Grain Yield Stability of Quality Protein Maize Genotypes across Diverse Environments of Terai and Mid Hills in Nepal

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Abstract: Maize is produced in diverse environmental conditions in Nepal. National Maize Research Program regularly tests maize genotypes for their grain yield stability in highly diverse environments. The objective of this paper is to estimate grain yield stability of quality protein maize genotypes across different environments. Two quality protein maize genotypes namely Poshilo Makai-1 and S99TLYQ-HG-B along with Farmer's variety were tested at nine different locations of Nepal in four consecutive years before 2013 under farmer's fields. Alpha-lattice design with two replications was used. The results of these studies revealed that S99TLYQ-HG-B was more stable followed by Poshilo Makai-1 as compare to Farmer's variety. The overall higher mean grain yield and regression coefficient (b) near to unity showed that S99TLYQ-HG-B is the most adaptive genotype across the tested environments. However, more than unity regression coefficient (b) indicates that Poshilo Makai-1 could be the recommended variety for better environments under farmers' management.

Keywords: Quality protein maize; grain yield stability; environments

1. Introduction

Maize is one of the most important staple food crops in Nepal where the area and productivity of maize is 8.49 million hectare and 2.3 t ha^{-1}, respectively (MoAD, 2013). It contributes to about 25.02% in total for cereal production, 6.54% in AGDP and 3.15% in GDP (MoAD, 2013). It is also an important feed ingredient for poultry and livestock and hence the demand of quality protein maize (QPM) is increasing. Poshilo Makai-1 is the single QPM variety out of 25 varieties released in Nepal. The QPM contains higher amount of lysine and tryptophan which is essential for mono-gastric animals. Lysine and tryptophan are the most limiting amino acids for humans which can be supplied through normal maize in negligible amount (Kies *et al.*, 1965). The biological value of QPM protein is about 80%, that of milk is about 90% and that of normal maize is only about 45% (FAO, 1992).

The maize growing environments of Nepal is very diverse and varied along north to south parts of the country. It is the only crop which is adaptive to across different agro-ecological zones because of its great diversity (Ferdu *et al.*, 2002). The improved varieties give high and stable yields across environments where they are adapted (CIMMYT, 1991). The ability to develop high yielding stable cultivars is a primary focus in most breeding programs and is ultimately of more importance than the identification of unstable cultivars.

The regression values above 1.0 describe genotypes with higher sensitivity to environmental change (below average stability), the regression coefficient below 1.0 provides a measurement of greater resistance to environmental change (above average stability) and the regression values near unity shows more stability (Finley and Wilkinson, 1963; Wachira *et al.*, 2002). The information on stability of QPM genotypes under terai and mid-hill environments of Nepal is not sufficient. So, these studies were carried out to identify superior stable QPM genotypes for terai and mid-hill regions of Nepal.

2. Materials and Methods

These studies included three genotypes, namely S99TLYQ-HG-B as experimental yellow QPM variety, Poshilo Makai-1 as white QPM standard check and Farmer's variety (Rampur Composite) as local check. The general description of maize genotypes used in these studies are given in Table 1. These genotypes were tested in nine different sites (Lumle, Khumaltar, Kabre, Pakhribas, Dailekh, Surkhet, Rajahar, Rampur and Madi) covering east to west terai and mid-hills in Nepal. The sites of these studies are also shown in figure 1.

In each site the trial was planted in farmers' fields using alpha-lattice design with two replications. The studies were conducted in 2009, 2011, 2012 and 2013 during summer seasons (March to September). The individual plots were 13.5 m^2 (3 m ´ 4.5 m) where genotypes were seeded at the standard seeding rate of 20 kg ha^{-1}. The net area harvested was 13.5 m^2. The spaces between row to row and plant to plant were 75 and 25 cm, respectively. Two seeds per hill were planted and thinned to a single plant per hill after first weeding.

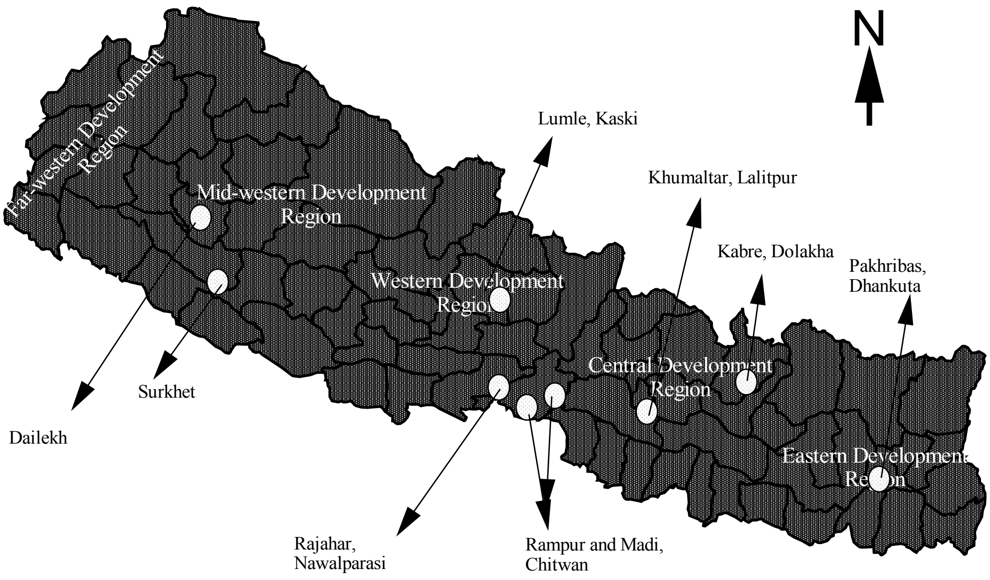

Figure 1. Map of study sites in Nepal

Fertilizers were applied at the rate of 120:60:40 kg ha^{-1} N: P_2O5,: K_2O, respectively in addition to 15 t farmyard manure per hectare. Half dose of N and full doses of P and K were applied basally and remaining half of N was applied as side dressing at knee-high stage. The plots were kept free of weeds manually. Same levels of inputs and cultural practices were provided at all the locations.

Grain yield (kg ha^{-1}) at 15% moisture content was calculated using fresh ear weight with the help of the below formula:

$$\text{Grain yield}\left(\frac{kg}{ha}\right) = \frac{F.W.\left(\frac{kg}{plot}\right)(100-\text{moisture},\%)\times S\times 10{,}000}{85\times \text{Harvested area}(m^2)}$$

Where,

F.W. = Fresh weight of ear in kg per plot at harvest.

Moisture (%) = Grain moisture content at harvest.

85= Required moisture percentage 15%.

S= Shelling co-efficient (0.80).

Harvested area= net harvested plot size, m^2

Table 1. Description of maize genotype used in studies

Genotype	Parentage	General description
Poshilo Makai-1	Formed using inbreds from heterotic group A and B	Its place of origin is CIMMYT, Mexico and introduced in Nepal in 2002 as S99 TLWQ-HG-AB. It is open pollinated white QPM variety released in 2008. It is suitable for terai and mid hill production in Nepal.
S99TLYQ-HG-B	Formed using inbreds from heterotic group B	Its place of origin is CIMMYT, Mexico, introduced in Nepal in 2002. It is open pollinated yellow QPM prerelease variety. It is suitable for terai and mid hill production in Nepal.
Farmer's Variety (Rampur Composite)	Formed from Thai composite-1 x Suwan-1	Its place of origin is Thailand. It is yellow open pollinated and full season variety released in 1975. It is suitable for terai and mid hill production in Nepal.

Regression analysis was performed to determine stability and identify superior genotypes across environments on the basis of regression coefficient. Finlay and Wilkinson (1963) considered genotypes with high mean yield, regression coefficient equal to unity (b=1).

The AMMI model, which combines the standard analysis of variance with principal component analysis (Zobel *et al.*, 1988), was used to investigate the nature of G x E interaction. The AMMI model first fits additive effects for the main effects of genotypes and environments, using the additive analysis of variance procedure.

3. Results and Discussion

The genotype responds differently across range of environments and therefore, the relative performance of the varieties depends upon the environment. The pattern of change is not same from one genotype to another in the same environment or for same genotype in different environment. Stability in the yield performance is the major concern to the breeder and influenced mostly by genotype x environment interaction (GEI). GEI is the major concern to the breeder because a genotype interacts with its environment either positively or negatively. If an interaction is present, then a particular genotype will perform differently when placed in different environments.

Yield stability is the ability of a genotype to avoid substantial fluctuations in yield over a range of environments. Varieties with high and stable performance are desirable. The stability in the performance of the genotype can be estimated either by statistical approach or by genetic approach. Joint regression analysis and Additive Main Effect and Multiplicative Interaction (AMMI) model are commonly used statistical approach to estimate the stability.

The pooled analysis of variance for grain yield (Table 2) showed that the effect of year within environment was highly significant but the effect of environment, genotypes and genotype x environment effect was non-significant. This clearly indicates that effect of year is more influential than others.

Table 2. Analysis of Variance derived from AMMI Analysis

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Env	8	35289755	4411219	0.8635	0.5766439
Year(Env)	9	45976454	5108495	4.6070	0.0003503 ***
Gen	2	2376339	1188170	1.0715	0.3523526
Env:Gen	16	9114340	569646	0.5137	0.9240347
Residuals	39	43245392	1108856		

Signif. codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05

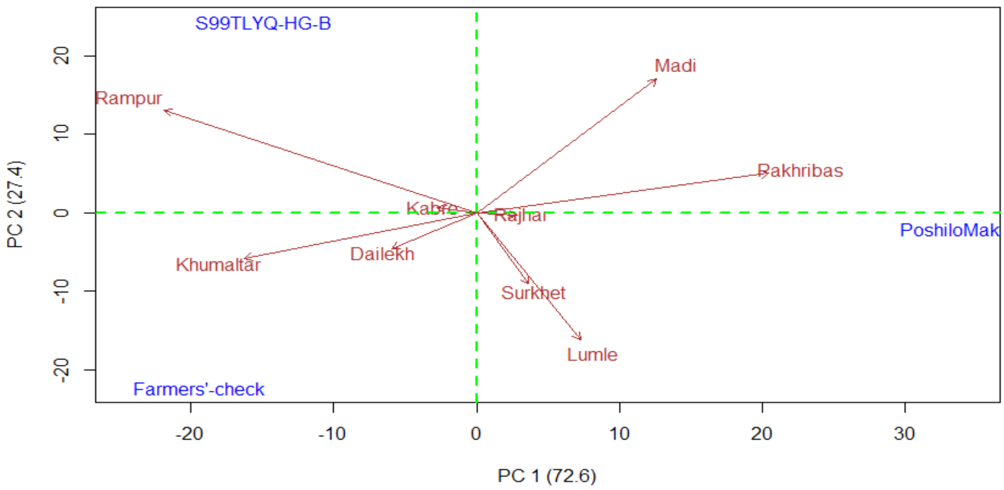

Figure 2. Stability of S99TLYQ-HG-B over standard check and local check in coordinated farmers’ field trials across the tested locations.

Table 3. Regression parameters of maize hybrids from multi-location trials (n=18) where variety mean grain yield (kg/ha) was regressed on trial mean yield from 2009, 2011, 2012 and 2013

Sn	Genotype	Mean ± SEM	Range	CV,%	R^2 (%)	b	SEb	t value
1	S99TLYQ-HG-B	4712 ± 263	2768 -7000	23.65	86.3	0.94**	0.0936	10.05
2	Poshilo Makai-1	4699± 337	2043 - 7954	30.42	80.0	1.16**	0.1454	7.99
3	Farmer's variety	4297±259	2033 - 5887	25.54	81.3	0.90**	0.1076	8.37

SEM: Standard Error of Mean, R^2 : Coefficient of determination, SEb : Standard Error of b

Figure 2 showed that Poshilo Makai-1 is more suitable in Rajhar whereas S99TLYQ-HG-B is more suited to Kabre as of explained by PC_1 and PC_2. Similarly, the performance of Poshilo Makai-1 seems better in Rajhar, Madi, Pakhribas, Surkhet and Lumle. The maize genotype S99TLYQ-HG-B performed good at Kabre and Rampur.

The coefficient of regression (b) explains the adaptiveness of the tested genotypes over the evaluated environments. The varieties with b-value near to unity and highest mean grain yield show the more average stability. The S99TLYQ-HG-B with highest mean grain yield and b value near to unity shows highly stable over the tested environment. Upadhyay *et al.* (2009) also reported that S99 TLYQ-HG-B had produced higher mean grain yield as well as b-value close to unity in Lumle, Pakhribas, Dailekh and Kabre. Therefore, it is well adapted to all environments and is an average stable genotype. Similarly, Poshilo Makai-1 higher mean grain yield and b-value larger than unity indicates that this variety can perform better yield in favorable environments. Varieties with above average stability produce well in poor environments are insensitive to changes in environmental conditions while the reverse is true for varieties with below average stability (Finlay and Wilkinson, 1963). Primomo *et al.* (2002) considered varieties with b values of 0.70-1.30 to have average stability, < 0.70 and > 1.30 to have above and below average stability respectively.

The coefficient of variation (CV) of each genotype as a measure of stability; A high yielding genotype with a low CV is considered stable (Francis and Kannenberg, 1978). Given the data presented in Table 3, it is noted that S99TLYQ-HG-B has the lowest CV (23.65%) among the tested genotypes. So, S99TLYQ-HG-B is more stable variety.

4. Conclusion

It can be concluded that S99TLYQ-HG-B could be the high yielding and stable yellow quality protein maize variety instead of white QPM namely Poshilo Makai-1. Therefore, it is better to proceed this variety for official release, large scale seed multiplication and distribution to the farmers as early as possible.

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