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AMMI analysis of sea weed treatments for enhanced wheat yield and more number of ear heads evaluated under multi locations trials

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ABSTRACT

*AMMI analysis of twelve sea weed formulations evacuated at fifteen major locations under coordinated system had observed highly significant variations due to locations, Treatments x Locations interactions effects and seaweed formulations treatments with respective share of 78.4%, 8.7% and 3.4% respectively towards total sum of squares in ANOVA table for yield. First significant AMMI component contributed for 39.8% whereas AMMI2, AMMI3, AMMI4, AMMI5 accounted for 24.4%, 13.5%, 9.5%, 5.2% of interactions sum of squares in ANOVA table. Total contributions of significant components were 91.4% while first two significant components accounted for 63.3% of significant interaction effects for number of ear heads per m^2. AMMI analysis based measure ASV1 considered first two significant components pointed for T_5, T_7, T_9 treatments and ASV measure settled for T_7,T_5,T_4 for better yield performance. MASV1 measure had utilized most of the significant interaction effects of the study for number of ear heads per m^2 found T_4, T_7, T_2 as suitable whereas as per MASV treatmentsT_4,T_7,T_8 would be desirable. Adaptability measures for yield PRVG and PRVG*G had found the more values achieved by T_{12}, T_{11}, T_6 treatments whereas HMPRVG and HMPRVG*G measures selected the same treatments. Maximum average values for number of ear heads per m^2 exhibited by T_{12}, T_{11}, T_6 and values of GAI and HM had also favoured the T_{12}, T_{11}, T_6 treatments. Biplot analysis had found CV formed a cluster with IPC6 value and next quadrant observed the cluster of ASV, ASV1, W1, W2, W3, W4, W5, W6, WAASB with CVu measures besides the cluster of stdev with stdevu values for yield. Adaptability measure indexes for number of ear heads per m^2 irrespective of BLUE and BLUP of treatments effects while considering mean, HM, GAI, PRVG, HMPRVG, PRVGu, HMPRVGu, PRVG*G, HMPRVG*G formed a cluster with more members, adjacent cluster of Stdev, CVu, Stdevu measures were also found.*

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

INTRODUCTION

The wheat crop provides about 20% of the calories, proteins, minerals, and B vitamins to the human beings and plays an extraordinary significance to combat hunger (Sarkar *et al.,* 2023). After the tremendous production in green revolution the agricultural systems around the world have focusing on organic, sustainable, and ecologic crop production. One of new approaches is the use of plant bio stimulants, to stimulate the plant nutrition process (Najafi *et al.,* 2022). Main purpose of their applications is to improve the functions of the plant, e.g., nutrient efficiency, abiotic stress tolerance, humification etc (Stirk *et al.,* 2020). The bio stimulants cause the reduction of fertilizers while increasing plant tolerance to biotic and abiotic stresses (Kumar *et al.,* 2020). However, bio stimulant effects of the seaweed have been recorded only recently though the use of seaweed in agriculture has many advantages (Kasim *et al.,* 2015). In addition to delaying senescence, the biologically active phytochemicals in seaweed extracts promote root and shoot growth, chlorophyll content, and antioxidant activity (Chanthini *et al.,* 2022). Furthermore, seaweed extract was found to boost the activity of anti oxidative and nitrogen metabolizing enzymes (such as glutamine synthetase) (Cozzolino *et al.* 2021). The seaweed extracts significantly up regulated the genes involved in carbon fixation resulting in enhanced photosynthetic efficiency (Goñi *et al.,* 2021). Consequently, seaweeds have been recognized as a major source of macro- and micronutrients necessary for regular metabolism and proper plant growth (Dal Cortivo *et al.,* 2021). Seaweed extract is a new generation natural organic fertilizer that contains highly effective nutrients that stimulates vegetative growth and production while also improving biotic and abiotic stress resistance in many crops (Nakashima *et al.,* 2022). Seaweed extract too grasps alginates which bound the soil **R.P.**

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particles and form aggregates resultant in healthier soil structure to nurture crops and similarly subsidize to remedy the harsh effect of modern chemical agriculture (Laurent *et al.,* 2020). Unlike chemical fertilizers, extract derived from seaweeds are biodegradable, non-toxic, non-polluting and non- hazardous to humans, animals and birds besides having a low cost of production (Yuanyuan *et al.,* 2020). Seaweed extracts induce changes in the physiological and biochemical process, leading to improved nutrient uptake and better plant growth (Rafi *et al.,* 2021). They induce early seed germination, improve root growth, increase leaf chlorophyll, improve crop yield, and enhance resistance to biotic and abiotic stress. In addition, seaweed extracts also improve the physico-chemical, and biological properties of soil. Seaweed has been favoured not individual owing to their nitrogen, phosphorus, potash and micronutrients content, but also it contains some metabolites that act as plant growth regulators similar indole compounds which help the development of plant roots and buds; cytokinines are hormones which helps in rapid growth by the process of cell division, when it is applied as a foliar spray on the leaves, rejuvenate stimulate photosynthesis (Vafa *et al.,* 2021). Foliar spray it is directly assimilated by crop foliage within limited hours after application, as well as it is used as green manure, compost etc. The advantageous properties of seaweed are early seed germination, improved crop performances, elevated resistance to biotic and abiotic stress. The current study was conducted to evaluate the effect of sea weed formulations on yield and number of ear heads on wheat crop at number of locations in the country.

MATERIALS AND METHODS

Twelve treatment combinations comprises of seed treatment with sea weed extracts (@ 3ml/kg seed and foliar applications of formulations were evaluated for enhanced thousands grains weight and more grains per spike in wheat crop at major locations of the country under all india coordinated wheat and barley improvement program i.e. Akola, Bajaura, Coochbehar, Delhi, Dhandhuka, Dharwad, Durgapura, Gurdaspur, Jammu, Malan, Niphad, Ranchi, Sabour, Sriganaganagar, Udaipur, Varanasi during 2021-22 cropping season. Field evaluation of sea weed formulations based treatments was carried out with three replications, gross plot was of 14.40 sq meter with 1.80 m and 8 meter to accommodate 9 rows with a spacing of 20 cm. Harvest was recorded from 9.80sq meter plot (1.40m x 7 m) as only seven inner rows each of seven meter was considered. Field was ploughed thoroughly and recommended fertilizer dose as for the zone was applied. 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. Details of sea weed formulation treatments and locations of the evaluations are reflected in table for completeness. 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 $ASV = [(\frac{SSIPC\,1}{SSIPC\,2}PCI)^2 + (PC2)^2]^{1/2}$

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

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

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

HM = 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 $HMRPGV_{i.}$ = 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 (Olivoto *et al.,* 2019) as

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

Table 1: Details of sea weed formulations treatments and locations of the study

Code	Treatment details	Code	Locations	Code	Locations
T_1	Foliar application of seaweed extract (CP*)@ 2ml/litre water at tillering stage	L1	Delhi	L13	Akola
T_2	Foliar application of seaweed extract (CP*)@ 4ml/litre water at tillering stage	L2	Gurdaspur	L14	Dharwad
T_3	Foliar application of seaweed extract (CP*)@ 2ml/litre water at heading stage	L3	Jammu	L15	Niphad
T_4	Foliar application of seaweed extract (CP*)@ 4ml/litre water at heading stage	L4	Coochbehar		
T_5	Foliar application of seaweed extract (CP*)@ 2ml/litre water at tillering & heading stage	L5	Ranchi		
T_6	Foliar application of seaweed extract (CP*)@ 4ml/litre water at tillering & heading stage	L6	Sabour		
T_7	Seed treatment with sea weed extracts (@ 3ml/kg seed) + Foliar application of seaweed extract (CP*)@ 2ml/litre water at tillering stage	L7	Varanasi		
T_8	Seed treatment with sea weed extracts (@ 3ml/kg seed) + Foliar application of seaweed extract (CP*)@ 4ml/litre water at tillering stage	L8	Bajaura		
T_9	Seed treatment with sea weed extracts (@ 3ml/kg seed) + Foliar application of seaweed extract (CP*)@ 2ml/litre water at heading stage	L9	Malan		
T_{10}	Seed treatment with sea weed extracts (@ 3ml/kg seed) + Foliar application of seaweed extract (CP*)@ 4ml/litre water at heading stage	L10	Dhanduka		
T_{11}	Seed treatment with sea weed extracts (@ 3ml/kg seed) + Foliar application of seaweed extract (CP*)@ 2ml/litre water at tillering & heading stage	L11	Durgapura		
T_{12}	Seed treatment with sea weed extracts (@ 3ml/kg seed) + Foliar application of seaweed extract (CP*)@ 4ml/litre water at tillering & heading stage	L12	Udaipur		

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

Analysis of Variance

Yield

Larger values were observed at Coochbehar location followed by Delhi and Gurdaspur centres. Moreover the highest value had expressed by treatment T12 at Coochbehar, Udaipur and Durgapura locations as compared to T11 treatment. All the considered treatments were unable to achieve the good harvest at Dhanduka location. AMMI analysis observed highly significant variations due to locations, TxL interactions effects and seaweed formulations treatments with respective share of 78.4%, 8.7% and 3.4% respectively towards total sum of squares in ANOVA table (Table 2). AMMI1 contributed for 53.4% whereas AMMI2, AMMI3, AMMI4 accounted for 17.1%, 16.6%, 5.3%, respectively of TxL interactions effects (Olivoto *et al.,* 2019). Total contributions of significant components were 92.3% while first two significant components accounted for 70.5% of significant interaction effects. The sum of squares for signal and noise were to the tune of 61.8 and 38.2 of total TxL sum of squares. While signal and noise factors had accounted for 1.85 and 0.98 times of treatments effects. Moreover the first interaction component accounted for 1.37 times of treatments main effects.

Ear heads per m^2

Delhi had expressed more values for number of ear heads per m^2 followed by Akola and Malan centres. Lowest values were observed for Dharad center. Largest value of 540.3 followed by 529 and 516 by treatments T12, T11 and T6 during this study.

Table 2: Analysis of variance for sea weed formulations based treatments evaluated under multi location trials

Source of variations	Degree of freedom	Mean Sum of Squares		% share of factors		TxY interaction Sum of Squares (%)		Cumulative Sum of Squares (%) by IPCA's	
		Yield	Ear heads per m^2	Yield	Ear heads per m^2	Yield	Ear heads per m^2	Yield	Ear heads per m^2
Treatments (T)	11	134.86	18.09	3.40	2.176				
Locations (L)	14	2444.74	487.23	78.35	74.589				
TxL interactions effects	154	24.69	5.035	8.70	8.479				
IPC1	24	84.53	12.883			53.36	39.87	53.36	39.87
IPC2	22	29.62	8.260			17.14	23.43	70.50	63.31
IPC3	20	31.48	5.218			16.56	13.46	87.06	76.77
IPC4	18	11.16	4.074			5.28	9.46	92.34	86.22
IPC5	16	9.80	2.510				5.18		91.40
IPC6	14	5.33	2.088						
IPC7	12	2.98	1.180						
Residual	28	0.86	0.831						
Error	360	11.59	3.7486						
Total	539	81.05	16.967						
TxL total		3802.24	775.41405						
TxL noise		1452.85 or 38.21%	547.07 or 70.55%						
TxL signal		2349.38 or 61.79%	228.34 or 29.45%						

Least value of 197 and 210 were expressed by T_{12} and T_7 at Dharwad center. All the treatments had showed the lower values at Dharwad and Dhanduka locations. Table 2 reflected the highly significant variations due to locations, TxL interactions effects and seaweed formulations treatments with share of 74.6%, 8.5% and 2.2% respectively (Olivoto *et al.,* 2019). First significant AMMI component contributed for 39.8% whereas AMMI2, AMMI3, AMMI4, AMMI5 accounted for 24.4%, 13.5%, 9.5%, 5.2% respectively of interactions sum of squares in ANOVA table. Total contributions of significant components were 91.4% while first two significant components accounted for 63.3% of significant interaction effects. The sum of squares for signal and noise were to the tune of 29.5% and 70.5% of total TxL sum of squares. While signal accounted for 1.15 times and noise was of 2.8 times of treatments effects in this study.

Performance behavior of treatments as per AMMI based measures

Yield

Values of IPC1 selected T_9, T_5, T_6 treatments of the study whereas T_4, T_{11}, T_{12} treatments as per IPC2 measure and T_8,T_9,T_7 by IPC3 while T_5,T_3,T_1 by IPC4 (Table 3). IPC5 values settled for, T_4, T_9, T_{10} and IPC6 favoured T_5, T_4, T_2 and lastly T_3, T_9, T_{11}. Measure ASV1 pointed for T_5, T_7, T_9 and T_7, T_5, T_4 by ASV (Anuradha *et al.,* 2022). MASV1 and MASV had utilized most of the significant interaction effects of the study found T_3, T_4, T_1 and T_4, T_3, T_5 treatments of the study. Adaptability measures PRVG and PRVG*G had found the more values achieved by T_{12}, T_{11}, T_6 treatments whereas HMPRVG and HMPRVG*G measures selected the same T_{12}, T_{11}, T_6 treatments. Large average values exhibited by T_{12}, T_{11}, T_6 whereas least one by T1. Values of standard deviation pointed T_8, T_2, T_3 for their consistent performance and CV measure settled for T_8, T_6, T_4 treatments. Values of GAI and HM

Table 3: Performance behaviour of sea weed formulations judged by AMMI analysis based measures for yield

	IPC1	IPC2	IPC3	IPC4	IPC5	IPC6	IPC7	ASV1	ASV	MASV1	MASV	PRVG	PRVG*G	HMPRVG	HMPRVG*G	Mean	Stdev	CV	SIMe	GAI	SIG	HM	SIHm
T_1	-1.826	-0.673	-1.520	-0.304	0.566	0.663	-0.641	5.724	3.291	12.795	5.427	0.951	43.602	0.948	43.468	43.60	8.34	19.14	13.35	42.85	13.35	42.08	29.25
T_2	-2.028	-1.006	-1.280	-0.461	-0.723	-0.160	0.378	6.391	3.716	15.892	5.857	0.973	44.584	0.970	44.472	44.55	8.24	18.50	23.23	43.83	23.88	43.07	30.05
T_3	-1.031	0.838	0.802	0.228	-0.470	1.415	0.075	3.316	2.002	9.776	4.248	0.971	44.520	0.970	44.443	44.56	8.28	18.58	38.45	43.78	38.41	42.92	29.38
T_4	-0.983	0.093	1.181	-0.425	-0.097	-0.120	1.026	3.061	1.737	10.030	3.721	0.989	45.344	0.988	45.299	45.38	8.35	18.41	52.29	44.61	52.56	43.76	29.75
T_5	-0.182	-1.099	1.337	-0.028	1.002	-0.016	0.311	1.236	1.145	15.081	5.036	1.001	45.903	1.001	45.874	45.99	8.67	18.85	64.98	45.16	64.75	44.27	30.54
T_6	0.191	-2.036	1.569	0.665	-0.411	-0.615	-0.738	2.121	2.063	15.859	5.687	1.028	47.109	1.026	47.049	47.05	8.32	17.68	73.09	46.34	74.63	45.59	31.62
T_7	-0.322	0.962	-0.686	0.645	1.767	-0.489	-0.235	1.389	1.117	28.550	7.832	0.968	44.377	0.967	44.318	44.45	8.50	19.12	43.85	43.65	43.48	42.79	30.56
T_8	-0.647	1.503	-0.312	1.691	-1.107	-0.550	-0.146	2.514	1.888	37.659	9.287	1.010	46.307	1.009	46.229	46.15	7.66	16.60	61.14	45.54	63.83	44.90	32.44
T_9	0.146	1.572	0.328	-1.174	0.136	-0.876	0.106	1.636	1.593	23.908	6.104	1.000	45.840	0.999	45.787	45.87	8.52	18.58	65.25	45.09	65.58	44.27	30.91
T_{10}	1.797	0.962	0.912	-0.762	-0.157	0.649	-0.732	5.677	3.314	16.876	5.462	1.015	46.533	1.013	46.453	46.59	8.91	19.11	54.96	45.76	54.77	44.89	31.09
T_{11}	1.825	-0.496	-1.277	-1.029	-0.736	-0.394	-0.148	5.702	3.258	24.286	6.978	1.034	47.399	1.032	47.280	47.36	8.75	18.48	64.31	46.59	65.30	45.83	32.23
T_{12}	3.059	-0.620	-1.053	0.953	0.231	0.493	0.745	9.542	5.433	21.987	7.467	1.058	48.506	1.053	48.255	48.48	9.39	19.36	65.00	47.62	65.00	46.75	33.00

Table 4: Ranking of sea weed formulations by superiority and BLUP indexes for yield

	W1	W2	W3	W4	W5	W6	W7	PRVGu	PRVG*Gu	HMPRVGu	HMPRVG*Gu	Meanu	Stdevu	CVu	SIMu	GAIu	SIGu	HMu	SIHmu
T_1	1.826	1.527	1.526	1.439	1.387	1.365	1.352	0.94	43.20	0.94	43.02	43.24	8.67	20.05	13.35	42.43	13.35	41.62	28.95
T_2	2.028	1.762	1.658	1.573	1.523	1.481	1.462	0.97	44.63	0.97	44.42	44.66	8.94	20.03	29.91	43.82	26.77	42.98	29.99
T_3	1.031	0.981	0.942	0.891	0.866	0.883	0.870	0.96	44.12	0.96	44.01	44.08	7.73	17.54	37.21	43.37	36.63	42.55	29.14
T_4	0.983	0.752	0.845	0.815	0.773	0.752	0.757	0.99	45.34	0.99	45.26	45.33	8.07	17.81	57.13	44.58	53.69	43.75	29.74
T_5	0.182	0.420	0.618	0.576	0.601	0.583	0.578	1.00	45.87	1.00	45.80	45.93	8.50	18.52	69.90	45.11	64.44	44.21	30.50
T_6	0.191	0.670	0.864	0.850	0.824	0.818	0.816	1.03	47.29	1.03	47.14	47.17	8.17	17.32	80.77	46.47	74.11	45.72	31.71
T_7	0.322	0.488	0.531	0.539	0.611	0.607	0.601	0.95	43.70	0.95	43.62	43.80	8.60	19.64	40.22	42.97	38.85	42.09	30.10
T_8	0.647	0.869	0.749	0.816	0.833	0.824	0.813	1.01	46.43	1.01	46.29	46.21	7.49	16.20	67.75	45.63	64.44	45.02	32.51
T_9	0.146	0.516	0.475	0.525	0.502	0.513	0.507	1.00	46.06	1.00	45.97	46.08	8.55	18.56	73.80	45.29	68.35	44.45	31.03
T_{10}	1.797	1.581	1.436	1.388	1.316	1.295	1.285	1.01	46.47	1.01	46.30	46.51	8.98	19.31	59.69	45.65	52.63	44.76	31.00
T_{11}	1.825	1.480	1.436	1.407	1.368	1.338	1.317	1.05	47.95	1.04	47.77	48.00	9.75	20.30	79.25	47.10	68.71	46.23	32.49
T_{12}	3.059	2.426	2.129	2.045	1.939	1.894	1.874	1.07	48.97	1.06	48.58	49.03	10.38	21.16	79.01	48.01	65.00	47.01	33.17

had also favoured the T_{12}, T_{11}, T_6 treatments. Superiority index measure while considering average and stable performance values in 65 and 35 ratios settled for T_6, T_9, T_{12} treatments. Values of SIG measure pointed towards T6, T9, T_{11} while treatments T_{12}, T_8, T_{11} were selected by superiority index measures based on HM measure values.

Ear heads per m^2

Treatments T5, T6, T10 of the study were selected by IPC1 whereas T1,T4,T7 treatments as per values of IPC2 measure and T3,T4,T8 by IPC3 while T8,T9,T4 by IPC4 (Table 6). IPC5 values settled for T12, T7, T3 and T12, T6, T6 and lastly T3, T10, T2 . ASV1 pointed for T5, T4, T6 and T5, T4, T7 by ASV. MASV1 and MASV had utilized most of the significant interaction effects of the study for number of ear heads per m^2 found T4, T7, T2 and T4, T7,T8 treatments of the study (Anuradha *et al.,* 2022). Adaptability measures PRVG and PRVG*G had found the more values achieved by T12, T11, T6 treatments whereas HMPRVG and HMPRVG*G measures selected the same T12, T11, T6 treatments. Maximum average values exhibited by T12, T11, T6 whereas least one by T1. Consistent performance would be by T9, T4, T3 treatments and CV measure settled for T9, T4, T3 treatments. Values of GAI and HM had also favoured the T12, T11, T6 treatments. Superiority index measure while considering average and stable performance values in 65 and 35 ratios settled for T12, T6, T11 treatments. Values of SIG measure pointed towards T12, T6, and T11 while treatments T6, T11, T12 were selected by superiority index measures based on HM measure values.

Ranking of treatments assessed by Superiority and BLUP measures

Yield

Values of W1 settled for T9, T5, T6 and by W2 treatments T5,T7, T9 while W3 pointed for T9,T7,T5 while W4 selected the T9,T7,T5 treatments (Table 4). Measure W5 found suitability of T9, T5, T7 and W6 was hopeful for T9, T5, T7 and lastly values of W7 (WAASB) identified T9,T5,T7 treatments. Average of BLUP effects of treatments observed more values for T_{12}, T_{11}, T_{10} while consistent performance would be of T_8, T_3, T_4 as per least values of standard deviations. Moreover the CV measure had favoured T_8, T_3, T_4 out of evaluated treatments. Measures GAIu and HMu selected the $T1_2$, T_{11}, T_6 and T_{12}, T_{11}, T_6 treatments. Adaptability measures PRVGu and PRVG*Gu calculated values from the BLUP effects of treatments settled for T_{12}, T_{11}, T_6 and same of treatments had mentioned by measures HMPRVGu and HMPRVG*Gu also. Superiority index measures while considering weighted mean of average value and stability measure in ratios of 65 and 35 found suitability of T_6, T_{11}, T_{12} other superiority index measures for GAI and HM T_6, T_{12}, T_{11} and T_{12}, T_8, T_{11} treatments.

Ear heads per m^2

Values of W1 settled for T4, T12, T5 and by W2 treatments T12,T4, T3 while W3 pointed for T3,T12,T7 while W4 selected the T4,T5,T8 treatments (Table 7). Measure W5 found suitability of T4, T5, T8 and W6 was hopeful for T4, T5, T8 and WAASB measure identified T4, T5, T8 treatments. Average of BLUP effects of treatments observed more values for T12, T11, T6 while consistent performance would be of T9, T3, T4 as per least values of standard deviations. Moreover the CV measure had favoured T9, T3, T4 out of evaluated treatments. Measures GAIu and HMu selected the T12, T11, T6 and T12, T11, T6 treatments. Adaptability measures PRVGu and PRVG*Gu calculated values from the BLUP effects of treatments settled for T12,T11,T6 and same of treatments had mentioned by measures HMPRVGu and HMPRVG*Gu also. Superiority index measures while considering weighted mean of average value and stability measure in ratios of 65 and 35 found suitability of T12,T6,T11 other superiority index measures for GAI and HM T6,T12,T11 and T12,T11,T6 treatments

Association analysis among treatments and measurements

Yield

First two significant components of the biplot analysis had explained 77.8% of variations among the sea weed formulations treatments

Table 6: Performance behaviour of sea weed formulations by AMMI analysis based measures for Ear heads per m^2

	IPC1	IPC2	IPC3	IPC4	IPC5	IPC6	IPC7	ASV1	ASV	MASV1	MASV	PRVG	PRVG*G	HMPRVG	HMPRVG*G	Mean	Stdev	CV	SIMe	GAI	SIG	HM	SIHm
T_1	-1.398	0.070	0.268	-0.864	-0.326	-0.925	0.232	2.381	1.826	3.741	2.925	0.97	351.1	0.96	350.1	351.23	71.24	20.28	5.69	344.27	5.69	337.07	5.69
T_2	-0.662	-1.127	-0.760	-0.205	0.328	0.147	0.059	1.593	1.420	2.957	2.464	0.98	355.9	0.98	354.9	356.53	74.67	20.94	21.94	348.97	21.61	341.07	20.99
T_3	-1.356	0.404	-0.019	1.780	-0.284	-0.224	-0.010	2.342	1.814	4.496	3.588	0.98	356.1	0.98	355.1	355.24	66.46	18.71	8.51	349.14	11.26	342.81	14.62
T_4	-0.410	-0.132	0.072	-0.162	0.797	0.565	-0.789	0.710	0.551	2.196	1.878	0.98	356.8	0.98	355.8	355.72	64.18	18.04	44.30	349.87	47.71	343.54	51.25
T_5	-0.129	0.418	-1.007	-0.338	-1.045	0.634	-0.453	0.472	0.451	3.129	2.705	0.99	360.6	0.99	360.3	360.33	67.96	18.86	44.67	353.93	47.72	347.02	50.79
T_6	0.257	1.160	-0.928	-0.297	0.673	0.144	0.768	1.240	1.208	3.257	2.805	1.02	372.5	1.02	372.0	372.90	74.19	19.89	59.81	365.53	63.05	357.56	66.28
T_7	-0.848	-0.343	0.813	-0.524	-0.170	0.476	0.352	1.484	1.159	2.673	2.193	0.99	360.3	0.99	359.1	361.60	78.78	21.79	36.10	353.18	34.78	344.27	32.66
T_8	0.525	-0.984	-0.109	0.070	0.600	-0.775	-0.376	1.329	1.199	3.017	2.450	1.00	362.6	1.00	362.3	362.84	71.74	19.77	43.87	355.90	46.16	348.59	48.70
T_9	0.958	-1.048	1.021	0.151	-0.499	0.408	0.336	1.938	1.631	3.471	2.895	1.00	364.7	1.00	363.3	361.84	58.48	16.16	22.02	357.41	29.81	352.96	39.91
T_{10}	0.380	1.228	1.092	0.192	0.536	0.252	-0.048	1.388	1.325	3.381	2.873	1.00	364.6	1.00	363.7	364.31	70.78	19.43	38.84	357.59	41.92	350.53	45.51
T_{11}	1.264	0.902	0.205	-0.347	-0.494	-0.623	-0.433	2.332	1.879	3.389	2.710	1.04	378.4	1.04	377.8	379.01	76.73	20.25	57.99	371.28	61.60	362.96	65.35
T_{12}	1.419	-0.547	-0.649	0.546	-0.116	-0.079	0.361	2.476	1.931	3.132	2.508	1.05	380.4	1.04	379.1	382.55	84.13	21.99	65.29	372.94	65.29	361.98	62.84

Table 7: Ranking of sea weed formulations by superiority and BLUP indexes for Ear heads per m^2

	W1	W2	W3	W4	W5	W6	WAASB	PRVGu	PRVG*Gu	HMPRVGu	HMPRVG*Gu	Meanu	Stdevu	CVu	SIMu	GAIu	SIGu	HMu	SIHmu
T_1	0.662	1.323	1.242	0.773	0.738	0.750	0.733	0.98	355.28	0.98	354.69	355.15	69.03	19.44	5.69	348.57	5.69	341.64	1.02
T_2	1.356	1.543	1.440	0.744	0.712	0.678	0.658	0.99	358.52	0.98	357.94	358.74	71.73	19.99	22.21	351.76	22.12	344.40	12.11
T_3	0.410	0.472	0.504	0.925	0.876	0.837	0.810	0.99	359.18	0.99	358.60	358.32	65.12	18.17	10.16	352.41	13.65	346.10	19.40
T_4	0.129	0.379	0.878	0.243	0.285	0.302	0.318	0.99	359.54	0.99	359.20	359.01	65.97	18.38	47.10	352.87	50.08	346.22	19.29
T_5	0.257	0.957	1.559	0.386	0.436	0.448	0.448	1.00	362.93	1.00	362.83	362.76	68.32	18.83	49.69	356.32	52.97	349.35	32.34
T_6	0.848	1.021	1.719	0.623	0.626	0.598	0.603	1.02	370.40	1.02	370.22	370.79	73.23	19.75	63.94	363.62	67.58	355.91	59.06
T_7	0.525	1.105	0.690	0.662	0.624	0.615	0.607	0.99	359.30	0.99	358.81	359.89	72.97	20.28	29.45	352.56	28.58	344.75	13.44
T_8	0.958	1.558	2.833	0.517	0.524	0.539	0.533	1.00	362.66	1.00	362.49	362.76	70.47	19.43	43.66	356.02	45.89	348.87	30.30
T_9	0.380	1.116	2.232	0.885	0.856	0.829	0.813	1.00	365.10	1.00	364.51	363.36	62.39	17.17	25.78	358.21	33.79	352.89	46.82
T_{10}	1.264	1.761	2.669	0.707	0.694	0.668	0.647	1.01	365.54	1.00	365.15	365.42	70.29	19.24	43.94	358.74	47.37	351.64	41.70
T_{11}	1.419	1.692	2.819	0.861	0.833	0.821	0.808	1.02	371.36	1.02	370.98	372.05	76.05	20.44	53.41	364.46	56.05	356.45	61.23
T_{12}	0.149	0.345	0.551	0.934	0.871	0.824	0.809	1.03	374.29	1.03	373.46	375.85	81.15	21.59	65.29	367.11	65.29	357.61	65.88

and recent analytic measures considered for this study (Vaezi *et al.,* 2019). First component accounted for 51.1% while second component augmented with 26.7% of share (Table 5). Meanu, GAI, HM, PRVG, mean, PRVG*G, PRVGu, PRVG*Gu, GAIu contributed more of share in first component while for second mostly accounted by W1, W3, W5, W6, WAASB, ASV1,W2, W4 measures. Treatments T12, T1, T11 and T1, T12, T2 had been observed the larger contributors for first and second component respectively.

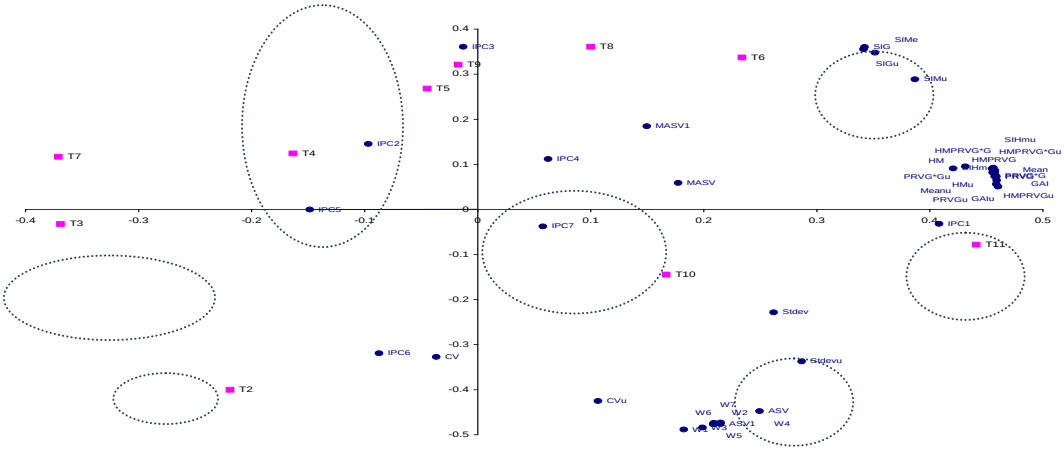

Figure 1: Biplot analysis for the clustering pattern of sea weed formulations and measures for yield

Treatments corresponding to T1, T3, T7 and T12 were observed at far places from the origin as compared with T10, T4, T5 treatments as far as harvested yield in concerned (Figure 1). Measure IPC6 had expressed direct relation with CV values as evident from acute angle between corresponding rays. Tight association of ASV observed with strongly associated ASV1, W1, W2, W2, W3, W4, W5, W6, and WAASB with CVu measures on left side while with stdev with stdevu values on the right side. Very tight association had been observed among the adaptability measures irrespective of BLUE and BLUP effects of treatments and superiority index measures based on HM values of treatments. Acute angles among rays corresponding to SIMu, SiGu, SiM, SIG, MASV1, IPC4 express the direct association. Straight line angle had observed for IPC2 with ASV values, obtuse angles had been seen between IPC5 and IPC1, IPC4 with IPC6, CV with MASV1 measures. Right angles expressed by superiority index measures for mean and GAI values with WAASB, W6, W5, W4, W3, ASV rays. Measure CV formed a cluster with IPC6 value in the biplot analysis of evaluated sea weed formulations treatments and measures considered in the study for the harvest yield of wheat.

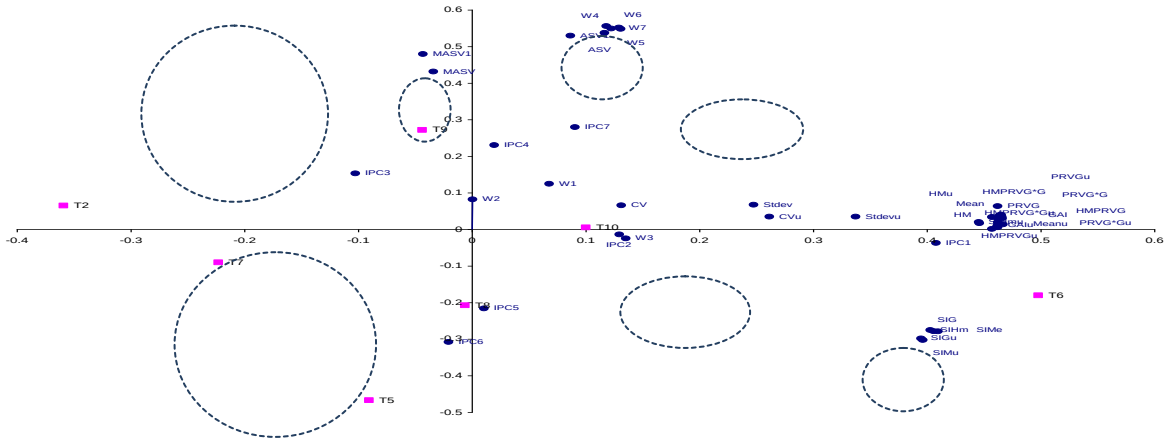

Figure 2: Biplot analysis for clustering pattern of sea weed formulations and measures for Ear heads per m^2

Next quadrant observed the cluster of ASV, ASV1, W1, W2, W3, W4, W5, W6, WAASB with CVu measures besides the cluster of stdev with stdevu values. Adaptability measures based on BLUE and BLUP of sea weed formulations treatments and superiority index measures while considered HM of treatments were placed with mean, GAI, HM values in a cluster of third quadrant. Superiority index measures while considering the mean and GAI of treatments effects formed a separate cluster. Values of MASV, MASV1 constituted a cluster with IPC4 measure. Last cluster of IPC2, IPC3 was placed in last quadrant of the biplot analysis.

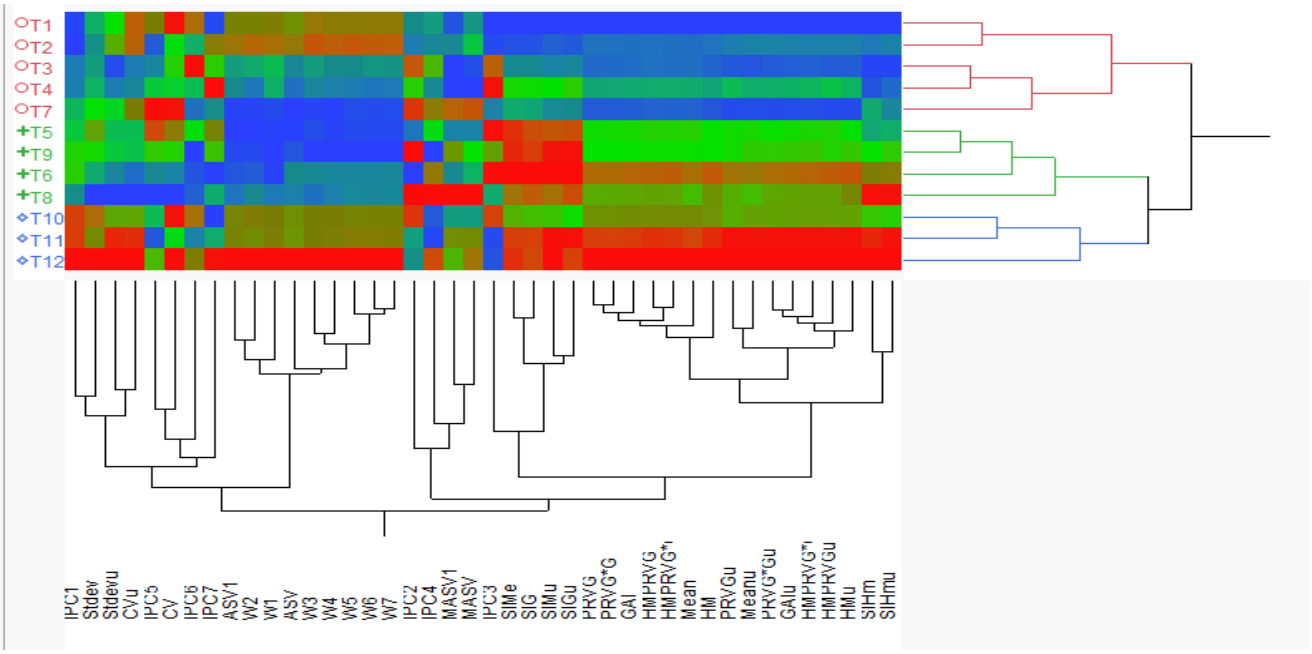

Figure 3: Multivariate hierarchical Clustering for sea weed formulations and measures for yield

Ear heads per m^2

Total of 70.34% variations among evaluated treatments and locations along with measures had been accounted by first two significant principal components in the biplot analysis for number of ear heads per m^2 in the present study (Table 5). First factor contributed 49.5% while second shared only 20.9% towards the total. Measures Meanu, HMPRVG*G, GAI, PRVG*G, Mean, PRVGu, PRVG*Gu, HMPRVGu, HMPRVG*Gu accounted more for first while W6, WAASB W4 W5 ASV, ASV1 in the second. T12, T11, T1 were accounted for more of variations in first component while treatments T4, T3, T5 were for the second component.Treatment T4, T1, T3, T11, T12 were placed at far places from the origin as compared to T8, T9, T10 in the study (Figure 2). Superiority index measures considering the weight mean of trait value and stable performance measure as per GAI, HM expressed very tight direct relationship among them (Vaezi *et al.,* 2019). Tight relation of IPC1 also observed with W3 and IPC2 values. Adaptability measures had significant direct association among themselves irrespective of BLUE and BLUP effects of treatments as with Stdev, CV, Stdevu, CVu values. Values of IPC7 measure had maintained direct relationship with W1 on one side while with ASV, ASV1, W4, W5, W6, WAASB measures. Strong bondage of MASV, MASV1 was found with W2 and IPC3 values. Right degree angle observed between rays of IPC3 with W1, MASV, MASV1 with Stdev, Stdevu. Set of ASV, ASV1, W4, W5, W6, WAASB had exhibited ninety degree relationship with superiority index measures. IPC6 showed right angle with IPC1 values in the current study. Straight line angle of MASV, MASV1 were evident with IPC5 measure and of IPC6 with IPC4 values. Measures IPC5 formed a cluster with IPC2 and W3 values in second quadrant while another cluster of superiority index measures based on GAI and HM values was placed in same quadrant. Adaptability measure indexes irrespective of BLUE and BLUP of treatments effects while considering mean, HM,

GAI, PRVG, HMPRVG, PRVGu, HMPRVGu, PRVG*G, HMPRVG*G formed a cluster with more members, adjacent cluster of Stdev, CVu, Stdevu measures were also found. Next cluster of IPC4, W1, W2, CV, IPC7 was also placed in same quadrant. Last cluster of this quadrant consisted of ASV, ASV1, W4, W5, W6, WAASB values. MASV and MASV1 values formed the cluster in fourth quadrant of the biplot analysis.

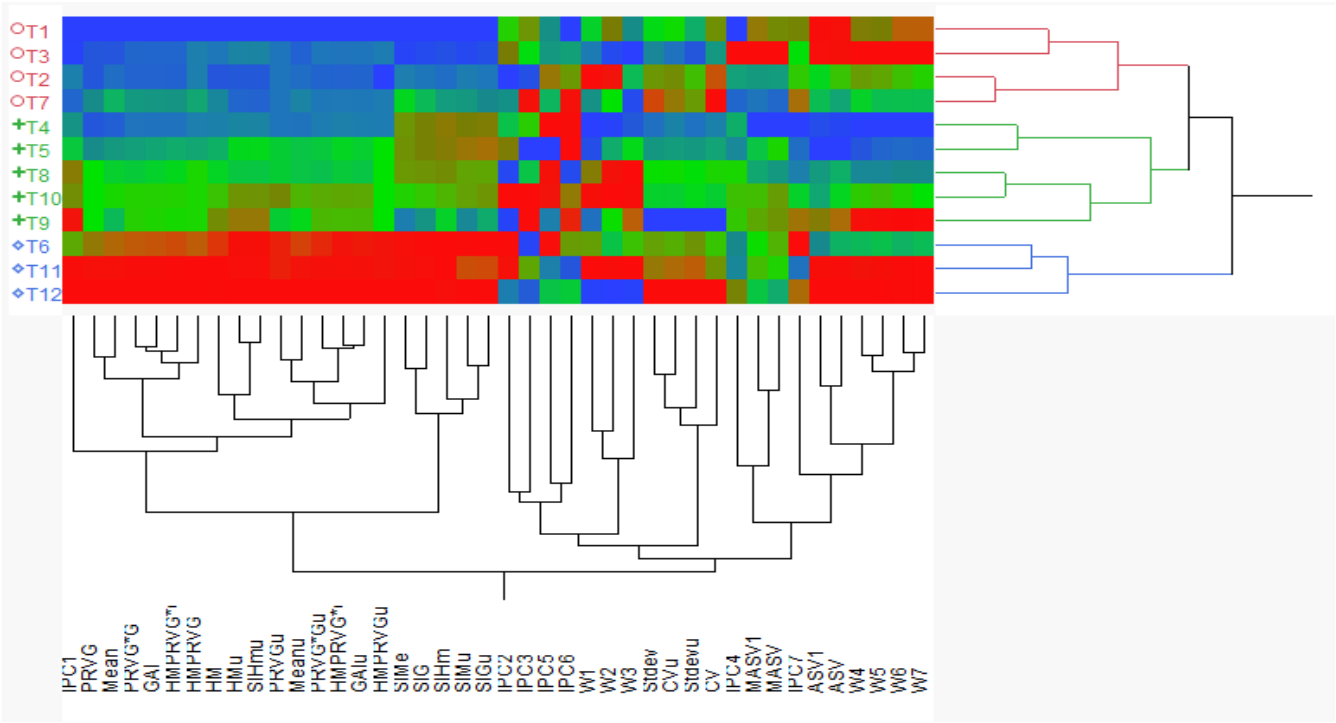

Figure 4: Multivariate hierarchical Clustering for sea weed formulations and measures for Ear heads per m^2

Multivariate Hierarchical

Clustering

Yield

Last cluster of T10, T11, T12 treatments was observed while using multivariate hierarchical clustering as per Ward's method (Figure 3). First cluster consisted of T1,T2,T3,T4,T7 while other was of T5,T6,T8,T9 treatments based on the deviations in values corresponding to performance of sea weed treatments in regards to yield. W7 (WAASB) value separated the measures in groups with measures based on AMMI along with W3, W4, W5, W6, stdev, stdevu on one broad group while adaptability and superiority index measure based on BLUE and BLUP effects of treatments in separate group at first node.

Ear heads per m ^{2}

Hierarchical clustering of treatments based on the performance of sea weed treatments formulations for number of ear heads per m^2 observed last cluster consisted of T6,T11,T2 treatments out of the three clusters with T1,T2,T3 T7 and T4,T5,T8,T10,T9 (Figure 4). The deviation in treatments performance had been observed. Measure IPC2 expressed the point of classification among the studied measures superiority index along with adaptability measures had placed in separate group as AMMI based measures along with W1, W2, W3, W4, W5, W6, WAASB in other group at the first node of classification. The latter group had further classified by CV measure into groups of IPC4, MASV1, MASV, IPC7 and of ASV1, ASV, W4, W5,W6,W7(WAASB) values. Similarly meanu measure grouped other measures further in sub groups.

Table 5: Loadings of sea weed formulations and measures as per first two significant principal components

Measures	Principal Component 1	Principal Component 2	Principal Component 1	Principal Component 2
	Yield		Ear heads per m^2	
IPC1	0.190	-0.017	0.191	-0.021
IPC2	-0.045	0.079	0.061	-0.008
IPC3	-0.006	0.197	-0.048	0.089
IPC4	0.029	0.061	0.009	0.134
IPC5	-0.069	0.000	0.005	-0.125
IPC6	-0.041	-0.174	-0.010	-0.179
IPC7	0.027	-0.021	0.042	0.163
ASV1	0.100	-0.260	0.040	0.308
ASV	0.116	-0.245	0.054	0.313
MASV1	0.070	0.101	-0.020	0.279
MASV	0.082	0.032	-0.016	0.251
PRVG	0.213	0.040	0.216	0.037
PRVG*G	0.213	0.040	0.218	0.023
HMPRVG	0.212	0.051	0.216	0.018
HMPRVG*G	0.212	0.050	0.218	0.018
Mean	0.213	0.040	0.217	0.023
Stdev	0.122	-0.125	0.116	0.039
CV	-0.017	-0.179	0.061	0.038
SIMe	0.159	0.194	0.190	-0.162
GAI	0.213	0.045	0.218	0.020
SIG	0.159	0.197	0.192	-0.162
HM	0.213	0.047	0.214	0.020
SIHm	0.195	0.050	0.189	-0.160
W1	0.085	-0.267	0.032	0.073
W2	0.097	-0.259	0.000	0.048
W3	0.092	-0.264	0.063	-0.014
W4	0.100	-0.258	0.057	0.319
W5	0.098	-0.260	0.061	0.319
W6	0.097	-0.260	0.055	0.323
WAASB	0.097	-0.260	0.060	0.321
PRVGu	0.213	0.031	0.216	0.005
PRVG*Gu	0.213	0.035	0.216	0.012
HMPRVGu	0.212	0.045	0.214	0.001
HMPRVG*Gu	0.212	0.047	0.216	0.003
Meanu	0.214	0.028	0.219	0.008
Stdevu	0.133	-0.184	0.158	0.021
CVu	0.049	-0.232	0.122	0.020
SIMu	0.180	0.158	0.186	-0.176
GAIu	0.213	0.041	0.216	0.008
SIGu	0.163	0.190	0.185	-0.173
HMu	0.211	0.049	0.209	0.010
SIHmu	0.200	0.052	0.209	0.012
T_1	-0.410	-0.457	-0.417	0.319
T_2	-0.185	-0.397	-0.237	0.054
T_3	-0.311	-0.032	-0.285	0.456
T_4	-0.138	0.123	-0.213	-0.616
T_5	-0.038	0.266	-0.060	-0.383
T_6	0.197	0.334	0.329	-0.147
T_7	-0.313	0.116	-0.147	-0.074
T_8	0.084	0.358	-0.004	-0.170
T_9	-0.015	0.318	-0.029	0.223
T_{10}	0.141	-0.144	0.066	0.005
T_{11}	0.372	-0.078	0.443	0.178
T_{12}	0.615	-0.407	0.555	0.155
% share of factors	51.12%	26.73%(77.84%)	49.48%	20.86%(70.34%)

CONCLUSIONS

AMMI analysis of twelve sea weed formulations evacuated at fifteen major locations under coordinated system had observed highly significant variations due to locations, Treatments x Locations interactions effects and seaweed formulations treatments in ANOVA. AMMI analysis based measure ASV1 considered first two significant components pointed for T5, T7, T9 treatments and ASV measure settled for T7, T5, T4 for better yield performance. MASV1 measure had utilized most of the significant interaction effects of the study for number of ear heads per m^2 found T4, T7, T2 as suitable whereas as per MASV treatmentsT4, T7, T8 would be desirable. Adaptability measures for yield PRVG and PRVG*G had found the more values achieved by T12, T11, T6 treatments whereas HMPRVG and HMPRVG*G measures selected the same treatments. Maximum average values for number of ear heads per m^2 exhibited by T12, T11, T6 and values of GAI and HM had also favoured the T12, T11, T6 treatments. Biplot analysis had found CV formed a cluster with IPC6 value and next quadrant observed the cluster of ASV, ASV1, W1, W2, W3, W4, W5, W6, WAASB with CVu measures besides the cluster of stdev with stdevu values for yield. Adaptability measure indexes for number of ear heads per m^2 irrespective of BLUE and BLUP of treatments effects while considering mean, HM, GAI, PRVG, HMPRVG, PRVGu, HMPRVGu, PRVG*G, HMPRVG*G formed a cluster with more members, adjacent cluster of Stdev, CVu, Stdevu measures were also found.

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CONFLICT OF INTEREST

No conflicts of interests among authors have been mentioned in this publication.

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