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COMBINING ABILITY OF QUALITY CHARACTERISTICS OF WHEAT CULTIVARS GROWN IN LESOTHO

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ABSTRACT

Wheat (*Triticum aestivum*) industry in Lesotho is at an infancy stage consisting of farmers producing poor quality that fetches low price for their produce. The aim of this study was to evaluate parents, F_1 and F_2 progeny from a diallel cross for quality characteristics of wheat cultivars grown in Lesotho. The quality characteristics were breakflour yield, flour protein content, mixogram development time, Sodium dodecyl sulphate sedimentation volume, and single kernel weight, single kernel diameter and single kernel hardness. There were significant differences among parents, F_1 and F_2 progeny for all characteristics. SST 124 and Wanda were the best general combiners. In F_1 progeny, Wanda x Nata and SST 124 x Nata exhibited good SCA while in F_2, SST 124 x Nata showed good SCA. GCA/SCA ratio in F_1 progeny showed non-additive gene action in all characteristics except one; while F_2 progeny indicated that break flour yield, flour protein content, single kernel characterisation system hardness and mixogram development time were controlled by non-additive gene action. Sodium dodecyl sulphate sedimentation volume, single kernel weight and single kernel hardness were controlled by additive gene action. Genetic diversity among promising parents, F_1 and F_2 progeny can be combined for high quality characteristics through gene pyramiding.

Key Words: GCA, gene action, SCA, *Triticum aestivum*

RÉSUMÉ

L'industrie du blé (*Triticum aestivum*) au Lesotho est au niveau préliminaire consistant en la production de basse qualité et par conséquent le prix bas du produit. L'objectif de cette étude était d'évaluer les parents, les progénies F1 et F2 à partir des croisements d'allèles pour les caractéristiques de qualité de cultivars de blé cultivés au Lesotho. Les caractéristiques de qualité étaient le rendement en farine, le contenu de la farine en protéine, le temps de développement du mixogramme, le volume de sédimentation du sulfate dodecyle du sodium, ainsi que le poids d'un seul grain, le diamètre d'un seul grain et la dureté d'un seul grain. Aucune différence significative n'était trouvée parmi les parents, les progégénies F1 et F2 pour toutes les caractéristiques. Dans la progénie F1, Wanda x Nata et SST 124 x Nata ont exhibé un bon SCA pendant que dans F2, SST 124 x Nata ont montré un bon SCA. Le rapport GCA/SCA dans F1 a montré une action de gène non-additive dans toutes les caractéristiques sauf une seule; pendant que F2 a indiqué que le rendement en farine, le contenu de la farine en protéine, la caractérisation du système de dureté d' un seul grain et le temps de développement du mixogramme étaient controlés par une action du gène non-additif. Le volume de sédimentation du sulfate de sodium dodecyle, le poids d'un seul grain et la dureté d'un seul grain étaient controlés par une action de gène additif. La diversité génétique parmi les parents promettants, les progénies F1 et F2 peuvent être combinées pour des caractéristiques supérieurs à travers le pyramidage de gènes.

Mots Clés: GCA, action de gène, SCA, *Triticum aestivum*

INTRODUCTION

Wheat (*Triticum aestivum*) quality is important to bakers and millers alike. Quality is a complex concept, determined by a number of characteristics influenced by environment, genotype and their interaction (Fischer and Byerlee, 1991). Both milling and baking industries need cultivars that have good quality to produce good flour. High prices are offered to the farmers for good quality wheat; as a result, there is a high demand among farmers for cultivars having good baking and milling quality (Byerlee and Moya, 1993). The unexploited gene pool of wheat grown in Lesotho could be evaluated in order to improve wheat quality in local material through breeding. This could be achieved by identifying progeny from test crosses that have potential to be integrated into the breeding programme. Breeders are interested in parameters that are highly heritable and reproducible (Neacºu *et al*., 2009), and this can be estimated from specific crossing models.

Griffing (1956) developed a diallel method for determining combining ability of lines and quantifying the nature and magnitude of gene action. This method identifies lines with good general and specific combining ability. The good general combiners can be crossed to produce optimal hybrid combinations with the purpose of selecting promising genotypes from the segregating population (Dey *et al*., 2010). Where additive gene action is predominant, selection should be effective. In Lesotho, the wheat industry is still at an infancy stage without a rigorous breeding programme for improving bread making quality. Hence, cultivars with good bread making quality are required.The aim of this study was to evaluate parents, F_1 and F_2 progeny from a diallel cross for quality characteristics of wheat cultivars grown in Lesotho.

MATERIALS AND METHODS

Two cultivars with poor, one with medium and two with good bread making quality were selected and crossed in all combinations. Kariega and SST124 were high quality, hard red spring wheat from South Africa, and Wanda (intermediate quality) and Nata and Sceptre (poor quality) were cultivars grown in Lesotho. The F_1 progeny and the parental lines were grown in Bloemfontein, South Africa, in a randomised complete block design, with three replications. Each plot measured 2 m x 1.8 m with the intra-row and inter-row spacing of 10 cm and 45 cm, respectively. Enough seed was harvested from this trial to plant the F_2 trial, with the parents in the following season, also using a randomised block design and the same trial dimensions. The F_2 trial was planted adjacent to the area where the F_1 trial was planted in the first season. The trials were irrigated in order to ensure optimum growing conditions. The harvested F_1 and F_2 material with the parents were sent to the Small Grains Institute in Bethlehem, South Africa, for quality analysis.

Laboratory analysis. To determine breakflour yield, all wheat samples were milled on a pneumatic mill, Bühler model MLU-202 (Bühler Bros., Inc., Uzwil, Switzerland). The AACC 26-21A method for milling hard wheat was followed (AACC, 2000). A combustion method was used to determine protein according to the AACC 46-30 method (AACC, 2000). Hardness index, kernel diameter and kernel mass were determined using the AACC 55-31 method (AACC, 2000) with the SKCS model 4100 instrument. AACC 56-70 method was followed (AACC, 2000) to determine SDS sedimentation values. Mixing development time was determined on a 35 g mixograph according to the AACC 54-40A method (AACC, 2000).

Statistical analysis. Analysis of variance and diallel analysis according to Griffing (1956) was performed. Agrobase Generation11 was used to analyse the dataset. Mean separation was performed using least significant difference at 5% level.

RESULTS

There were highly significant mean squares ($P \leq 0.01$) for entry for the parents, F_1 and F_2 progeny for breakflour yield (BFLY), flour protein content (FPC), mixograph development time (MDT), SDS sedimentation volume (SDSSV), and single kernel weight (SKW), diameter (SKD) and hardness (SKH) (Table 1). Variance due to GCA and SCA were highly significant ($P \leq 0.01$) for all

TABLE 1. Mean squares for measured quality characteristics for F_1 and F_2 progeny from the diallel of wheat grown in Lesotho

Source of variation	Generation	Df	FLY	FPC	MDT	SDSSV	SKW	SKD	SKH
Replication	F_1	2	5.588	0.244	0.011	7.453	17.940	0.038	7.452
	F_2	2	2.775	0.345	0.036	0.040	2.381	0.09	18.606
Entry	F_1	24	24.088**	3.165**	0.825**	295.365**	53.840**	0.144**	397.096**
	F_2	24	14.597**	1.239**	1.305**	147.330**	28.141**	0.083**	445.217**

* P<0.001, ** P<0.005

TABLE 2. Mean squares for general and specific combining ability and the ratio between them for measured quality characteristics for F_1 and F_2 trials grown in Lesotho

Source of variation	Generation	Df	BFLY	FPC	MDT	SDSS	SKW	SKD	SKH
GCA	F_1	4	7.24**	0.113**	0.011**	61.270**	5.47**	0.019*	137.195**
	F_2	4	4.50**	0.262**	0.113	55.942**	11.56	0.034**	69.154**
SCA	F_1	10	10.83*	0.991*	0.221*	107.827*	22.40*	0.071*	69.032*
	F_2	10	4.91**	0.288**	0.536**	36.537**	7.27**	0.016**	151.84**
GCA:SCA	F_1		0.668	0.114	0.050	0.568	0.244	0.264	1.99
ratio	F_2		0.920	0.910	0.210	1.600	1.59	2.125	0.456

*P<0.001, **P<0.005

quality characteristics in both the F_1 and F_2 material except, for GCA for MDT in the F_2 diallel (Table 2).

General combining ability. Wanda had a good GCA effect for BFLY, SDSSV and SKH. Kariega exhibited good to medium GCA effect for flour protein, SKW and SKH (Table 3). SST124 was a good general combiner for BFLY, SDSSV and SKW. Sceptre was also a good combiner for BFLY, protein content and SKH. In the F_2 progeny, Wanda was a good general combiner for BFLY, SDSSV and SKH, while Sceptre had good GCA for BFLY, SKW and SKH (Table 3).

Specific combining ability. Positive and significant SCA effects were shown by the cross Sceptre x Kariega in the F_1 generation for SKW, SKD, FPC and BFLY (Table 4). The SST 124 x Kariega combination had the lowest SCA effects which exhibited the lowest value in all characteristics studied. In the F_2 generation, Wanda x Nata and Sceptre x SST 124 revealed a relatively high SCA effect for BFLY, SKW and SKH, and FPC, SDSSV and SKW, respectively. It is noteworthy that a cross with SST 124 in both generations appeared to have a high SCA. It is apparent that for most of the F_1 progeny which exhibited high SCA effects, the parental lines involved were the best performers, for example SST 124 and Wanda. Critical examination of the findings showed that at least one of the parental lines with high GCA was involved in most of the hybrids exhibiting high SCA effects.

Variance due to general combining ability and specific combining ability were highly significant for all characteristics studied. Among the parents, SST 124 was the best general combiner for BFLY, SDSSV and SKD while Wanda was the best combiner for BFLY, SDSSV and SKH.

DISCUSSION

The significant differences obtained among parents, F_1 and F_2 progeny (Table 1) indicate the presence of genetic diversity from which superior

TABLE 3. General combining ability effects for measured quality characteristics in the F_1 and F_2 progeny grown in Lesotho

Parent	Generation	FLY	FPC	MDT	SDSSV	SKW	SKD	SKH
Nata	F_1	-0.5586	-0.0387	0.0073	0.4200	-1.0315	-0.0649	1.49
	F_2	0.4665	0.0707	-0.1327	-0.2467	1.3697	0.0611	-0.9922
Wanda	F_1	0.7387	-0.1087	0.0307	0.4533	-0.4778	-0.0019	3.20
	F_2	0.4895	-0.2310	0.0840	0.3867	0.0287	0.0355	3.5598
Kariega	F_1	-1.1603	0.1013	0.0207	-1.7467	0.2785	0.0571	2.58
	F_2	-1.1489	-0.0693	0.1307	-2.4467	-1.2177	-0.0482	0.9168
SST 124	F_1	0.8161	-0.0787	-0.0027	3.6533	0.7879	0.0021	-5.73
	F_2	0.0448	0.2023	-0.0293	3.7533	-0.8803	-0.0739	-3.6255
Sceptre	F_1	0.1641	0.1247	-0.0560	-2.7800	-0.4429	0.0075	1.49
	F_2	0.1481	0.0273	-0.0527	-1.4467	0.6997	0.0255	0.1411

TABLE 4. Specific combining ability effects for measured quality characteristics from the F_1 and F_2 progeny grown in Lesotho

Crosses	Gen	FLY	FPC	MDT	SDSS	SKW	SKD	SKH
Wanda x Nata	F_1	0.712	0.722	0.3160	-4.353	-0.267	-0.0148	6.45
	F_2	-0.726	-0.2940	0.4227	-0.687	-2.603	-0.1178	6.90
Kariega x Nata	F_1	-3.133	-0.455	0.5260	-3.153	-3.631	-0.1188	2.57
	F_2	-0.501	0.1843	0.4360	-3.687	-0.576	-0.0531	3.80
Kariega x Wanda	F_1	-1.137	-1.051	-0.3140	-9.520	0.797	0.1065	7.18
	F_2	-1.158	-0.3757	0.5893	-6.153	-1.445	-0.0038	5.59
SST124 x Nata	F_1	0.759	0.375	-0.4507	0.447	3.204	0.1462	-1.04
	F_2	0.783	0.1843	-0.0673	3.280	1.043	0.0562	-2.89
SST124 x Wanda	F_1	-1.583	-0.505	0.3260	-1.920	-2.586	-0.0968	2.11
	F_2	0.1481	0.0273	-0.0527	-1.4467	0.6997	0.0255	0.141
SST124 x Kariega	F_1	-1.684	0.085	0.0193	-1.887	-1.907	-0.1425	-3.03
	F_2	-2.246	-0.5090	-0.3640	-2.353	-0.734	-0.1228	17.98
Sceptre x Nata	F_1	0.836	-0.228	-0.1473	6.047	-1.149	-0.1525	-4.10
	F_2	0.568	0.0260	-0.3273	1.813	0.015	0.0269	-4.03
Sceptre x Kariega	F_1	1.474	-0.391	0.1293	0.513	1.697	0.0745	-6.86
	F_2	1.264	0.3327	0.4093	-0.153	0.311	0.0245	7.31
Sceptre x SST124	F_1	1.995	-0.688	-0.1040	4.480	1.205	0.0539	2.12
	F_2	0.113	0.1110	0.5860	1.813	-2.113	-0.0765	7.45
Wanda x Sceptre	F_1	1.535	0.682	0.1727	-5.120	6.153	0.3722	-2.29
	F_2	1.262	-0.4890	-0.0773	-3.513	0.104	-0.0108	-5.33

genes for quality characteristics could be drawn and utilised in the breeding programme. Furthermore, analysis of variance (Table 1) revealed significant differences among parents for the characteristics studied. Among the parents, SST 124 and Wanda possessed most desirable quality characteristics while Nata and Sceptre performed poorly on the same characteristics. Similarly, significant differences were shown among and within F_1 and F_2 progeny for all characteristics (Table 1). These differences broaden genetic base for improving desirable characteristics.

The findings were consistent with previous research studies conducted in India which showed significant difference among parents, F_1 and F_2 where combining ability analysis was conducted in wheat quality characteristics (Joshi *et al*. 2004). The high GCA estimate suggests that the mean of a particular parent, when crossed with all parents, is superior to the general mean of all combinations of parental crosses. This implies that desirable genes are transmitted from parents to off-spring at high frequency and shows the presence of predominantly additive genes. Franco *et al*. (2001) suggested that crosses obtained from genotypes with higher estimates of GCA should be potentially superior for the selection of lines in the advanced generation. Early generation selection can be adopted for the crosses that show high heritability of desirable quality characteristics. As for the progeny showing low to medium heritability, selection can be delayed until a later stage when in F_7 to F_8 generation. The progeny exhibiting high SCA could be used for hybrid breeding. The general combining ability effect of F_2 showed a similar trend, where Wanda was a good general combiner for BFLY, SDSSV and SKH. SST 124 followed as a good general combiner for FPC and SDSSV. Sceptre was a poor general combiner in both F_1 and F_2 generations. GCA/SCA ratio in F_1 progeny revealed non-additive gene action in all characteristics, although some of the values were close to 1. In F_2 progeny, BFLY, FPC, SKH and MDT were controlled by non-additive action, whereas SDSSV, SKW and SKD were controlled by additive gene action.Thus, both kinds of gene effects were important in controlling the inheritance of the characteristics studied.

Similar findings were obtained by Pokhrel *et al*. (1993) who found that some wheat quality characteristics showed additive gene action. Sharma (1997) reported the roles of both additive and non-additive effects for wheat quality characteristics.

To improve or enhance quality, parents such as Wanda, SST 124 and Sceptre should be utilised into the breeding programme through pyramiding of genes where many genes from different parents and progeny will be combined to produce a cultivar with high quality characteristics. The crosses such as Sceptre x Kariega, SST 124 x Nata, Wanda x Nata, Sceptre x Wanda, Kariega x Wanda, Kariega x Sceptre, SST 124 x Sceptre, Wanda x SST 124, Nata x Kariega and Nata x SST 124 could also be incorporated in the programme where gene pyramiding should be used to combine all desirable genes to produce good quality characteristics of wheat.

This would indicate that both additive and non-additive gene effect influenced the measured characteristics. In order to get an effective response to selection, crosses obtained from parents with high GCA should be chosen. The estimate of GCA of a parent in the diallel analysis is an effective indicator of its potential for producing superior progeny.

It is well documented that where two or more parental lines with high GCA are involved in a cross, F_1 progeny exhibit good results (Munshi and Siroshi, 1993). There was no pattern of difference between the F_1 and F_2 generation. In some cases the effects were similar for the two generations, and in some it was very different.

CONCLUSION

The study has established that among wheat cultivars grown in Lesotho, there are some which have good quality characteristics for bread making and these cultivars which have been identified can be incorporated into the breeding programme together with their progeny to improve quality characteristics. For the progeny that show desirable quality characteristics at an early stage, early generation selection can be adopted. This signifies a high heritability of the trait. Nonetheless, wheat cultivars with low heritability in quality characteristics can be selected in later generations. A broad genetic variability for wheat quality characterictics among cultivars grown in Lesotho exists which can be explored through gene pyramiding to produce novel cultivars for breadmaking quality.

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REFERENCES

AACC. 2000. Approved methods of American Association of Cereal Chemists. Minnesota, USA.

Agrobase, 2005. Agrobase Generation 11 user's manual. Version 11, Revised edition. www.agronomix.com.Agronomix software, Winnipeg, MB. Canada.

Byerlee, D. and Moya, P. 1993. Impact of International wheat Breeding Research in the developing world. pp. 12-16. In: Klatt, A.R. (Ed.). Wheat production prospects: past, present and future, 1966 - 1990. CIMMYT, Mexico.

Dey, S.S., Behera, T.K. and Munshi, A.D. 2010. Gynoecious inbred with better combining ability improves yield and earliness in bitter gourd (*Momordica charantia* L.). *Euphytica* 173: 37 - 47.

Fischer, R.A. and Byerlee, D.R. 1991. Trends of wheat production in warmer areas: Issues and economic consideration. In: Saunders, A.D. (Ed.). Wheat for non-traditional, warm areas. CIMMYT, Mexico. 322pp.

Franco, M.C., Cassini, S.T., Olivier, V.R., Vieira, C., Tsai, S.M. and Cruz, C.D. 2001. Combining ability for nodulation in common bean (*Phaseolus vulgaris* L.) genotypes from Andean and Middle American gene-pools. *Euphytica* 118:265-270.

Griffing, B. 1956. Concept of general combining and specific combining ability in relation to diallel crossing systems. *Australian Journal of Biological Sciences* 9:463 - 493.

Joshi, S.K., Sharma, S.N., Shinghania, D.L. and Sain, R.S. 2004. Combining ability in F_1 and F_2 generations of diallel cross in hexaploid wheat (*Triticum aestivum* L. em. Thell). *Hereditas* 141: 115 - 121.

Munshi, A.D. and Siroshi, P.S. 1993. Studies on heterosis in better gourd (*Momorrdica charantia* L.). *Vegetable Science* 20:147 - 151.

Neacºu, A., Stanciu, G. and Sãulescu, N.N. 2009. Most suitable mixing parameters for use in breeding breadwheat for processing quality. *Cereal Research Communications* 37: 83-92.

Pokhrel, P.R., Burden, A.M. and Dragautsev, V.A. 1993. Harvest index and its components in wheat. *Indian Journal of Genetics* 43:229-231.

Sharma. J. 1997. Direct and residual effects of compost enriched with Musoovic rock phosphate in wheat-rice sequence. *Indian Journal of Agricultural Sciences* 67:299-302.