



DIALLEL ANALYSIS OF RESISTANCE TO FUSARIUM EAR ROT (*Fusarium verticillioides*) IN MAIZE (*Zea mays* L.)

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ABSTRACT

The experiment was conducted during the dry season of 2018 at Lushi irrigation station Bauchi and was evaluated at Bauchi and Yola during the rainy season of 2019 to determine the diallel analysis of resistance to fusarium ear rot in maize. Six maize inbred lines resistant to the disease and a farmers' variety (local variety) X- lawanti susceptible to fusarium ear rot were crossed. A nursery trial for the formation of an initial F_1 breeding population using full diallel mating design was carried out at Lushi Irrigation Station Bauchi. Six parents and their resultant 36 F_1 were evaluated in a Randomized Complete Block Design (RCBD) with three replications at Bauchi and Yola. The results of the study revealed a Significant difference among the genotypes studied. The combining ability analysis revealed significant difference in all the traits except number of leaves per plant, cob length, number of husks and silks per ear, DS 4%, DS 5% and hundred grain weight. The findings also indicated that both additive and non-additive gene actions in maize were important in controlling grain yield and other agronomic traits. For most traits genotypes SMLW 28X SMLW 183, SMLW 51 X LV and LV X SMLW 28 been identified as good general combiners while SMLW 28 X SMLW 20 AND SMLW 183 X LV was identified as good specific general combiners for kernel yield. Parents SMLW 51, SMLW 21, SMLW 58 and SMLW 183 were found to be resistant to fusarium ear rot across locations for all traits except number of leaves per plant, number of silks per ear DS 0%, DS2% and 100 grain weight.

Keywords: Additive, Action, Gene, Inbreed and Lines

INTRODUCTION

Maize (*Zea mays*, L.) is a significant cereal crop due to its high yield, ease of processing, ease of digestion and lower cost than other cereals (Jaliya *et al.*, 2008). In Nigeria, maize is a staple food crop of great socio-economic importance. In Nigeria, the demand for maize is increasing at a faster rate on daily basis due to the fact that grain is being used for feeding poultry and also serve as the main food for many house hold (Oguniyi, 2011). In addition to calories, maize is a source of micro nutrients and phytochemicals, such as anthocyanins, carotenoids phenolics, as well as dietary fiber, and these are vital for disease prevention Ekpa, *et al.* (2019) that reside both in urban and several locations in Sub-Saharan Africa. Maize is essentially regarded as an important feed and feed crop as it provides energy and protein for both human and livestock (Diallo *et al.*, 2001; Ngaboyisonga *et al.*, 2008). Maize is a vital cereal crop for global food security as its importance is seen in the wide economic uses ranging from direct human consumption to processing into other food materials, animal feeds, and industrial products. It is ranked first among the cereals with annual global production of one billion metric tones (FAOSTAT, 2014). Because of its very wide utilization, the main goal of all maize breeding programmes is to obtain new inbred and hybrids that will outperform existing hybrids



with respect to a number of traits. In working towards this goal, particular attention is paid to grain yield as the most important agronomic characteristics (Zorana *et al.*, 2010).

The diallel mating scheme is probably the most frequently used mating design in plant research and is an excellent scheme to determine how parents perform in crosses. Diallel mating design is used to evaluate several inbred lines in terms of combining ability variances and effects. (Madhu *et al.*, 2017). As a result, there is an urgent need to increase maize crop productivity through breeding in order to stabilize grain yield and meet Nigeria's increasing demand for food and feed. Increasing maize production can be accomplished through the use of improved agronomic techniques as well as the development and adoption of superior yielding varieties. The maize breeding programme places a strong emphasis on the development of improved varieties with superior qualitative and quantitative traits, as well as resistance to biotic and abiotic stresses, for commercial use to meet the growing demand for human food and animal feed. The information about the genetic structure and combining ability of parents is one of the most important criteria for identifying high yielding hybrids (Begna, 2021).

However, to breed high yielding varieties, breeders often face difficulties in selecting parents and crosses. In this context, the diallel analysis method introduced by Schimit in 1919 and developed by Jinks and Hayman in 1954 and also Griffing 1956 was used to obtain information on the nature of combining abilities of genotypes and their behavior and performance in a hybrid combination. This study was carried out to determine the resistance of maize inbred lines and hybrids for yield and yield determining traits to ear rot so as to ascertain their possible value in current and future maize improvement programmes. It was also to determine the combining ability variances and estimate the general combining ability effects of parents and specific combining ability effects of crosses for grain yield and other yield traits and also to compare yield performance of crosses and their reciprocal for grain yield and its other related traits.

MATERIALS AND METHODS

The formation of initial breeding population through a diallel mating design was conducted in 2018 dry season at Lushi Irrigation Station, Bauchi, Nigeria. Lushi is located on Latitude 10° 17' N; 9° 49' E at an altitude of 690.2 m above sea level. In 2019 rainy season, 36 F₁ genotypes were evaluated in two locations viz Bauchi and Yola. The experiments were conducted at Abubakar Tafawa Balewa University Bauchi Research Farm Bauchi State Nigeria and Modibbo Adama University Research Farm Yola, Adamawa State, Nigeria. The total of five inbred lines and a local variety were used for the study. The inbred lines were obtained from the institute for Agricultural research (IAR), Ahmadu Bello University Zaria, while the local variety X-Lawanti was obtained through Bauchi State Agricultural Development Program (BSADP).

The inbred line SMLW 20, was early maturity and resistant to Fusarium ear rot, SMLW 26 was characterized as high yielding, resistant and early maturity, SMLW 51 was late maturity and resistant while SMLW 183 have good grain quality, resistant and late maturity also SMLW 28 have good quality seed, resistant to fusarium ear rot and early maturity, the local variety was very susceptible to fusarium and late maturity. The inbred lines were sown at 3m x 2m on 6 rows plots with a spacing of 0.5m x 0.5m between and within rows respectively at Lushi in January 2018. The male was sown on the outer row with the female intended crops occupying the inner rows. Prior to sowing, land preparation was done manually and later ploughed before field layout. The late maturing inbred lines were sown early with interval of eleven days before the early maturing inbred lines were sown to observe stagger planting as the inbred lines have



different maturity period or flowering period. The sowing was done with good spacing to allow proper observation and ease hand pollination. Manual weeding was carried out at three weeks' interval and as the need may be. The crosses or hybrids were obtained from crossing the male and female parents in all possible direction at the emergence of the silks and ears, the ear were covered with the shoot bags to prevent contamination by foreign pollen grains, long observed silks were cut off to allow easy access to pollen grains by the silks. The shoot bags were folded tightly to avoid accessing any pollen grains and stapled. Blooming of the inflorescence started at the tassel near the tip of the central axis and it produced down wards. Before putting the tassel bag on the tassel, one of the leaves at the top were removed to allow the bags fit more easily, it was done with extra care as the top of the maize inbred lines were fragile and easy to damage. Immediately after the silk emergence, the stigma was receptive and pollens were collected from a particular plant tassel that was covered a day before with a tassel bag by bending the stem of the plant with covered tassel and gently tapped the envelope as pollens dropped in the envelopes. The envelopes were gently removed in an erect position to prevent pollens from falling down. The envelopes containing the pollens were dusted on the silk (receptive silks) after removing the shoot bags covering the ear. As soon as the dusting of the ear was carried out, the shoot bag was replaced to allow for fertilization to take place without contamination by unknown pollen grain. After the kernels got matured, each cross was harvested separately and manually thrashed and the kernels were stored in cool dry environment. A total of 15 crosses, six 6 parents and 15 reciprocals making thirty-six entries were obtained.

Land preparation for the evaluation in 2019 cropping season started with manual clearing followed by ploughing and harrowing to break the crumbs. Manual leveling was done to provide fine tilt for seedling growth and establishment. Field was laid out in a randomized complete block design with three replications each. The experimental area was 20.5m X 20.5m (420.25m²) the whole area was replicated three times containing thirty-six treatments. All F₁ hybrids were planted manually under rain-fed conditions on 14th June 2019 and 25th June in Bauchi respectively and later thinned to two plants per stand at two weeks after planting. Stand that did not have plants were gap-filled during first weeding, planting was done for each plot 4m X 3m with 1m intra row between replications and 0.50m in inter row spacing. Compound fertilizer of NPK 15:15:15 was applied at 400kg/ha rate at 14days after planting and later top dressed with urea (46:0:0) at 35days after planting. During the trial plots were kept weed free using a mixture of Atrazine and Gramoxone applied at rate 4.5 and 1.0L/ ha respectively supplemented with hoe weeding. The prevalence of stem borer attack on maize necessitated the use 'pawa' insecticide (lambda cyhalothrin) at two weeks after planting and four weeks after planting at the rate of 2.0L/ha. In addition, carbofuran was applied at the rate of 2kgL/ha at 6weeks after planting into whorls of each plant, losses from rodents' attack (ground squirrel) were minimized using numerous control measures through trap setting and baiting materials.

Harvesting of ears was done at physiological maturity. Five plants were harvested per plot. Harvested ears were bagged in labeled large brown envelopes and used for data collection on yield and yield traits. Samples were dried to 15% moisture content for yield assessment. Five plant were randomly tagged for recording observations of each entry. For all quantitative traits except for days to 50% tasseling and silking. Mean of five plants for each entry in each replication was worked out for statistical analysis. Data were collected on all required parameters. Data obtained were subjected to analysis of variance as described by Obi (2002). Fishers least significant difference (FLSD) was used to detect significant difference for mean separation among treatments. Combining ability variance and effects were determined and computed according to diallel analysis method according to Manjit *et al.* (2017).



The variance for general and specific combining abilities were tested against their respective error variances derived from analysis of variance of different traits. Additive and dominance genetic variance (δ^2A and δ^2D) were calculated by taking inbreeding coefficient (f) equal to one. Significant test for general combining ability and specific combining ability effects were performed using t-test. Estimation of proportional contributions of parents, hybrids and their reciprocal interaction to total variance was also computed.

RESULTS AND DISCUSSION

Estimate of General Combining Ability Effects

The results of estimates of GCA effects of parents, hybrids and reciprocals are presented in Table 3. Results showed that SMLW 20 had significant positive GCA effects at level of probability 0.05 or 0.01 for days to 50% anthesis, days to 50% silking, number of husks and silks per ear, weight of husks and silks per ear, number of silks per ear, length of silks per ear DS 0%, DS 2%, DS 4% and DS 5% respectively. SMLW 26 recorded highly significant positive GCA effects for days to 50% anthesis, days to 50% silking, length of silks per ear, DS 1%, DS 3%, DS 4% and DS 5% while parent's local variety (LV) had highly significant or significant positive GCA also for days to 50% silking, leaf area, ear height, weight of husks and silks per ear number of silks per ear, DS 0%, DS 1%, hundred grain weight and grain yield per hectare. Result indicated that, parent SMLW 51 recorded highly significant or significant positive GCA effects for plant height, number of leaves per plant, leaf area, ear height, weight of husks and silks per ear, number of silks per ear, length of silks per ear, cob length, DS 1%, DS 2%, DS 3%, DS 4%, DS 5%, hundred grain weight and grain yield per hectare. Parent SMLW 183 had significant positive GCA effects for Plant height leaf area, ear height, weight of husks and silks per ear, DS 2%, DS 3%, DS 5% and hundred grain weight SMLW 28 had significant positive GCA effects at level of probability 0.05 and 0.01 for the traits plant height, number of leaves per plant, leaf area, ear height, cob length, DS 0%, hundred grain weight and grain yield per hectare. Combining ability is the ability of parent to transmit desirable traits to its progeny. It is the capacity of the parents to produce superior progeny or otherwise when crossed with another parents (Izge *et al.*, 2007).

Combining ability analysis helps to identify superior parents to be used in breeding programs or to identify promising cross combinations for cultural development Acquah, (2007). The GCA effects revealed that SMLW 51 was the best general combiner for ear height and SMLW 20 was a good general combiner for number of husks and silks per ear while SMLW 28 indicated high level of resistance against fusarium ear rot among the inbred lines for grain yield. Inbred lines identified for good general combining ability could be utilized in maize grain improvement programmes for traits of interest as these lines have high potentials to transfer desirable traits to their progenies as reported by Ahmed (2003) and Shenawy *et al.* (2009).



Table 3: General Combining Ability for Fourteen Agronomic Traits during 2019 Rainy Season at Yola and Bauchi

PARENT S	DFA	DFS	PHT (cm)	NLP (cm)	LAR (cm ³)	EHT (cm)	NHE	WHS (g)	NSE	LSN (cm)	CLT (cm)	DS 0 (%)	DS 1 (%)	DS 2 (%)	DS 3 (%)	DS 4 (%)	DS 5 (%)	HGW (g)	GYH (kg)
SMLW 20	1.29*	0.73*	- 2.99*	- 0.11*	-4.35*	- 5.15**	0.60*	0.02**	3.48*	0.34*	-0.24*	0.37	-0.37*	0.14*	-0.36	0.06*	0.07*	- 0.01**	- 0.11**
SMLW 26	1.49* *	1.75* *	- 4.90* *	- 0.09*	- 16.60* *	- 4.22* *	- 0.19*	-0.01*	- 11.67*	0.78**	- 0.39* *	- 4.09**	1.90**	-0.12	0.87**	1.13**	0.25*	- 0.01**	-0.09
LV	-0.37	0.16	- 0.24*	-0.02	2.71	2.68**	-0.02	0.01*	7.97*	- 0.65**	-0.20	2.36*	0.58*	-0.67*	-0.87*	-0.64*	-0.37*	0.00	0.17**
SMLW 51	- 0.46*	-0.11	4.26* *	0.06*	7.84**	3.68**	- 0.12*	0.00	20.14**	0.12*	0.29*	- 3.92**	1.08*	1.66**	0.59*	0.56*	0.07*	0.00	0.03*
SMLW 183	- 1.03* *	- 1.25* *	2.38* *	- 0.05*	3.95*	0.02	- 0.21* *	0.00	- 16.70**	-0.43*	-0.14*	-1.89	-0.17	0.53*	0.83**	-0.05	0.90**	0.00	-0.01*
SMLW28	- 0.91*	- 1.29* *	1.58	0.21* *	6.46*	2.99*	-0.06	-0.02**	-3.21	-0.17	0.68* *	7.19**	- 3.03**	- 1.54**	- 1.06**	- 1.07**	- 0.92**	0.01**	0.01*
S_E ±	0.11	0.17	0.80	0.05	3.85	1.21	0.22	0.01	10.09	0.61	0.39	0.93	0.65	0.53	0.39	0.41	0.38	0.01	0.08

*=significant at 0.05 Probability level, ** = significant at 0.01 probability level

KEY

DFA = DAYS TO 50% ANTHESIS

EAR DS 2 = DESEASE SEVERITY 21-40%

DFS = DAYS TO 50% SILKING

DS 3 = DISEASE SEVERITY 41-60%

NLP = NUMBER OF LEAVES PER PLANT

DS 4 = DISEASE SEVERITY 61-80%

DS 1= DISEASE SEVERITY 1-20%

LV= LOCAL VARARIETY

GYH = GRAIN YEILD PER HECTARE

EHT = EAR HEIGHT

NHE = NUMBER OF HUSKS AND SILKS PER EAR

WHS = WEIGHT OF HUSKS AND SILKS PER EAR

LAR =LEAF AREA

DS 5 = DISEASE SEVERITY 81-100%

HGW = HUNDRED GRAIN WEIGHT

LSN = LENGTH OF SILKS PER

CLT = COB LENTH

DS 0 = DISEASE SEVERITY 0%

NSE = NUMBER OF SILKS PER EAR



Estimate of Specific Combining Ability Effects

The result of specific combining ability effects is presented in Table 4. The results revealed that, the fifteen hybrids had highly significant or significant positive SCA effects for days to 50% anthesis, days to 50% silking, plant height., number of leaves per plant, leaf area, ear height, number of husks and silks per ear, length of silks per ear, cob length, DS 0%, hundred grain weight and grain yield per plant. The grain yields of LV X SMLW 20, LV X SMLW 26, SMLW 51 X SMLW 26, SMLW 51 X LV, SMLW 183 X SMLW 20, SMLW 183 X SMLW 26, SMLW 183 X LV, SMLW 183 X SMLW 51, SMLW 28 X SMLW 20, and SMLW 28 X SMLW 51 had highly significant or significant positive SCA effects at probability level of 0.05 or 0.01 for grain yield per hectare. The exploitation of heterosis through useful cross combination is determined by specific combining ability. Fellahi *et al.* (2013) reported that, even though SCA effects do not contribute tangibly in the improvement of self – pollinated crops (except in situations where exploitation of heterosis is feasible). Best hybrids are expected to generate transgressive segregants which could be selected as potential homozygous lines. SMLW 51 X LV, SMLW 183 X LV and SMLW 28 X SMLW 20 were good specific combiners in grain yield. This result is in agreement with that of Igbal *et al.* (2007) who reported a significant and highly significant level of SCA effects in most of the crosses studied and especially for grain yield in maize. SMLW 51 X SMLW 20, SMLW 51 X SMLW 26 were good specific combiners for plant height. Estimates of SCA effects in ear height were highly significant for the crosses SMLW 26 X SMLW 20, SMLW 28 X SMLW 20 and SMLW 28 X SMLW 183. SMLW 26 X SMLW 20, SMLW 51 X SMLW 25 and SMLW 183 X SMLW 51 were best specific combiners for number of husks and silks per ear. SMLW 51 X SMLW 20, SMLW 28 X SMLW 26 and SMLW 28 X LV showed significant positive SCA effects for number of silk per ear. The result further indicated that, for length of silk per ear, crosses SMLW 51 X SMLW 26 showed highly significant difference likewise the cross SMLW 28 X SMLW 51 indicated highly significant positive SCA for cob length. SMLW 26 X SMLW 20, SMLW 51 X LV, SMLW 183 X SMLW 51 and SMLW 28 X SMLW 51 have indicated highly significant positive SCA effects for disease severity 0% to 100%. The positive specific combining ability effects could be a result of dominant and epistatic gene actions or due to additive dominance interaction as reported by Began (2021).



Table 4: Specific Combining Ability for Fourteen Agronomic Traits during 2019 Rainy Season at Yola and Bauchi

MALE	FEMALE	DFA	DFS	PHT (cm)	NLP (cm)	LAR (cm ³)	EHT (cm)	NHE	WHS (g)	NSE	LSN (cm)	CLT (cm)	DS 0 (%)	DS 1 (%)	DS 2 (%)	DS 3 (%)	DS 4 (%)	DS 5 (%)	HGW (g)	GYH (kg)
SLMW 26	X SLMW 20	-0.02	-0.75	-1.23	0.14*	30.87**	5.94**	-0.03	0.03**	-9.46	1.20*	0.92*	12.37**	-3.73*	-2.14**	-2.46**	-1.56*	-2.87**	0.01	-0.13
LV	X SLMW 20	-0.38	-1.36*	2.97*	0.03	14.40*	-2.56*	0.23	-0.02*	2.51	-0.02	0.22	-10.72**	3.67*	1.44*	1.20*	3.43**	0.19	-0.03**	-0.19*
LV	X SLMW 26	-2.34**	-1.20	-1.18	0.07*	1.63	0.58	0.23	-0.04**	-31.85**	-1.09*	-0.22	1.25	-1.60*	-0.63*	1.81*	-0.56	0.68	0.01	-0.35**
SLMW 51	X SLMW 20	1.96*	1.40	4.09**	-0.05	-7.06	-1.86	0.18	-0.02	42.43**	-0.65	-0.10	3.31*	-1.25	0.69	0.00	-2.94**	0.17	0.02*	0.00
SLMW 51	X SLMW 26	-1.32	-1.19*	4.73**	0.01	21.02*	-2.64*	-0.41*	0.03**	-3.18	4.82**	-0.43	-1.72	2.32	1.21*	-0.81	0.41	-1.68*	-0.02*	0.13*
SLMW 51	X LV	1.20	1.23	-4.95*	-0.07*	-41.18**	0.19	-0.35	-0.05**	-7.08	-0.43	-0.69*	-12.26**	6.72**	1.17*	0.51	1.93*	2.94**	0.02*	0.15*
SLMW 183	X SLMW 20	1.95*	1.96*	3.17*	0.04	-7.50	3.09*	-0.52**	0.00	11.15	0.12	0.51	-6.05*	3.09*	0.24	0.43	1.26*	2.42**	0.04**	-0.18*
SLMW 183	X SLMW 26	3.58**	3.36**	-3.45*	-0.22**	-27.73*	-1.26	-0.09	0.02*	18.59*	-1.20**	0.37*	2.00	-0.51	-0.58	-0.38	0.69	-1.68	0.01	0.06
SLMW 183	X LV	-2.81**	-1.88**	-1.80	-0.04	-17.87	-1.37	-0.31	0.03**	-13.97	0.09	0.26	2.88	-0.28	-0.28	-0.90	-1.30*	-0.14	-0.01	0.21**
SLMW 183	X SLMW 51	0.53	0.72	-0.79	-0.05*	19.11*	1.66	0.05	0.03**	-20.32*	-0.52	-0.58*	-7.42*	0.06	3.63**	2.39**	-0.16	1.08*	-0.02*	-0.17*
SLMW 28	X SLMW 20	-1.01	-0.33	-8.40**	-0.03	-36.42**	-5.87**	0.24*	-0.03	-28.30**	0.27	-0.34	-2.55	1.62	0.64	-0.10	-0.14	-0.01	0.01	0.42**
SLMW 28	X SLMW 26	0.29	-0.18	1.78	-0.01	-13.10	-0.42	0.24*	0.01*	22.02**	-1.07*	-0.90**	-10.17**	3.02*	0.99	2.76**	1.20	2.48**	0.01	0.11
SLMW 28	X LV	3.64**	2.91**	1.88	0.04	7.50	-2.62*	-0.52	0.01*	21.87**	0.81*	-0.34	3.63*	-0.66	0.87	-1.67*	-1.36*	-1.15*	0.00	-0.13
SLMW 28	X SLMW 51	-0.59	-1.66**	2.09	0.27**	24.39**	2.58*	-0.21	-0.01	-13.11*	-1.46**	2.87**	11.33**	-4.66**	-3.30**	-1.38*	-0.23	-1.77*	-0.01	-0.19*
SLMW 28	X SLMW 183	-1.27	-0.94	-2.39*	0.04	0.60	-5.53**	0.41**	0.00	7.54	0.39	-0.50	-6.12	1.84	1.16*	1.13*	1.30*	0.73	0.01	-0.12
S_E ±		0.26	0.39	1.83	0.11	8.78	2.77	0.51	0.02	23.00	1.40	0.90	2.13	1.47	1.22	0.88	0.93	0.88	0.01	0.19



CONCLUSION AND RECOMMENDATIONS

The research was conducted to study the diallel resistance to fusarium ear rot (*Fusarium verticillivides*) in 5 maize inbred lines and one local variety (X-Lawanti) susceptible to the disease, this comprises of parents, crosses and reciprocals making 36 entries evaluated in other to establish vital genetic information for identifying promising parents, F₁ hybrids and reciprocals with good breeding values of important agronomic traits for developing high yielding maize varieties. Diallel mating design was used to cross five maize inbred lines resistant to fusarium ear rot with one farmer's local variety. Thirty-six entries were evaluated in two locations and replicated three times each in a Complete Randomized Block Design.

The analysis of variance found the significant difference among the parents, hybrids and reciprocals for most traits revealing the presence of genetic variability among these genotypes which could be exploited to enhance selection for further population improvement in maize. The study found the importance of both gene actions in the control of maize traits. Highest positive GCA traits numbers of silks per ear and leaf area are desirable for yield. Analysis for GCA indicated further that parent SMLW 26 and SMLW 20 were identified as good general combiners and all expressed highly significant difference values for all the traits except DS0% and DS4%. The result for specific combining ability showed that SMLW 26 X SMLW 20 had appeared to be the good specific combiners for the positive traits number of silks per ear and leaf area. Inbred lines, SMLW 51, SMLW 21, SMLW 58 and SMLW 183 were resistant to fusarium ear rot across the locations and genotype. SMLW 20 and SMLW28 had both general and specific combining abilities for good grain yield resistance to the disease fusarium ear rot and can be deployed in breeding programmes. Negativity in days to 50% anthesis, days to 50% silking, plant height and ear height could mature early and escape lodging. Minimum days to 50% anthesis, days to 50% silking, plant height and ear height are needed for crop early maturing and lodging. For the genotypes SMLW 28 X SMLW 183, SMLW 20 X LV, and LV X SMLW 28 showed outstanding traits for earliness across locations and can be fully utilized by farmers for cultivation.

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