0.733           -0.067           -0.667           y metal tree           GRPE           0           -0.066           0           -0.667           y metal tree           -0.066           -0.066           -0.066           -0.066           -0.066           -0.060           -0.667	Tains weig           T <sub>3</sub> -0.333           -0.667           atments (C           T <sub>3</sub> 7           0.667           3           -0.333           0.667           0.63	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 3 5.583 3 0.613 7 10.170 -0.600	leavy meta T1 -0.920 5.850 -4.930 omium (Cr T1 5.987 6.567 -12.553 -7.947 5.283	Concentrat           T2           1.673           4.453           -6.127           C), Lead (Pb)           GYP           -3.207           1.463           1.743           -1.057           0.813	ion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023 1.537 3.487 -3.507 -7.947	T₀ -3.863 -1.733 5.597 ned (Cr + F -1.820 6.500 -4.680 -1.087 -2.767	100 G T1 -3.557 0.873 2.683 b). 100 G T1 4.190 0.410 -4.600 1.307 -4.373	T2           -0.400           -0.060           0.460           W           T2           1.933           0.293           -2.227           -3.350           -1.290	T3           0.697           -0.603           -0.093           T3           1.687           1.413           0.273           1.647           8.847	T <sub>0</sub> 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	H T1 -0.297 0.113 0.183 -0.183 -0.183 -0.703 0.537 0.167 0.430 -0.280	T2           0.040           -0.390           0.350             MCG           T3           0.527           -0.143           -0.383           0.293           -0.177	T3           0.067           -0.063           -0.003             T4           0.083           0.013           -0.097           1.117           -0.503	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri F-167 × Sulltan F-168 × Agatti 8 F-168 × Sonneri F-168 × Sulltan	T₀ -0.00 0.03 0.03 eral com es 34 i 34 i	T           67         -0.0           33         -0.0           33         0.0           abining al           To           0.067           -0.03           -0.03           -0.03           -0.03           -0.03           -0.03           -0.03           -0.03           -0.03	CPP           033         -(           033         0           067         0           011ity (GC/         0           033         0.03           3         -0.06           7         0.03           3         -0.06           7         0.03           3         -0.06	$\begin{array}{c} \mathbf{T}_2 \\ \hline \mathbf{T}_2 \\ \hline 0.100 \\ 0.000 \\ 0.100 \\ \hline \mathbf{A} \ of test \\ \hline \mathbf{CPP} \\ \hline \mathbf{T}_2 \\ \hline \mathbf{T}_3 \\ 0.10 \\ \hline 3 \\ 0.00 \\ \hline 57 \\ -0.1 \\ \hline 3 \\ 0.00 \\ \hline 57 \\ -0.1 \end{array}$	T3         0.100           -0.100         0.000           ers grown         0.23           2         T3           00         0.567           00         -0.23           00         -0.26           00         -0.33           00         -0.26           00         -0.33	To           -0.133           -0.133           0.267           under diffe           7           -0.533           3           1.067           7           -0.200           7           0.200           3           0.067           3           0.060	T1           0.800           -0.400           -0.400           erent heavy           T1           3         0.200           3         -0.600           0         0.867           0         0.867           0         -0.933	$\begin{array}{c} \hline GW=100\ G\\ \hline PE \\ \hline \hline 12 \\ 0.733 \\ -0.067 \\ -0.667 \\ \hline y\ metal\ tree \\ \hline GRPE \\ \hline \hline 2 \\ 0 \\ -0.066 \\ 0 \\ 0.733 \\ 0 \\ -0.66 \\ 7 \\ -0.40 \\ 7 \\ -0.60 \\ 3 \\ 1.000 \end{array}$	$\begin{array}{c} \hline {\bf T_3} \\ -0.333 \\ -0.333 \\ 0.667 \\ \hline {\bf atments} (0 \\ \hline {\bf T_3} \\ 7 \\ 0.667 \\ \hline {\bf 3} \\ -0.333 \\ 0 \\ -1.667 \\ 0 \\ 0 \\ 0.333 \\ 0 \\ 1.333 \end{array}$	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 3 5.583 3 0.613 7 10.170 -0.600 -9.570	leavy meta T1 -0.920 5.850 -4.930 omium (Cr T1 5.987 6.567 -12.553 -7.947 5.283 2.663	Concentrat           T2           1.673           4.453           -6.127           ), Lead (Pb)           GYP           -3.207           1.463           1.743           -1.057           0.813           0.243	ion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023 1.537 3.487 -3.507 -7.947 11.453	T₀ -3.863 -1.733 5.597 ned (Cr + F -1.820 6.500 -4.680 -1.087 -2.767 3.853	100 G T1 -3.557 0.873 2.683 b). 100 G T1 4.190 0.410 -4.600 1.307 -4.373 3.067	T2           -0.400           -0.060           0.460           W           T2           1.933           1.933           0.293           -2.227           -3.350           -1.290           4.640	T3           0.697           -0.603           -0.093           T3           1.687           1.413           0.273           1.647           8.847           0.493	T <sub>0</sub> 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	H T1 -0.297 0.113 0.183 -0.183 -0.703 0.537 0.537 0.167 0.430 -0.280 -0.280 -0.150	$\begin{tabular}{ c c c c } \hline $T_2$ \\ \hline $0.040$ \\ $-0.390$ \\ $0.350$ \\ \hline $0.350$ \\ \hline $0.527$ \\ $-0.143$ \\ $-0.383$ \\ $0.293$ \\ $-0.177$ \\ $-0.117$ \\ \hline \end{tabular}$	T <sub>3</sub> 0.067           -0.063           -0.003           -0.003           -0.003           -0.003           -0.003           -0.003           -0.003           -0.003           -0.003           -0.003	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri F-167 × Sulltan F-168 × Agatti 8 F-168 × Sonneri F-168 × Sulltan 1335-2B × Agatt	To -0.06 0.03 0.03 eral com es 34 i 34 i ti 84	T           67         -0.0           33         -0.0           33         0.0           bining al           To           0.0657           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.034	CPP           033         -(           033         0           067         0           011ty (GC/         0           011ty (GC/         0           0111ty (GC/         0	T2           0.100           0.000           0.100           A) of test           CPP           T:           3         0.10           3         0.00           67         -0.1           3         0.00           67         -0.1           3         0.00           67         -0.1           33         0.00	T3         0.100           -0.100         0.000           ers grown         0.23           2         T3           00         0.567           00         -0.23           00         -0.23           00         -0.26           00         -0.23           00         -0.26           00         -0.23           00         -0.26           00         -0.33           00         -0.26           00         -0.33	To           -0.133           -0.133           0.267           under diffe           7           -0.533           3           1.067           7           -0.533           3           -0.673           3           -0.600           -0.7           0.200	T1           0.800           -0.400           -0.400           erent heavy           T1           3         0.200           3         -0.600           9         0.400           0.800         -0.600           0.0067         0.0067           0         -0.933           0         -0.460	$\begin{array}{c} \hline GW=100\ G\\ \hline PE \\ \hline \hline 12 \\ 0.733 \\ -0.067 \\ -0.667 \\ \hline y\ metal\ tree \\ \hline GRPE \\ \hline \hline 2 \\ 0 \\ -0.066 \\ 0 \\ 0.733 \\ 0 \\ -0.66 \\ 7 \\ -0.40 \\ 7 \\ -0.60 \\ 3 \\ 1.000 \\ 7 \\ 0.266 \end{array}$	$\begin{array}{c} \hline {\bf T_3} \\ -0.333 \\ -0.333 \\ 0.667 \\ \hline {\bf atments} (0) \\ \hline {\bf T_3} \\ 7 \\ 0.667 \\ \hline {\bf 3} \\ -0.333 \\ 0 \\ -1.667 \\ 0 \\ 0 \\ 0.333 \\ 0 \\ 1.333 \\ 7 \\ 0.667 \end{array}$	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 5.583 3 0.613 7 10.170 -0.600 -9.570 -6.780	leavy meta T1 -0.920 5.850 -4.930 omium (Cr T1 5.987 6.567 -12.553 -7.947 5.283 2.663 -4.430	T2           1.673           4.453           -6.127           ), Lead (Pb)           GYP           -3.207           1.463           1.743           -1.057           0.813           0.243           2.360	ion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023 1.537 3.487 -3.507 -7.947 11.453 0.177	T₀ -3.863 -1.733 5.597 ned (Cr + F -1.820 6.500 -4.680 -1.087 -2.767 3.853 1.747	100 G T1 -3.557 0.873 2.683 b). 100 G T1 4.190 0.410 -4.600 1.307 -4.373 3.067 -3.510	$\begin{array}{c} \mathbf{W} \\ \hline \mathbf{T}_2 \\ -0.400 \\ -0.060 \\ 0.460 \\ \hline \\ \mathbf{W} \\ \hline \mathbf{T}_2 \\ 1.933 \\ 1 \\ 0.293 \\ -2.227 \\ -2.227 \\ -3.350 \\ -1.290 \\ -1.290 \\ -4.640 \\ 10 \\ -0.067 \\ -0 \\ \hline \end{array}$	T3           0.697           -0.603           -0.093           T3           1.687           1.413           0.273           1.647           8.847           0.493           0.563	T <sub>0</sub> 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	H T1 -0.297 0.113 0.183 -0.183 -0.703 0.537 0.167 0.430 -0.280 -0.150 0.097	$\begin{tabular}{ c c c c } \hline $T_2$ \\ \hline $0.040$ \\ $-0.390$ \\ \hline $0.350$ \\ \hline $0.350$ \\ \hline $0.350$ \\ \hline $0.73$ \\ \hline $0.527$ \\ $-0.143$ \\ $-0.383$ \\ $0.293$ \\ $-0.177$ \\ $-0.117$ \\ $-0.173$ \\ \hline \end{tabular}$	T <sub>3</sub> 0.067           -0.063           -0.003             T4           0.083           0.013           -0.097           1.117           -0.503           -0.613           -0.767	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri F-167 × Sulltan F-168 × Agatti 8 F-168 × Sonneri F-168 × Sulltan 1335-2B × Agatti 1335-2B × Sonneri	To -0.06 0.03 0.03 eral com es 34 i 34 i ti 84 heri	T           67         -0.0           33         -0.0           33         0.0           bining al           To           0.0657           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.032           -0.033           -0.032	CPP           033         -(           033         0           067         0           011ty (GC/         0           011ty (GC/         0           0111ty (GC/         0	T2           0.100           0.000           0.100           A) of test           CPP           T;           3           0.10           3           0.10           3           0.11           3           0.11           3           0.11           3           0.11           3           0.11           3           0.11           3           0.11           3           0.11           3           0.11           3           0.11           0.31           0.32	T3         0.100           -0.100         0.000           ers grown         0.23           2         T3           00         0.567           00         -0.23           00         -0.23           00         -0.33           00         -0.26           00         -0.33           00         -0.26           00         -0.33           00         -0.26           00         -0.33           00         -0.26           00         0.333           00         -0.10           00         0.100	To           -0.133           -0.133           0.267           under diffe           7           -0.533           3           1.067           7           -0.533           3           0.200           7           0.200           0           0           0           0           0           0           0           0           0	T1           0.800           -0.400           -0.400           erent heavy           T1           3         0.200           3         -0.600           0         0.867           0         0.867           0         0.867           0         -0.400           0         0.867           0         -0.933           0         -0.461           0         -0.733	$\begin{array}{c} \hline GW=100\ G\\ \hline FE \\ \hline \hline 100\ GPE \\ \hline 0.733 \\ -0.067 \\ -0.667 \\ \hline \hline y\ metal\ tree \\ \hline GRPE \\ \hline \hline \hline 2 \\ \hline 0 \\ -0.066 \\ \hline 0 \\ 0 \\ 0 \\ -0.66 \\ \hline 7 \\ -0.40 \\ \hline 7 \\ 0 \\ -0.60 \\ \hline 3 \\ 1.000 \\ \hline 7 \\ 0.26 \\ \hline 8 \\ 0 \\ 0.066 \end{array}$	$\begin{array}{c} \hline \mathbf{T_3} \\ -0.333 \\ -0.333 \\ 0.667 \\ \hline \mathbf{atments} (\mathbf{C}) \\ \hline \mathbf{T_3} \\ 7 & 0.667 \\ \hline \mathbf{T_3} \\ 7 & 0.633 \\ 7 & -0.333 \\ 0 & -1.667 \\ 0 & 0.333 \\ 0 & 1.333 \\ 7 & 0.667 \\ 7 & -0.333 \\ \hline \mathbf{T_3} \\ 0 & -1.333 \\ \hline \mathbf{T_3} \\ -0.333 \\ \hline \mathbf{T_3} \\ $	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To Control, Chr To Control, Chr To Control, Chr Control, Chr Chr Chr Chr Chr Chr Chr Chr	leavy meta T1 -0.920 5.850 -4.930 omium (Cr T1 5.987 6.567 -12.553 -7.947 5.283 2.663 -4.430 11.550	T2           1.673           4.453           -6.127           ), Lead (Pb)           GYP           -3.207           1.463           1.743           -1.057           0.813           0.243           2.360           4.680	ion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023 1.537 3.487 -3.507 -7.947 11.453 0.177 0.987	T₀ -3.863 -1.733 5.597 ned (Cr + F -1.820 6.500 -4.680 -1.087 -2.767 3.853 1.747 -2.583	100 G T1 -3.557 0.873 2.683 b). 100 G T1 4.190 0.410 -4.600 1.307 -4.373 3.067 -3.510 2.660	T2           -0.400           -0.060           0.460           W           T2           1.933           1.933           -2.227           -1.290           4.640           -0.067           -0.343	T3           0.697           -0.603           -0.093           T3           1.687           0.273           1.647           0.493           0.493           0.563           0.937	T <sub>0</sub> 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	H T1 -0.297 0.113 0.183 -0.183 -0.703 0.537 0.167 0.430 -0.280 -0.280 -0.150 0.097 -0.113	$\begin{tabular}{ c c c c } \hline $T_2$ \\ \hline $0.040$ \\ $-0.390$ \\ $0.350$ \\ \hline $0.350$ \\ \hline $0.527$ \\ $-0.143$ \\ $-0.383$ \\ $0.293$ \\ $-0.177$ \\ $-0.117$ \\ $-0.173$ \\ $-0.443$ \\ \hline \end{tabular}$	T <sub>3</sub> 0.067           -0.063           -0.003           T4           0.083           0.013           -0.097           1.117           -0.503           -0.613           -0.767           1.263	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri F-167 × Sulltan F-168 × Sonneri F-168 × Sonneri F-168 × Sulltan 1335-2B × Agatti 1335-2B × Sonn 1335-2B × Sulltan	T₀ -0.00 0.03 0.03 eral com es 34 i 34 i i 34 i ti 84 heri an	<b>T</b> <b>67</b> -0.0 <b>33</b> -0.0 <b>33</b> -0.0 <b>33</b> -0.0 <b>33</b> -0.0 <b>35</b> -0.03	$\begin{array}{c} \hline CPP \\ \hline 1 \\ \hline 033 & -( \\ 033 & 0 \\ \hline 033 & 0 \\ \hline 67 & 0 \\ \hline 011 \\ \hline 011 \\ \hline 7 & 0.03 \\ \hline 3 & 0.03 \\ \hline 3 & -0.06 \\ \hline 7 & 0.03 \\ \hline 3 & -0.06 \\ \hline 7 & 0.03 \\ \hline 3 & -0.06 \\ \hline 0 & -0.13 \\ \hline 0 & -0.13 \\ \hline 0 & -0.13 \\ \hline 0 & -0.26 \\ \hline \end{array}$	$\begin{array}{c} \mathbf{T}_2 \\ \hline \mathbf{T}_2 \\ \hline 0.100 \\ \hline 0.000 \\ \hline 0.100 \\ \hline \mathbf{A}) \text{ of test} \\ \hline \mathbf{CPP} \\ \hline \mathbf{T}_2 \\ \hline 3 \\ 0.10 \\ \hline 3 \\ 0.00 \\ \hline 57 \\ -0.1 \\ \hline 3 \\ 0.10 \\ \hline 3 \\ 0.00 \\ \hline 57 \\ -0.1 \\ \hline 3 \\ 0.10 \\ \hline 33 \\ 0.10 \\ \hline 57 \\ -0.1 \\ \hline 57 \\ 57$	T3         0.100           -0.100         0.000           ers grown         0.23           2         T3           00         0.567           00         -0.23           00         -0.33           00         -0.26           00         -0.06           00         -0.33           00         -0.10           00         -0.10           00         -0.10           00         -0.10	To           -0.133           -0.133           0.267           under diffe           7           -0.533           3           -0.533           3           -0.600           7           -0.200           7           0.200           0           0           0           0           0           0           0           0           0           0           0	T1           0.800           -0.400           -0.400           erent heavy           T1           3         0.200           3         -0.600           7         0.400           0.800         -0.400           0.800         -0.400           0.900         -0.400           0.0007         0.400	$\begin{array}{c} \hline GW=100\ G\\ \hline F=\\ \hline \\ 0.733\\ -0.067\\ -0.667\\ \hline \\ \hline$	$\begin{array}{r} \hline {\bf T_3} \\ -0.333 \\ -0.333 \\ 0.667 \\ \hline {\bf atments} (0) \\ \hline {\bf T_3} \\ \hline {\bf 7} & 0.667 \\ \hline {\bf 3} & -0.333 \\ \hline {\bf 7} & -0.333 \\ \hline {\bf 0} & -1.665 \\ 0 & 0.333 \\ \hline {\bf 0} & -1.333 \\ \hline {\bf 7} & 0.667 \\ \hline {\bf 7} & -0.333 \\ \hline {\bf 3} & -0.333 \\ \hline {\bf 5} & -0.333 \\ \hline $	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 5.583 6.613 7 10.170 6 -0.600 6 -9.570 7 -6.780 8 -5.150 8 11.930	leavy meta T1 -0.920 5.850 -4.930 omium (Cr T1 5.987 6.567 -12.553 -7.947 5.283 2.663 -4.430 11.550 -7.120	T2           1.673           4.453           -6.127           ), Lead (Pb)           GYP           2           -3.207           1.463           1.743           -1.057           0.813           0.243           2.360           4.680           -7.040	ion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023 1.537 3.487 -3.507 -7.947 11.453 0.177 0.987 -1.163	T₀ -3.863 -1.733 5.597 ned (Cr + F -1.820 6.500 -4.680 -1.087 -2.767 3.853 1.747 -2.583 0.837	100 G T1 -3.557 0.873 2.683 b). 100 G T1 4.190 0.410 -4.600 1.307 -4.373 3.067 -3.510 2.660 0.850	T2           -0.400           -0.060           0.460           W           T2           1.933           1.933           -2.227           -0.3350           -1.290           4.640           -0.067           -0.343           -1.277	T₃           0.697           -0.603           -0.093           T₃           L.687           1.413           0.273           1.647           0.493           0.563           1.937	T <sub>0</sub> 0.000 0.000 0.000 T <sub>1</sub> 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	H T1 -0.297 0.113 0.183 0.183 -0.703 0.537 0.167 0.430 -0.280 -0.280 -0.280 -0.150 0.097 -0.113 0.017	$\begin{tabular}{ c c c c } \hline $T_2$ \\ \hline $0.040$ \\ $-0.390$ \\ $0.350$ \\ \hline $0.350$ \\ \hline $MCG$ \\ \hline $T_3$ \\ $0.527$ \\ $-0.143$ \\ $-0.383$ \\ $0.293$ \\ $-0.177$ \\ $-0.177$ \\ $-0.117$ \\ $-0.173$ \\ $-0.443$ \\ $0.617$ \\ \hline \end{tabular}$	T3           0.067           -0.063           -0.003           T4           0.083           0.013           -0.097           1.117           -0.503           -0.613           -0.767           1.263           -0.497	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri F-167 × Sulltan F-168 × Agatti 8 F-168 × Sulltan 1335-2B × Agatti 1335-2B × Sonn 1335-2B × Sullta	To -0.06 0.03 0.03 eral com es 34 i 34 i ti 84 heri an 84	<b>T</b> <b>67</b> -0.0 <b>33</b> -0.0 <b>33</b> -0.0 <b>33</b> -0.0 <b>33</b> -0.0 <b>35</b> -0.03 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.040	$\begin{array}{c} \hline CPP \\ \hline r_1 \\ \hline 033 & -(0) \\ \hline 033 & 0 \\ \hline 067 & 0 \\ \hline 011 \\ $	$\begin{array}{c} \mathbf{T}_2 \\ \hline \mathbf{T}_2 \\ \hline 0.100 \\ \hline 0.000 \\ \hline 0.100 \\ \hline \mathbf{A} \ ) of test \\ \hline \mathbf{CPP} \\ \hline \mathbf{T}_2 \\ \hline \mathbf{T}_3 \\ \hline 0_1 \\ \hline 3 \\ 0.00 \\ \hline 57 \\ -0.1 \\ \hline 3 \\ 0.10 \\ \hline 57 \\ 0.11 \\ \hline 3 \\ 0.00 \\ \hline 57 \\ -0.1 \\ \hline 3 \\ 0.11 \\ \hline 3 \\ 0.00 \\ \hline 57 \\ -0.1 \\ \hline 3 \\ 0.11 \\ \hline 3 \\ 0.00 \\ \hline 7 \\ -0.1 \\ \hline 3 \\ 0.10 \\ \hline 3 \\ 0.10 \\ \hline 7 \\ -0.1 \\ \hline 3 \\ 0.10 \\ \hline 7 \\ -0.1 \\ \hline 3 \\ 0.10 \\ \hline 7 \\ -0.1 \\ \hline 3 \\ 0.10 \\ \hline 7 \\ -0.1 \\ \hline 3 \\ 0.10 \\ \hline 7 \\ -0.1 \\ \hline 7 \\ 7 \\ -0.1 \\ \hline 7 \\ 7 \\ -0.1 \\ 7 \\ 7 \\ -0.1 \\ 7 \\ 7 \\ -0.1 \\ 7 \\ \mathbf$	T3         0.100           -0.100         0.000           ers grown         0.000           2         T3           00         0.567           00         -0.233           00         -0.233           00         -0.233           00         -0.236           00         -0.233           00         -0.236           00         -0.233           00         -0.236           00         -0.236           00         -0.206           00         -0.100           00         0.100           00         0.100           00         0.100           00         0.100           00         0.100           00         0.100	To           -0.133           -0.133           0.267           under diffe           7           -0.533           3           1.067           7           -0.200           3           -0.600           0           0.200           0      0	Ti           0.800           -0.400           -0.400           erent heave           T1           3         0.200           3         -0.600           7         0.400           0.3         -0.600           0         0.867           0         -0.933           0         -0.460           0         -0.733           0         -0.267           7         -0.466	$\begin{array}{c} \hline \textbf{GW} = 100 \text{ G} \\ \hline \textbf{F} \\ \hline \textbf{T}_2 \\ 0.733 \\ -0.067 \\ -0.667 \\ \textbf{y metal tree} \\ \hline \textbf{GRPe} \\ \hline \textbf{GRPe} \\ \hline \textbf{C} \\ \textbf{GRPe} \\ \hline \textbf{C} \\ \textbf{O} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ $	$\begin{array}{r} \hline {\bf T_3} \\ \hline -0.333 \\ -0.333 \\ 0.667 \\ \hline {\bf atments} (0 \\ \hline {\bf T_3} \\ 7 \\ 0.667 \\ \hline {\bf atments} (0 \\ -1.667 \\ 0 \\ 0.333 \\ 0 \\ -1.667 \\ 0 \\ 0.333 \\ 0 \\ -1.633 \\ 0 \\ -3.33 \\ 0 \\ -3.33 \\ 0 \\ -3.33 \\ 3 \\ 0.333 \\ 0 \\ -3.33 \\ 0 \\ -3$	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 5.583 0.613 7 10.170 -0.600 -9.570 -6.780 3 -5.150 3 11.930 -8.730	T1           -0.920           5.850           -4.930           comium (Cr           T1           5.987           6.567           -12.553           -7.947           5.283           2.663           -4.430           11.550           -7.120           5.837	Concentrat           T2           1.673           4.453           -6.127           C), Lead (Pb)           GYP           T2           -3.207           1.463           1.743           -1.057           0.813           0.243           2.360           4.680           -7.040           0.293	ion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023 1.537 3.487 -3.507 -7.947 11.453 0.177 0.987 -1.163 6.143	T₀ -3.863 -1.733 5.597 ned (Cr + F T₀ -1.820 6.500 -4.680 -1.087 -2.767 3.853 1.747 -2.583 0.837 1.080	100 G T1 -3.557 0.873 2.683 b). 100 G T1 4.190 0.410 -4.600 1.307 -4.373 3.067 -3.510 2.660 0.850 0.673	Tz           -0.400           -0.060           0.460           Tz           1.933           1.933           1.223           -2.227           -1.290           4.640           -0.067           -0.3350           -1.290           -1.290           -1.343           -0.067           -0.250	T3           0.697           -0.603           -0.093           T3           L.687           1.413           0.273           0.497           0.493           0.563           0.937           1.373           1.530	T <sub>0</sub> 0.000 0.000 0.000 T <sub>1</sub> 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	H           -0.297           0.113           0.183           -0.703           0.537           0.167           0.430           -0.280           -0.150           0.097           -0.113           0.017           0.063	T2           0.040           -0.390           0.350             MCG           T3           0.527           -0.143           -0.383           0.293           -0.117           -0.173           -0.443           0.617           -0.507	T₃           0.067           -0.003	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri F-167 × Sulltan F-168 × Agatti 8 F-168 × Sonneri F-168 × Sulltan 1335-2B × Sulltan 1335-2B × Sonne 1335-2B × Sonne	To -0.06 0.03 0.03 eral com es 34 i 34 i ti 84 heri an 38 eri 84 eri	<b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b>	CPP           033         -(0)           033         0           067         0           011ity (GCA)         0           0111         7           0000         0           0111         7           0111         7           0111         0           01111         0	$\begin{array}{c} \mathbf{T}_2 \\ \hline \mathbf{T}_2 \\ \hline 0.100 \\ \hline 0.000 \\ \hline 0.100 \\ \hline \mathbf{A}) of test \\ \hline \mathbf{CPP} \\ \hline \mathbf{T}_2 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 57$	T3         0.100           -0.100         0.000           ers grown         0.000           2         T3           00         0.567           00         -0.23           00         -0.23           00         -0.26           00         -0.06           00         -0.010           00         -0.100           00         -0.100           00         -0.100           00         -0.100           00         -0.100           00         -0.100           00         -0.100           00         -0.100           00         -0.100           00         -0.100           00         -0.100	To           -0.133           -0.133           0.267           under diffe           7           -0.533           3           -0.600           7           -0.200           7           0.200           0           0           0           0           0           0           0           0           0           0           0           0           0           0           0           0	Ti           0.800           -0.400           -0.400           erent heave           T1           3         0.200           3         -0.600           0         0.867           0         0.400           0         0.867           0         -0.600           0         -0.400           0         -0.633           0         -0.633           0         -0.267           7         -0.466           3         -0.267	$\begin{array}{c} \hline \textbf{GW} = 100 \text{ G} \\ \hline \textbf{F} \\ \hline \textbf{T}_2 \\ 0.733 \\ -0.067 \\ -0.667 \\ \hline \textbf{y metal tree} \\ \hline \textbf{GRPe} \\ \hline \textbf{T}_2 \\ \hline \textbf{0} & -0.066 \\ 0 & 0.733 \\ 0 & -0.666 \\ 7 & -0.40 \\ 7 & -0.60 \\ 3 & 1.000 \\ 7 & -0.66 \\ 7 & -0.40 \\ 7 & -0.63 \\ 7 & -0.33 \\ 7 & -0.73 \\ 7 & 0.066 \end{array}$	$\begin{array}{r} \hline rains weig \\\hline \hline T_3 \\ -0.333 \\ -0.333 \\ 0.667 \\\hline atments (C \\\hline \hline T_3 \\ 7 \\ 0.667 \\\hline \hline 0 \\ 0 \\ 0 \\ 0 \\ 1.333 \\\hline 0 \\ 1.333 \\\hline 0 \\ 0 \\ 1.333 \\\hline 0 \\ 0 \\ 0 \\ 1.333 \\\hline 0 \\ 0 \\ 0 \\ 3 \\ 0 \\ 0 \\ 3 \\ 0 \\ 3 \\ 0 \\ 3 \\ 0 \\ 3 \\ 0 \\ 0$	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 5.583 0.613 7 10.170 -0.600 -9.570 -9.570 -6.780 3 -5.150 3 11.930 -8.730 7 -4.750	T1           -0.920           5.850           -4.930           comium (Cr           T1           5.987           6.567           -12.553           -7.947           5.283           -4.430           11.550           -7.120           5.837           -18.733	T2           1.673           4.453           -6.127 <b>C), Lead (Pb) GYP</b> 1.463           1.743           -1.057           0.813           0.243           2.360           4.680           -7.040           0.293           -10.287	ion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023 1.537 3.487 -3.507 -7.947 11.453 0.177 0.987 -1.163 6.143 1.403	T₀ -3.863 -1.733 5.597 ned (Cr + F T₀ -1.820 6.500 -4.680 -1.087 -2.767 3.853 1.747 -2.583 0.837 1.080 -2.150	100 G T1 -3.557 0.873 2.683 b). 100 G T1 4.190 0.410 -4.600 1.307 -4.373 3.067 -3.510 2.660 0.850 0.673 -0.357	Tz           -0.400           -0.060           0.460           Tz           1.933           1.933           1.293           -2.227           -3.350           -1.290           4.640           10.343           1.277           -0.250           -0.250	T3           0.697           -0.603           -0.093           T3           L.687           1.413           0.273           1.647           0.493           0.563           .937           1.373           1.530	T <sub>0</sub> 0.000 0.000 0.000 T <sub>1</sub> 0.0000 0.0000 0.00000 0.0000 0.0000 0.0000000 0.0000 0.0000 0.00000000	H           -0.297           0.113           0.183           -0.703           0.537           0.167           0.430           -0.280           -0.150           0.097           0.013           0.017           0.063           -0.047	T2           0.040           -0.390           0.350             MCG           T3           0.527           -0.143           -0.383           0.293           -0.117           -0.173           -0.617           -0.507           0.273	T <sub>3</sub> 0.067           -0.003           -0.007           1.117           -0.613           -0.767           1.263           -0.497           0.150           -1.120	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri F-168 × Agatti 8 F-168 × Sulltan T-168 × Sulltan 1335-2B × Sullta 1335-2B × Sullt 2P-735 × Sonne 2P-735 × Sulltan	To -0.06 0.03 0.03 eral com es 34 i 34 i ti 84 heri an 84 eri an 84 eri n	<b>T</b> <b>67</b> -0.0 <b>33</b> -0.0 <b>33</b> -0.0 <b>33</b> -0.0 <b>33</b> -0.0 <b>35</b> -0.03 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.030 -0.040	$\begin{array}{c} \hline CPP \\ \hline r_1 \\ \hline 033 & -(0) \\ \hline 033 & 0 \\ \hline 067 & 0 \\ \hline 011 \\ $	$\begin{array}{c} \mathbf{T}_2 \\ \hline \mathbf{T}_2 \\ \hline 0.100 \\ \hline 0.000 \\ \hline 0.100 \\ \hline \mathbf{A}) of test \\ \hline \mathbf{CPP} \\ \hline \mathbf{T}_2 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 57 & -0.1$	$\begin{array}{c} \hline \textbf{GYP=Grain} \\ \hline \textbf{T}_3 \\ \hline 0.100 \\ -0.100 \\ 0.000 \\ \hline \textbf{ers grown} \\ \hline \textbf{ers grown} \\ \hline \textbf{c}_2 \\ \hline \textbf{T}_3 \\ \hline \textbf{00} \\ 0.561 \\ \hline \textbf{00} \\ -0.23 \\ \hline \textbf{00} \\ -0.10 \\ \hline \textbf{00} \\ 0.000 \\ \hline \textbf{00} \hline \textbf{00} \\ \hline \textbf{00} \hline \hline \textbf{0} \hline \hline \textbf{0} \hline \hline \textbf{0} \hline \textbf{0} \hline \hline \textbf{0} \hline \hline \textbf{0} \hline \textbf{0} \hline \textbf{0} \hline \hline \hline \hline \hline \hline \textbf{0} \hline \hline \hline \hline \hline \hline \hline \hline \textbf{0} \hline $	To           -0.133           -0.133           0.267           under diffe           7           -0.533           3           -0.673           3           -0.600           7           0.200           7           0.800           0           0           0           0           0           0           0           0           0           0           0           0           0           0	Ti           0.800           -0.400           -0.400           erent heave           T1           3         0.200           3         -0.600           7         0.400           0.800         -0.600           0         0.867           0         0.067           0         -0.460           0         -0.733           0         -0.267           7         -0.466           3         -0.267           7         -0.466           3         -0.267	$\begin{array}{c} \hline \textbf{GW} = 100 \text{ G} \\ \hline \textbf{F} \\ \hline \textbf{T}_2 \\ 0.733 \\ -0.067 \\ -0.667 \\ \hline \textbf{y metal tree} \\ \hline \textbf{GRPe} \\ \hline \textbf{T}_2 \\ \hline \textbf{y metal tree} \\ \hline \textbf{GRPe} \\ \hline \textbf{0} \\ 0.733 \\ 0 \\ -0.066 \\ 7 \\ -0.40 \\ 7 \\ -0.60 \\ 3 \\ 1.000 \\ 7 \\ -0.63 \\ 7 \\ -0.73 \\ 7 \\ 0.266 \\ 7 \\ -0.73 \\ 7 \\ 0.266 \\ 7 \\ -0.73 \\ 7 \\ 0.066 \\ 8 \\ 0.666 \end{array}$	$\begin{array}{r} \hline rains weig \\\hline \hline T_3 \\ -0.333 \\ -0.333 \\ 0.667 \\\hline atments (C \\\hline \hline T_3 \\ 7 \\ 0.667 \\\hline \hline 0 \\ -0.333 \\\hline 7 \\ -0.333 \\\hline 0 \\ -1.667 \\\hline 0 \\ 0 \\ 0 \\ -3.33 \\\hline 0 \\ -0.333 \\\hline 7 \\ -0.333 \\\hline 3 \\ -0.333 \\\hline 7 \\ -0.667 \\\hline 7 \\ -0.333 \\\hline 7 \\ -0.667 \\\hline 7 \\ -0.333 \\\hline 7 \\ -0.667 \\\hline 7 \\ 0 \\ -0.333 \\\hline 7 \\ -0.667 \\\hline 7 \\ 0 \\ -0.333 \\\hline 7 \\ -0.667 \\\hline 7 \\ 0 \\ -0.333 \\\hline 7 \\ -0.667 \\\hline 7 \\ 0 \\ -0.333 \\\hline 7 \\ -0.667 \\\hline 7 \\ 0 \\ -0.333 \\\hline 7 \\ -0.667 \\\hline 7 \\ -0.567 \\\hline 7 \\ -0.575 \\\hline 7 \\ -0$	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 5.583 0.613 7 10.170 -0.600 -9.570 -6.780 3 -5.150 3 11.930 -8.730 7 -4.750 3 13.480	T1           -0.920           5.850           -4.930           comium (Cr           T1           5.987           6.567           -12.553           -7.947           5.283           2.663           -4.430           11.550           -7.120           5.837	Concentrat           T2           1.673           4.453           -6.127           C), Lead (Pb)           GYP           T2           -3.207           1.463           1.743           -1.057           0.813           0.243           2.360           4.680           -7.040           0.293	ion in grain T <sub>3</sub> 2.607 0.997 -3.603 and combi T <sub>3</sub> -5.023 1.537 3.487 -3.507 -7.947 11.453 0.177 0.987 -1.163 6.143	T₀ -3.863 -1.733 5.597 ned (Cr + F T₀ -1.820 6.500 -4.680 -1.087 -2.767 3.853 1.747 -2.583 0.837 1.080	100 G T1 -3.557 0.873 2.683 b). 100 G T1 4.190 0.410 -4.600 1.307 -4.373 3.067 -3.510 2.660 0.850 0.673	$\begin{array}{c c} \hline \mathbf{W} \\ \hline \mathbf{T}_2 \\ \hline -0.400 \\ -0.060 \\ 0.460 \\ \hline \hline \\ \hline \\ \mathbf{W} \\ \hline \\ \hline \\ \mathbf{T}_2 \\ \hline \\ 1.933 \\ 1 \\ 0.293 \\ -1 \\ -2.227 \\ -(1.3350 \\ -3.350 \\ -1 \\ -3.350 \\ -1 \\ -1.290 \\ -8 \\ 4.640 \\ 10 \\ -0.067 \\ -0.067 \\ -0.067 \\ -0.067 \\ -0.0250 \\ -1 \\ -0.250 \\ -1 \\ -0.040 \\ 7 \\ 0.290 \\ -5 \\ \hline \end{array}$	T3           0.697           -0.603           -0.093           T3           L.687           1.413           0.273           1.647           0.493           0.563           1.937           1.373           0.530           0.5490	T <sub>0</sub> 0.000 0.000 0.000 T <sub>1</sub> 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	H           -0.297           0.113           0.183           -0.703           0.537           0.167           0.430           -0.280           -0.150           0.097           -0.113           0.017           0.063	T2           0.040           -0.390           0.350             MCG           T3           0.527           -0.143           -0.383           0.293           -0.117           -0.173           -0.443           0.617           -0.507	T₃           0.067           -0.003	
Testers Agatti 84 Sonneri Sulltan Table 6. Gene Crosse F-167 × Agatti 8 F-167 × Sonneri F-167 × Sulltan F-168 × Agatti 8 F-168 × Sonneri F-168 × Sulltan 1335-2B × Sulltan 1335-2B × Sonne 1335-2B × Sonne	To -0.06 0.03 0.03 eral com es 34 i 34 i ti 84 heri an 84 eri an 84 eri n ti 84	<b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b>	$\begin{array}{c} \hline CPP \\ \hline r_1 \\ \hline 033 & -(0) \\ \hline 033 & 0 \\ \hline 067 & 0 \\ \hline 011 \\ $	$\begin{array}{c} \mathbf{T}_2 \\ \hline \mathbf{T}_2 \\ \hline 0.100 \\ \hline 0.000 \\ \hline 0.100 \\ \hline \mathbf{A}) of test \\ \hline \mathbf{CPP} \\ \hline \mathbf{T}_2 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.10 \\ \hline 3 & 0.11 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.11 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.14 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.04 \\ \hline 3 & -0.4 \\ \hline 3 & $	$\begin{array}{c} \hline \textbf{GYP=Grain} \\ \hline \textbf{T}_3 \\ \hline 0.100 \\ -0.100 \\ 0.000 \\ \hline \textbf{ers grown} \\ \hline \textbf{ers grown} \\ \hline \textbf{c}_2 \\ \hline \textbf{T}_3 \\ \hline \textbf{00} \\ 0.561 \\ \hline \textbf{00} \\ -0.23 \\ \hline \textbf{00} \\ -0.10 \\ \hline \textbf{00} \\ 0.000 \\ \hline \textbf{00} \\ 0.000 \\ \hline \textbf{00} \\ 0.000 \\ \hline \textbf{00} \\ -0.10 \\ \hline \textbf{00} \\ 0.000 \\ \hline \textbf{00} \\ -0.10 \\ \hline \textbf{00} \\ 0.000 \\ \hline \textbf{00} \\ -0.10 \\ \hline \textbf{00} \hline \textbf{00} \hline \textbf{00} \hline \textbf{00} \hline \hline \textbf{00} \hline \textbf{00} \hline \hline \textbf{00} \hline \textbf{00} \hline \textbf{00} \hline \textbf{00} \hline \textbf{00} \hline \textbf{00} \hline \hline \textbf{00} \hline \textbf{0} \hline \textbf$	To           -0.133           -0.133           0.267           under diffe           7           -0.533           3           -0.600           7           -0.800           3           -0.600           0<	$\begin{array}{c} \mbox{plant, 1000} \\ \hline \mbox{GRI} \\ \hline \mbox{GRI} \\ \hline \mbox{I} \hline \hline \mbox{I} \\ \hline \mbox{I} \hline \hline \mbox{I} \hline$	$\begin{array}{c} \mathbf{GW} = \ 100 \ \mathbf{G} \\ \mathbf{F} \\ \hline \mathbf{T}_2 \\ 0.733 \\ -0.067 \\ -0.667 \\ \mathbf{y} \ \mathbf{metal tree} \\ \mathbf{GRPe} \\ \hline \mathbf{T}_2 \\ 0 & -0.066 \\ 0 & 0.733 \\ 0 & -0.66 \\ 7 & -0.40 \\ 7 & -0.60 \\ 3 & 1.000 \\ 7 & -0.60 \\ 3 & 1.000 \\ 7 & -0.63 \\ 7 & -0.33 \\ 7 & -0.73 \\ 7 & 0.066 \\ 3 & 0.066 \\ 3 & 0.933 \end{array}$	$\begin{array}{r} \hline rains weig \\\hline \hline T_3 \\ -0.333 \\ -0.333 \\ 0.667 \\\hline \hline atments (0 \\\hline \hline T_3 \\ 7 \\ 0.667 \\\hline \hline atments (0 \\\hline 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1.333 \\\hline 7 \\ 0.667 \\\hline 0 \\ 0 \\ 0 \\ 0 \\ 3 \\ 0 \\ 0 \\ 1.333 \\\hline 0 \\ 0 \\ 0 \\ 0 \\ 3 \\ 0 \\ 0 \\ 3 \\ 0 \\ 3 \\ 0 \\ 3 \\ 0 \\ 3 \\ 0 \\ 0$	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 5.583 0.613 7 10.170 -0.600 -9.570 -6.780 3 -5.150 3 11.930 -8.730 7 -4.750 13.480 0 11.537	leavy meta GY T1 -0.920 5.850 -4.930 comium (Cr T1 5.987 6.567 -12.553 -7.947 5.283 2.663 -4.430 11.550 -7.120 5.837 -18.733 12.897	Concentrat           T2           1.673           4.453           -6.127           C), Lead (Pb)           GYP           2           -3.207           1.463           1.743           -1.057           0.813           0.243           2.360           4.680           -7.040           0.293           -10.287           9.993	$\begin{array}{r} \hline \mbox{in grain} \\ \hline \mbox{T}_3 \\ \hline \mbox{2.607} \\ 0.997 \\ -3.603 \\ \hline \mbox{and combi} \\ \hline and combi$	T₀ -3.863 -1.733 5.597 ned (Cr + F T₀ -1.820 6.500 -4.680 -1.087 -2.767 3.853 1.747 -2.583 0.837 1.080 -2.150 1.070	100 G T1 -3.557 0.873 2.683 b). 100 G T1 4.190 0.410 -4.600 1.307 -4.373 3.067 -3.510 2.660 0.850 0.673 -0.357 -0.317	T2           -0.400           -0.060           0.460           T2           1.933           1.933           0.293           -2.227           -0.3350           -1.290           4.640           10.067           -0.0667           -0.250           -0.250           -0.250           -1.277           1.343           1.733	$\begin{array}{c c} \mathbf{T}_{3} \\ \hline 0.697 \\ -0.603 \\ -0.093 \\ \hline \end{array}$	T₀           0.000           0.000           0.000           0.000           T₁           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000	H           -0.297           0.113           0.183           -0.703           0.537           0.167           0.430           -0.280           -0.150           0.097           -0.113           0.017           0.063           -0.047	T2           0.040           -0.390           0.350             MCG           T3           0.527           -0.143           -0.383           0.293           -0.117           -0.173           -0.443           0.617           -0.507           0.273           0.233	T <sub>3</sub> 0.067           -0.003           -0.007           1.117           -0.003           -0.007           1.263           -0.497           0.150           -1.120           0.970	
TestersAgatti 84SonneriSulltanTable 6. GeneCrosseF-167 × Agatti 8F-167 × SulltanF-168 × Agatti 8F-168 × Sulltan1335-28 × Agatti1335-28 × Sulltan1335-28 × Sulltan1335-28 × Sulltan2P-735 × Agatti2P-735 × SulltanK54TMS × Agatti	To -0.06 0.03 0.03 eral com es 34 i 34 i i 34 i i 34 i i 84 eri an 84 eri an ti 84 heri an ti 84 heri an ti 84 heri	T           67         -0.0           33         -0.0           33         0.0           abining al           To           0.067           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.030           0.067           -0.300           0.0675           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.033           -0.100	$\begin{array}{c} \hline CPP \\ \hline r_1 \\ \hline 033 & -(0) \\ \hline 033 & 0 \\ \hline 067 & 0 \\ \hline 011 \\ $	$\begin{array}{c} \mathbf{T}_2 \\ \hline \mathbf{T}_2 \\ \hline 0.100 \\ 0.000 \\ 0.100 \\ \hline \mathbf{A} \ of test \\ \hline \mathbf{CPP} \\ \hline \mathbf{T}_2 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.10 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 3 & 0.00 \\ \hline 57 & -0.1 \\ \hline 50 & 0.00 \\ $	$\begin{array}{c} \hline \text{GYP= Grain} \\ \hline \textbf{T}_3 \\ \hline 0.100 \\ -0.100 \\ 0.000 \\ \hline \textbf{ers grown} \\ \hline \textbf{ers grown} \\ \hline \textbf{z} \\ \hline \textbf{T}_3 \\ \hline \textbf{00} \\ 0.561 \\ \hline \textbf{00} \\ -0.23 \\ \hline \textbf{00} \\ -0.10 \\ \hline \textbf{00} \\ 0.000 \\ \hline \textbf{00} \\ 0.000 \\ \hline \textbf{00} \\ 0.000 \\ \hline \textbf{00} \\ -0.10 \\ \hline \textbf{00} \\ 0.000 \\ \hline \textbf{00} \\ -0.10 \\ \hline \textbf{00} \\ 0.000 \\ \hline \textbf{00} \\ -0.10 \\ \hline \textbf{00} \\ 0.100 \\ \hline \textbf{00} \\ \hline \textbf{00} \\ 0.100 \\ \hline \textbf{00} \\ \hline \textbf{00} \\ \hline \textbf{00} \\ 0.100 \\ \hline \textbf{00} \hline \textbf{00} \hline \hline \textbf{00} \\ \hline \textbf{00} \hline \textbf{00} \hline \hline \textbf{00} \hline \hline \textbf{00} \hline \hline \textbf{00} \hline \hline \textbf{00} \hline \hline \textbf{00} \hline \textbf{00} \hline \hline \textbf{0} \hline \textbf{0} \hline \hline \textbf{0} \hline \hline \hline \textbf{0} \hline \hline \hline \textbf{0} \hline \hline \hline \hline \hline \textbf{0} \hline \hline \hline \textbf{0} \hline \hline \hline \hline \hline $	To           -0.133           -0.133           -0.133           0.267           under diffe           7           -0.533           3           -0.600           7           -0.800           3           -0.600           0           0.2000           0           0.2000           0           0.2000           0	Ti           0.800           -0.400           -0.400           erent heavy           T1           3         0.200           3         -0.600           7         0.400           0.3         -0.600           7         0.400           0         0.867           0         0.067           0         -0.466           0         -0.733           0         -0.266           7         -0.466           3         -0.266           7         -0.463           3         -0.263           7         -0.463           3         -0.263           7         -0.433	$\begin{array}{c} \hline \textbf{GW} = 100 \text{ G} \\ \hline \textbf{GW} = 100 \text{ G} \\ \hline \textbf{F} \\ \hline \textbf{C} \\ \hline \textbf{C} \\ 0.733 \\ -0.067 \\ -0.667 \\ \hline \textbf{y metal tree} \\ \hline \textbf{GRPe} \\ \hline \textbf{GRPe} \\ \hline \textbf{C} \\ \textbf{GRPe} \\ \hline \textbf{C} \\ \textbf{O} \\ 0.733 \\ 0.066 \\ 70.40 \\ 70.60 \\ 3. 1.000 \\ 70.66 \\ 3. 0.066 \\ 3. 0.933 \\ 70.26 \\ 3. 0.933 \\ 70.26 \\ \hline \textbf{G} \\ \textbf{O} \\ O$	$\begin{array}{r} \hline rains weig \\\hline \hline T_3 \\ -0.333 \\ -0.333 \\ 0.667 \\\hline \hline atments (C \\\hline \hline T_3 \\ 7 \\ 0.667 \\\hline \hline atments (C \\\hline 0 \\ -1.667 \\\hline 0 \\ 0 \\ -1.667 \\\hline 0 \\ 0 \\ -1.667 \\\hline 0 \\ 0 \\ -1.333 \\\hline 0 \\ -0.333 \\\hline 0 \\ -0.667 \\\hline 0 \\ -0.667 \\\hline 0 \\ -0.67 \\$	ht, HMC= H To -1.953 -2.433 4.387 Control, Chr To -6.197 3 5.583 3 0.613 7 10.170 5 -0.600 5 -9.570 7 -0.600 5 -9.570 7 -6.780 3 -5.150 3 11.930 5 -8.730 7 -4.750 5 13.480 9 11.537 9 4.917	leavy meta GY T1 -0.920 5.850 -4.930 comium (Cr T1 5.987 6.567 -12.553 -7.947 5.283 2.663 -4.430 11.550 -7.120 5.837 -18.733 12.897 0.553	Concentrat           T2           1.673           4.453           -6.127           C), Lead (Pb)           GYP           T2           -3.207           1.463           1.743           -1.057           0.813           0.243           2.360           4.680           -7.040           0.293           -10.287           9.993           1.610	T <sub>3</sub> 2.607           0.997           -3.603           and combin           T <sub>3</sub> -5.023           1.537           3.487           -3.507           -7.947           11.453           0.177           0.987           -1.163           6.143           1.403           -7.547           2.210	T₀           -3.863           -1.733           5.597           ned (Cr + F           -1.820           6.500           -4.680           -1.087           -2.767           3.853           1.747           -2.583           0.837           1.080           -2.150           1.070           0.080	100 G T <sub>1</sub> -3.557 0.873 2.683 b). 100 G T <sub>1</sub> 4.190 0.410 -4.600 1.307 -4.373 3.067 -3.510 2.660 0.850 0.673 -0.357 -0.317 -2.660	T2           -0.400           -0.060           0.460           T2           1.933           1.933           0.293           -2.227           -0.3350           -1.290           4.640           10.067           -0.067           -0.250           -0.250           -0.250           -0.290           -5           1.733           -0.307	T3           0.697           -0.603           -0.093           T3           L687           1.413           0.273           1.647           0.563           0.563           1.373           1.530           7.020           2.053           1.303	T₀           0.000           0.000           0.000           0.000           T₁           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000	H           -0.297           0.113           0.183           -0.703           0.537           0.167           0.430           -0.280           -0.150           0.097           -0.113           0.017           0.063           -0.047           -0.113	$\begin{tabular}{ c c c c } \hline $\mathbf{T}_2$ \\ \hline $0.040$ \\ $-0.390$ \\ \hline $0.350$ \\ \hline $\mathbf{MCG}$ \\ \hline $\mathbf{T}_3$ \\ \hline $0.527$ \\ $-0.143$ \\ $-0.383$ \\ $0.293$ \\ $-0.177$ \\ $-0.173$ \\ $-0.443$ \\ $0.617$ \\ $-0.507$ \\ $0.273$ \\ $0.233$ \\ $-0.140$ \\ \hline \end{tabular}$	T₃           0.067           -0.063           -0.003           T4           0.083           0.013           -0.097           1.117           -0.503           -0.613           -0.767           1.263           -0.497           0.150           -1.120           0.970           -0.583	

Table 7. Specific combining ability of yield and yield related parameters grown under different heavy metal treatments (Control, Chromium (Cr), Lead (Pb) and Combined (Cr + Pb).

(T<sub>0</sub>= Control, T<sub>1</sub>= 5 mM Chromium chloride, T<sub>2</sub>= 5 mM Lead chloride, T<sub>3</sub>= Chromium chloride + Lead chloride 2.5 mM of each) CPP=Cobs per plant, GRPE=Grain rows per ear, GYP= Grain yield per plant, 100GW= 100 Grains weight, HMC= Heavy metal concentration in grain

Heavy metals concentration in grain: For all of the treatments (Chromium, Lead, and Chromium+Lead), the ANOVA was very significant for treatment, parents, crosses, parents versus crosses, lines, tester, and line×tester interaction (table 4). The highest general combining abilities (GCA) values were recorded for 2P-735 (0.24), K54TMS (0.21), and F-168 (1.05), whereas lowest GCA values were found for F-167 (-0.38), F-168 (-0.12), and K54TMS (-0.84) when exposed to chromium, lead, and combination treatment (Cr + Pb). The Sulltan (0.18), Sulltan (0.35), and Agatti 84 (0.06) were found to have the highest general combining ability values, whereas Agatti 84 (-0.29), Sonneri (-0.39), and Sonneri (-0.06) showed the lowest values for chromium, lead, and combination treatment (Cr+Pb) respectively (tables 5 & 6). Based on these findings, it can be hypothesized that genotypes (K54TMS, 2P-735, and F-168) with high GCA values can be utilized to create synthetic varieties with high yields due to the existence of additive gene activity. The SCA was found to be greatest for F-167 × Sonneri (0.53), 1335-2B×Sulltan (0.61) and 1335-2B×Sonneri (1.26), while, F-167×Agatti 84 (-0.70), 2P-735×Agatti 84 (-0.50), and 2P-735×Sonneri (-1.12) showed the lowest specific combining ability (SCA) values under chromium, lead, and combined treatment (Cr+Pb), respectively (table 7). We may infer from these findings that the crosses (1335-2B×Sulltan, F-167×Sonneri, and 1335-2B×Sonneri) that exhibited the greatest SCA value can be utilized to create hybrids with the required features. The genotypes (Sulltan and K54TMS×Agatti 84) that take up heavy metals at the lowest concentrations can be suggested for commercial growth and employed in the future breeding program. Ghani, (2010), Mukhtar et al. (2010) and Avesha Oaisar et al. (2014) all provided support for these findings. **CONCLUSIONS** In conclusion, the genotype Sulltan and hybrid (K54TMS × Agatti 84) were found to only absorb a minimal quantity of the metals (Cr and Pb) both separately and in combination. This suggests that they should be used in breeding programs going forward to increase the genotypes' resistance to heavy metal absorption. Also, the genotypes with high GCA values can be utilized to create synthetic varieties with high yields due to the existence of additive gene activity whereas the crosses which shown highest SCA value can be used for future breeding program for the development of hybrids for desired traits.

**CONFLICT OF INTEREST:** All the authors mentioned in this paper declared that they have no conflict of interest regarding this paper. **ACKNOWLEDGEMENT:** This study was carried out in the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan.

- **REFERENCES:** Ali, S., P. Bai, F. Zeng, S. Cai, I. H. Shamsi, B. Qiu, F. Wu and G. Zhang, 2011. The ecotoxicological and interactive effects of chromium and aluminum on growth, oxidative damage and antioxidant enzymes on two barley genotypes differing in al tolerance. Environmental experimental botany, 70(2-3): 185-191.
- Aliu, S., B. Gashi, I. Rusinovci, S. Fetahu and R. Vataj, 2013. Effects of some heavy metals in some morpho-physiological parameters in maize seedlings. American journal of biochemistry biotechnology, 9(1): 27.
- Atta, M. I., A. B. Gulshan, A. Nazir and S. Sadia, 2014. Toxicological study of heavy metals on early growth responses of sunflower (*Helianthus annuus* L.). Journal of agricultural biological science, 9(2): 46-50.
- Ayesha Qaisar, A. Q., S. I. Sumera Iqbal, K. J. Khajista Jabeen and S. L. Saba Latif, 2014. Response of maize to hydrogen peroxide priming under chromium stress. Mycopath. 12(2): 123-127.
- Datta, J., A. Bandhyopadhyay and A. Banerjee, 2011. Phytotoxic effect of chromium on the germination, seedling growth of some wheat (*Triticum aestivum* L.) cultivars under laboratory condition. Journal of agricultural technology, 7(2): 395-402.
- Dawod, K. M., M. A. H. Al-Falahy and A.-S. A. Mohammad, 2012. Genetic variations and gene effect controlling grain yield and some of its components in maize. Journal of agricultural science technology. B 2(7B): 814.
- Ghani, A., 2010. Toxic effects of heavy metals on plant growth and metal accumulation in maize (*Zea mays* L.). Iranian journal of toxicology. 3: 325-334.

- GOP, 2023. Economic survey of pakistan, ministry of finance, government of pakistan. Economic Advisors Wing, Islamabad.
- Haddadi, M. H., M. Eesmaeilof, R. Choukan and V. Rameeh, 2012. Combining ability analysis of days to silking, plant height, yield components and kernel yield in maize breeding lines. African journal of agricultural research, 7(36): 5153-5159.
- Hussain, A., N. Abbas, F. Arshad, M. Akram, Z. I. Khan, K. Ahmad, M. Mansha and F. Mirzaei, 2013. Effects of diverse doses of lead (pb) on different growth attributes of *Zea mays* L. Agricultural sciences, 5: 262-265.
- Hussain, F., S. A. Malik, M. Athar, N. Bashir, U. Younis, M. Hassan and B. Mahmood, 2010. Effect of tannery effluents on seed germination and growth of two sunflower cultivars. African journal of biotechnology, 9(32): 5113-5120.
- John, R., P. Ahmad, K. Gadgil and S. Sharma, 2009. Heavy metal toxicity: Effect on plant growth, biochemical parameters and metal accumulation by *Brassica juncea* L. International journal of plant production, 3:65-76.
- Kanagarasu, S., G. Nallathambi and K. J. Ganesan, 2010. Combining ability analysis for yield and its component traits in maize (*Zea mays* L.). Electronic journal of plant breeding, 1(4): 915-920.
- Kempthorne, O., 1957. An introduction to genetic statistics. Journal of phytoremediation.
- Liang ChangCong, L. C., L. T. Li Tao, X. Y. Xiao YanPing, L. M. Liu MaoJun, Z. H. Zhang HanBo and Z. Z. Zhao ZhiWei, 2009. Effects of inoculation with arbuscular mycorrhizal fungi on maize grown in multi-metal contaminated soils. Journal of phytoremediation, 11(8), 692-703.
- Mahmood, T., K. Islam and S. J. Muhammad, 2007. Toxic effects of heavy metals on early growth and tolerance of cereal crops. Pakistan journal of botany, 39(2): 451.
- Malik, R. N., S. Z. Husain and I. J. Nazir, 2010. Heavy metal contamination and accumulation in soil and wild plant species from industrial area of Islamabad, Pakistan. Pakistan journal of botany, 42(1): 291-301.
- Mapanda, F., E. Mangwayana, J. Nyamangara, K. J. A. Giller, Ecosystems and Environment, 2005. The effect of long-term irrigation using wastewater on heavy metal contents of soils under vegetables in harare, zimbabwe. Agriculture, ecosystems & environment, 107(2-3): 151-165.
- Martin, S. and W. Griswold, 2009. Human health effects of heavy metals. Environmental science technology briefs for citizens, 15(5).
- Mukhtar, S., H. N. Bhatti, M. Khalid, M. A. U. Haq and S. M. Shahzad, 2010. Potential of sunflower (*Helianthus annuus* L.) for phytoremediation of nickel (ni) and lead (pb) contaminated water. Pakistan journal of botany, 42(6): 4017-4026.
- Pavan, R., H. Lohithaswa, M. Wali, G. Prakash and B. Shekara, 2011. Correlation and path coefficient analysis of grain yield and yield contributing traits in single cross hybrids of maize (*Zea mays* L.). Electronic journal of plant breeding, 2(2): 253-257.
- Sengar, R. S., M. Gautam, S. K. Garg, R. Chaudhary and K. J. R. j. o. p. Sengar, 2008. Effect of lead on seed germination, seedling growth, chlorophyll content and nitrate reductase activity in mung bean (*Vigna radiata*). Research journal of phytochemistry, 2: 61-68.
- Shanker, A. K., C. Cervantes and H. Loza-Tavera, 2005. Chromium toxicity in plants. Environment international, 31(5): 739-753.
- Singh, S., P. K. Srivastava, D. Kumar, D. K. Tripathi, D. K. Chauhan and S. M. Prasad, 2015. Morpho-anatomical and biochemical adapting strategies of maize (*Zea mays* L.) seedlings against lead and chromium stresses. Biocatalysis agricultural biotechnology, 4(3): 286-295.
- Steel, R. D., J. P. Torrie. Statistics. 1960. Principles and procedures of statistics. A biometrical approach (3rd Ed.).
- Zare, M., R. Choukan, M. Bihamta, H. E. MAJIDI and M. Kamelmanesh, 2011. Gene action for some agronomic traits in maize (*Zea mays* L.). Crop breeding journal, 42(2), 279-285.
- Zou, J., K. Yu, Z. Zhang, W. Jiang and D. Liu, 2009. Antioxidant response system and chlorophyll fluorescence in chromium (vi)treated zea mays l. Seedlings. Acta Biologica Cracoviensia Series Botanica, 51(1): 23-33.

Except where otherwise noted, this item's licence is described as © **The Author(s) 2024**. Open Access. This item is licensed under a <u>Creative Commons Attribution 4.0 International License</u>, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the <u>Creative Commons license</u>, and indicate if changes were made. The images or other third party material in this it are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.