Medicon Agriculture & Environmental Sciences
Volume 4 Issue 5 May 2023
Research Article

Nano urea Fertilization on Wheat Morphology under Restricted Irrigation Conditions Evaluated under Multi Locations Trails by AMMI and BLUP Analysis

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Received: May 10, 2023; **Published:** May 16, 2023

DOI: 10.55162/MCAES.04.112

Abstract

Highly significant variations of locations (L), treatments (T) and TxL interactions were observed by AMMI analysis of nine treatments consisted of nano urea formulations evaluated under multi location trails of wheat under restricted irrigation conditions. Plant height found nearly 90. 7% of TxL interactions was due to first two components while total of 97. 9% by all significant components. Total contributions for biomass of the significant components were 98. 2% while of two components accounted for 79. 4%. Approximately 85. 2% for ear heads per m2 was contributed by first two while significant components augmented to total of 96. 6%. More average values for plant height observed for T5, T8 treatments while consistent more plant height would be of T5, T8 based on superiority index measure. AMMI analysis based measures identified T4, T3 by MASV, MASV1, ASV and ASV1 values for biomass. Analytic adaptability measure PRVG and PRVG*GM, HMPRVG and HMPRVG*GM for ear heads per m2 had pointed for T5, T7 treatments. Higher average of treatments effects as per BLUP estimates favoured T5, T8 treatments also supported by GAIu and Hmu values. Consistent more biomass would be achieved by T5 and T6 treatments as per superiority index measures while considering the BLUP of treatments. The adaptability measures as per BLUP effects of treatments found suitability of T5 and T7 for ear heads per m2. Biplot analysis for plant height found tight relation of IPC1 with superiority and adaptability measures. Biomass observed right angle of IPC5 with superiority index measures. Centers Vijapur, Shillongani maintained ninety degree angle with IPC2 value. Clustering pattern for ear heads per m2 exhibited MASV, MASV1 with IPC4 values and W1, W2, W3, WAASB ASV, ASV1 constituted the respective clusters.

Keywords: AMMI; BLUP; Biplot; Superiority index; WAASB

Introduction

Nearly 35-40 % of the crop production depends upon balanced use of fertilizer as some of the fertilizer directly affects the plant growth (Ali et al., 2021). Country imports the raw materials for these fertilizers from other countries so the input costs of fertilizers are rising on day to day basis. Besides the reduction in farmer's income, an indiscriminate and imbalanced use of fertilizers has adversely affected the soil health, human well-being etc. To subsidise the ill effects of fertilizers, nanotechnology holds good future and nano-fertilizers can go a long way in ensuring sustainable soil health and crop production (Bhardwaj et al., 2022). Owing to the growing awareness of the harmful effects of fertilizers, the last decade has witnessed extensive research into biofertilizers, microbiomes, and soil health (Kannoj et al., 2022). Nanotechnology and its associated applications have gained tremendous importance in the present age, as this branch of technology has greatly revolutionised modern science; moreover, this field of science is growing at an exponential rate (Kumari and Singh, 2019; Astaneh et al., 2021). These high performance and efficient fertilizers enhanced the crop production while protecting ecology (Verma et al., 2022). Mostly farmers use urea, about 82 per cent of the total fertilizer consumption in coun-

try, approximately 30- 40 per cent of nitrogen from urea is utilized by plants and the rest drained out due to leaching, volatilization, denitrification and run off etc. The nano urea has high nitrogen use efficiency along with environment friendly approach (Nongbet et al., 2022). The present study was conducted to find out the advantages of nano urea over conventional use of urea fertilizer on wheat phenology by evaluation of different formulations under multi location trails during the last year.

Method and Materials

The treatments were evaluated at Ayodhya, Kanpur, RPCAU Pusa, Shillongani. Indore, Udaipur, Vijapur centers during 2021-22 cropping season with objective to maximize wheat productivity by optimizing the nitrogen dose and nano urea under restricted irrigation 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 x 8 m = 14. 40 sq. m. (9 rows at 20 cm spacing). Nano urea has applied in quantity of 4 ml /litre of water. The solution has been sprayed as of 400 litre of water/ha. Harvest of net plot size 1. 40 m x 7 m = 9. 80 sq. m. (7 inner rows x 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.

Code	*Treatment details*	*Code*	*Major locations*
T 1	One Nano Urea Spray at tillering stage (40-45 DAS)	L 1	Ayodhya
T 2	Two Nano Urea Spray at tillering (40-45 DAS) & Jointing stage (60-65 DAS)	L 2	Kanpur
T 3	Recommended N (1/3rd basal, 2/3rd CRI- Recommended N)	L 3	RPCAU PUSA
T 4	Recommended N + One Nano Urea Spray at tillering stage (40-45 DAS)	L 4	Shillongani
T 5	Recommended N + Two Nano Urea Spray at tillering (40-45 DAS) & Jointing stage (60-65 DAS)	L 5	Indore
T 6	Recommended N + One Urea (5%) Spray at tillering stage (40-45 DAS)	L 6	Udaipur
T 7	Recommended N + Two Urea (5%) Spray at tillering (40-45 DAS) & Jointing stage (60-65 DAS)	L 7	Vijapur
T 8	Recommended N + One Urea (5%) Spray+ Nano Urea at tillering stage (40-45 DAS)		
T 9	Absolute Control		

Table 1: Details of Nano fertilization treatments and locations of the study.

ASV

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

ASV1

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

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

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

HM

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

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

Relative performance of genotypic values across environments

$$RPGV_{ij} = \sum GV_{ij} / \sum GV_j$$

Harmonic mean of Relative performance of genotypic values

$$HMRPGV_{i.} = \text{Number of environments} / \sum_{j=1}^{k}\frac{1}{RPGV_{ij}}$$

Geometric Adaptability Index

$$GAI = \sqrt[n]{\prod_{k=1}^{n}\bar{X}_k}$$

The stability measure as weighted Average of Absolute Scores has been defined as:

$$\text{WAASB} = \sum_{k=1}^{p} |IPCA_{ik} \times EP_k| \,/\, \sum_{k=1}^{p} EP_k$$

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 kth IPCA, and EP_k was the amount of the variance explained by the *k*th IPCA. Superiority index has been devised (Olivoto et al., 2019) 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

Plant height

Variation in plant heights observed under treatment combinations showed the highly significant variations of 79. 8%, 8. 5% and 7. 4% by locations, treatments and TxL interactions as reported by Vaezi et al., 2019 (Table 2). First component of AMMI analysis shared share of about 66. 7% while second and third contributed for 24. 0%, 7. 2% respectively of interactions effects. Nearly 90. 7% was share of first two components while total of 97. 9% by significant components. Estimated sums of squares for T×L signal was 77. 7% and 22. 3% by noise factor towards total of interaction effects. Sum of squares for signal was 0. 67 times and of noise were 0. 19 times of the treatments effects. Even just IPC1 alone was 0 . 58 times the treatments main effects.

Source of variations	*Degree of freedom*	*Mean Sum of squares*			*% share of factors*			*TxL interaction Sum of Squares (%)*		
		plant height	*biomass*	*ear heads per m²*	*plant height*	*biomass*	*ear heads per m²*	*plant height*	*biomass*	*ear heads per m²*
Treatments (T)	8	260.43	4495.93	20329.4	8.52	25.38	18.0			
Locations (L)	6	3250.04	12199.05	84840.1	79.75	51.66	56.3			
T x L Interactions	48	37.69	475.32	2351.2	7.40	16.10	12.5			
IPC1	13	92.81	1393.96	5169.3				66.70	79.43	59.5
IPC2	11	39.51	265.97	2627.8				24.03	12.82	25.6
IPC3	9	14.52	149.49	1435.9				7.22	5.90	11.5
IPC4	7	2.29	47.69	343.7						
IPC5	5	2.81	16.39	190.4						
Residual	3	2.33	2.40	156.7						
Error	126	8.42	77.14	953.8						
Total	188	130.07	753.71	4812.3						

Table 2: ANOVA analysis of Nano treatments evaluated under restricted irrigation at multi locations trial.

Biomass

AMMI analysis observed highly significant variations due to locations, treatments and TxL interactions with 51. 6%, 25. 4% and 16. 1% respectively (Table 2). AMMI1 contributed for 79. 4% whereas AMMI2, AMMI3, accounted for 12. 8%, 5. 9% respectively of TxL interactions effects. Total contributions of significant components were 98. 2% while first two significant components accounted for 79. 4% of significant interaction effects. Estimated sums of squares for T×L signal and noise were 85. 9% and 14. 1% of total T×L respectively. Sum of squares for TxL-signal was 0. 55 times that for treatments main effects. Also note that TxL-noise was 0. 09 times of the treatments effects. The first interaction principal component accounted nearly 0. 50 times the treatments effects.

Ear heads per m^2

Highly significant variations due to locations, treatments and TxL interactions were observed in analysis with 56. 3%, 18. 0% and 12. 5% respectively (Table 2). First component of AMMI analysis shared share of about 59. 5% while second and third contributed for 25. 6%, 11. 5% respectively of TxL interactions effects. Nearly 85. 2% of the contributions were of first two while total of 96. 6% by significant components. Estimated sums of squares for T×L signal was 59. 4% and 40. 6% by noise factor towards total of interaction effects. Sum of squares for TxL-signal was 0. 41 times that for treatments main effects. Also note that TxL-noise was 0. 28 times of the treatments effects.

Adaptability of treatments based on AMMI based measures

Plant Height

Large values of plant height were observed at Udaipur center followed by Indore and Ayodhya (Table 3). Treatments T4, T3 pointed by least value of IPC1 measure. T4 and T5 treatments identified by IPC2 values while T6, T8 by IPC3 and IPC4 settled for T5, T2 whereas IPC5 measure settled for T3, T2 would be of stable performance. Both measures MASV and MASV1 based on 97. 9% of interaction effects identified treatments T6, T8 and adaptability measures based on first two components of AMMI analysis settled for T4, T3 only. More average values observed for T5, T8 treatments while consistent more plant height would be of T5, T8 as per superiority index measure based on mean and WAASB values in 0. 65 and 0. 35 proportions. Measure GAI found maximum values for T5 followed by T8 and T8, T5 treatments also identified by HM also. Treatments T5 and T8 would be of stable plant height as per measures SiGe and SiHe values. Analytic adaptability measure PRVG and PRVG*GM had pointed for T5, T8 treatments and HMPRVG along with HMPRVG*GM found more values expressed by T5 and T8 treatments formulations of Nano fertilization.

	IPC1	*IPC2*	*IPC3*	*IPC4*	*IPC5*	*MASV1*	*MASV*	*ASV1*	*ASV*	*Mean*	*SIMe*	*GAI*	*SIGe*	*HM*	*SIHe*	*PRVG*	*PRVG *GM*
T 1	-2.002	1.569	0.829	-0.360	-0.291	10.36	5.33	5.78	3.69	91.33	22.92	90.44	22.57	89.44	21.72	0.960	91.12
T 2	-1.330	1.659	-0.858	0.257	-0.164	9.84	4.87	4.05	2.77	92.08	38.43	91.22	38.11	90.25	37.24	0.968	91.88
T 3	0.675	-0.826	1.257	-0.446	0.128	10.91	4.37	2.05	1.40	96.40	74.86	95.87	75.37	95.30	75.63	1.017	96.50
T 4	0.629	0.034	-0.586	-0.658	0.683	5.27	2.38	1.75	1.05	96.88	89.06	96.27	88.95	95.60	88.47	1.021	96.89
T 5	1.293	0.188	-1.388	0.002	0.266	11.98	4.75	3.59	2.16	97.70	100.00	97.15	100.00	96.54	99.68	1.030	97.80
T 6	1.278	-0.205	0.221	1.003	-0.329	4.34	2.72	3.55	2.14	96.95	85.35	96.50	86.24	96.02	86.86	1.024	97.15
T 7	1.044	0.625	1.064	0.399	0.531	9.50	3.96	2.96	1.85	97.24	89.23	96.69	89.37	96.09	89.19	1.026	97.33
T 8	1.177	-0.803	-0.265	-0.485	-1.033	4.98	2.98	3.37	2.12	97.63	91.03	97.13	91.39	96.60	91.49	1.030	97.78
T 9	-2.764	-2.241	-0.273	0.287	0.209	11.17	6.62	7.99	5.12	88.01	25.30	87.03	25.30	86.00	25.30	0.925	87.77

Table 3: Adaptability of Nano treatments evaluated by AMMI based measures for plant height.

Biomass

More values of biomass were observed in table 4 at Vijapur center followed by Kanpur and Shillongani. Value of IPC1 pointed for the by T4, T3 while maximum unstable performance of T1 as evident by large value. T5 and T4 treatments identified by IPC2 values while T9, T8 by IPC3 and IPC4 settled for T9, T1 whereas as per IPC5 measure T9, T8 would be of stable performance. Treatments T4, T3 were identified by both measures MASV and MASV1 while utilizing 98. 2% of interaction effects and adaptability measures based on AMMI analysis as per first two components settled for T4, T3 only. More average values observed for T5, T7 treatments while consistent more biomass would be of T5, T6 as per superiority index measure based on mean and WAASB values in 0. 65 and 0. 35 proportions. Measure found maximum values for T5 followed by T7 as same treatments also identified by HM also. Treatments T5 and T8 would be of stable more biomass as per measures SiGe and SiHe.

	IPC1	*IPC2*	*IPC3*	*IPC4*	*IPC5*	*MASV1*	*MASV*	*ASV1*	*ASV*	*Mean*	*SIMe*	*GAI*	*SIGe*	*HM*	*SIHe*	*PRVG*	*PRVG *GM*
T 1	-4.318	1.345	1.438	0.221	-0.979	27.62	11.52	26.78	10.83	97.43	17.51	91.78	12.95	85.34	8.28	0.837	95.37
T 2	-4.194	2.886	-0.971	-0.604	0.663	27.31	11.93	26.14	10.83	99.84	21.65	93.76	16.16	86.67	10.31	0.856	97.52
T 3	1.844	-0.442	2.098	-1.028	0.926	15.06	7.07	11.43	4.61	119.36	53.94	117.96	54.22	116.70	54.74	1.054	120.00
T 4	0.422	-0.305	-1.817	1.291	1.275	9.76	5.30	2.63	1.09	121.60	80.40	120.15	80.37	118.71	80.40	1.071	122.02
T 5	2.098	-0.028	-2.699	-0.434	-1.055	17.29	8.12	12.99	5.22	125.82	100.00	124.63	100.00	123.47	100.00	1.115	126.96
T 6	3.023	0.954	1.693	0.601	-0.167	20.29	8.70	18.75	7.58	123.55	81.87	121.87	81.30	120.37	81.05	1.091	124.30
T 7	2.427	0.462	0.415	1.717	-0.412	16.80	7.29	15.04	6.06	125.49	76.83	124.07	76.50	122.78	76.35	1.109	126.36
T 8	2.318	-0.459	-0.336	-1.968	-0.149	16.66	7.36	14.36	5.79	124.15	81.18	123.01	81.42	121.93	81.71	1.100	125.29
T 9	-3.620	-4.412	0.180	0.203	-0.103	24.81	11.97	22.85	10.03	87.82	19.99	84.44	19.99	80.59	19.99	0.766	87.25

Table 4: Adaptability of Nano treatments evaluated by AMMI based measures for biomass.

Ear heads per m²

Treatments T7 and T6 pointed by IPC1 measure (Table 5). IPC2 values favoured to T3 and T5 treatments while T8, T6 by IPC3 and IPC4 settled for T3, T9 whereas as per IPC5 measure T6, T7 would be of stable performance. MASV and MASV1 while utilizing 96. 6% of interaction effects identified T8, T6 treatments by both measures and adaptability measures ASV and ASV1 based on AMMI analysis as per first two components settled for T5, T7 only. More average values for ear heads per m2 observed for T5, T7 treatments while consistent expression would be of T7, T8 as per superiority index measure based on mean and WAASB values in 0. 65 and 0. 35 proportions. Measure GAI found maximum values for T5 followed by T7 as same treatments also identified by values of HM measure also. Treatments T7 and T6 would be of stable more biomass as per measures SiGe and SiHe. Analytic adaptability measure PRVG and PRVG*GM had pointed for T5, T7 treatments and HMPRVG along with HMPRVG*GM found more values expressed by T5 and T7 treatments formulations of Nano fertilization.

	IPC1	*IPC2*	*IPC3*	*IPC4*	*IPC5*	*MASV1*	*MASV*	*ASV1*	*ASV*	*Mean*	*SIMe*	*GAI*	*SIGe*	*HM*	*SIHe*	*PRVG*	*PRVG *GM*
T 1	-3.506	-3.796	4.048	0.649	1.853	25.47	13.58	8.99	6.56	325.84	17.86	316.26	15.93	304.77	13.06	0.913	321.85
T 2	1.334	-6.383	-1.587	2.034	-1.106	19.00	12.96	7.10	6.70	328.34	36.04	321.13	36.00	312.42	35.10	0.925	326.11
T 3	5.138	0.519	2.483	0.061	-1.866	18.22	10.25	11.96	7.85	361.45	73.22	358.04	74.43	354.45	75.64	1.029	362.90
T 4	4.263	1.192	-3.826	1.446	1.870	23.72	12.29	9.98	6.61	357.33	65.05	354.35	66.87	351.27	68.70	1.018	358.98
T 5	-1.590	-0.772	-1.878	-2.973	1.500	13.79	7.98	3.78	2.54	378.55	84.91	374.96	84.91	371.00	84.91	1.077	379.63
T 6	1.186	4.601	-1.131	1.003	-0.024	13.43	9.14	5.36	4.94	367.03	89.39	364.08	90.64	361.07	92.00	1.047	369.07
T 7	-0.458	3.978	4.025	0.688	0.432	24.16	12.52	4.12	4.04	376.34	92.77	372.80	92.95	369.19	93.35	1.072	377.77
T 8	2.588	-0.996	0.082	-3.341	-1.005	11.22	7.69	6.10	4.07	370.08	88.11	367.13	89.18	363.94	90.24	1.054	371.71
T 9	-8.954	1.656	-2.217	0.433	-1.653	24.51	15.16	20.88	13.75	308.02	32.20	299.41	32.20	290.34	32.20	0.865	304.98

Table 5: Adaptability of Nano treatments evaluated by AMMI based measures for ear heads per m^2.

Performance of treatments as per Superiority index measures

Plant Height

Table 6 found W1 measure found suitability of T4, T3 while W2 values identified T4, T3 and W3 values settled for T4, T3 and WAASB measure had identified the same treatments. Higher average of treatments effects as per BLUP estimates by T5, T8 while least one of T9 as similar behaviour of these treatments also supported by GAIu and Hmu values (Koundinya et al., 2021). Consistent plant height would be achieved by T5 and T6 treatments of the study. Values of analytic adaptability measures while considering the BLUP effects of treatments found suitability of T5 and T8 only.

	HM-PRVG	HM-PRVG *GM	W1	W2	W3	W4	W AASB	Mea-nu	SIMu	GAIu	SIGu	Hmu	SIHu	PRVGu	PRVGu *GM	HM-PRVGu	HMPRVGu *GM
T 1	0.958	90.91	2.00	1.87	1.77	1.75	1.72	91.49	19.63	90.65	19.68	89.70	19.33	0.962	91.31	0.960	91.14
T 2	0.966	91.73	1.33	1.43	1.37	1.35	1.33	92.54	37.94	91.70	37.66	90.74	36.97	0.973	92.35	0.972	92.21
T 3	1.016	96.45	0.67	0.72	0.77	0.77	0.76	95.99	71.11	95.47	71.98	94.92	72.88	1.013	96.10	1.012	96.06
T 4	1.021	96.87	0.63	0.45	0.47	0.47	0.47	96.61	86.72	96.01	86.79	95.35	86.81	1.018	96.63	1.018	96.61
T 5	1.030	97.73	1.29	0.96	1.01	0.99	0.98	97.66	100.00	97.10	100.00	96.49	100.00	1.030	97.74	1.029	97.70
T 6	1.023	97.08	1.28	0.96	0.88	0.89	0.88	96.94	85.01	96.48	85.92	95.97	86.88	1.023	97.11	1.023	97.06
T 7	1.025	97.28	1.04	0.92	0.93	0.92	0.92	96.78	85.71	96.25	86.21	95.67	86.69	1.021	96.89	1.020	96.83
T 8	1.029	97.71	1.18	1.07	0.99	0.98	0.98	97.25	88.40	96.75	88.96	96.21	89.61	1.026	97.39	1.025	97.33
T 9	0.921	87.40	2.76	2.61	2.38	2.35	2.31	88.95	25.30	87.98	25.30	86.96	25.30	0.935	88.70	0.931	88.37

Table 6: Superiority Index measures for Nano treatments formulations based on BLUP effects for plant height.

Biomass

Analytic adaptability measure PRVG and PRVG*GM had pointed for T5, T7 treatments and HMPRVG along with HMPRVG*GM found more values expressed by T5 and T7 treatments formulations of Nano fertilization. W1 measure found suitability of T4, T3 while as per W2 values T4, T3 and W3 values settled for T4, T3 and WAASB measure had identified the same treatments (Table 7). Higher average of treatments effects as per BLUP estimates by T5, T7 while least one of T9 as similar nature of these treatments also supported by GAIu and Hmu values. Consistent more biomass would be achieved by T5 and T6 treatments of the study. Values of analytic adaptability measures while considering the BLUP effects of treatments found suitability of T5 and T7 only.

	HM-PRVG	HM-PRVG *GM	W1	W2	W3	W4	W AASB	Meanu	SIMu	GAIu	SIGu	Hmu	SIHu	PRVGu	PRVGu *GM	HM-PRVGu	HM-PRVGu *GM
T 1	0.796	90.68	4.32	3.84	3.64	3.55	3.53	98.45	16.44	92.84	11.85	86.47	7.32	0.846	96.39	0.806	91.81
T 2	0.812	92.47	4.19	3.98	3.74	3.66	3.63	100.74	20.77	94.77	15.26	87.85	9.58	0.864	98.46	0.822	93.61
T 3	1.049	119.46	1.84	1.62	1.66	1.64	1.64	118.97	53.97	117.64	54.37	116.41	54.97	1.051	119.65	1.046	119.14
T 4	1.070	121.87	0.42	0.40	0.52	0.54	0.55	120.70	79.85	119.24	79.82	117.80	79.85	1.063	121.11	1.062	120.94
T 5	1.107	126.04	2.10	1.77	1.84	1.81	1.80	124.83	100.00	123.68	100.00	122.57	100.00	1.106	125.98	1.098	125.09
T 6	1.081	123.10	3.02	2.69	2.61	2.56	2.54	123.12	82.55	121.61	82.13	120.25	81.98	1.088	123.96	1.079	122.92
T 7	1.102	125.50	2.43	2.11	1.97	1.97	1.95	124.67	77.11	123.32	76.78	122.08	76.61	1.103	125.59	1.095	124.76
T 8	1.092	124.43	2.32	2.02	1.88	1.88	1.87	123.27	81.11	122.18	81.40	121.14	81.72	1.093	124.44	1.085	123.59
T 9	0.740	84.24	3.62	3.75	3.45	3.37	3.34	90.29	19.99	86.71	19.99	82.64	19.99	0.786	89.48	0.760	86.56

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

Ear heads per m²

W1 measure found suitability of T7, T6 while as per W2 values T5, T7 and W3 values settled for T5, T8 and WAASB measure had identified T5, T8 (Table 8) treatments. Higher average of treatments effects as per BLUP estimates expressed by T5, T7 while least one of T9 as similar nature of these treatments also supported by GAIu and Hmu values. Consistent more ear heads per m2 would be achieved by T7 and T6 treatments of the study as pointed by superiority index measures based on mean, GAI and HM measures along with WAASB values. Values of analytic adaptability measures while considering the BLUP effects of treatments found suitability of T5 and T7 only by PRVGu, HMPRVGu.

	HM-PRVG	HM-PRVG *GM	W1	W2	W3	W4	W AASB	Meanu	SIMu	GAIu	SIGu	Hmu	SIHu	PRVGu	PRVGu *GM	HM-PRVGu	HM-PRVGu *GM
T 1	0.902	317.94	3.51	3.60	3.67	3.56	3.53	325.84	17.86	316.26	15.93	304.77	13.06	0.913	321.85	0.902	317.94
T 2	0.918	323.67	1.33	3.04	2.81	2.78	2.75	328.34	36.04	321.13	36.00	312.42	35.10	0.925	326.11	0.918	323.67
T 3	1.026	361.66	5.14	3.58	3.41	3.29	3.26	361.45	73.22	358.04	74.43	354.45	75.64	1.029	362.90	1.026	361.66
T 4	1.016	358.12	4.26	3.23	3.32	3.25	3.23	357.33	65.05	354.35	66.87	351.27	68.70	1.018	358.98	1.016	358.12
T 5	1.075	379.16	1.59	1.31	1.40	1.46	1.46	378.55	84.91	374.96	84.91	371.00	84.91	1.077	379.63	1.075	379.16
T 6	1.043	367.73	1.19	2.34	2.15	2.11	2.07	367.03	89.39	364.08	90.64	361.07	92.00	1.047	369.07	1.043	367.73
T 7	1.068	376.67	0.46	1.64	2.01	1.97	1.94	376.34	92.77	372.80	92.95	369.19	93.35	1.072	377.77	1.068	376.67
T 8	1.053	371.23	2.59	2.05	1.75	1.80	1.79	370.08	88.11	367.13	89.18	363.94	90.24	1.054	371.71	1.053	371.23
T 9	0.854	300.95	8.95	6.49	5.83	5.64	5.56	308.02	32.20	299.41	32.20	290.34	32.20	0.865	304.98	0.854	300.95

Table 8: Superiority Index measures for Nano treatments formulations based on BLUP effects for ear heads per m^2.

Association pattern as per Biplot analysis

Plant height

Among the set of AMMI and BLUP based measures about 84. 8% of the total variations had explained by the two significant principal components (Table 9) with share of 69. 4% & 15. 5% share. Analytic measures of adaptability HMPRVGu, HMPRVGu*GM, Meanu, Hmu, GAIu, IPC1, PRVGu, PRVGu*GM, accounted more in first whereas IPC4, W3, ASV, W2, W3, ASV, W4, WAASB were major contributors in second components. Treatment T1, T2, T9 and T9, T2, T4 were large contributors for first and second principal components in biplot analysis. Centers RPCAU PUSA, Ayodhya, whereas Kanpur, Shillongani were major contributors for first and second components respectively.

Measures and treatments	Plant height		Biomass		Ear heads per m^2	
	Principal Component 1	Principal Component 2	Principal Component 1	Principal Component 2	Principal Component 1	Principal Component 2
IPC1	0.1763	0.0590	-0.1659	0.0634	-0.1120	-0.1022
IPC2	0.0121	-0.4106	-0.0181	0.3382	-0.0738	0.4233
IPC3	-0.0027	-0.2986	0.0442	0.0871	-0.0134	-0.0782
IPC4	-0.0212	0.1716	-0.0112	-0.1230	0.0879	-0.0056
IPC5	0.0077	-0.1516	-0.0208	-0.2518	-0.0390	-0.2016
MASV1	-0.0867	-0.0827	0.1576	0.2168	0.1145	0.0516
MASV	-0.1506	0.0411	0.1659	0.1405	0.1514	0.0463
ASV1	-0.1605	0.2052	0.1495	0.2521	0.1414	0.2911
ASV	-0.1653	0.1806	0.1542	0.2257	0.1532	0.2588
W1	-0.1564	0.2217	0.1484	0.2577	0.1237	0.3008
W 2	-0.1684	0.1504	0.1578	0.2055	0.1597	0.2281
W 3	-0.1690	0.1342	0.1573	0.2131	0.1608	0.2193
W 4	-0.1691	0.1346	0.1570	0.2147	0.1614	0.2162
W AASB	-0.1689	0.1359	0.1571	0.2146	0.1614	0.2146
Mean	0.1778	-0.0051	-0.1741	0.0896	-0.1795	0.0230
SIMe	0.1722	0.1190	-0.1702	0.0403	-0.1703	0.1576
GAI	0.1779	-0.0011	-0.1754	0.0668	-0.1795	0.0343

SIGe	0.1722	0.1212	-0.1703	0.0241	-0.1695	0.1634
HM	0.1778	0.0055	-0.1758	0.0455	-0.1790	0.0516
SIHe	0.1720	0.1254	-0.1700	0.0090	-0.1682	0.1726
PRVG	0.1778	0.0012	-0.1749	0.0779	-0.1794	0.0351
PRVG*GM	0.1778	0.0012	-0.1749	0.0779	-0.1794	0.0351
HMPRVG	0.1779	-0.0033	-0.1759	0.0547	-0.1795	0.0344
HMPRVG*GM	0.1779	-0.0033	-0.1759	0.0547	-0.1795	0.0344
Meanu	0.1778	0.0222	-0.1741	0.0896	-0.1795	0.0230
SIMu	0.1706	0.1404	-0.1701	0.0408	-0.1703	0.1576
GAIu	0.1778	0.0229	-0.1753	0.0673	-0.1795	0.0343
SIGu	0.1708	0.1402	-0.1701	0.0249	-0.1695	0.1634
Hmu	0.1778	0.0263	-0.1755	0.0468	-0.1790	0.0516
SIHu	0.1708	0.1415	-0.1698	0.0103	-0.1682	0.1726
PRVGu	0.1778	0.0254	-0.1747	0.0786	-0.1794	0.0351
PRVGu*GM	0.1778	0.0254	-0.1747	0.0786	-0.1794	0.0351
HMPRVGu	0.1778	0.0205	-0.1757	0.0551	-0.1795	0.0344
HMPRVGu*GM	0.1778	0.0205	-0.1757	0.0551	-0.1795	0.0344
Ayodhya	0.1690	0.1316	-0.1729	0.0367	-0.1660	0.1723
Kanpur	0.1407	-0.2614	-0.1538	0.1191	-0.1731	-0.0479
RPCAU PUSA	0.1646	0.1547	-0.1714	0.0525	-0.1662	0.1403
Shillongani	0.0969	0.1995	-0.1343	0.1058	-0.1166	-0.1564
Indore	0.1757	-0.0233	-0.1566	0.1728	-0.1741	-0.0047
Udaipur	-0.0514	-0.4096	0.0005	-0.4406	-0.0434	0.1740
Vijapur	0.0953	-0.2261	-0.1463	0.2099	-0.1440	-0.1901
T 1	-0.4086	-0.4170	0.4534	0.1661	0.3947	-0.4532
T 2	-0.2644	-0.2767	0.4054	0.3237	0.2746	-0.5543
T 3	0.1580	-0.2417	-0.1352	-0.1702	-0.0813	0.2482
T 4	0.2630	-0.1819	-0.3097	-0.6375	-0.0360	0.0831
T 5	0.2533	0.3671	-0.3041	0.1742	-0.3573	-0.1734
T 6	0.2180	0.2867	-0.1710	0.3852	-0.2434	0.1792
T 7	0.2017	-0.3321	-0.2347	0.1053	-0.3017	0.1488
T 8	0.2520	0.3129	-0.2363	0.1285	-0.2840	-0.0544
T 9	-0.6731	0.4826	0.5323	-0.4753	0.6343	0.5759
% share of variation	76.35%	7.22%	77.38%	10.26%	74.79%	8.97%

Table 9: Loadings of adaptability and superiority index measures basedon first two principal components.

Distant placed treatments T1, T9, would be more unstable as compared to T3 and T4 treatments. Close association of Udaipur observed with MASV1 and IPC3 values in first quadrant. Superiority index measures showed very tight association among themselves and similar behaviour expressed by adaptability measures (Figure 1). Tight relation of IPC1 was also found with both groups of superiority and adaptability measures. W2, W3, WAASB showed direct relation with MASV on one side and ASV, ASV1, W1 on other side. IPC2 had showed right angle with adaptability measures while IPC5 with superiority index measures. Shillongani center maintained ninety degree angle with W1, ASV, ASV1 values and IPC3 with MASV value. Udaipur showed the similar nature of relationship with MASV, MASV1 measures. Straight line angles of W2, W3, WAASB exhibited with Vijapur, Shillongani centers. Similar type observed for Kanpur with MASV, MASV1 measures.

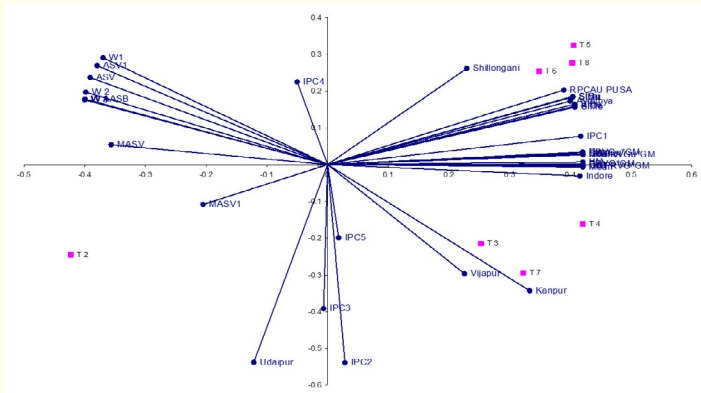

Figure 1: Biplot analysis of Nano treatments and adaptability measures based on PC1 vs PC2 for plant height.

MASV1 formed cluster with IPC3, Udaipar center values for plant height. Next cluster was constituted of IPC5, IPC2 with Vijapur and Kanpur centers (Figure 2). Shillonani, RPCAU PUSA with superiority index measures SiMe, Simu, SiGe, SiGu,, adaptability measures PRVG*Gme, HMPRVG, PRVG, HMPRVGu, PRVGu, HMPRVG*Gme, PRVG*Gmu, mean, meanu, Hm, Hmu, GAI, GAIu with IPC1 in other cluster. Last cluster was of AMMI based ASV, ASV1, MASV and stability measures W1, W2, W3, WAASB values.

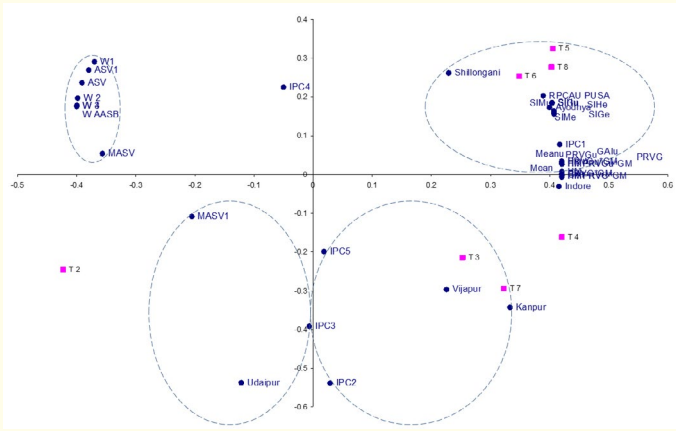

Figure 2: Clustering pattern of measures for Nano treatments evaluation for plant height.

Biomass

The first two significant principal components among set of AMMI and BLUP based measures had explained about 87. 6% of the total variations by biplot analysis (Table 9) with respective share of 77. 4% & 10. 3%. Measures HMPRVG, HMPRVG*GM, HM, HMPRVGu, HMPRVGu*GM GAIu, accounted more in first principal component whereas IPC2, IPC5, W1, ASV, ASV1, WAASB, W4, were major contributors in PC2. In terms of treatment combinations T9, T1, T2 and T4, T9, T6 were large contributors for first and second principal components in biplot analysis. Centers Ayodhya, Sillongani and Udaipur, Vijapur were major contributors for first and second components respectively.

Vectors of measures and treatments were used to highlight the association by the degree of angle between them (Zuffo et al., 2020). A right-angle depicts no correlation for measures and treatments as acute or obtuse angle indicated positive and negative correlation values (Koundinya et al., 2019). The distance of the treatment or measure vectors nearer to biplot origin stands for less interactive and would be suitable for selection with mean performance and adaptability (Rea et al., 2020). Treatments T5, T6, T2 and T1 would be more unstable as compared to T3 treatment (Figure 3). IPC1 expressed tight association with Shillongani, Vijapur, IPC3, IPC5, Indore and Kanpur center. Measures W2, W3, WAASB showed very tight association among them and direct relation with MASV, MASV1 on one side and ASV, ASV1, W1 on other side. Superiority index measures based on mean, GAI, HM expressed very tight association among them and direct association with IPC2, Udaipur on one side whereas adaptability analytic measures PRVG*Gmu, HMPRVGu, HMPRVG*Gmeu, HMPRVG*Gmu with mean, GAI, HM measures. IPC5 had showed right angle with superiority index measures. Vijapur, Shillongani centers maintained ninety degree angle with IPC2 value. Udaipur showed the similar nature of relationship with MASV, MASV1 measures. Straight line angles of W2, W3, WAASB exhibited with Vijapur, Shillongani centers. Similar type observed for Kanpur with MASV, MASV1 measures.

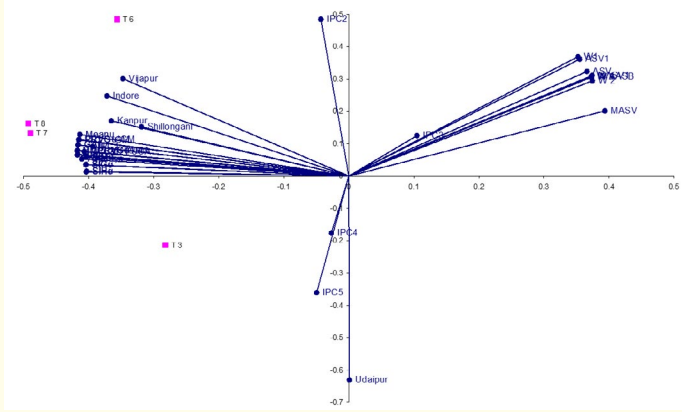

Figure 3: Biplot analysis of Nano treatments and adaptability measures based on PC1 vs PC2 for biomass.

First cluster of Udaipur with IPC4, IPC5 was observed for biomass values (Figure 4). IPC3 measure expressed bondage with AMMI based measures ASV, ASV1 MASV, MASV1 with W1, W2, W3, WAASB values in second cluster placed in third quadrant. Vijapur, Indore, Kanpur, were found near to superiority index measures SiMe, Simu, SiGe, SiGu, and adaptability measures PRVG*Gme, HMPRVG, PRVG, HMPRVGu, PRVGu, HMPRVG*Gme, PRVG*Gmu, mean, meanu Hm, Hmu, GAI, GAIu measures in last cluster.

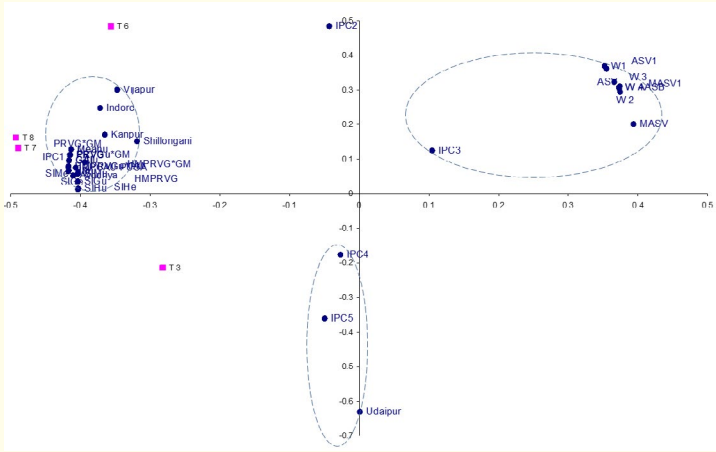

Figure 4: Clustering of studied measures for Nano treatments evaluation for biomass.

Ear heads per m²

About 83. 8% of the total variations among AMMI and BLUP based measures had been by first two significant principal components by biplot analysis (Table 9) with 74. 8% & 8. 9% respective share. Measures HMPRVG, HMPRVG*GM, Meanu, GAIu, HMPRVGu, HMPRVGu*GM, GAI accounted more in first principal whereas IPC2, W1, ASV1, W2, W3, W4, WAASB, were major contributors in second component. Treatments T9, T1, T5 and T9, T2, T1 were large contributors for first and second principal components in biplot analysis. Centers Kanpur, Indore major contributors for first and Udaipur, Vijapur were for second components.

Treatments T9, T1, T2 would be of unstable ear heads per m2 as compared to T3, T4 observed near to origin of biplot. Shillongani, Vijapur expressed direct association with Indore, Kanpur, IPC1, IPC3, IPC5 values (Figure 5). Measures W2, W3, WAASB showed very tight association among them and direct relation with MASV, MASV1 on one side and ASV, ASV1, W1 on other side. Superiority index measures based on mean, GAI, HM expressed very tight association among them and direct association with IPC2, Udaipur on one side whereas adaptability analytic measures PRVG*Gmu, HMPRVGu, HMPRVG*Gmeu, HMPRVG*Gmu with mean, GAI, HM measures. IPC5 had showed right angle with superiority index measures. Vijapur, Shillongani centers maintained ninety degree angle with IPC2 value. Udaipur showed the similar nature of relationship with MASV, MASV1 measures. Straight line angles of W2, W3, WAASB exhibited with Vijapur, Shillongani centers. Similar type observed for Kanpur with MASV, MASV1 measures.

Four clusters of were observed as measures IPC1, IPC3, IPC5 with Kanpur, Vijapur and Shillongani centres formed the first cluster and observed in the first quadrant of in biplot analysis (Figure 6). Two clusters were found in second quadrant i. e. measures MASV, MASV1with IPC4 and W1, W2, W3, WAASB ASV, ASV1 constituted the respective clusters. Last cluster of mean, meanu, SiMe, Simu, PRVG*Gme, GAI, GAIu, SiGe, SiGu, Hm, Hmu, HMPRVG, PRVG, HMPRVGu, PRVGu, HMPRVG*Gme, PRVG*Gmu with Superiority index while considering average of BLUP effects with stability measure.

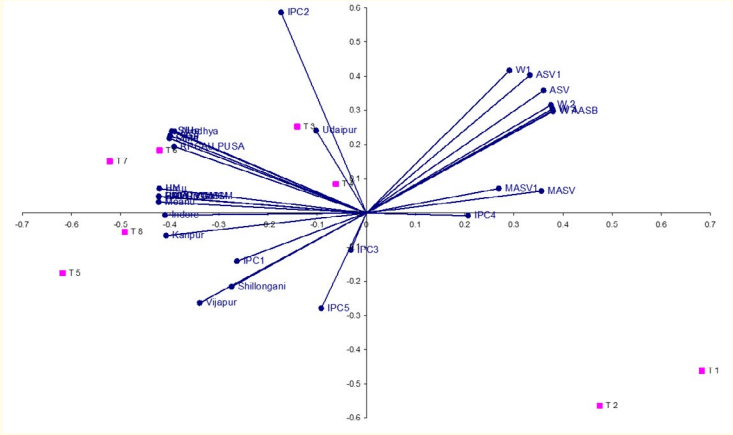

Figure 5: Biplot analysis of Nano treatments and adaptability measures based on PC1 vs PC2 for ear heads per m^2.

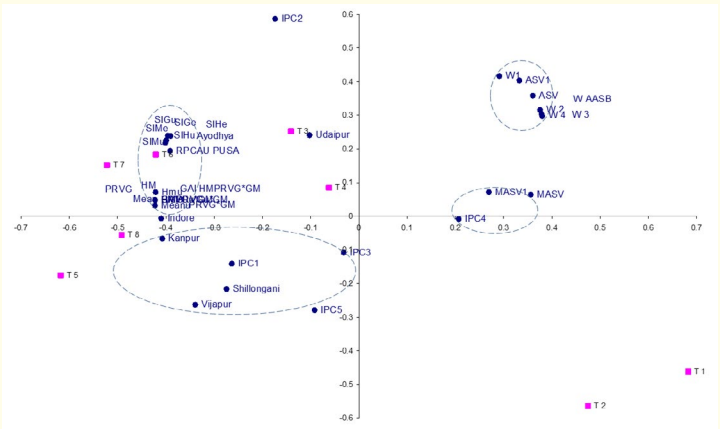

Figure 6: Clustering of studied measures for Nano treatments evaluation for ear heads per m^2.

Conclusion

Highly significant variations of locations (L), treatments (T) and TxL interactions were observed by AMMI analysis of nine treatments consisted of nano urea formulations evaluated under multi location trails of wheat under restricted irrigation conditions. More average values for plant height observed for T5, T8 treatments while consistent more plant height would be of T5, T8 based on superiority index measure. AMMI analysis based measures identified T4, T3 by MASV, MASV1, ASV and ASV1 values for biomass. Analytic adaptability measure PRVG and PRVG*GM, HMPRVG and HMPRVG*GM for ear heads per m2 had pointed for T5, T7 treatments. Higher average of treatments effects as per BLUP estimates favoured T5, T8 treatments also supported by GAIu and Hmu values. Consistent more biomass would be achieved by T5 and T6 treatments as per superiority index measures while considering the BLUP of treatments. The adaptability measures as per BLUP effects of treatments found suitability of T5 and T7 for ear heads per m2. Biplot analysis

for plant height found tight relation of IPC1 with superiority and adaptability measures. Biomass observed right angle of IPC5 with superiority index measures. Centers Vijapur, Shillongani maintained ninety degree angle with IPC2 value. Clustering pattern for ear heads per m2 exhibited MASV, MASV1 with IPC4 values and W1, W2, W3, WAASB, ASV, ASV1 constituted the respective clusters. Multi location evaluation of treatments by adaptability and superiority indexes by augmenting higher and consistent performance of treatments would be more acceptable for general recommendations.

Acknowledgements

Authors sincerely acknowledge the hard work of all the staff of coordinating center under All India Coordinated Project on Wheat and Barley improvement for successful conduct of the field evaluation.

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Volume 4 Issue 5 May 2023