BLUP’s to Quantify Yield Gain under Wheat Coordinated System for Northern Hills Zone by Factor Analytic Approach

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ABSTRACT
Trend in linear manner has been observed for wheat production under irrigated timely and late sown along with rainfed timely sown trials of Northern Hills Zone of country. Production elevated to the level of 53, 30 and 36q/ha for irrigated timely, late sown and rainfed timely sown trials. By the end of considered period 0.81, 0.61 and 2.06 quintal per hectare could be added in subsequent trials. Low values of R² for irrigated timely and late sown trials suggested marginal increase in linear fashion in production values. More over consistent improvement observed in rainfed timely sown trials as justified by highly significant value of R².

Key words: BLUP, FA, Fixed and random effects, Mixed model, REML.

INTRODUCTION
Several statistical methods have been exploited to estimate/predict the breeding value of genotypes, depending on the assumption of fixed, random, or mixed effects models (Baretta et al. 2017, Piepho et al. 2008). Powerful methodology was developed by augmentation of the best linear unbiased prediction (BLUP) method with the restricted maximum likelihood (REML) (Borges et al. 2010, Olivoto et al. 2017). Breeding values of genotypes were predicted using the additive model in multi environment trials (Crespo et al. 2017). Mixed model approach may improve the estimation of fixed genotypes and random environmental along with interaction effects, resulting in less biased predictions and better ranking of the genotypes (de Pelegriń et al. 2017). Main advantages of the mixed models (REML/BLUP) to predict genotypic values and generating information more accurately and predicts genotypic values unbiased augments to maximize the selection gain (Eileen et al. 2015; Gustavo et al. 2016). Factor Analytic is an efficient and flexible procedure for reducing the dimensionality and complexity of the variance–covariance matrix that combines the main effects of genotypes and the G x E interaction (Burgueño et al. 2008, Mendes et al. 2012). Fitting a FA structure, made it possible to model the effects of genotypes and the G x E interaction efficiently; by doing this, the precision of the prediction of breeding values increases. Considering the theoretical advantages of BLUP, objective of present study was to present application of widely used method of analysis involves a linear mixed model with factor analytic (FA) variance structures for the variety by environment effects. (Piepho 1998; Burgueño et al. 2008; Smith et al. 2015).

MATERIALS AND METHODS
Wheat is cultivated in the hills at different altitude under different crop rotation adapted at different elevations. In NHZ, sowing is generally done under rainfed conditions in October/ November with residual moisture and harvesting takes place in May/June. In higher hills of Leh (J and K) and Lahaul and Spiti (H.P.), the winter is severe, causing the crop is to be raised between May to September. Development of high yielding varieties for moisture stress condition is the major objective of wheat improvement programmes in NHZ. Region encompasses the hilly terrain of Northern region extending from Jammu and Kashmir to North Eastern States. The NHZ comprises J and K (except Jammu and Kathua distt.); Himachal Pradesh (except Una and Paonta Valley); Uttarakhand (except Tarai area); Sikkim, hills of West Bengal and North Eastern states (Fig 1). The wheat grown in the NHZ generally has productivity of 15-16 q/ha. Moisture stress is the major factor responsible for low productivity besides soil fertility, soil depth, frost damage, small and fragmented holdings, low and imbalanced use of fertilizers. High incidences of weeds and diseases, particularly yellow rust, brown rust and loose smut etc. are the other factors that limit the productivity.

Estimation of the variance parameters carried out by using residual maximum likelihood (REML) along with estimation/prediction of the fixed as well as random effects. Quite popular and widely cited ASReml-R package exploited to fit models which uses the average information algorithm for REML estimation of variance parameters. The implementation for FA models in ASReml-R package handles the situations of where rank of interaction matrix is of less than full rank.

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Under MET g genotypes are evaluated in e environments and analysed as per model

\[ y_{ijk} = \mu + \tau_i + \delta_j + (\tau \delta)_{ij} + \gamma (\delta)_{jk} + \varepsilon_{ijk} \]

\( y_{ijk} \) yield of k replication of i-th genotype in j environment
\( \mu \) overall mean
\( \tau_i \) Effect of genotype
\( \delta_j \) Effect of environment
\( (\tau \delta)_{ij} \) Interaction effect
\( \gamma (\delta)_{jk} \) Effect of k-th replication in j-th environment
\( \varepsilon_{ijk} \) Random error
\( i= 1,2,3,….g; j=1,2,3,….e; k=1,2,3,….r \)

Possible three versions of equation are: (i) Random model with all effects being random except \( \mu \); (ii) fixed model with all effects being fixed except \( \gamma (\delta)_{jk} \) and \( \varepsilon_{ijk} \); (iii) mixed model with genotypic effect is fixed whereas the others are random.

When it is considered that the genotypic effect is fixed and the environmental effect is random, \( \mu \) and \( \tau_i \) are fixed effects while \( \delta_j, (\tau \delta)_{ij}, \gamma (\delta)_{jk} \) are independently and normally distributed with zero mean and variances \( \sigma^2_\delta, \sigma^2_{\tau \delta} \) and \( \sigma^2_{\gamma (\delta)} \) respectively.

**RESULTS AND DISCUSSION**

Highly significant change in wheat production had been observed during the studied time period span for irrigated timely sown, late sown and rainfed timely sown conditions in Hilly Zone of country as reflected in ANOVA tables (1,2 and 3). Highly significant values of intercept for three conditions along with highly significant slope for rainfed timely sown conditions observed. Significant values of slope for irrigated timely and late sown conditions also seen.

Scatter plots of BLUP's of wheat production versus year were plotted to examine the coefficient of determination \( R^2 \) and linear trend for assessing progress in wheat production for irrigated timely, irrigated late and rainfed timely sown conditions. Regression analysis for production revealed that under rainfed timely-sown condition, the \( R^2 \) value was highly significant (P<0.01). Under the rain fed timely-sown conditions, area under cultivations had decreased in zone so trials were discontinued for 2015-16, 2016-17 years though yield improvement was highly significant. Advanced varietal trials were also discontinued for 2015-16 and 2016-17 due to shortage of promising genotypes to next levels. Significant improvement was also visible in rainfed timely-sown conditions of the zone.

Linear trend in the year-wise wheat production in different conditions revealed an increase in average production of promising genotypes in zone by the end of 2015. The production Figs elevated to the level of 53q/ha (Fig 2) for irrigated timely, of 30q/ha (Fig 4) for irrigated late sown and 36q/ha (Fig 6) for rainfed timely sown trials. However, in 2008-09, average production was 46q/ha 41q/ha 20q/ha and by the end of period 0.81, 0.61 and 2.06

**Table 1:** ANOVA for irrigated timely sown conditions.

| Source | SS    | MSS | F value | Pr > F | Root MSE | R-Square | Coeff Var | Std Error | t value | Pr > |t| |
|--------|-------|-----|---------|--------|----------|----------|-----------|-----------|---------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---
**Fig 1:** Agro climatics zones for wheat cultivation in country.

**Fig 2:** Best Linear Unbiased Predictors for promising genotypes for timely sown conditions.

**Fig 3:** Regression analysis of BLUP’s for promising genotypes for irrigated timely sown.
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**Fig 4:** Best Linear Unbiased Predictors for promising genotypes for late sown conditions.

**Fig 5:** Regression analysis of BLUP's for promising genotypes for irrigated late sown.

**Fig 6:** Best Linear Unbiased Predictors for promising genotypes for rainfed timely sown conditions.
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quintal yield respectively could be added in subsequent trials. Although highest yield levels of 53 q/ha (2014-15), 38 q/ha (2010-11) and 38 q/ha (2013-14) were obtained in irrigated timely, late and rainfed timely sown trials but low values of $R^2$ for irrigated timely (Fig 3) and late sown conditions (Fig 5) suggested high variability in production values. More over consistent improvement observed in rainfed timely sown trials as justified by highly significant value of $R^2$ (Fig 7).

Study revealed that during studied period of seven years the wheat production had progressed nicely in this zone. Fitted straight-line equations by SAS software displayed in corresponding Figs indicate that the linear growth was observed under all sown conditions of the zone. During the year 2008-09, the base yield level was 4216, 2849 and 1987 kg/ha respectively (as reflected by intercept of the equation). Rainfed sown conditions of the zone expressed significant yield increase over years ($R^2=0.4734^{**}$) was registered and the linear trend was noticed from the base yield level of 1987 kg/ha with annual increment of 206 kg/ha. Comparatively large values of CV reflected consistent yield improvement under rainfed timely conditions as compared to other considered situations.

BLUP analyses of wheat trials showed continuous increase in the grain yield of the genotypes developed by Indian coordinated Wheat Program. This finding also corroborates with studies on coordinated wheat production estimated by BLUE approach (Mohan et al. 2017). More over in present study FA structure of the variance–covariance matrix of GxE was considered to estimate the BLUP of wheat yield.

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REFERENCES

Baretta D., Nardino, M., Carvalho, I.R., Pelegrin, A.J., Ferrari, M., Szareski, V.J., (2017). Estimates of genetic parameters and genotypic values prediction in maize landrace populations by REML/BLUP Procedure. Genetics and Molecular Research. 16: 1-14.

Borges V, Ferreira PV, Soares L, Santos GM, Santos AMM. (2010). Sweet potato clone selection by REML/BLUP procedure. Acta Sci Agron. 32(4): 643-649.

Burgueño J., J. Crossa, P.L. Cornelius and R.C. Yang. (2008). Using factor analytic models for joining environments and genotypes without crossover genotype x environment interaction. Crop Sci. 48:1291-1305.

Crespo-Herrera, L.A., J. Crossa, J. Huerta-Espino, E. Autrique, S. Mondal, G. Velu,. et al. (2017). Genetic yield gains in CIM-MYT’s international Elite Spring Wheat Yield Trials by modeling the genotype x environment interaction. Crop Sci. 57: 789-801.

de Pelegrin, A.J., Carvalho, I.R., Nunes, A.C.P., Demari, G.H., Szareski, V.J., et al. (2017). Adaptability, stability and multivariate selection by mixed Models. American Journal of Plant Sciences. 8: 3324.

Eileen Azevedo Santos, Alexandre Pio Viana, Josie Cloviane de Oliveira Freitas, et al. (2015). Genotype selection by REML/BLUP methodology in a segregating population.
Gustavo H.F. Oliveira, Camila B. Amaral, Flávia A.M. Silva, Sophia M.F. Dutra, et al (2016). Mixed models and multivariate analysis for selection of superior maize genotypes. Chilean Journal of Agricultural Research. 76: 427-431.

Mohan D., Tiwari, V. and Gupta R. K. (2017). Progression in yield and value addition of Indian bread wheat – An Analysis. Indian J. Genet. 77(1): 16-24.

Mendes F.F.; Guimarães, L.J.M.; Souza, J.C.; Guimarães, P.E.O.; Pacheco, C.A.P.; et al (2012). Adaptability and stability of maize varieties using mixed models methodology. Crop Breeding and Applied Biotechnology. 12: 111-117.

Olivoto T., Nardino, M., Carvalho, I.R., Follmann, D.N., Ferrari, M., Szareski, V.J., et al (2017). REML/BLUP and sequential path analysis in estimating genotypic values and inter relationships among simple maize grain yield-related traits. Genetics and Molecular Research. 16: 1-10.

Piepho HP, Möhring J, Melchinger AE and Büchse A. (2008). BLUP for phenotypic selection in plant breeding and variety testing. Euphytica. 161: 209-228.

Piepho H.P. (1998). Empirical best linear unbiased prediction in cultivar trials using factor analytic variance–covariance structures. Theor. Appl. Genet. 97:195-201.

Smith A., A. Ganesalingam, H. Kuchel and B.R. Cullis. (2015). Factor analytic mixed models for the provision of grower information from national crop variety testing programs. Theor. Appl. Genet. 128:55-72.