

Analyzing the variability in Maize (*Zea mays* L.) genotypes using principal component analysis under varied ecosystems

Abstract

Maize is a cereal cross-pollinated crop which belongs to the family poaceae. It is grown over a wider range of environment than any other cereal crop. The present study was conducted to study genetic variability using principal component analysis. Twenty maize genotypes were used in the study. Ten characters *viz.*, plant height, ear height, days to 50 % tasselling, days to 50 % silking, ASI, cob length, number of rows per cob, hundred seed weight, shelling percentage and yield were recorded for the study. In the PCA, four principal components exhibited eigen value more than 1.0 exhibiting 84.54 percent of the variability for the characters under irrigated conditions. The PC1 negative loadings for the flowering traits, *viz.*, days to 50 % silking (-0.3886), ASI (-0.3233) and days to 50 % tasselling (-0.2972) and positive loadings with higher contribution from cob length (0.4033), no of rows per cob (0.3480) followed by shelling percentage were observed. Positive loadings were exhibited by days to tasselling (0.4780), plant height (0.4670) and hundred seed weight (0.4518) in PC2. In PC3 positive loadings for the characters *viz.*, number of rows per cob (0.5338), ASI (0.5226) and cob length (0.3299) and negative loadings for the traits grain yield (-0.3815), ear height (-0.2658) and plant height (-0.2437) and in PC4 positive loadings for plant height (0.4953), ear height (0.2546) and negative loadings were shown by days to grain yield (-0.6632), shelling percentage (-0.3751), ASI (-0.2369) and 50 % silking (-0.0648) were observed. In rainfed conditions, the two principal components had eigen value of more than 1. Under normal irrigated condition, PC1 and PC2 had eigen value of 5.689 and 1.6439. Plant height (0.3866), cob length (0.3726), number of rows per cob (0.3551), shelling % (0.3196), grain yield (0.2941), and hundred seed weight (0.2847) contributed positively to PC1. PC 2 had highest positive contributions from days to 50 % tasselling (0.5676), days to 50 % silking (0.5249), shelling % (0.3885), hundred seed weight (0.3763) and grain yield (0.2007). Negative loadings were shown by ear height (-0.1356) and plant height (-0.0093). Positive loadings were contributed by days to 50 % tasselling (0.5676), Days to 50 % silking, shelling percentage (0.3885) and hundred grain weight (0.3763).

Key words: PCA, anthesis silking interval, cob length, number of rows per cob and grain yield

Introduction

Maize, a cereal crop is the third important food crop in the world having highest yield potential. The crop requires 500 mm of rainfall for a season. However, in rainfed farming systems, where precipitation is uncertain, the crop has chance of exposing to climate variability and stress. Over the last two decades, drought caused a direct loss of USD 29 billion in developing countries (FAO, 2021). Among the maize growing countries in the world, India rank 4th in area and 7th in production, representing around 4% of the world maize area and 2% of total production. It has diversified uses as human food, animal feed

and as a source for large number of industrial products. Maize has 60-70% of carbohydrates, 9-11.5% of crude protein, 2-3.5% crude fibre and 3-5% of lipids. This crop is used to a higher level of industrial utilization than any other cereal grain because of its very high production potential, wider adaptability industrial value. (Bharathi *et al* 2021). Maize starch is used for the production of glucose, dextrose ethyl alcohol, acetone and lactic acid. It is also used in making adhesive, preservatives, and antiseptic agents. By products obtained in the manufacturing of maize starch is used as cattle feed. The corn oil finds many uses in the industry. Maize is the prime driver of world agricultural economy due to its multiple uses. There is an urgent need to increase the production and productivity of maize crop to meet the demand of the ever-growing population (Fang and Xiong, 2015). This role requires an increase in crop yields either by reducing the gap between potential and actual yields (Premalatha and Kalamani, 2010). Plants exhibit multiple plant metabolic pathways prevented plants from senescing under water limited conditions (Zhang *et al.*, 2018). Hence, there is a need to understand the factors that can contribute to improvements in maize productivity, reduce the yield gap and enhance food security. Principal Component Analysis (PCA) can be used to find out the relative contribution of the traits towards the total variability (Zaman and Alam, 2013 & Gupta and Khandelwal, 2022). Genotypes with narrow genetic base are vulnerable to biotic and abiotic stress and genetically diverse genotypes is highly essential for any crop improvement programme (Yadav *et al.*, 2011). The main aim is to extract the total variation of characters into a limited number of factors (Kanganathakur and Sarma, 2023). The newly developed hybrids developed using promising inbreds were evaluated under varied ecological conditions for identification of traits that can be given importance in selection of traits that will contribute to obtain maximum yield potential. Hence, the present investigation is done to dissect out the traits contributing the grain yield by Principal Component Analysis.

Materials and methods

The experiment was conducted in Maize Research Station, Tamil Nadu Agricultural University during Rabi 2021 - 22. The study was conducted with twenty-two hybrids raised in Randomized block design in two replications. The genotypes were raised in irrigated and rainfed conditions simultaneously. The genotypes were raised in two rows of 4 m length and spacing of 60 cm x 25 cm. All the recommended management practices were adopted for the crop. The ten biometrical traits *viz.*, plant height, ear height, days to 50 % tasselling, days to 50 % silking, Anthesis Silking Interval, cob length, number of rows per cob, hundred seed weight, shelling percentage and yield were recorded in the twenty-two genotypes (Table 1a.)

used for the study. The plant traits that contributed to the maximum variation among the maize genotypes were identified by PCA method using STAR software.

Results and Discussion

The experimental results of the biometrical traits of the genotypes under both irrigated and the rainfed condition is represented in the tables 1a. and 1c. The results of principal component analysis for grain yield and the yield associated traits under irrigated condition and rainfed condition is presented in the table 2. Out of 10 components, only four principal components exhibited eigen value more than 1.0 and showed 84.54 percent of the variability for the characters. The PC1, PC2, PC3 and PC4 exhibited 39.79, 20.67, 12.73 and 11.35 percent of variability respectively. Mehrnaz *et al.*, (2014), Muhammad *et al.*, (2015) and Hughes *et al.*, (2015) had studied the genetic divergence studies in maize using principal component analysis. The PC1 with eigen value of 3.97 had negative loadings for the flowering traits, *viz.*, days to 50 % silking (-0.3886), ASI (-0.3233) and days to 50 % tasselling (-0.2972). The remaining traits showed positive loadings with higher contribution from cob length (0.4033), no of rows per cob (0.3480) followed by shelling percentage. In PC2 all the traits showed positive loadings except number of rows per cob. Days to tasselling (0.4780), plant height (0.4670) and hundred seed weight (0.4518) had the highest positive loadings. The PC3 with eigen value of 1.272 exhibited 12.73 % variability with positive loadings for the characters *viz.*, number of rows per cob (0.5338), ASI (0.5226) and cob length (0.3299) and negative loadings for the traits grain yield (-0.3815), ear height (-0.2658) and plant height (-0.2437). PC4 had eigen value of 1.135 and variability of 11.35 %. Negative loadings were shown by days to grain yield (-0.6632), shelling percentage (-0.3751), ASI (-0.2369) and 50 % silking (-0.0648). In rainfed conditions, the two principal components had eigen value of more than 1. PC1 had eigen value of 5.689. Positive loadings were contributed by the plant height (0.3866), cob length (0.3726), number of rows per cob (0.3551), shelling percentage (0.3196), grain yield (0.2941) and hundred seed weight (0.2847). Similar PCA study was reported by Ali *et al* 1999. PC 2 had eigen value of 1.6439 with highest positive contributions from days to 50 % tasselling (0.5676), days to 50 % silking (0.5249), shelling % (0.3885), hundred seed weight (0.3763) and grain yield (0.2007). Negative loadings were shown by ear height (-0.1356) and plant height (-0.0093). Principal component analysis, resulted in more divergent assessment under normal irrigated conditions with four numbers of principal components with eigenvalue ≥ 1 and cumulative variability of 84.54 percent. Under water limited rainfed conditions, two number of principal components with eigenvalue ≥ 1 were observed with cumulative variability of 73.34. The trend of the

scree plot (Fig.1.) and the biplot of the principal components under normal irrigated and rainfed conditions are represented in the Fig. 2&3 respectively. The different principal components with important characters coming together and contributing towards variability have the tendency to remain interrelated (Sinha and Mishra 2013).

Conclusion

Thus, for a trait-based selection, elucidation of the relative merits of component traits will be the basis for planning maize improvement programme. Among the twenty hybrids evaluated, the hybrid VaMH 21007 (7450 kg/ha) followed by VaMH 21019 (7300 kg/ha) exhibited higher yield under rainfed conditions. Cob length, days to 50 % silking, no of kernel rows per cob is found to contribute maximum genetic variability in maize. Therefore, using the above results, selection of genetically diverse genotypes will help in evolving new highly heterotic adaptive hybrids in crop breeding programmes under varying ecological and stress conditions.

References

- Bharathi, P., Ravikesavan, R., Yuvaraja, A., Iyanar, K. and Manikanda Boopathi, N. Genetic variability and correlation in maize inbred lines under irrigated and moisture stress condition. *Electronic Journal of Plant Breeding*. 2021;12(3): 928-933
- FAO. The Impact of Disasters and Crises on Agriculture and food Security. Rome: Food and agriculture organization of the United Nations. 2021.
- Fang, Y.; Xiong, L. General mechanisms of drought response and their application in drought resistance improvement in plants. *Cell. Mol. Life Sci*. 2015; 72: 673–689.
- Gupta D and Khandelwal V. Principal component analysis for yield and its attributing characters of pearl millet (*Pennisetum glaucum* [L.] R.Br.). *Annals of Plant and Soil Research*. 2022; 24(3): 408–14
- Hughes, A. N., Louise Akanvou., Arsène Irié, Z. B and Charles Konan, K. Phenotypic diversity of farmer's traditional maize (*Zea mays* L) Varieties in Cote d'Ivoire. *Maydica*. 2015;60(2): 112-118.
- Kanganathakur and Sarma M.K. Genetic diversity and principal component analysis in cultivated rice (*Oryza sativa*) varieties of Assam. *Indian Journal of Agricultural Sciences*. 2023; 93 (2): 145–150
- Mehrnaz, T., Elham, B., Ali, R, A and Ali, R, A. K. Genetic Diversity of 13 Maize (*Zea mays* L.) Hybrids based on multivariate Analysis Methods. *International Journal of Farming and Allied Sciences*. 2014-3-5:467-470.

- Muhammad, R.W., Qayyum, A., Hamza, A., Ahmad, M.Q., Naseer. N.S., Liaqat, S., Ahmad, B., Malik, W and Noor, E. Analysis of genetic traits for drought tolerance in maize. *Genetics and Molecular Research*. 2015; 28: 14(4): 13545-65.
- Premalatha, M and Kalamani, A. Correlation studies in maize (*Zea mays* L.) *International Journal of Plant Sciences*. 2010; 5(1): 376-380
- Sinha K A, and Mishra P K. Agro-morphological characterization and morphology based genetic diversity analysis of landraces of rice variety (*Oryza sativa* L.) of Bankura district of west Bengal. *International Journal of Current Research*. 2013; 5(10): 2764–69
- Yadav V K, Singh Y, Soni S K and Yadav A K. 2011. Genetic divergence analysis in salt tolerance rice (*Oryza sativa* L.) genotypes. *Plant Archives*. 2011; 11(2): 593–95.
- Zaman MA and Alam M. Genetic Diversity in Exotic Maize (*Zea mays* L.) Hybrids. *Bangladesh J. Agric. Res*. 2013; 38(2): 335
- Zhang, X.; Lei, L.; Lai, J.; Zhao, H.; Song, W. Effects of drought stress and water recovery on physiological responses and gene expression in maize seedlings. *BMC Plant Biol*. 2018; 18:68

Table 1a. The hybrids used in the study

S.No.	Name of the Hybrid	S.No.	Name of the Hybrid
1	VaMH 21001	12	VaMH 21013
2	VaMH 21002	13	VaMH 21014
3	VaMH 21003	14	CO6
4	VaMH 21004	15	VaMH 21016

5	VaMH 21005	16	VaMH 21017
6	VaMH 21006	17	VaMH 21018
7	VaMH 21007	18	VaMH 21019
8	VaMH 21008	19	VaMH 21020
9	VaMH 21036	20	VaMH 21021
10	VaMH 21010	21	VaMH 21022
11	VaMH 21012	22	VaMH 21023

Table 1b. The biometrical traits of the 22 genotypes under irrigated conditions

S.No.	Name of the Hybrid	Plant Height cm	Ear height cm	Days to 50 % tasselling	Days to 50 % Silking	Anthesis Silking Interval	Cob Length cm	No of rows per cob	Hundred seed weight	shelling percentage	Grain yield Kg/ha
1	VAH 21001	187	89.5	55.5	60	4.5	14.75	13	25.5	76.8	7688
2	VAH 21002	195	96.5	55	58	3	14.9	13	30.5	79.7	8646
3	VAH 21003	198.5	92	54.5	58	3.5	16.4	15	35	79.65	8813
4	VAH 21004	190.5	88.5	57	61.5	4.5	15.5	13	31.5	79.15	7688
5	VAH 21005	202.5	91.5	55	58.5	3.5	16.15	14	29.5	79.2	8813
6	VAH 21006	200.5	96	56	58.5	2.5	16.6	14	33.5	79.6	8938
7	VAH 21007	212	91	54.5	58	3.5	19.8	15	35	80.7	9604
8	VAH 21008	188.5	95	55	58.5	3.5	15.2	14	30	79.1	7438
9	VAH 21036	191	91.5	53.5	57.5	4	15.5	14	29	77.5	8250
10	VAH 21010	198	98.5	55	58.5	3.5	18.55	16	34.5	80.05	6521
11	VAH 21012	182	89	56	59.5	3.5	15	13	28	76.35	7417
12	VAH 21013	190	94	55	59	4	15.95	14	34.5	78.8	7875
13	VAH 21014	1205	92.5	56.5	59.5	3	16.6	14	38.5	79.05	8000
14	CO6	209	108	54.5	57.5	3	17	13	34	78.5	8333
15	VAH 21016	197.5	98	55.5	59.5	4	17.15	14	34.5	79.4	8729
16	VAH 21017	182	90	56	59.5	3.5	14.95	13	26.5	76.95	7708
17	VAH 21018	196	94.5	55	58.5	3.5	14.85	14	28	78.1	8417
18	VAH 21019	200	104	54.5	57.5	3	19.55	15	34.5	80.05	9208
19	VAH 21020	200	89.5	54.5	58	3.5	17.95	15	32	78	6625
20	VAH 21021	201	101.5	54	56.5	2.5	17.4	15	32	79.8	8708
21	VAH 21022	195	90.5	55.5	59.5	4	16.85	15	33	79.65	8167
22	VAH 21023	180	103.5	54.5	58	3.5	16.25	15	29	76.25	6542

Table 1c. The biometrical traits of the 22 genotypes under rainfed conditions

S.No.	Name of the Hybrid	Plant Height cm	Ear height cm	Days to 50 % tasselling	Days to 50 % Silking	Anthesis Silking Interval	Cob Length cm	No of rows per cob	Hundred seed weight	shelling percentage	Grain yield Kg/ha
1	VAH 21001	172.5	85.5	55	58	3	12.8	11	24.5	76.3	6083
2	VAH 21002	185	92.5	54	56	2	14.8	12	29.5	79.2	6850
3	VAH 21003	189	93.5	53.5	56	2.5	14.7	13	34	79.15	6817
4	VAH 21004	174.5	86.5	56	59.5	3.5	13.5	12	30.5	78.65	6083
5	VAH 21005	192.5	92.5	54	56.5	2.5	14.15	12	28.5	78.7	6817
6	VAH 21006	190	95	55	56.5	1.5	14.6	13	32.5	79.1	6583
7	VAH 21007	204.5	97.5	53.5	56	2.5	18.9	16	34	80.2	7450
8	VAH 21008	183.5	91	54	57	3	13.2	11	29	78.6	5883
9	VAH 21036	181	87.5	52.5	55.5	3	13.5	12	28	77	6500
10	VAH 21010	195.5	97.5	54	56.5	2.5	17	14	33.5	79.55	7017
11	VAH 21012	172	86	55	57.5	2.5	13	11	27	75.85	5867
12	VAH 21013	180	90	54	57	3	13.95	11	33.5	78.3	6233
13	VAH 21014	187	93.5	55.5	57.5	2	14.6	12	37.5	78.55	6333
14	CO6	199	104	53.5	55.5	2	15	12	33	78	6583
15	VAH 21016	192	94	54.5	57.5	3	15.15	12	33.5	78.9	6750
16	VAH 21017	172	86	55	57.5	2.5	12.95	12	25.5	76.45	6100
17	VAH 21018	186	90.5	54	56.5	2.5	12.85	12	27	77.6	6667
18	VAH 21019	201.5	100	53.5	55.5	2	17.55	15	33.5	79.55	7300
19	VAH 21020	201	93	53.5	56	2.5	15.95	13	31	77.5	5233
20	VAH 21021	193.5	97.5	53	54.5	1.5	15.4	14	31	79.3	6950
21	VAH 21022	185	91.5	54.5	57.5	3	14.85	13	32	79.15	6467
22	VAH 21023	177.5	99.5	53.5	56.5	3	14.25	12	28	75.75	5167

Table 2. Eigen Values, Proportion of Variance and Cumulative Proportion of maize genotypes under irrigated and rainfed conditions

PC	Normal irrigated conditions			Rainfed conditions		
	Eigen Values	Proportion of Variance	Cumulative Proportion	EigenValues	Proportion of Variance	Cumulative Proportion
PC1	3.9789	0.3979	0.3979	5.6895	0.5689	0.5689
PC2	2.0671	0.2067	0.6046	1.6439	0.1644	0.7333
PC3	1.2727	0.1273	0.7319	0.8336	0.0834	0.8167
PC4	1.1354	0.1135	0.8454	0.7640	0.0764	0.8931
PC5	0.6161	0.0616	0.9070	0.4858	0.0486	0.9417
PC6	0.4143	0.0414	0.9485	0.2345	0.0234	0.9651
PC7	0.2621	0.0262	0.9747	0.1810	0.0181	0.9832
PC8	0.1551	0.0155	0.9902	0.1178	0.0188	0.9950
PC9	0.0983	0.0098	1.0000	0.0499	0.0050	1.0000

Table 3. Contribution of first four principal components to variation of maize genotypes under irrigated and rainfed conditions

Parameters	Normal irrigated conditions				Rainfed conditions	
	PC1	PC2	PC3	PC4	PC1	PC2
Plant height	0.0245	0.4670	-0.2437	0.4963	0.3866	-0.0093
Ear height	0.3102	0.2123	-0.2658	0.2546	-0.3378	-0.1356
Days to 50 % tasselling	-0.2972	0.4780	-0.1204	0.0683	-0.2242	0.5676
Days to 50 % silking	-0.3886	0.3804	0.1662	-0.0648	-0.2987	0.5249
Anthesis Silking Interval	-0.3233	0.0260	0.5226	-0.2369	0.2498	0.1573
Cob length	0.4033	0.1434	0.3299	0.0015	0.3726	0.1327
No of kernel rows per cob	0.3480	-0.0142	0.5388	0.1759	0.3551	0.0929
Hundred Seed Weight	0.3334	0.4518	0.0742	0.1118	0.2847	0.3763
Shelling %	0.3433	0.3394	0.0672	-0.3751	0.3196	0.3885
Grain yield	0.2155	0.1516	-0.3815	-0.6632	0.2941	0.2007

Fig. 1. Scree plot under irrigated and rainfed conditions

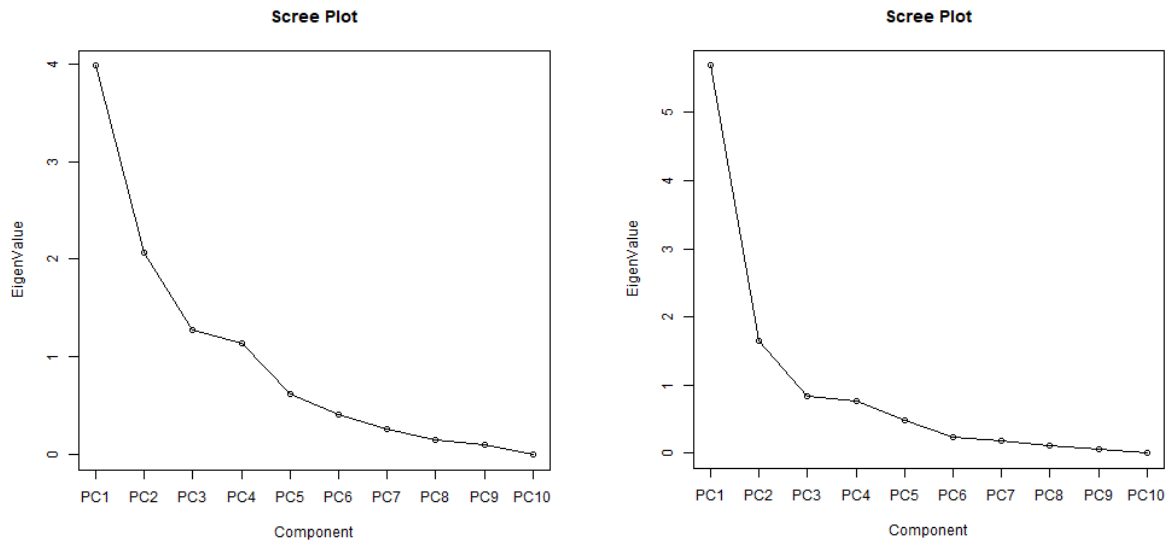


Fig. 2. Principal Component Analysis – Biplot (irrigated condition)

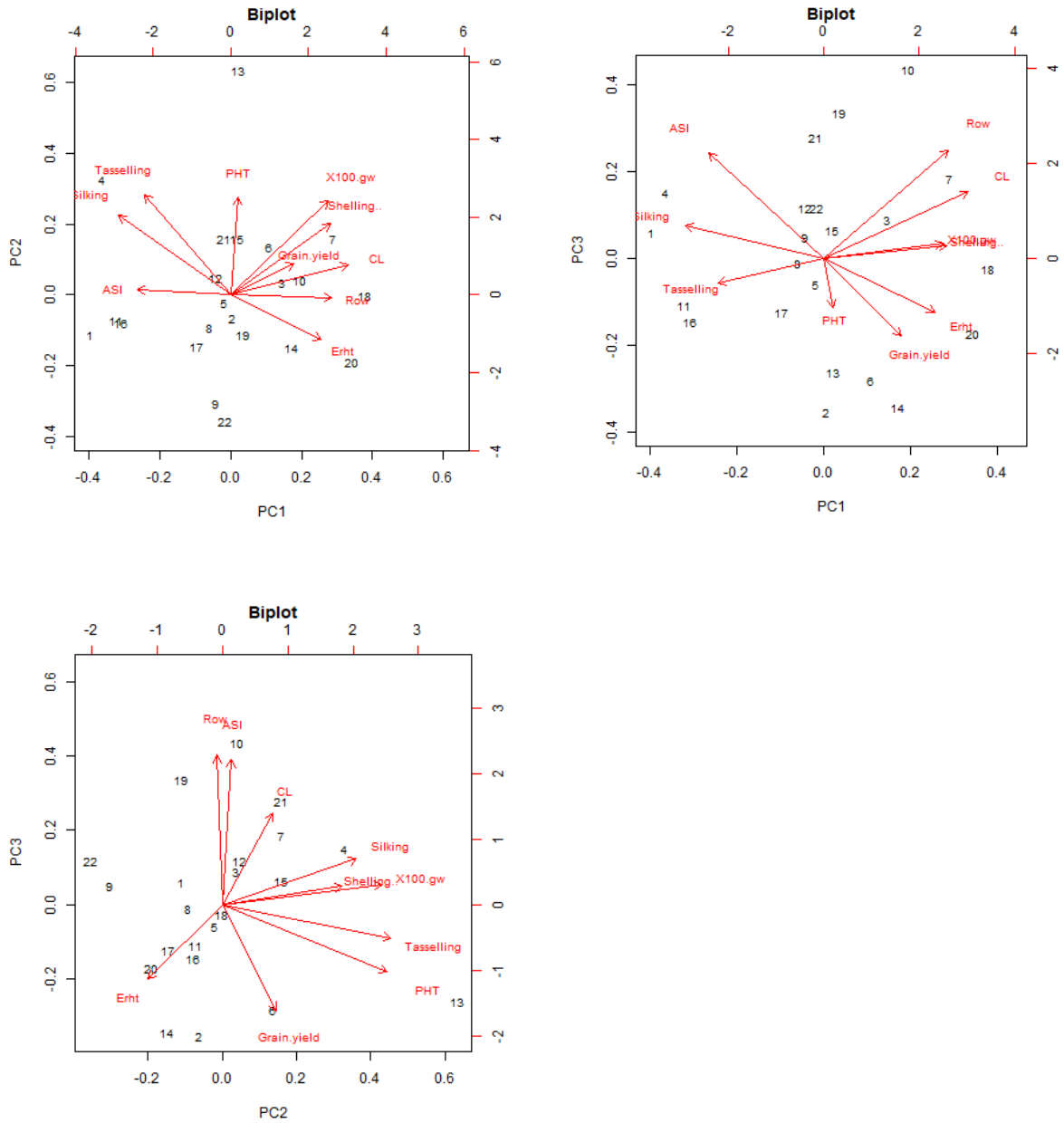


Fig. 3. Principal Component Analysis – Biplot (rainfed condition)

