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Statistical analysis of multi-environmental rice yield trial in Bastar district of Chhattisgarh

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ABSTRACT

The adaptability of crop varieties in multi-location trials (MVAT) is a problem in the presence of genotype by environment (G X E) interaction. Various statistical techniques are available to analyse the data in MVAT. But, the information on these methods and their relative performance on evaluation of adaptability of rice varieties are limited. Therefore, a study was conducted to statistical analyze the multi-environmental rice yield data to compare the statistical methods available for analysis. MVATs data of rice were collected from farmer's field of five diverse locations of Bastar district. It consisted of data on performance of varieties at 5 locations over 03 replicated fields. The statistical techniques such as stability parameters, ranking and multivariate techniques were tested with the yield data. Different stability methods consider different aspect of variability across environment and hence produce different results for the same data. Therefore, interpretations of stability of varieties vary according to different parameters considered. Multivariate methods describe G X E interaction effectively with plots that are easy to understand.

Key words: *Rice varieties, G× E interaction, stability measures, multivariate techniques*

India is a predominantly agriculture based country and productivity of crop increased in India due to increase in irrigated area; introduction of HYVs and improved management practices (Kumar et al., 2016a). Chhattisgarh in particular due to diverse crop growing environment, land situations, physiographic and socio-economic conditions and has a tremendous agricultural potential with a diversity of soil and climate, mountains, plateau, rivers, natural vegetation and forest. It is unique in sense in many ways. The total annual rainfall ranges from 800 mm to 1700 mm in different years. Diversified crops and cropping systems are typical characteristics of Chhattisgarh. Rice is the major crop of the region, on the other hand kharif potato are being grown in plateau area of northern hills, while in Bastar plateau, crops like coconut, coffee and wide range of tuber crops, spices and medicinal plants are being grown. Keeping in view livelihood importance of paddy for Bastar tribes, the present enquiry related to its production and yield stability planned. Breeder always wants to screen the varieties for two purposes (i) for further improvements and (ii) to release the best varieties on commercial scale (Kumar et al., 2016b). For the second purpose he should consider two criteria, i.e. genetic potential of varieties and stability or consistency in performance.

The term stability refers to the behaviour of a crop in varying environments. The main aim is to develop varieties that are stable across range of environments. Environments may be locations or years or combinations of both. Effect of genotype and environment on phenotype may not be always independent. Phenotypic response to change in environment is not same for all genotypes; the consequences of variation in phenotype depend upon the environment. The interplay in the effect of genetic and non-genetic on development is termed as 'genotype-environment interaction. Peipho (1993) has shown the evidence that interaction effects for a variety may at times be non-normally distributed. Hence, there is a need to identify the robust and reliable measures of stability under varying situations. Genotype environment interaction (GEI) is major problem in comparison of genotype performances. researches very often ignored GEI in their recommendation for crop growing. It is necessary to use corresponding statistical techniques for efficient assessment of interaction. Interaction among genotypes and environment studied and interpreted by a wide variety of statistical models and methodologies. Performance of crop variety actually depends on effect of its genotype and environment in which it grows.

Simulation of environment and experiment

The study pertains to Bastar district of Chhattisgarh including 8 recommended varieties of paddy at 5 diverse locations namely; Bastanar (L_1), Bakawand (L_2), Tokapal (L_3), Jagdalpur (L_4) and Bastar (L_5) block. The yield data of high yielding genotypes or varieties of paddy from farmer's field of Bastar, Chhattisgarh during three years (2012 to 2015) were collected for statistical assessment of yield stability analysis.

Statistical assessment

The same data used to estimate different stability measures (1) Descriptive method for grouping of genotypes (Francis and Kennenber, 1978) (2) Ecovalence W_i, Wricke (1962) defined it as the mean performance of genotypes/varieties are important and from these mean performance an estimate of stability (3) Eberhart and Russell (1966) model, (mean performance of genotype, regression coefficient, (b_i)and deviation from regression ($S^2 d_i$), (4) Hanson's (1970) model of stability developed a Hanson's stability index or composite measure of genotype stability (D_i) and is defined as square root of sum of squared deviation of expected yield from expected stable yield and (5) GGE bi-plot analysis was recently developed to use some of time function of these methods jointly. Bi-plot method originated with Gabriel (1971), and its use subsequently expanded by Kempton (1984) and Zobel et al., (1988). The extensive usefulness of GGE bi-plot, where G = Genotype + G E = Genotype by environment effect, has only recently been elucidated (Yan, 2001). GGE bi-plot analysis also used to generate graphs showing; comparison of environment to ideal environment (Yan and Kang, 2003)"which-won-where" pattern and environment. Angles between environment vectors were used to judge correlations (similarities) between pairs of environments (Yan and Kang, 2003). These aspects make GGE bi-plot a most comprehensive tool in quantitative genetics and varietal stability.

Measure of variability by box plot

Box plot of paddy crop presented in Fig. 1 and box plot splits data set into quartiles. Body of box plot consists of "box", which goes from first quartile (Q_1) to the third quartile (Q_3). Within box, a horizontal line is drawn at Q_2, median of different genotypes of paddy crop in Bastar. Two vertical lines, called whiskers, extend from front and back of the box. The front whisker goes from Q_1 to the smallest non-outlier in data set, and back whisker goes from Q_3 to largest non-outlier. Additionally, box plots display two common measures of the variability or spread in a paddy crop. Range

Table 1. Descriptions of recommended varieties

Symbol	Variety	Maturity duration (days)	Yield(t/ha)	Specific Characters
V_1	Chandrahasini	115-120	5.0	Gall midge resistant, brown hopper tolerant
V_2	IR-64	115-120	4.5	Gall midge and blast tolerant
V_3	MTU-1010	112-120	4.5	Brown hopper tolerant
V_4	Swarna	145-150	4.5	Medium slender grain, dwarf plant
V_5	Karma Mahsuri	125-130	5.0	Gall midge resistant,blast tolerant
V_6	Kranti	125-130	5.0	Drought tolerant & Bold seeded
V_7	Mahamaya	125-130	5.5	Gall midge resistant, bold seeded
V_8	MTU-1001	130-135	4.5	Brown hopper tolerant

display the yield spread of all the genotypes, it is represented on a box plot by vertical distance between smallest value and the largest value, including any outliers. Inter quartile range display the middle half of a paddy data set falls within inter quartile range. In a box plot, inter quartile range is represented by the width of box (Q_3 minus Q_1) and, box plots often provide information about shape (Skewness) of a data set. According to box plot, MTU-1010 (V_3) are symmetrically distributed, V_4 (Swarna), V_5 (Karma Masuri) and V_8 (MTU-1001) are positively skewed and rest of the genotype showed negatively skewed (Fig. 1). Stability and box plot analysis reported by Azri et al., (2014), which studied lowland rice promising varieties evaluated in large multi-location trials.

Stability analysis

Stability describes variability of yields among environment. Varieties with minimum variability across environments are referred as stable genotype. The results of stability analysis are shown in Table 2. Coefficient of variation (CV) indicates yields from mean yield of the production genotype. On the basis of idea, genotypes with minimum variance for yield across different environments are considered as stable. This idea of stability may be considered as biological/static concept of stability (Becker and Leon, 1988). This concept of stability is not accepted by most of the breeders and agronomists, who would prefer an agronomic or dynamic concept of stability; therefore they prefer genotype with high mean yield and potential to respond to agronomic inputs under better environment (Leon, 1988). Hence, genotype Mahamaya (1.51) is the most stable genotype according to criteria CV. The results of deviation parameter from regression are appropriate to compare variability of different varieties. Result indicates that genotype Swarna (0.51) followed by Mahamaya (0.63) is the most stable genotype. Same results reported by (Farshadfar et al., 2012) in chickpea varieties. Ecovalance (W_i^2) consider the genotype×season interaction mean square as criteria for stability. The minimum ecovalance value indicates the stable genotypes, which is Mahamaya (0.528) followed by MTU-1010 (0.95) and IR-64 (1.08). The ranking of varieties according to Handson's stability parameter (D_i) lower value of (D_i) observed for genotype Mahamaya (4.47) is the most stable varieties followed by MTU-1010 (4.55) and ranked 1st and 7th for grain yield, respectively. These findings are in close agreement with those obtained with rice crop by Parmar et al., (2016).

Comparison of results of different statistical methods

Results of different statistical methods tested in this study are summarized in Table 2. Information indicates different statistical methods to identify different variety. The selection of best method is a problem as a standard is not available for comparisons of different stability method. Therefore, further studies on development of indicators to evaluate the efficiency of stability methods are required. In present study, variety identified by majority of statistical methods according to total ranked could be declared as the most stable variety Mahamaya (5) and MTU-1010 (13).

Method of deviation of yields from the maximum

Deviations of varieties from maximum yield recorded in different locations averaged over different season (Table 3). The data indicate that overall mean deviation of varieties is lowest compared to that of other varieties tested. Moreover, variance of deviations of these

Table 2. Results of stability analysis

Variety	CV	Rank	$s_{d_i}^{-2}$	Rank	W_i^2	Rank	D_i	Rank	Rank Total
Chandrahasini	4.17	8	1.28	8	2.78	7	6.28	7	30
IR-64	3.48	7	1.16	5	1.08	3	4.81	3	18
MTU-1010	1.55	2	1.25	7	0.95	2	4.55	2	13
Swarna	2.93	6	0.51	1	2.55	6	6.75	6	19
Karma Mahsuri	2.66	4	1.19	6	4.69	8	13.08	8	26
Kranti	2.96	5	1.10	4	1.11	4	4.99	4	17
Mahamaya	1.51	1	0.63	2	0.528	1	4.47	1	5
MTU-1001	2.46	3	0.99	3	1.16	5	5.31	5	16

CV-Coefficient of variation, $s_{d_i}^{-2}$ deviation parameter from regression (Eberhart and Russel's), W_i^2 - Wrick ecovalance, D_i- Handson's stability parameter

Table 3. Mean and variance of deviations of variety yields over locations

Variety	Mean yield (t/ha) of locations					Mean	Variance
	L_1	L_2	L_3	L_4	L_5		
Chandrahasini	4.70	4.43	4.20	4.47	4.33	4.43	0.34
IR-64	4.37	4.13	4.00	4.17	4.03	4.14	0.21
MTU-1010	4.20	4.17	4.03	4.13	4.10	4.13	0.04
Swarna	4.27	4.10	4.07	4.27	4.00	4.14	0.15
Karma Mahsuri	4.73	4.50	4.43	4.63	4.50	4.56	0.15
Kranti	4.70	4.53	4.33	4.47	4.47	4.50	0.18
Mahamaya	5.10	5.03	5.00	5.07	5.20	5.08	0.06
MTU-1001	4.23	4.07	3.97	4.10	4.17	4.11	0.10

varieties received rank 2 compared to other varieties. Results of deviation method suggest that overall production and stability of varieties. Mahamaya-5 (0.589) and MTU-1010 (0.411) is better than other variety hence it is best variety in term of adaptability.

Which-won-where pattern of genotypes

GGE bi-plot uses genotype and G×E components in a XY graph. The first two PCA scores are used to represent environments as well as genotypes. The PC 1 and PC 2 axes explained 97.3 and 1.9% of total GEI. The position of two genotypes in the graph is connected by drawing a line between them. One of the smartest facial appearances of a GGE bi-plot is its facility to show the which-won-where model of a genotype by environment yield data set. Many researchers find this use of bi-plot intriguing, as it graphically addresses important concepts such as crossover GE, mega environment differentiation, particular adaptation (Yan and Tinker, 2005). Genotypes located on vertices of the polygon performed either the best or the poorest in one or more environments since they had long distance from origin of bi-plot. The perpendicular lines are equality lines between adjacent genotypes on polygon, which facilitate visual comparison of them. Use of bi-plot to quantify the genotype environment interaction (GEI) is widespread. GE effect can be visualized in single graph, which facilitates comparison of genotypes and their interaction with environment (Balestre et al., 2010). Lines 1 are Mahamaya, Karma Mahsuri, Kranti and Chandrahasini and line 2 are perpendicular to side Chandrahasini-IR-64; line 3 is perpendicular to side IR-64, Swarna and MTU-1010; similarly, line 4 is perpendicular to side MTU-1010 and Mahamaya. These 4 lines divide the bi-plot into 4 sectors, and the environments fall into 1 of them (Fig. 2). An interesting feature of this view of a GGE bi-plot is that the vertex genotype(s) for each sector has higher (sometimes the highest) yield than the others in all environments that

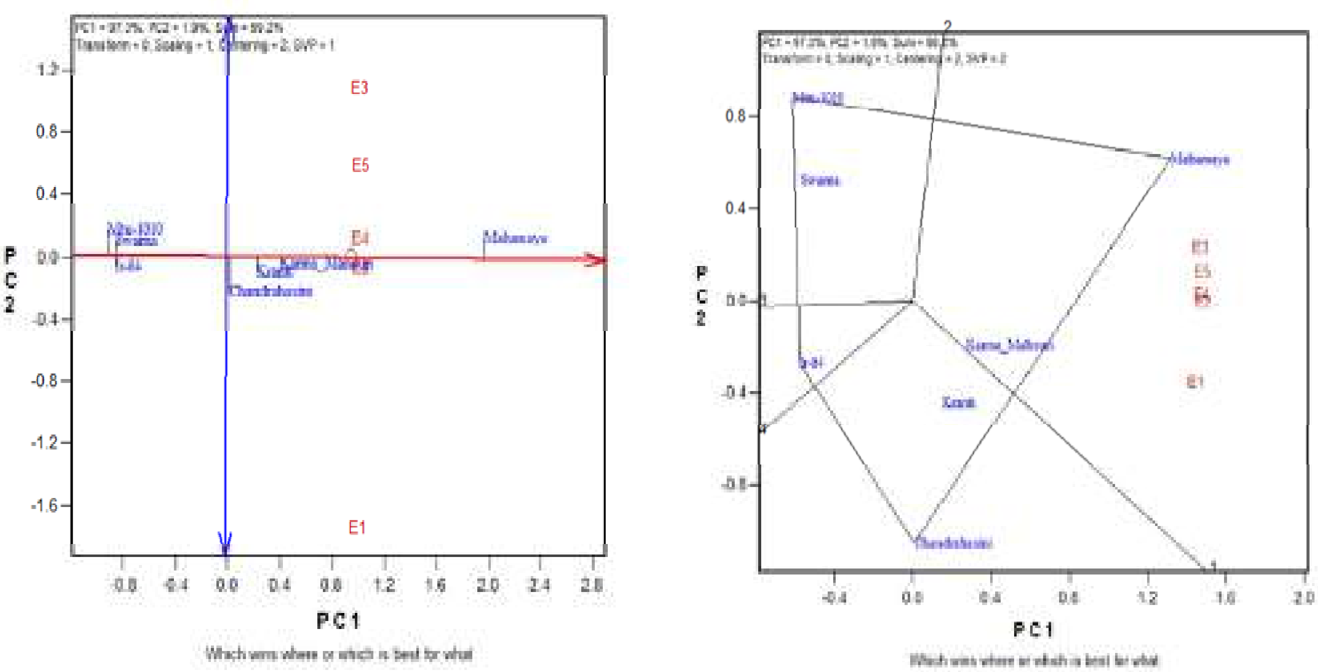

Fig 2. Principal component of bi-plot of eight varieties

fall in the sector. Thus, all 5 environment fall into sector 1 delineated by lines 2, 3 and 4, and vertex genotypes for this sector were Mahamaya-5 (G7) and Karma Mahsuri (G5).

Ranking of genotypes based on yield and stability

The ranking of genotypes based on their mean grain yield and yield stability for environments is shown in below (Fig. 2). It has been reported that when PC1 in a GGE bi-plot approximates G (mean performance), PC2 must approximate G×E associated with each genotype, which is measure of instability (Yan and Kang, 2003). Yield performance and stability of genotypes evaluated by an average environment coordination (AEC) method (Yan and Tinker, 2005). Within a single mega-environment, genotypes should be evaluated on both mean performance and stability across environments. Environment coordination (AEC) view of GGE bi-plot presented in Fig 2. The single-arrowed line is AEC abscissa, it points to higher mean yield across the environment. Thus, V7 (Mahamaya), V5 (Karma Masuri), V6 (Kranti) and V1 (Chandrahasini) had the highest mean yield. The double-arrowed line is the AEC ordinate; it points to greater variability (poorer stability) in either direction. Thus, V1 (Chandrahasini), V5 (Karma Mahsuri) and V6 (Kranti) were highly unstable whereas V7, V3 and V4 were highly stable.

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