Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

ANSInet
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http://ansinet.com

Asian Journal of Plant Sciences 5 (2): 385-389, 2006
ISSN 1682-3974

Performance of Locally Constituted Quality Protein Maize Hybrids-A Fortune for Malnourished People and Feed Industry in Pakistan

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Abstract: Maize, the leading world cereal is the third most important cereal in Pakistan following Wheat and Rice. Although, its direct utilization as human food (25%) is declining, its industrial (29%) and feed (35%) use is increasing. The normal maize lacks two of six essential amino acids, that is, lysine and tryptophan. The Quality Protein Maize (QPM) with higher protein and much higher tryptophan and lysine content has been shown to improve animal and human health. Keeping these facts in mind, a number of QPM hybrids have been constituted at National Agricultural Research Centre (NARC), Islamabad from the temperate and subtropical originated lines from CIMMYT. The data presented in this study indicate that 4 selected QPM hybrids performed well in comparison to commercial maize hybrids. The results on yield and other agronomic characteristics along with lysine content of QPM hybrids are presented and discussed. With high yield and better quality, the new QPM hybrids can lead to food, feed and nutritional security and help to alleviate poverty among resource-poor farmers of the country.

Key words: Quality protein maize, *Zea mays* L., hybrids, performance, nutrition, feed

INTRODUCTION

Globally, maize has become the fore most important cereal crop both in terms of total production as well as productivity per unit area (FAO, 2004). In Pakistan, maize is the third most important cereal after wheat and rice. It is grown on about one million hectares of land with an average yield of 3097 kg ha^{-1} (FAO, 2004). In spite of the recent increase in yield (63%), it is still far below the yields realized in spring hybrid maize in the country (7.0 t ha^{-1}). In Pakistan, more than 35% of maize production is consumed in the form of animal feed and about 25% for human consumption. Thus, there is great need to improve productivity and nutritional quality of maize in the country to improve the animal and human health (Hussain *et al*., 2003; Chughtai *et al*., 2002; Rajaram *et al*., 1998; CIMMYT, 1989).

Maize is a major crop for livestock feed and human nutrition in a number of developed and developing countries. Millions of people particularly in developing countries derive protein and calorie requirements from maize. Like other cereals, the maize proteins (zeins) have poor nutritional value for monogastric animals and human beings because of reduced content of essential amino acids lysine and tryptophan (Bjarnason and Vasal, 1992). The zein can be brought into favourable amino acid balance by opaque gene incorporation. Discovery of maize mutants in the mid 1960s containing the *opaque-2* gene (Mertz *et al*., 1964) which enhances levels of lysine and tryptophan in the endosperm protein (zein), opened a new era in breeding for improvement of quality in maize. However, these mutants also came with several undesirable traits such as opaque and chalky grain textures, low grain yield, higher levels of ear rot, slow dry down and increased incidence of store products pests. The CIMMYT scientists continued their research efforts for more than two decades to incorporate modifier genes that remedied most drawbacks. Through an interdisciplinary research work, CIMMYT scientists developed what is now called as Quality Protein Maize or QPM (Vasal, 1999; Vasal *et al*., 1993). This special type of maize has exactly the same qualities as normal maize in grain texture, taste and colour but possess almost double the levels of lysine and tryptophan, high yield and tolerance to biotic and abiotic stresses. In 1993, 33 tropical and 22 subtropical QPM lines were released by CIMMYT and the hybrids from these and subsequent lines created excitement in the developing world (Cordova *et al*., 2000). CIMMYT and the national program partners working together tested these new QPM hybrids in several environments for release and adoption by farmers. The nutritive value of QPM both as human food and as an animal feed especially for poultry has been widely demonstrated in many countries (Graham *et al*., 1989, 1990). Several QPM hybrids have been released for cultivation in the developing world. More than 23

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developing countries have released and are now producing QPM in Asia, Latin America and Africa (Srinivasan *et al*., 2004; Fan *et al*., 2004; Cordova and Listman, 2002; Cordora *et al*., 2000).

Several countries in Asia including China, Vietnam, Philippines, India, Bangladesh and Indonesia have actively participated in CIMMYT testing programme of QPM hybrids. Unfortunately, Pakistan was not included in the testing network in the initial stages. However, during 1999 and 2000, some of the CIMMYT QPM trials were evaluated in Pakistan by the scientists at the National Agricultural Research Centre (NARC). Based on the performance of the QPM germplasm, the parental materials were requested from CIMMYT. The QPM lines were utilized for local constitution of a number of hybrids. The results on pioneer work at NARC regarding development and initial testing of the locally constituted QPM germplasm were described earlier (Hussain *et al*., 2003). The current study describes the performance of the selected QPM hybrids constituted at NARC in comparison to the local commercial hybrids included as checks. This study also discusses the future potential of QPM for promoting food, feed and nutritional security and alleviating poverty in Pakistan.

MATERIALS AND METHODS

Four selected locally constituted quality protein maize hybrids utilizing CIMMYT inbred lines were evaluated in comparison with three leading commercial and two indigenous (normal) hybrids designated as checks. The trials were conducted during kharif 2001 and 2002 and spring 2002 at the National Agricultural Research Centre (NARC), Islamabad. The quality protein hybrids were NRHQ-1, NRHQ-2, NRHQ-3 and NRHQ-4, while normal indigenous NARC developed hybrids were NC-2005 and NC-2006. The commercial exotic hybrids were Bemisal-202 from Engro Chemicals Pakistan Ltd., P-3012 from Pioneer Pakistan Seeds Ltd. and C-919 (for Kharif) and Dekalb-6525 (for spring) from Monsanto Pakistan Agri. Tech. Pvt. Ltd.

The experiment was planted under Randomised Complete Block Design (RCBD) with three replications. Each genotype was sown in two row plot (5.0 m long and 0.75 m apart with 25 cm plant to plant distance). Both of the rows were used for observations and data recording. All other inputs and cultural practices followed were same in each experiment. Data regarding agronomic traits were recorded. The observations were recorded on days to 50% silking and pollen shedding as maturity indicator and plant and ear heights as idiotype parameter. Fresh ear weight and grain moisture for computing grain yield were also recorded. The grain yield kg ha^{-1} was computed using the following formula at 15% grain moisture:

$$\text{Grain yield (kg ha}^{-1}) = \text{FEW} \times \frac{100 - \text{M\%}}{85} \times 0.8 \times \frac{10{,}000}{7.5}$$

Where

FEW	=	Fresh ear weight in field at harvest
M%	=	Grain moisture %age at harvest with moisture tester
100 - M/85	=	Conversion of grain moisture at 15% level
0.8	=	Grain/cob ratio (shelling %age) i.e. for the hybrids planted, it is 80% grains.
10,000/7.5	=	Conversion of grain yield per plot (7.5 m^2) on hectare basis

Data were analysed statistically for individual trials separately as well as by using two way Analysis of Variance and Duncan's Multiple Range Test (Gomes and Gomes, 1987). The chemical analysis for the lysine contents was performed in the laboratory at Quaid-i-Azam University, Islamabad.

RESULTS AND DISCUSSION

With the succeeding efforts on the conversion of the soft *opaque-2* kernels into a hard vitreous one for eliminating the adverse effects of the mutation (Paez *et al*., 1969), reactivation of QPM development efforts by CIMMYT and increasing global awareness about food security during late nineties, it was decided by the scientists at Maize, Sorghum and Millet Programme, National Agricultural Research Centre to go for quality protein maize hybrid development along with traditional hybrids (Hussain *et al*., 2003; Chughtai *et al*., 2002). A number of QPM hybrids were developed and initially tested for their yield performance and adaptability under the local agro-climatic conditions (Hussain *et al*., 2003). During Kharif 2001, 4 of the selected QPM hybrids along with 2 locally developed normal hybrids were tested at NARC in comparison with leading commercial hybrids from multinationals (Table 1). The leading commercial kharif hybrid C-919 was the best producer (9885 kg ha^{-1}), with desired plant and ear heights. The QPM hybrids had acceptable yield level ranging from 7750-8525 kg ha^{-1} which was statistically comparable to the commercial checks included in the trial (Table 1). However, the plants of QPM hybrids were taller (168-226 cm) and had higher placed ears (89-126 cm). These traits will need more rigorous selection in future. During spring 2002 (Table 2), these QPM hybrids were again evaluated in comparison to the normal commercial and NARC (public sector) hybrids. The QPM hybrids were later in maturity but comparable in yield levels with the top commercial hybrids

Table 1: Performance of quality protein and normal maize hybrids at NARC, Islamabad during Kharif 2001

Hybrid	Grain yield (kg ha^{-1})	50% Pollen shed (Days)	50% Silk (Days)	Plant height (cm)	Ear ss height (cm)
C-919	9885	54	55	191	98
P-3012	9601	55	55	215	113
Bemisal-202	9131	54	54	198	88
NRHQ-4	8825	52	53	168	89
NRHQ-2	8625	53	54	221	126
NRHQ-3	8465	54	54	178	106
NRHQ-1	7750	54	54	226	121
NC-2006	7211	52	52	175	78
NC-2005	6493	54	54	173	76
CV (%)	12.50	1.48	1.91	4.48	6.49
LSD (0.05)	1837	1.40	1.81	15.41	11.47

Table 2: Performance of quality protein and normal maize hybrids at NARC, Islamabad during spring 2002

Hybrid	Grain yield (kg ha^{-1})	50% pollen shed (Days)	50% silk (Days)	Plant height (cm)	Ear height (cm)
Dekalb-6525	10049	76	77	172	85
Bemisal-202	9825	76	78	189	82
P-3012	9360	80	84	178	91
NRHQ-2	9105	80	82	197	110
NRHQ-4	8814	84	87	203	107
NRHQ-3	8656	79	81	171	89
NRHQ-1	8571	79	81	184	98
NC-2005	7658	76	80	169	83
NC-2006	7338	74	77	181	81
CV (%)	9.42	1.96	1.94	3.89	7.03
LSD (0.05)	NS	3.55	3.65	156.36	14.85

(Bemisal-202, DK-6525 and P-3012).The differences in yield were statistically non significant, indicating that these hybrids may perform well in Punjab during spring. However, these QPM hybrids may not be suitable for rainfed and highland areas, where early maturity is needed to fit in the cropping system. When tested during Kharif 2002 (Table 3), the QPM hybrids were comparable in maturity to the commercial hybrids (58-60 days). In grain yield, only one of the commercial hybrids (P-3012) was better (9970 kg ha^{-1}) than NRHQ-2 and NRHQ-1 (9641 and 9431 kg ha^{-1}, respectively). These differences were, however, not statistically significant. These two QPM hybrids had better yield potential than the other two checks C-919 and Bemisal-202, which had 7328 and 6288 kg ha^{-1}, respectively. In summary, the results clearly indicate that the locally constituted QPM hybrids were on par with or better than the leading commercial normal maize hybrids during both kharif and spring seasons. Therefore, if released and adopted, the farmers are not going to pay the yield penalty. They will rather gain a lot in terms of superior protein quality and higher amino acid content of the QPM hybrids. Locally constituted quality protein hybrids have temperate blood in their make up along with sub-tropical blood. These could have brighter chances to fit in temperate ecology as suggested by several researchers (Ivanovic and Kojic, 1990; Russell, 1991; Tollenaar, 1991; Duvick, 1992; Eyherabide *et al*., 1994).

The protein and lysine content of the QPM hybrids together with the leading commercial hybrid C-919 is presented in Table 4. While the crude protein content in QPM hybrids is slightly improved, their lysine content is improved by 82 to 98% of the normal hybrid (C-919). On the relative basis in whole grain, these hybrids have almost double the amount of lysine (186-211) compared with the normal maize C-919 (100). Its amount is increased by two folds on hectare basis as well, that is, from 24 in normal hybrid to 37-46 in QPM hybrids (Table 4). From these results, it is concluded that the yield potential of the QPM hybrids, constituted at the National Agricultural Research Centre (NARC), is comparable to those of commercial hybrids marketed by the companies. Moreover, the improvement of protein quality in these hybrids is so significant that it can bring a revolution in the food quality and feed industry. Poultry feed industry with a strong base in Punjab, is flourishing at about 10% annual growth rate. Poultry consumption rate is related with raise in socio-economic status of people, which is presently attaining momentum. Hence, growth in use of poultry in Pakistan is expected to continue in near future. The yellow grain of the locally constituted QPM hybrids have the edge of being preferred by the feed manufacturers because of the luster it imparts to the final product and also by the poultry egg sector where dark yellow color of egg yolk is especially liked by the end users. Yellow grain color also imparts better quality due to additional vitamin A. Repeated studies in several countries have shown that animal and poultry raised on QPM based feeds, gains weight faster and produces more than the animals raised on normal maize-based feeds (Vasal, 1999; Vasal *et al*., 1993;Vasal, 1994; Zhang and Shi, 2000; Cordova and Listman, 2002). Thus, maize being

Table 3: Performance of quality protein and normal maize hybrids at NARC, Islamabad during kharif 2002

Hybrid	Grain yield (kg ha^{-1})	50% Pollen shed (Days)	50% silk (Days)	Plant height (cm)	Ear height (cm)
NC-2006	11381	67	68	143	63
P-3012	9970	53	54	153	63
NRHQ-2	9641	55	58	169	73
NRHQ-1	9431	56	58	186	87
NRHQ-4	8545	57	59	178	86
NC-2005	8520	69	69	142	68
NRHQ-3	8118	58	60	167	70
C-919	7328	58	59	145	54
Bemisal-202	6288	57	56	157	64
CV (%)	17.14	3.22	5.34	9.76	14.62
LSD (0.05)	3581	4.46	3.76	36.35	23.43

Table 4: Comparative lysine content in quality protein and normal maize hybrids

		Crude protein		Lysine in protein		Lysine in grain		
Hybrid	Grain yield (kg ha^{-1})	(%)	Relative	%	Relative	(%)	Relative	Lysine kg ha^{-1}
NRHQ-1	7750	11.9	103	4.17	192	0.452	186	39
NRHQ-2	8625	11.8	102	3.97	182	0.468	187	40
NRHQ-3	8465	11.7	101	4.03	185	0.471	189	37
NRHQ-4	8825	12.2	106	4.30	198	0.527	211	46
C-919	9885	11.5	100	2.17	100	0.250	100	25

a major component of animal feed in Pakistan, the improvement of protein quality will play an important role in our future expansion in animal production, especially the poultry production. QPM can revolutionize nutritional status of maize consumers in the country. It will facilitate the poor people to improve their status of nutrition. People in the mountainous regions of NWFP and AJK are already deriving their protein and calories from maize as staple food. Improvement in protein quality and making their staple food more balanced in amino acids will significantly improve their health without changing their customs and food habits. QPM in addition to higher lysine and tryptophan content has a generally more balanced amino acid content that greatly enhances its nutritive value. Research suggests that QPM can help reduce protein deficiency ailments, particularly in young children in settings where maize dominates in diets (Graham *et al*., 1989). In some countries malnourished children have been restored to health on controlled diets combating Kwashiorkar, a severe protein deficiency disease, using QPM (Graham *et al*., 1990)

The feed industry in Pakistan is already giving premium on dark yellow and orange colour of maize grain. It is expected that with the up date in awareness about quality food and health consciousness of the consumer, premium on QPM may be initiated to motivate the producer for quality maize cultivation.

Currently, CIMMYT has a very dynamic QPM programme. Superior QPM hybrids and varieties have been evaluated in more than 40 nations. QPM hybrids often had a yield advantage of one ton/ha or more over the best normal hybrid checks (Cordova and Listman, 2002; Srinivasan *et al.,* 2004). In 23 countries, QPM hybrids and varieties are in use and additional releases are expected in several countries. Pakistan is also one of the beneficiaries in this regard. A number of trials consisting of quality protein open pollinated varieties (OPVs) and hybrids from CIMMYT have been tested. The populations and inbred lines have been requested and at NARC the work on QPM variety and hybrid development is in progress. The data on QPM hybrid performance have been presented and discussed in this paper. Experimental varieties have performed well at NARC. Rakaposhi, one of the quality protein maize varieties, has performed well in Gilgit. Data on OPVs will be presented in a separate study.

In countries like Pakistan where maize is and it will remain, an important component of the human diet and animal feed, the development, release and adoption of QPM offers an opportunity to not only improve maize production but also to greatly improve the nutritional status and livelihood of the farmers, particularly the poor subsistence maize growers in the northern hilly areas of NWFP and AJK. The pioneer work on QPM has been initiated and significant progress has been made as is evident from the data presented in this study and in an earlier communication (Hussain *et al*., 2003). It is evident that QPM has tremendous potential to provide food, feed and nutritional security to resource-poor farmers in Pakistan and thereby help in reducing poverty.

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