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AMMI Analysis of Nano urea formulations Evaluated under Irrigated conditions at North Western Plains Zone and Central Zone for the Yield Contributing Traits of Wheat Crop

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ABSTRACT: AMMI analysis for grains per head had highlighted highly significant variations due to locations, T×L interactions and treatments, with 73.9%, 12.2% and 3.6% respectively. First interaction AMMI factor contributed 48.9% whereas AMMI2, AMMI3, AMMI4 accounted for 22.2%, 13.1%, 6.1% respectively. Number of ear heads per m^2 observed First two significant components accounted for 67.8% whereas the total contributions of significant components were 93.7%. While 70.3% and 29.7% of total T×L sums of squares were for signal and noise. AMMI based measures while considering only 71.2% T×L interaction sum of squares recommended (T7, T6, T8) as of stable performance for grains per ear head. Adaptability measures MASV and MASV1 used 93.7% of T×L interactions, sum of squares had settled for T6, T8, T7 treatments for Superiority index measures for grains per ear heads considered value and stable performance in 65 and 35 ratios in weighted average found utility of T6, T5, T12 treatments. Adaptability measures for number of ear heads per m^2 pointed towards T3, T2, T4 treatments. Biplot analysis had found tight positive relationship among AMMI based measures with W1, W2, W3, W4, W5, W6, WAASB values. Analytic adaptability measures PRVG, HMPRVG, PRVGu, HMPRVGu expressed strong bondage with measures of central tendency mean, GAI, HM for grains per par heads. Clustering pattern among measures expressed superiority index measures irrespective of BLUE and BLUP estimates formed a cluster and placed with cluster of analytic adaptability measures number of ear heads per in the present study.

Keywords: AMMI, Association analysis, BLUP, Superiority index, WAASB.

INTRODUCTION

Wheat (*Triticum aestivum* L.) has been established as one of the most important cereal crops at the world level to provide carbohydrate to population (Sarkar *et al*., 2023). The tremendous increase in production under conventional agriculture was depended on the regular use of inorganic fertilizers, to boost the growth of all crops (Pappu *et al*., 2021). It is true that chemical fertilizers have played an indispensable role in the growth of agricultural since the era of the green revolution (Jha *et al*., 2022). The intensive farming systems at most of the countries had utilized organic, inorganic and mineral manures in order to ensure essential nutrients to cultivated plants (Kumar *et al*., 2021). Among mineral nutrients, nitrogen is the foremost nutrient required for crop plants as it is the constituent of chlorophyll and many proteins and enzymes and plays a significant role during the vegetative growth of crops (AL-Abody *et al*., 2021). Loss of nitrogen as nitrous oxide and nitrates leaching has resulted in eutrophication and manifesting the impacts of global warming and climate change (Nongbet *et al*., 2022). Nano fertilizer, the most important field of agriculture has been to the attention of the soil scientists as well as the environmentalists due to its capability to increase yield, improve soil fertility, reduce pollution and make a favorable environment for microorganisms (Ali *et al*., 2021; Verma *et al*., 2022). Nanofertilizers applied alone and in conjunction with organic materials have the potential to reduce environmental pollution owing to significant less losses and higher absorption rate (Astaneh *et al*., 2021). In addition, nanomaterials were recorded to improve germination rate, plant height, root development and number of roots, leaf chlorophyll and fruits antioxidant contents (Bhardwaj *et al*., 2022). Moreover, controlled and slow released fertilizers having coating of nanoparticles, boost nutrient use efficiency and absorption of photosynthetically active radiation along with considerably lower wastage of nutrients.

MATERIALS AND METHODS

The thirteen treatments based on nano urea formulations were evaluated at fifteen major locations *viz*. Delhi, Gurdaspur, Gwalior, Hisar, Jammu, Karnal, Ludhiana, Pantnagar, Bilaspur, Durgapura, Indore, Jabalpur, Junagadh, Powarkheda, and Vijapur during 2021-22 cropping season to evaluate grains per ear head and umber fear heads per m^2 of wheat genotype by optimizing the nitrogen dose and nano urea formulations under irrigated conditions. The recommended agronomical interventions were followed after thorough ploughing and field layering. One third of nitrogen along with full phosphorus and potash as basal dose as per treatments and the remaining 2/3rd nitrogen as 1/3rd at first irrigation and 1/3rd at second irrigation wherever required as per treatment. Well labelled plots were of gross size of 1.80 m × 8 m = 14.40 sq. m. (9 rows at 20 cm spacing). Quantity of Nano urea will be 4 ml /litre of water. Quantity to spray solution will be 400 litre of water/ha. Harvest of net plot size 1.40 m × 7 m = 9.80 sq. m. (7 inner rows × 7 m long) were analysed statistically by AMMI soft and SAS 9.3 version software's. A number of AMMI and BLUP measures (Anuradha *et al.*, 2022) mentioned below for ready reference and details about treatments and locations in Table 1.

ASV $$ASV = \left[\left(\frac{SSIPC\,1}{SSIPC\,2}PCI\right)^2 + (PC2)^2\right]^{1/2}$$

ASV1 $$ASV1 = \left[\frac{SSIPC\,1}{SSIPC\,2}(PCI)^2 + (PC2)^2\right]^{1/2}$$

Modified AMMI stability Value $$MASV = \sqrt{\sum_{n=1}^{N-1}\frac{SSIPC_n}{SSIPC_{n+1}}(PC_n)^2 + (PC_{n+1})^2}$$

MASV1 $$MASV1 = \sqrt{\sum_{n=1}^{N-1}\left(\frac{SSIPC_n}{SSIPC_{n+1}}PC_n\right)^2 + (PC_{n+1})^2}$$

HM = Number of environments $$/\Sigma_{j=1}^{k} = \frac{1}{GV_{ij}}$$

GV_{ij} genetic value of ith genotype in jth environments

Relative performance of genotypic values across environments $$RPGV_{ij} = \Sigma\, GV_{ij} / \Sigma GV_j$$

Harmonic mean of Relative performance of genotypic values $$HMRPGV_{i.} = \text{No. of environments} /\Sigma_{j=1}^{k} \frac{1}{RPGV_{ij}}$$

Geometric Adaptability Index $$GAI = n\sqrt{\Pi_{K=1}^{N}\ \bar{X}_k}$$

The stability measure as weighted Average of Absolute Scores has been defined (Olivoto *et al*., 2019) as

$$WAASB = \Sigma_{k=1}^{p} \mid IPCA_{ik} \times EP_k \mid / \Sigma_{k=1}^{p} = EP_k$$

where $WAASB_i$ was the weighted average of absolute scores of the i^{th} genotype; $IPCA_{ik}$ was the score of the i^{th} genotype (or environment) in the k^{th} IPCA, and EP_k was the amount of the variance explained by the *k*th IPCA. Superiority index has been devised that allowed weights between yield and WAASB as index

$$SI = \frac{(rG_i \times \theta_Y) + (rW_i \times \theta_S)}{(\theta_Y + \theta_S)};$$

where rG_i and rW_i were the rescaled values for yield and, respectively. The superiority index had weighted between yield and stable performance of treatments to be of 65% and 35% respectively.

RESULTS AND DISCUSSION

AMMI analysis

Grains per ear head. AMMI analysis observed highly significant variations due to locations, T×L interactions and treatments, with 73.9%, 12.2% and 3.6% respectively as mentioned by Vaezi *et al*. (2019) (Table 2). First interaction AMMI factor contributed 48.9% whereas AMMI2, AMMI3, AMMI4 accounted for 22.2%, 13.1%, 6.1% respectively of T×L interactions effects. Total contributions of significant components were 90.4% while first two significant components accounted for 71.2% of significant interaction effects. The sums of squares for T×L signal and noise were 66.1% and 33.9% of total T×L respectively. The sum of squares for signal and noise were 2.26 and 1.16 times of treatments main effects.

Number of ear heads per m^2. Highly significant variations due to locations, treatments and T×L interactions effects were observed with 63.2%, 19.9% and 10% respectively (Table 2). AMMI1, AMMI2, AMMI3, AMMI4 accounted for 37.6%, 30.2%, 15.9%, 5.7% respectively of interactions effects. First two significant components accounted for 67.8% whereas the total contributions of significant components were 93.7%. Nearly 70.3% and 29.7% of total T×L sums of squares were for signal and noise. Approximately 0.35 and 0.15 times of the treatments main effects were augmented by signal and noise effects.

Behaviour of treatments as per AMMI based measures

Grains per ear head. T7, T5, T6 pointed by IPCA-1 values and T2, T6, T7 treatments by as per IPCA-2 (Table 3). IPCA-3 favored T8, T7, T6 treatments while IPCA-4, T10, T9, T1 would be of stable performance. Values of IPCA-5 settled for T1, T7, T8 while as per IPCA-6 treatments T10, T13, T11 and lastly IPCA-7 pointed for T11, T2, T13. First two IPCAs in ASV & ASV1 measures utilized 71.2% of T×L interaction sum of squares. ASV1 measures recommended (T7, T6, T8) and ASV pointed towards (T7, T6, T8) as of stable performance. Adaptability measures MASV and MASV1considered all significant IPCAs of the AMMI analysis and used 90.4% of T×L interactions sum of squares (Koundinya *et al*., 2021). Values of MASV1 identified T8, T6, T11 treatments would express stable performance whereas T8, T6, T11 be of stable performance by MASV respectively. Higher mean values found for T1, T10, T12 treatments for more values. More values of GAI showed by T1, T10, T12 along with higher values of HM measure by same treatments. T7, T6, T12 treatments pointed by superiority indexes SiMe, SiGe, SiHMe based on average value and stable performance in 65 and 35 ratios. Analytic measures PRVG and HMPRVG settled for T1, T10, T12 treatments.

Number of ear heads per m^2. T9, T12, T6 pointed by IPCA-1 values and T11, T7, T1 treatments by as per

IPCA-2 (Table 6). IPCA-3 favored T2, T6, T8 treatments while IPCA-4, T5, T1, T13 would be of stable performance. Values of IPCA-5 settled for T13, T9, T6 while as per IPCA-6 treatments T8, T9, T2 and lastly IPCA-7 pointed for T4, T13, T1. First two IPCAs in ASV & ASV1 measures utilized 67.8% of T×L interaction sum of squares. ASV1 measures recommended (T6, T12, T8) and ASV pointed towards (T6, T12, T8) as of stable performance. Adaptability measures MASV and MASV1considered all significant IPCAs of the AMMI analysis and used 93.7% of T×L interactions sum of squares. Values of MASV1 identified T6, T8, T7 treatments would express stable performance whereas T6, T8, T7 be of stable performance by MASV respectively. Higher mean values found for T3, T2, T4 treatments for more values. More values of GAI showed by T3, T2, T4 along with higher values of HM measure by same treatments. T4, T3, T7 treatments pointed by superiority indexes SiMe, SiGe, SiHMe based on average value and stable performance in 65 and 35 ratios. Analytic measures PRVG and HMPRVG settled for T3, T2, T4 treatments.

Ranking of treatments based on Superiority Index measures

Grains per ear head. Values of W1 pointed for T7, T5, T6 and W2 pointed for T7, T6, T8 while as per W3 the T7, T6, T11 would be desirable while W4, W5 and W6 pointed for T6, T7, T8 treatments and lastly WAASB found T7, T6, T8 treatments (Table 4). Average values based on BLUP of treatments observed higher values for T1, T4, T10 while large values of GAIu T1, T12, T10 and HMu measures expressed by T1, T12, T6 treatments (Koundinya *et al.*, 2021). SiMu Index found utility of T6, T5, T12 considering average value and stable performance in 65 and 35 ratios, while index based on GAI and WAASB observed suitability of T6, T5, T12 whereas index considering HM and WAASB settled for T6, T5, T12 treatments. PRVGu and HMPRVGu settled for T1, T12, T10 treatments.

Number of ear heads per m^2. Values of W1 pointed for T9, T12, T6 and W2 pointed for T9, T12, T7 while as per W3 the T6, T8, T7 would be desirable while W4, W5 and W6 pointed for T6, T8, T7 treatments and lastly WAASB found T6, T8, T7 treatments (Table 7). Average values based on BLUP of treatments observed higher values for T3, T2, T4 while Large values of GAIu T3, T2, T4 and HMu measures expressed by T3, T2, T4 treatments. SiMu Index found utility of T4, T3, T7 considering average value and stable performance in 65 and 35 ratios, while index based on GAI and WAASB observed suitability of T4, T7, T6 whereas index considering HM and WAASB settled for T4, T7, T6 treatments. PRVGu and HMPRVGu settled for T3, T2, T4 treatments.

Association analysis among measures and treatments

Grains per ear head. Nearly 82.2% of the total variations among considered measures had been accounted by first two significant principal components with 66.9% & 15.3% respective contributions (Table 5). More of share of SiMu, SiHu, SiGuSiMe, SiGe, SiHe, HMPRVG, HMPRVGu measures accounted in first principal component whereas ASV, W2, W3, W4, W5, W6, IPC6, ASV1, WAASB,PRVGu were major contributors in PC2. In terms of treatment combinations T13, T6, T7 and T4, T7, T13 were large contributors for first and second principal components in biplot analysis.

Treatments T13, T1, T6, T7 would express unstable performance as compared to T2, T3, T9, T10 positioned near to origin of biplot analysis (Fig. 1). Very tight positive relationship observed among AMMI based measures ASV, ASV1, MASV, MASV1 and with W1, W2, W3, W4, W5, W6, WAASB values. Analytic adaptability measures PRVG, HMPRVG, PRVGu, HMPRVGu expressed strong bondage with measures of central tendency mean, GAI, HM and with IPC1 on one side whereas with Superiority indexes on other hand. IPC4 measure showed direct association with IPC5, IPC2, IPC6 values. Ninety degree angle of IPC4 found with IPC1 values, ASV, ASV1, MASV, MASV1 and with W1, W2, W3, W4, W5, W6, WAASB maintained right angles with IPC1 measure. Straight line angle of IPC5 values expressed with AMMI based WAASB measures. Further the Analytic adaptability measures PRVG, HMPRVG expressed straight line angles with IPC3 values. Obtuse angle of AMMI based, WAASB measuresobserved with adaptability measures as well as with superiority index measures for evaluated nano urea formulations treatments.

Second quadrat had observed cluster of IPC2, IPC5, IPC4, IPC6 measures out of total four clusters among the considered measures for the study (Fig. 2). have been observed as first consisted of superiority indexes corresponding to mean, GAI, HM of treatments effects irrespective of BLUE and BLUP estimates and next cluster of analytic measures PRVG, HMPRVG for treatments effects irrespective of BLUE and BLUP estimates with IPC1 measures in the present study. Next quadrant observed MASV, MASV1 W1, W2, W3, W4, W5, W6, WAASB, ASV, ASV1 values. IPC3 measure along with IPC4, IPC5 placed in fourth quadrant of biplot analysis.

Number of ear heads per m^2. Approximately 83.1% of the total variations among considered measures had been accounted by first two significant principal components along with 60.1% & 22.9% respective contributions (Table 5). More of share of SiMu, SiHu, SiGuSiMe, SiGe, SiHe, HMPRVG, HMPRVGu measures accounted in first principal component whereas W1, 1, W6, W4, W5, ASV, IPC3, W2, W3, ASV1, WAASB were major contributors in PC2. In terms of treatment combinations T13, T4, T6 and T1, T9, T6 were large contributors for first and second principal components in biplot analysis.

Treatments observed near to the biplot origin T11, T4 supposed to be of more or less same response to all the tested locations as compared to the treatments T1, T9, T6 that were positioned away (Fig. 4). Very tight positive relationship observed among AMMI based measures i.e. ASV, ASV1, W1, W2, W3, W4, W5, W6, WAASB MASV, MASV1 values IPC5 expressed direct association with IPC7, IPC1, IPC3 values. Superiority indexes exhibited very tight association among themselves. Further the Analytic adaptability measures PRVG, HMPRVG expressed strong bondage and direct relation with Superiority indexes measures in the present study. Right angle of IPC3 had expressed with Analytic adaptability measures PRVG, HMPRVG and IPC2 values. Obtuse angle of W1 found with superiority index measures for evaluated nano urea formulations treatments. AMMI based measures showed straight line angle with IPC6 value.

Four clusters among the considered measures have been observed as first consisted of IPC1, IPC7, IPC5, IPC6, IPC3 measures as observed from second quadrant of the biplot analysis (Fig. 5). The superiority index measures considering mean, GAI, HM of treatments effects irrespective of BLUE and BLUP estimates formed a second cluster and next cluster of analytic adaptability measures PRVG, HMPRVG for treatments effects irrespective of BLUE and BLUP estimates with IPC2 measures in the present study (Fig. 5). Next quadrant was consisted of MASV, MASV1 W1, W2, W3, W4, W5, W6, WAASB, ASV, ASV1 values.

Multivariate hierarchical clustering pattern

Grains per ear head. Treatment T13 had placed in separate and last place while treatments T1, T2, T3, T4, T9, T10, T11 were observed in first cluster while remaining T5, T6, T7, T8, T12 formed another group based on multivariate hierarchical clustering of treatment effects as per Ward's method in the current study (Fig. 3). Studied measures had expressed different kind of relationship among themselves as four groups with respective memberships was observed in 11,6, 6,11. Measure IPC7 had been observed as point of partition as Interaction principal component IPC1, Mean, PRVG, GAI, adaptability measures with superiority index measures IPC3, IPC4, IPC2 form a group and next group consisted of W1, W2, W3, W4, W5, W6, WAASB, ASV, ASV1, MASV, MASV1, IPC5, IPC6 values at the first node. Second node observed further bifurcation of W1, W2, W3, W4, W5, W6, WAASB and ASV, ASV1, MASV, MASV1values.

Number of ear heads per m^2. Treatment T13 had placed in separate group while others split into two groups with T6, T7, T8, T9, T10, T11, T12 and treatments T1, T2, T3, T4, T5 were observed in first group based on multivariate hierarchical clustering of treatment effects as per Ward's method in the current study (Fig. 6). Studied measures had expressed different kind of relationship among themselves as four groups with respective memberships was observed in 11,05, 11,6. Superiority index measure while considering GAI for BLUE effects of treatments partitioned the measures into two groups of W1, W2, W3, W4, W5, W6, WAASB, ASV, ASV1, MASV, MASV1, SiGu, SiMe, SiHe, SiHu values and IPC1, IPC3, IPC4, IPC5, IPC6, IPC2, IPC7 Mean, Meanu, GAI, GAIu, adaptability measures at the first node of classification.

Table 1: Description of Nano urea formulations and location details of the study.

Code	Treatment Details	Code	Locations	Code	Locations
T 1	Rec. N doses (1/3rd basal, 1/3rd CRI, 1/3rd tillering Rec. N) + water spray at tillering & jointing	L 1	Gwalior	L 14	Delhi
T 2	Rec. N + one spray of nano urea at tillering	L 2	Hisar	L 15	Gurdaspur
T 3	Rec. N + two spray of nano urea at tillering & jointing	L 3	Jammu		
T 4	Rec. N + two spray of urea (5%) at tillering & jointing	L 4	Karnal		
T 5	75% N + water spray at tillering & jointing	L 5	Ludhiana		
T 6	75% N + one spray of nano urea at tillering	L 6	Pantnagar		
T 7	75% N + two spray of nano urea at tillering & jointing	L 7	Bilaspur		
T 8	75% N + two spray of 5% urea at tillering & jointing	L 8	Durgapura		
T 9	50% N + water spray at tillering & jointing	L 9	Indore		
T 10	50% N + one spray of nano urea at tillering	L 10	Jabalpur		
T 11	50% N + two spray of nano urea at tillering & jointing	L 11	Junagadh		
T 12	50% N + Two spray of 5% urea at tillering & jointing	L 12	Powarkheda		
T 13	Control (without N only)	L 13	Vijapur		

Table 2: AMMI analysis of grains per ear head and number of ear heads per m^2 for Nano urea formulations treatments.

Source of variations	Degree of freedom	Mean Sum of Squares		% share of factors		T×L interaction Sum of Squares (%)		Cumulative Sum of Squares (%) by IPCA's	
		Grains per ear head	No. of ear heads per m^2	Grains per ear head	No. of ear heads per m^2	Grains per ear head	No. of ear heads per m^2	Grains per ear head	No. of ear heads per m^2
Treatments (T)	12	92.36	49619.60	3.57	19.90				
Locations (L)	14	1640.03	135056.70	73.96	63.19				
T × L interactions	168	22.55	1782.41	12.21	10.01				
IPC1	25	74.15	4507.53			48.93	37.63	48.93	37.63
IPC2	23	36.62	3929.76			22.23	30.18	71.16	67.82
IPC3	21	23.64	2279.78			13.10	15.99	84.26	83.80
IPC4	19	12.15	905.11			6.09	5.74	90.35	89.55
IPC5	17	7.57	728.60						
IPC6	15	6.67	620.86						
IPC7	13	4.43	353.89						
Residual	35	2.27	142.85						
Error	390	8.17	529.25						
Total	584	53.16	5123.43						

Table 3: Adaptability and stability measures for Nano treatments formulations based on AMMI analysis.

GPEH	IPC1	IPC2	IPC3	IPC4	IPC5	IPC6	IPC7	MASV1	MASV	ASV1	ASV	Mean	GAI	HM	SIMe	SIGe	SIHe
T 1	1.149	-2.982	-1.445	0.308	0.096	-0.773	0.276	7.45	5.96	3.91	3.44	32.84	32.05	31.31	76.27	76.27	76.27
T 2	1.555	0.025	0.640	-0.195	-0.907	0.519	-0.027	4.18	3.06	3.42	2.31	31.83	31.09	30.43	76.63	77.90	79.99
T 3	1.796	0.390	0.668	-0.494	1.447	-0.111	-0.449	5.06	3.82	3.97	2.69	32.13	31.26	30.46	75.26	74.96	75.48
T 4	2.109	0.921	1.019	-0.580	-1.010	-0.709	0.304	6.08	4.48	4.73	3.26	32.25	31.29	30.45	70.26	68.89	69.04
T 5	-0.228	1.001	0.482	1.015	0.323	-0.995	0.348	3.76	3.08	1.12	1.06	31.79	31.11	30.42	83.00	85.01	86.80
T 6	0.269	-0.098	-0.382	0.501	-0.192	1.205	-0.791	2.97	2.46	0.60	0.41	31.90	31.44	31.03	88.74	92.95	96.73
T 7	-0.033	0.124	0.342	2.216	0.106	0.341	0.097	4.69	3.81	0.14	0.13	31.85	31.32	30.82	88.85	92.43	95.60
T 8	0.440	-0.439	-0.165	-0.608	0.181	0.707	-0.419	2.38	1.92	1.06	0.79	31.89	31.31	30.76	86.66	89.54	92.27
T 9	-1.454	0.902	-1.530	-0.207	-1.039	-0.743	-0.925	5.72	4.38	3.32	2.34	31.64	31.07	30.50	68.06	71.33	74.22
T 10	-1.505	1.304	-0.454	-0.007	0.621	0.006	0.184	4.45	3.34	3.56	2.59	32.50	31.91	31.30	80.27	82.67	84.01
T 11	-0.651	0.205	-0.487	-0.996	0.901	-0.210	0.013	3.17	2.56	1.45	0.99	32.13	31.47	30.80	86.93	88.85	90.25
T 12	-0.633	0.366	-0.879	-0.527	-0.272	0.854	1.477	3.64	2.97	1.44	1.01	32.30	31.70	31.13	87.03	89.52	91.48
T 13	-2.815	-1.718	2.192	-0.427	-0.256	-0.091	-0.088	8.82	6.42	6.43	4.52	27.06	25.85	24.16	0.00	0.00	0.00

Table 4: Superiority Index measures for Nano treatments formulations based on BLUE and BLUP effects.

GPEH	PRVG	HMPRVG	W1	W2	W3	W4	W5	W6	WAASB	Meanu	GAIu	Hmu	SIMu	SIGu	SIHu	PRVGu	HMPRVGu
T 1	1.037	1.023	1.15	1.76	1.70	1.59	1.51	1.48	1.45	32.72	32.01	31.34	76.27	76.27	76.27	1.034	1.024
T 2	1.002	0.996	1.56	1.05	0.98	0.91	0.91	0.90	0.87	31.80	31.14	30.55	74.41	76.27	78.93	1.002	0.999
T 3	1.009	1.001	1.80	1.33	1.21	1.15	1.17	1.13	1.11	32.08	31.33	30.64	73.81	74.12	75.19	1.009	1.005
T 4	1.010	1.001	2.11	1.72	1.59	1.51	1.49	1.45	1.42	32.20	31.38	30.67	69.14	68.48	69.14	1.012	1.006
T 5	1.001	0.998	0.23	0.48	0.48	0.53	0.52	0.54	0.53	31.53	30.86	30.19	77.44	79.41	81.72	0.992	0.991
T 6	1.012	1.010	0.27	0.21	0.24	0.26	0.26	0.30	0.31	31.88	31.41	30.97	86.95	91.19	95.06	1.010	1.009
T 7	1.008	1.005	0.03	0.06	0.11	0.29	0.28	0.28	0.28	31.65	31.14	30.67	84.30	88.44	92.35	1.002	1.000
T 8	1.007	1.005	0.44	0.44	0.39	0.41	0.40	0.41	0.41	31.92	31.36	30.83	85.50	88.56	91.43	1.008	1.008
T 9	1.003	0.995	1.45	1.27	1.32	1.23	1.22	1.20	1.19	31.79	31.21	30.64	67.86	70.84	73.49	1.005	1.001
T 10	1.029	1.022	1.50	1.44	1.27	1.16	1.13	1.09	1.06	32.12	31.51	30.91	75.20	77.46	79.14	1.015	1.011
T 11	1.013	1.010	0.65	0.50	0.50	0.54	0.56	0.55	0.53	32.00	31.36	30.71	84.33	86.20	87.70	1.009	1.007
T 12	1.020	1.017	0.63	0.54	0.60	0.60	0.58	0.59	0.62	32.16	31.59	31.04	84.83	87.48	89.63	1.016	1.015
T 13	0.848	0.809	2.81	2.45	2.41	2.24	2.14	2.06	2.01	28.27	27.14	25.61	0.00	0.00	0.00	0.886	0.856

Table 5: Loadings of measures and treatments for first two principal components.

Measures	Principal Component 1	Principal Component 2	Principal Component 1	Principal Component 2
	Grains per ear head		Number of ear heads per m^2	
IPC1	0.091	0.200	0.0292	-0.0392
IPC2	0.084	-0.052	0.1861	0.1592
IPC3	-0.127	-0.159	0.0516	-0.2544
IPC4	0.052	-0.129	-0.0172	0.0277
IPC5	0.042	-0.044	0.0264	-0.1299
IPC6	0.062	-0.233	0.0601	-0.0518
IPC7	0.016	0.043	0.0074	-0.0778
MASV1	-0.175	0.168	-0.1725	0.1776
MASV	-0.164	0.173	-0.1777	0.1909
ASV1	-0.176	0.217	-0.1630	0.2372
ASV	-0.172	0.242	-0.1684	0.2253
W 1	-0.174	0.177	-0.0941	0.2913
W 2	-0.176	0.231	-0.1657	0.2139
W 3	-0.180	0.220	-0.1743	0.2192
W 4	-0.183	0.212	-0.1717	0.2235
W 5	-0.182	0.217	-0.1686	0.2283
W 6	-0.181	0.219	-0.1677	0.2309
WAASB	-0.181	0.220	-0.1677	0.2313
Mean	0.184	0.207	0.1902	0.1822
SIMe	0.208	0.043	0.2195	0.0426
GAI	0.191	0.176	0.1922	0.1771
SIGe	0.209	0.024	0.2198	0.0383
HM	0.196	0.153	0.1939	0.1720
SIHe	0.209	0.011	0.2199	0.0340
PRVG	0.188	0.193	0.1907	0.1814
HMPRVG	0.194	0.162	0.1938	0.1724
Meanu	0.178	0.230	0.1908	0.1804
SIMu	0.208	0.056	0.2196	0.0413
GAIu	0.186	0.199	0.1927	0.1756
SIGu	0.209	0.037	0.2199	0.0371
Hmu	0.192	0.174	0.1943	0.1709
SIHu	0.209	0.022	0.2201	0.0330
PRVGu	0.182	0.216	0.1912	0.1798
HMPRVGu	0.190	0.184	0.1942	0.1709
% share of variation	66.97%	15.26%(82.23%)	60.14%	22.93%(83.07%)
T 1	-0.031	0.573	-0.1695	0.5479

T 2	0.015	0.032	0.1537	0.3574
T 3	-0.020	0.193	0.1728	0.3238
T 4	-0.104	0.398	0.2349	0.1954
T 5	0.104	-0.212	-0.0399	0.1830
T 6	0.226	-0.292	0.2304	-0.3250
T 7	0.196	-0.331	0.2215	-0.1215
T 8	0.187	-0.220	0.2215	-0.1724
T 9	-0.055	0.179	-0.0895	-0.3412
T 10	0.040	0.183	-0.1346	-0.1815
T 11	0.156	-0.110	-0.0341	-0.1548
T 12	0.175	-0.067	0.0570	-0.2647
T 13	-0.890	-0.324	-0.8242	-0.0464

Table 6: Adaptability and stability measures for Nano treatments formulations based on AMMI analysis.

Ear head	IPC1	IPC2	IPC3	IPC4	IPC5	IPC6	IPC7	MASV1	MASV	ASV1	ASV	Mean	GAI	HM	SIMe	SIGe	SIHe
T 1	8.470	0.476	-7.105	-1.264	-1.415	-1.106	-0.414	23.89	17.13	10.57	9.47	380.64	375.52	369.94	57.10	58.26	59.58
T 2	-4.822	3.643	-0.237	-2.232	-3.462	-0.842	-0.735	12.21	10.49	7.03	6.50	403.84	397.03	389.62	80.35	80.84	81.45
T 3	-3.323	3.947	-1.699	5.167	1.040	0.862	-2.586	14.32	12.04	5.72	5.42	405.89	398.15	389.52	81.86	81.86	81.81
T 4	-2.322	3.957	0.904	-2.141	-2.456	3.379	0.052	13.24	10.70	4.90	4.73	403.76	396.80	389.15	85.29	85.70	86.17
T 5	-5.147	2.058	-3.205	-0.113	1.484	-4.245	2.357	15.93	12.22	6.74	6.10	374.39	367.99	361.35	63.73	64.12	64.74
T 6	1.111	-0.618	0.380	-0.355	-0.578	2.977	3.598	8.02	6.63	1.52	1.39	370.59	365.71	360.28	81.07	82.26	83.52
T 7	2.348	0.323	-1.663	1.931	2.416	2.520	0.682	9.65	7.73	2.95	2.64	382.24	376.89	370.73	81.84	82.89	83.91
T 8	1.701	1.160	1.185	-2.064	3.450	0.579	-2.237	8.66	7.53	2.42	2.23	379.32	374.35	368.80	80.58	81.81	83.13
T 9	-0.143	-4.115	1.941	-3.587	0.447	-0.619	-2.205	12.46	10.02	4.12	4.12	338.23	334.79	331.06	55.12	56.72	58.48
T 10	2.923	-2.669	3.150	2.016	-2.581	-1.746	-0.679	13.38	10.18	4.52	4.22	343.17	339.15	334.63	51.59	52.93	54.32
T 11	3.234	-0.064	4.663	3.189	-1.907	-1.499	0.709	16.07	11.64	4.03	3.61	355.24	350.13	344.48	61.15	62.03	62.95
T 12	1.075	1.692	4.056	-1.388	3.518	-1.214	1.399	14.43	10.57	2.16	2.07	359.05	353.95	348.39	66.38	67.31	68.33
T 13	-5.106	-9.790	-2.369	0.841	0.043	0.954	0.060	23.10	18.30	11.68	11.33	284.64	279.35	273.93	0.00	0.00	0.00

Table 7: Superiority Index measures for Nano treatments formulations based on BLUE and BLUP effects.

Ear head	PRVG	HMPRVG	W 1	W 2	W 3	W 4	W 5	W 6	WAASB	Meanu	GAIu	Hmu	SIMu	SIGu	SIHu	PRVGu	HMPRVGu
T 1	1.039	1.030	8.47	4.75	5.25	4.94	4.73	4.56	4.45	378.19	373.26	367.85	56.50	57.68	58.96	1.033	1.024
T 2	1.095	1.093	4.82	4.27	3.41	3.32	3.33	3.21	3.15	400.28	393.62	386.38	80.61	81.01	81.45	1.086	1.084
T 3	1.098	1.096	3.32	3.61	3.21	3.36	3.22	3.11	3.10	401.67	394.34	386.16	81.86	81.86	81.72	1.088	1.086
T 4	1.094	1.093	2.32	3.08	2.62	2.58	2.58	2.61	2.55	400.17	393.42	386.00	85.53	85.87	86.19	1.085	1.084
T 5	1.016	1.013	5.15	3.71	3.60	3.33	3.22	3.27	3.25	373.72	367.47	360.94	63.79	64.11	64.59	1.014	1.012
T 6	1.008	1.008	1.11	0.88	0.77	0.74	0.73	0.84	0.91	370.40	365.53	360.09	81.17	82.30	83.43	1.008	1.007
T 7	1.039	1.038	2.35	1.40	1.46	1.50	1.55	1.60	1.57	380.46	375.25	369.25	81.75	82.79	83.72	1.035	1.034
T 8	1.032	1.031	1.70	1.45	1.39	1.45	1.56	1.52	1.54	377.94	373.05	367.55	80.54	81.74	82.96	1.028	1.028
T 9	0.924	0.922	0.14	1.99	1.98	2.11	2.01	1.94	1.95	341.32	337.70	333.76	55.05	56.58	58.23	0.931	0.930
T 10	0.936	0.934	2.92	2.80	2.88	2.81	2.80	2.75	2.69	345.82	341.70	337.08	51.59	52.87	54.15	0.943	0.941
T 11	0.966	0.964	3.23	1.76	2.38	2.44	2.41	2.36	2.32	356.72	351.65	346.03	61.24	62.08	62.88	0.970	0.968
T 12	0.976	0.975	1.07	1.36	1.94	1.89	1.99	1.95	1.94	360.59	355.47	349.86	66.76	67.61	68.48	0.980	0.979
T 13	0.775	0.764	5.11	7.29	6.24	5.82	5.48	5.26	5.13	293.71	288.55	283.22	0.00	0.00	0.00	0.799	0.791

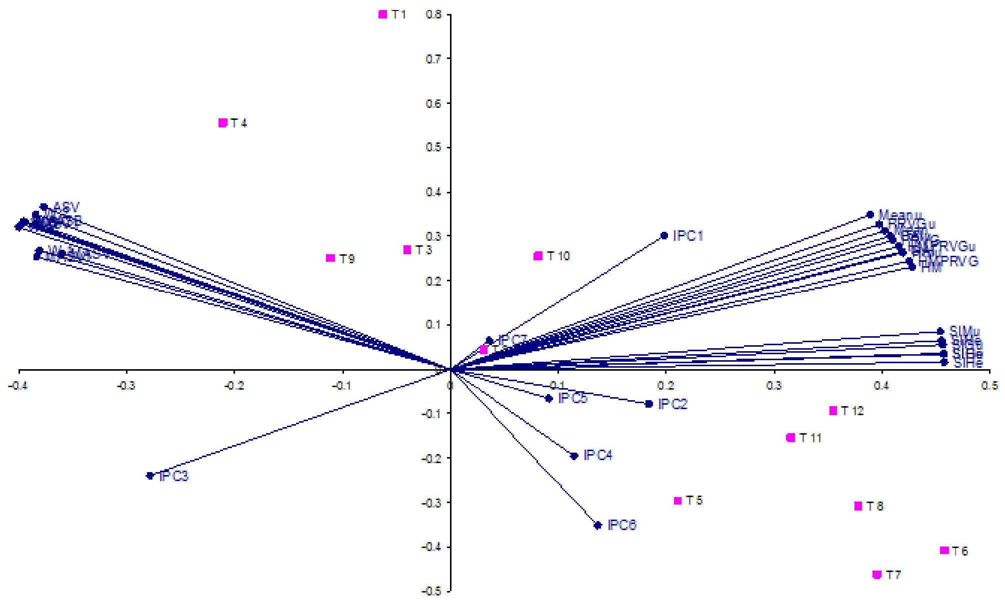

Fig. 1. Biplot analysis of Nano urea formulations treatments and adaptability measures.

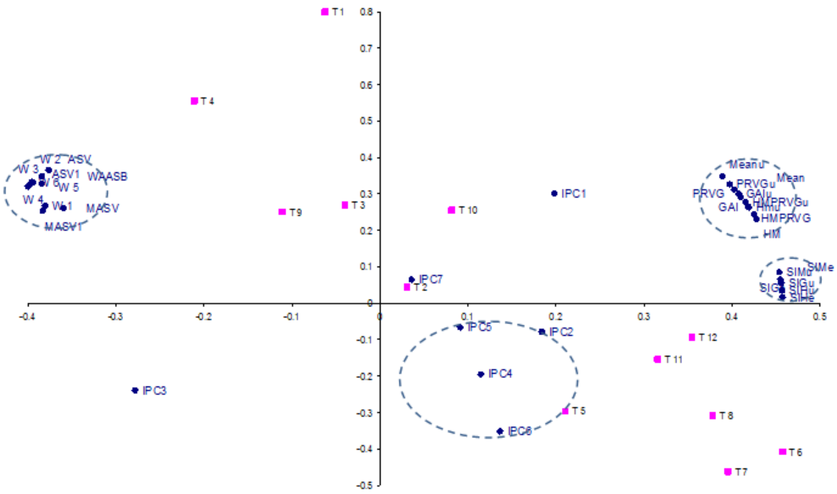

Fig. 2. Association analysis among measures and nano urea formulations treatments.

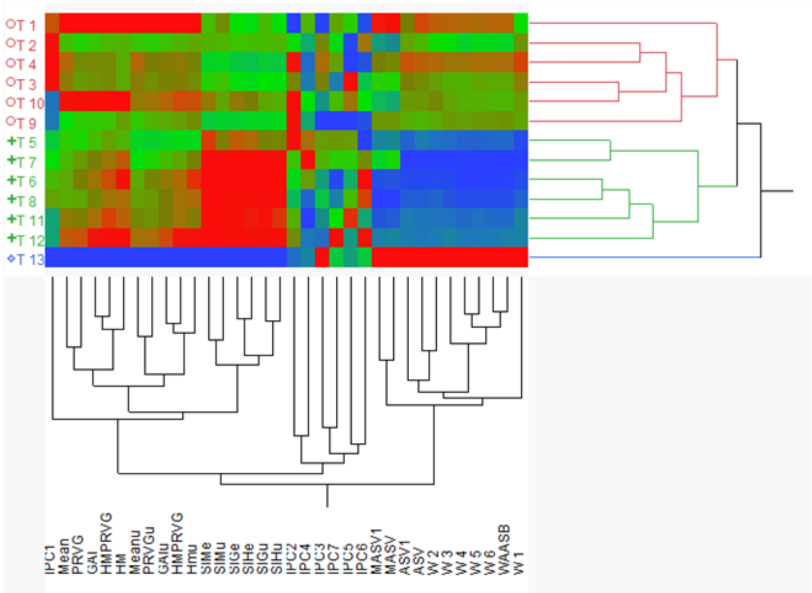

Fig. 3. Multivariate hierarchical clustering of treatments vis-a-vis adaptability measures as per Ward's method.

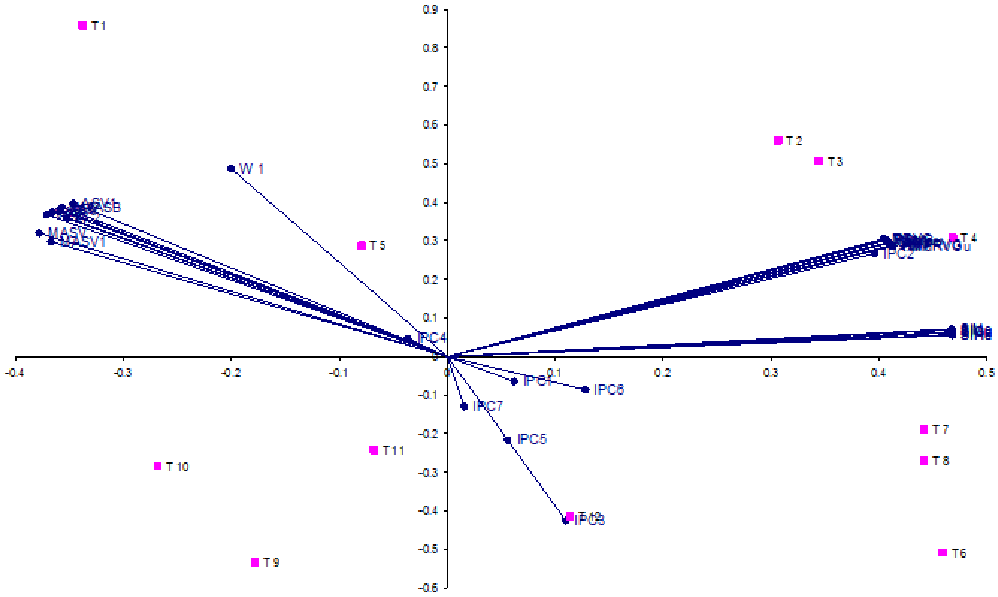

Fig. 4. Biplot analysis of Nano urea formulations treatments and measures.

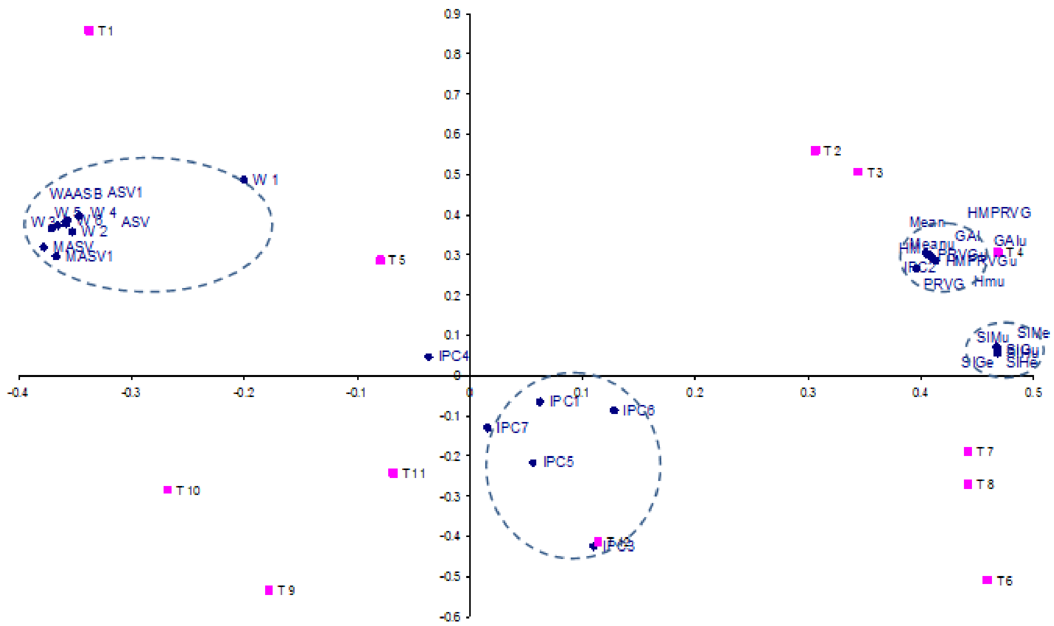

Fig. 5. Association analysis among measures and Nano urea formulations treatments.

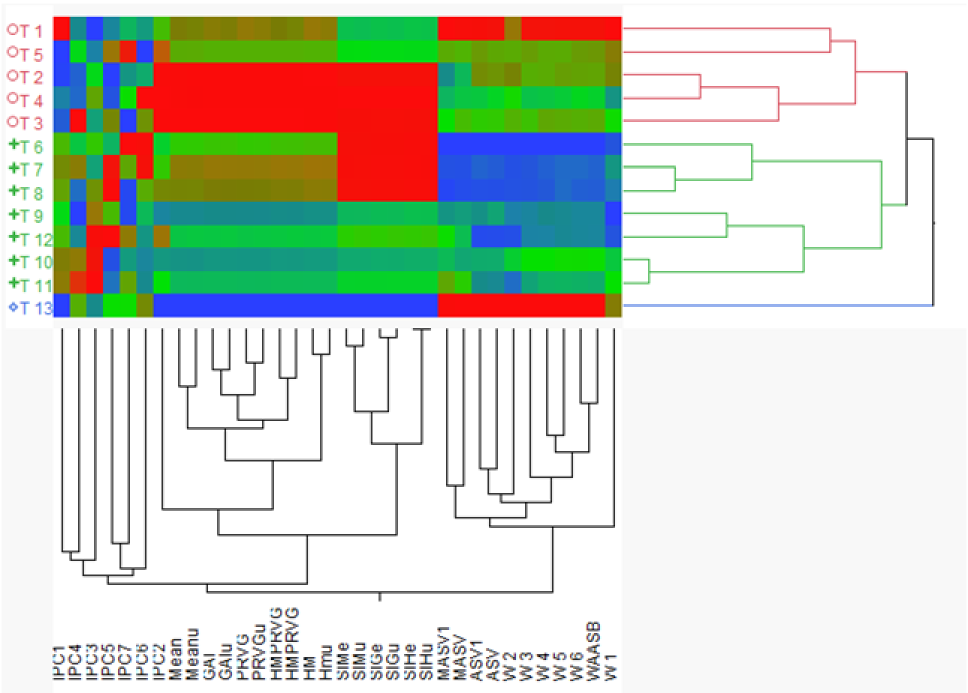

Fig. 6. Multivariate hierarchical clustering of treatments vis-a-vis adaptability measures as per Ward's method.

CONCLUSIONS

AMMI analysis had highlighted highly significant variations due to locations, T×L interactions and treatments effects. AMMI based measures recommended (T7, T6, T8) as of stable performance for grains per ear head. Adaptability measures MASV and MASV1 had settled for T6, T8, T7 treatments for number of ear heads per m^2. Superiority index measures as weighted average of trait value and stable performance in 65 and 35 ratios in found utility of T6, T5, T12 treatments. Biplot analysis had found tight positive relationship among AMMI based measures with W1, W2, W3, W4, W5, W6, WAASB values.

FUTURE SCOPE

Recent analytic adaptability measures PRVG, HMPRVG, PRVGu, HMPRVGu expressed strong bondage with measures of central tendency mean, GAI, HM for grains per par heads. Clustering pattern among measures expressed superiority index measures irrespective of BLUE and BLUP estimates formed a cluster and placed with cluster of analytic adaptability measures number of ear heads per in the present study.

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