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Sea weed treatments for enhanced thousands grains weight and grains per spike in wheat crop evaluated under multi locations trials by Superiority and AMMI based indexes

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Abstract
Analysis of variance for twelve sea weed formulations treatments evaluated at fifteen major locations of coordinated wheat and barley locations across the country during 2021-22 cropping seasons observed highly significant variations due to locations, Treatments x Locations interactions effects and treatments for thousands grains weight of wheat crop. The contributions of the significant components were of 84.1%, 4.5% and 0.2% of total sum of squares. First significant component of AMMI1analysis contributed for 38.6% whereas AMMI2, AMMI3, AMMI4, AMMI5 accounted for 24.4%, 13.5%, 10.1%, 5.3% respectively of TxL interactions effects for grains per ear heads. The Total contributions of significant components were of 92.1% while first two significant components accounted for 63.2%. First two interaction principal components in ASV1 and ASV measures utilized 55.1% of T×L interaction sum of squares for thousands grains weight recommended (T_5, T_{10}, T_7) and (T_5, T_{10}, T_6) as of stable performance. The analytic adaptability measures MASV and MASV1considered all significant components and based on 90.1% of interactions sum of squares had identified T_{11}, T_{10}, T_5 treatments. Measures PRVG and PRVG*Mean for grains per ear heads settled for T_8, T_3, T_4 whereas HMPRVG along with HMPRVG*Mean measures also identified the same treatments and large average values expressed by T_8, T_3, T_4 treatments only. Average values for thousands grains weight based on BLUP effects of sea weed formulations achieved by T_{12}, T_{11}, T_6 and measures GAIu and HMu observed the more values for the same treatments T_{12}, T_{11}, T_6 treatments. The superiority index as weighted average of trait value and stable performance in 65 to 35 ratios found T_8, T_5 T_2 as suitable treatments for grains per ear heads. Biplot analysis for thousands grains weight found tight direct association of MASV, MASV1 measures observed with IPC1 and W5, W6 and WAASB values. Values of W3 along with CVu expressed direct relationship with IPC3, IPC7, W1, W2, ASV, ASV1 measures on left side whereas also associated with stdev, stdevu, CV values o the right-hand side. Direct strong relations had observed among adaptability measures PRVG, PRVG*G, PRVG*Gu, mean, HMu, GAIu, meanu, HMPRVGu, HMPRVG values. The multivariate hierarchical clustering analysis based on Ward's method for grains per ear heads observed Superiority index measure while considering average values separated W1, W2, W3, W4, W5, W6, WAASB, ASV1, ASV IPC6, IPC4, MASV, MASV1 Stdev, Stdevu CV, IPC2, IPC3, SiG measures from IPC1, IPC5, IPC7, SiHm, SiHmu, Meanu, Adaptability measures, GAI, HM at the first node of classification.

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

Introduction
Wheat has extraordinary significance in human nutrition as it is considered an important measure to combat hunger, and it provides about 20% of the calories, proteins, minerals, and B vitamins (Najafi *et al.*, 2022) [6]. The use of conventional chemical fertilizers in agricultural systems has raised the wheat production level to ensure the food availability to the world's rapidly growing population (Nakashima *et al.*, 2022) [7]. However, the indiscriminate use of synthetic fertilizers in agriculture have resulted the numerous nuisance in environment and life of living organisms (Sarkar *et al.*, 2023) [10]. As a result, emphasis had placed to switch to bio fertilizers or organic farming rather than using synthetic agricultural fertilizers (Dal Cortivo *et al.*, 2020) [3]. The availability of seaweeds is abundant and sustainable resources have been available throughout coastlines even at worldwide levels (Chanthini *et al.*, 2022) [2]. Seaweeds have been employed as bio fertilizers in agriculture to sustain the soil health and environmental issues besides to enrich the agricultural production (Kumar *et al.*, 2020) [4]. The presence of plant growth–promoting molecules like indoleacetic acid (IAA), gibberellic acid

(GA), abscisic acid (ABA), cytokinins, and polyamines, in algal extracts and other important phytochemicals were identified in seaweed extracts including phenols, betaines, lipids, proteins, sugar alcohols, alginates, and laminarins (Rafi *et al*., 2021) [9]. 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 (Stirk *et al*., 2021) [11]. 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 (Vafa *et al*., 2021) [13]. The current study has evaluated the effect of foliar applications of sea weed formulations with seed treatments on thousands grains weight and grains per spike of wheat crop at number of locations.

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 meters to accommodate 9 rows with a spacing of 20 cm. Harvest was recorded from 9.80sq meter plot (1.40 m x 7 m) as only seven inner rows each of seven meters 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 1for completeness. A number of AMMI and BLUP measures (Anuradha *et al*., 2022) [1] 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 $MASV = \sqrt{\sum_{n=1}^{N-1} \frac{SSIPC_n}{SSIPC_{n+1}}(PC_n)^2 + (PC_{n+1})^2}$

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 (Olivoto *et al*., 2019) [8] as

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

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 *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

Thousands of grains weight

More values had expressed by treatments at Ranchi as followed by Bajaura and Sabour whereas the least ones observed at Varanasi conditions (Figure 1). Treatment T_{12} had achieved the maximum value at Udaipur followed by Niphad, Ranchi. Highly significant variations due to locations, TxL interactions effects and seaweed formulations treatments were observed in analysis of variance. The contributions of the significant components were of 84.1%, 4.5% and 0.2% respectively (Table 2). AMMI1 contributed for 37.6% whereas AMMI2, AMMI3, AMMI4, AMMI5 accounted for 17.5%, 15%, 10.8%, 9.6% respectively of TxL interactions effects (Vaezi *et al*., 2019) [12]. The total contributions of significant components were of 90.4% while first two significant components accounted for 55.1% for significant interaction effects sum of squares in the study.

Grains per ear heads

Dharwad, and Coochbehar Jammu locations have achieved more values of treatments combinations while maximum value had expressed by T_{12} at Dharwad location (Figure 5). Overall variation expressed values from 18.02 (T_7, Akola) to 51.12 (T_{12}, Dharwad). Treatment T_8 had maintained the more values at number of locations while the consistency in values showed by T_9. AMMI analysis observed highly significant variations due to locations, TxL interactions effects and seaweed formulations treatments, with 83.6%, 6.1% and 1.6% respectively (Vaezi *et al*., 2019) [12]. AMMI1 contributed for 38.6% whereas AMMI2, AMMI3, AMMI4, AMMI5 accounted for 24.4%, 13.5%, 10.1%, 5.3% respectively of TxL interactions effects (Table 2). Total contributions of significant components were 92.1% while first two significant components accounted for 63.2% of significant interaction effects. Sum of squares for signal and noise were to the tune of 53.5 and 46.5 of total TxL sum of squares. While signal accounted for 1.8 times and noise was of 2.0 times of treatments effects in this study. Moreover first interaction principal component was 1.5 of treatments effects.

Performance of treatments as per AMMI based measures
Thousands grains weight

Least values of IPCA1 pointed for T_5, T_{10}, T_7 whereas as per IPCA2, T_1, T_9 and T_5 treatments would be of choice (Table 3). IPCA3 favored T_3, T_{11}, T_{10} treatments. As per IPCA4, T_8, T_2, T_{12} and T_{12}, T_5, T_7 by IPC5 while as per IPC6 values T_1, T_{12}, T_8 and last measure IPC7 settled for T_2, T_8, T_3 would be of stable performance. First two IPCAs in ASV & ASV1 measures utilized 55.1% of T×L interaction sum of squares. ASV1 measures recommended (T_5, T_{10}, T_7) and ASV pointed towards (T_5, T_{10}, T_6) as of stable performance (Anuradha *et al*., 2022) [1]. Adaptability measures MASV and MASV1considered all significant IPCAs of the AMMI analysis and used 90.1% of TxL interactions sum of squares. Values of MASV1 identified T_{11}, T_{10}, T_5 treatments would express stable performance whereas T_{11}, T_{10}, T_5 be of stable performance by MASV respectively. PRVG and PRVG*Mean settled for T_{11}, T_6, T_5 whereas HMPRVG along with HMPRVG*Mean identified T_{11}, T_6, T_5 treatments. Large values expressed by T_{11}, T_5, T_{12} treatments and consistent performance of T_1, T_7, T_5 judged by standard deviation of values. Measures GAI and HM favouredT_5, T_{11}, T_{12} treatments. Little variations among CV values settled for T_1, T_5, T_3 treatments. Superiority index as weighted average of mean and WAASB stable performance measure in 65 to 35 ratios found T_{11}, T_{10}, T_6 treatments for stable high values of trait. T_{11}, T_{10}, T_6 by index while considering GAI and T_5, T_{10}, T_{11} for HM measure.

Grains per ear heads

Least values of IPCA1 pointed for T_6, T_8, T_5 whereas as per IPCA2, T_6, T_2, and T_{10} treatments would be of choice. IPCA3 favored T_{11}, T_4, T_{10} treatments (Table 6). As per IPCA4, T_{10}, T_7, T_{12} and T_2, T_5, T_{10} by IPC5 while as per IPC6 values T_1, T_6, T_8 and last measure IPC7 settled for T_9, T_{12}, T_1 would be of stable performance. First two IPCAs in ASV & ASV1 measures utilized 63.2% of T×Y interaction sum of squares. ASV1 measures recommended (T_{69}, T_8, T_5) and ASV pointed towards (T_6, T_8, T_5) as of stable performance. Adaptability measures MASV and MASV1considered all significant IPCAs of the AMMI analysis and used 9.1% of TxY interactions sum of squares. Values of MASV1 identified T_5, T_8, T_{10} treatments would express stable performance whereas T_5, T_{10}, T_8 be of stable performance by MASV respectively (Anuradha *et al*., 2022) [1]. PRVG and PRVG* Mean settled for T_8, T_3, T_4 whereas HMPRVG along with HMPRVG* Mean identified T_8, T_3, T_4 treatments. Large values expressed by T_8, T_3, T_4 treatments and consistent performance of T_{12}, T_2, T_5 judged by standard deviation of values. Little variations among CV values settled for T_8, T_5, T_2 treatments. Superiority index as weighted average of mean and WAASB stable performance measure in 65 to 35 ratios found T_8, T_5, T_3 treatments for stable high values of trait. T_8, T_5, T_{13} by index while considering GAI and T_6, T_9, T_5 for HM measure.

Ranking of treatments based on Superiority index measures
Thousands grains weight

T_5, T_{10}, T_2 treatments selected by values of W1 measure and W2 found suitability of T_5, T_{10}, T_1 treatment combinations (Table 4). Other measure W3 had favoured the treatments T_1, T_8, T_5 and as per W4 treatments T_{10}, T_5, T_1 would be desirable (Olivoto *et al*., 2019) [8]. Measures from W5 to WAASB had settled for same set of treatments T_5, T_{10}, T_{11}. Average of BLUP effects of sea weed formulation observed large values achieved by T_{12}, T_{11}, T_6 and consistent performance would be of T_1, T_7, T_5 and CV measure had settled for T_1, T_7, T_5 treatments. Measures GAIu and HMu while considering the BLUP effects observed the more values for treatments T_{12}, T_{11} T_6. Weighted average of trait value and stable performance in 65 to 35 ratios in superiority index measure found T_{11}, T_{10} T_5 as suitable treatments and values of SIGu favoured T_{12}, T_{11}, T_6 and last measure SiHMu settled for T_5, T_{10}, T_{11} treatments. Adaptability measures PRVGu and PRVG*Gu pointed towards for T_{12}, T_{11}, T_6 as same treatments identified by HMPRVGu and HMPRVG*Gu values.

Grains per ear heads

Treatments T_6, T_8, T_5 preferred by measure W1 and values of W2 found suitability of T_6, T_8, T_5 (Table 6). Other measures from W3 to WAASB settled for same set of treatments T_6, T_8, T_5 (Olivoto *et al*., 2019) [8]. Large average values of BLUP effects achieved by T_8, T_2, T_5 and consistent performance would be of T_9, T_5, T_6 and values of CV found T_9, T_5, T_6 treatments. Measures GAIu and HMu while considering the BLUP effects observed the more values for treatments T_8, T_5 T_2. Weighted average of trait value and stable performance in 65 to 35 ratios in superiority index measure found T_8, T_5 T_2 as suitable treatments and SiHMu settled for T_6, T_8 T_5 treatments. Adaptability measures PRVGu and PRVG*Gu pointed towards for T_8, T_5 T_4 as same treatments identified by HMPRVGu and HMPRVG*Gu values.

Association pattern-based o Biplot analysis
Thousands grains weight

First two significant components of the biplot analysis had explained 77.8% of variations among the sea weed formulations treatments and recent analytic measures considered for this study (Table 5). First component accounted for 51.1% while second component augmented with 26.7% of share. 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 T_{12}, T_1, T_{11} and T_1, T_{12}, T_2 had been observed the larger contributors for first and second component respectively.

Treatments placed at far places T_3, T_1, T_{11}, T_{12} would be of unstable performance as compared to T_4, T_6, T_7 treatments placed near to origin of biplot analysis (Figure 2). Tight direct association of MASV, MASV1 measures observed with IPC1 and W5, W6 and WAASB values. Values of W3 along with CVu expressed direct relationship with IPC3, IPC7, W1, W2, ASV, ASV1 measures on left side whereas also associated with stdev, stdevu, CV values o the right-hand side. Direct strong relations had observed among adaptability measures PRVG, PRVG*G, PRVG*Gu, mean, HMu, GAIu, meanu, HMPRVGu, HMPRVG values. Superiority index measures considered mean, GAI, Hum and stable performance measure in 65 to 35 ratios expressed direct relationship with adaptability measures PRVG, HMPRVG, HM, GAI values on one side while with superiority index measure considered HM measure of treatment effects. Right angles had been expressed in rays corresponding to IPC3, IPC7, W1, W2, ASV, ASV1 with PRVG, HMPRVG, HM, GAI values. MASV, MASV1 measures maintained ninety-degree angle with stdev, CV and stevu values. IPC7 expressed right degree angle with SiG and SIMe rays. Straight line angle of IPC5 observed with GAI, PRVG measures. W5, W6, WAASB with superiority index measures based on HM measure for BLUE and BLUP effects of treatments.

Eight clusters of small and large were observed in biplot analysis as MASV, MASV1, joined hands with W5, W6, WAASB values in first cluster, next quadrant had observed smaller cluster of W1, W2, W3, W4 with ASV and ASV1 values (Figure 3). Next cluster of large size consisted of IPC7, IPC3, with W3, CV, CVu, stdev, Stdevu measures and other cluster of same quadrants observed adaptability measures with mean, meanu, GAIu, HMu values. Adaptability measures PRVG, PRVG*G, HMPRVG, HMPRVG*G joined hands with GAI HM values in first quadrant of third quadrant. The superiority index measures while considering BLUE effects of treatments in the GAI, mean and meanu measures formed a cluster. While far placed cluster found memberships of superiority index measures based on HM measure for BLUE and BLUP effects of treatments. Last cluster of IPC2, IPC4 and IPC6 was also observed.

Grains per ear heads

First two significant principal components accounted for 69.9% of total variations among the measures with 50.8% and 19.1% respective share (Table 5). Largely SIMu, SIG HMu, PRVG*Gu, GAIu, HMPRVG*Gu measures contributed for first whereas IPC6, W5, W6, WAASB, SIHmu, W4 accounted more of share in second principal component. Treatments T_7, T_8, T_5 whereas T_6, T_{11}, T_3 were large contributors for PC1 & PC2 respectively of the study.

Treatments T_7, T_{11}, T_6, T_8 would be of unstable performance as placed far from origin in comparison to T_{10}, T_2, T_9 (Figure 6). Very tight direct relationship observed for W1, MASV, MASV1 with ASV, ASV1, W2, W3, W4, W5, W6, WAASB measures and this group of measures directl related to Stdev, Stdevu values on one side and with IPC3, IPC6 on other side. IPC4 values maintained positive association with IPC2 and CV values in the first quadrant. Direct relation of IPC7 with SIMu and other superiority index measures for HM values were expressed by acute angles in corresponding rays. Measures Mean, GAI, HM, PRVG, HMPRVG, PRVG*Mean, HMPRVG x*Mean also showed very tight association among themselves besides with IPC1, IPC4. Association of non-parametric with composite measures and AMMI based measures were also observed from biplot. Moreover Mean, GAI, HM, PRVG, HMPRVG, PRVG* Mean, HMPRVG* Mean measures expressed nearly right angle with Adaptability measure. Right angles of superiority index measures found with ASV, ASV1 values and of IPC4 with adaptability measures PRVG, HMPRVG. IPC7 value had maintained right angle with stdev measure of the study.

Seven clusters of measures were observed in biplot analysis as IPC2 joined hands with IPC4 values in first cluster, next quadrant had observed cluster of IPC1 with IPC7 and other of superiority index measures while considering HM with WAASB values in weighted average (Figure 7). Large cluster of adaptability measures with measures of central tendency irrespective of BLUE and BLUP effects of sea weed formulations treatments. Measures W1, MASV, MASV1 formed next cluster with IPC3 and Stdev values. ASV, ASV1, W2, W3, W4, W5, W6, WAASB values clustered together. Last cluster in fourth quadrant consisted of CV, CVu with Stdevu values. Measures IPC5, IPC6 and SiG were observed as outliers as placed away from other measures.

Multivariate Hierarchical Clustering of measurements Thousands grains weight

Last cluster of T_{10}, T_{11}, T_{12} treatments was observed while using multivariate hierarchical clustering as per Ward's method. First cluster consisted of T_1, T_2, T_3, T_4, T_7 while other was of T_5, T_6, T_8, T_9 treatments based on the deviations in values corresponding to performance of sea weed treatments (Figure 4). Value of 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.

Grains per ear heads

Based on grains per ear head, treatment combination T_7 separated as T_5, T_8 on one side and T_1, T_2, T_3, T_4, T_6, T_9, T_{10}, T_{11}, T_{12} had been observed separately as per multivariate hierarchical clustering analysis-based o Ward's method (Figure 8). Superiority index measure while considering average values separated W1, W2, W3, W4, W5, W6, WAASB, ASV1, ASV IPC6, IPC4, MASV, MASV1 Stdev, Stdevu CV, IPC2, IPC3, SiG measures from IPC1, IPC5, IPC7, SiHm, SiHmu, Meanu, Adaptability measures, GAI, HM at the first node of classification. Measure MASV1 at second node further marked difference in group of IPC4, CV, Stdev, CVu, Stdevu, IPC2, SiGe from group of W1, W2, W3, W4, W5, W6, WAASB, ASV1, ASV, MASV values.

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	L 1	Delhi	L 13	Akola
T_2	Foliar application of seaweed extract (CP*) @ 4ml/litre water at tillering stage	L 2	Gurdaspur	L 14	Dharwad
T_3	Foliar application of seaweed extract (CP*) @ 2ml/litre water at heading stage	L 3	Jammu	L 15	Niphad
T_4	Foliar application of seaweed extract (CP*) @ 4ml/litre water at heading stage	L 4	Coochbehar		
T_5	Foliar application of seaweed extract (CP*) @ 2ml/litre water at tillering & heading stage	L 5	Ranchi		
T_6	Foliar application of seaweed extract (CP*) @ 4ml/litre water at tillering & heading stage	L 6	Sabour		
T_7	Seed treatment with sea weed extracts (@ 3ml/kg seed) + Foliar application of seaweed extract (CP*) @ 2ml/litre water at tillering stage	L 7	Varanasi		
T_8	Seed treatment with sea weed extracts (@ 3ml/kg seed) + Foliar application of seaweed extract (CP*) @ 4ml/litre water at tillering stage	L 8	Bajaura		
T_9	Seed treatment with sea weed extracts (@ 3ml/kg seed) + Foliar application of seaweed extract (CP*) @ 2ml/litre water at heading stage	L 9	Malan		
T_{10}	Seed treatment with sea weed extracts (@ 3ml/kg seed) + Foliar application of seaweed extract (CP*) @ 4ml/litre water at heading stage	L 10	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	L 11	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	L 12	Udaipur		

Table 2: AMMI analysis of sea weed formulations 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	
		Thousands grains weight	Grains per ear head	Thousands grains weight	Grains per ear head	Thousands grains weight	Grains per ear head	Thousands grains weight	Grains per ear head
Treatments (T)	11	6.28	4237.30	0.17	1.60				
Locations (L)	14	2406.32	173471.46	84.06	83.58				
TxL interactions effects	154	11.65	1153.79	4.48	6.12				
IPC1	24	28.13	2876.16			37.61	38.85	37.61	38.85
IPC2	22	14.23	1969.76			17.45	24.39	55.06	63.24
IPC3	20	13.46	1194.82			15.00	13.45	70.06	76.69
IPC4	18	10.70	994.51			10.73	10.07	80.79	86.76
IPC5	16	10.78	588.17			9.61	5.30	90.40	92.06
IPC6	14	4.84	443.42						
IPC7	12	5.06	242.44						
Residual	28	1.56	178.41						
Error	360	12.57	701.85						
Total	539	74.35	5390.65						
GxE total		1794.78	177683.82						
GxE noise		1858.77	95008.22 or 53.47%						
GxE signal		63.98	82675.60 or 46.53%						

Table 3: Performance behaviour of sea weed formulations by AMMI analysis based measures for Thousands grains weight

	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	-0.873	0.230	-0.512	-0.574	1.633	0.037	0.650	1.895	1.302	5.056	3.601	0.99	40.5	0.99	40.5	40.44	3.11	7.68	30.64	40.33	33.06	40.22	47.27
T_2	-0.488	-1.287	-1.224	-0.210	0.626	-0.618	-0.019	1.662	1.473	3.650	3.159	0.99	40.6	0.99	40.5	40.56	3.82	9.42	38.42	40.39	37.67	40.22	48.29
T_3	1.353	1.105	0.091	1.184	0.900	-0.534	-0.165	3.120	2.274	4.614	3.617	0.98	40.3	0.98	40.2	40.26	3.64	9.04	6.72	40.10	6.72	39.95	32.69
T_4	1.642	-0.342	0.454	0.893	0.476	0.637	0.437	3.556	2.435	4.242	3.178	1.00	40.8	1.00	40.8	40.85	3.70	9.07	40.82	40.69	41.08	40.54	35.86
T_5	-0.191	-0.312	-1.344	0.193	-0.162	1.089	-1.335	0.518	0.420	3.234	3.014	1.00	41.0	1.00	41.0	40.99	3.60	8.78	73.86	40.85	74.66	40.70	61.46
T_6	-0.716	0.758	-0.948	1.035	-1.309	0.263	0.916	1.719	1.295	4.755	3.719	1.01	41.5	1.01	41.5	41.47	3.76	9.06	75.89	41.32	76.32	41.17	38.08
T_7	-0.491	1.138	1.449	-0.786	0.353	0.642	-0.511	1.554	1.347	3.725	3.352	0.99	40.7	0.99	40.6	40.62	3.34	8.22	36.24	40.50	37.89	40.37	43.18
T_8	1.302	-1.647	0.963	-0.120	-0.705	0.105	0.099	3.254	2.523	4.560	3.684	1.00	40.9	1.00	40.9	40.92	4.02	9.83	40.31	40.74	38.92	40.55	31.46
T_9	1.611	0.273	-0.607	-1.756	-0.571	-0.398	0.213	3.483	2.381	4.805	3.835	1.00	40.9	1.00	40.8	40.89	4.09	9.99	36.84	40.70	35.19	40.51	29.61
T_{10}	-0.486	0.399	0.379	0.439	-0.573	-1.344	-0.863	1.122	0.818	3.096	2.708	1.01	41.2	1.01	41.2	41.20	3.73	9.05	83.25	41.05	83.62	40.90	59.72
T_{11}	-0.779	0.894	0.199	-0.581	-0.687	0.180	0.368	1.902	1.452	3.052	2.392	1.01	41.5	1.01	41.5	41.48	3.95	9.53	92.44	41.31	92.02	41.14	54.18
T_{12}	-1.884	-1.208	1.101	0.284	0.020	-0.059	0.208	4.237	3.019	4.873	3.733	1.01	41.4	1.01	41.4	41.44	4.45	10.73	62.86	41.22	59.81	41.00	26.65

Table 4: Ranking of sea weed formulations by superiority and BLUP indexes for Thousands grains weight

	W1	W2	W3	W4	W5	W6	WAASB	PRVGu	PRVG*Gu	HMPRVGu	HMPRVG*Gu	Meanu	Stdevu	CVu	SIMu	GAIu	SIGu	HMu	SIHmu
T_1	0.873	0.657	0.622	0.614	0.756	0.714	0.710	0.98	40.07	0.98	40.03	40.01	3.13	7.83	21.35	39.90	3.05	39.78	46.99
T_2	0.488	0.756	1.157	0.763	0.744	0.737	0.695	0.98	40.29	0.98	40.26	40.30	3.81	9.46	31.93	40.12	10.75	39.95	48.12
T_3	1.353	1.270	1.337	1.017	1.001	0.974	0.927	0.98	40.00	0.98	39.93	40.00	3.97	9.92	6.72	39.82	0.47	39.63	32.47
T_4	1.642	1.205	1.489	1.003	0.930	0.912	0.885	1.00	40.87	1.00	40.86	40.87	3.71	9.07	38.55	40.71	31.42	40.56	35.88
T_5	0.191	0.232	0.726	0.451	0.411	0.451	0.502	1.00	41.03	1.00	41.01	41.00	3.46	8.44	68.60	40.87	36.26	40.74	61.48
T_6	0.716	0.730	1.343	0.823	0.891	0.854	0.857	1.01	41.48	1.01	41.44	41.48	3.94	9.49	60.91	41.31	51.48	41.14	38.06
T_7	0.491	0.708	1.511	0.871	0.799	0.789	0.773	0.99	40.59	0.99	40.56	40.55	3.32	8.20	35.22	40.42	20.98	40.30	43.13
T_8	1.302	1.418	0.704	1.117	1.060	1.003	0.951	1.00	40.88	1.00	40.86	40.91	4.11	10.05	35.60	40.72	31.45	40.53	31.44
T_9	1.611	1.161	2.071	1.145	1.065	1.026	0.978	1.00	40.97	1.00	40.92	41.01	4.35	10.61	37.14	40.79	34.14	40.57	29.64
T_{10}	0.486	0.457	0.883	0.438	0.457	0.509	0.530	1.01	41.30	1.01	41.26	41.30	3.96	9.60	76.70	41.12	45.13	40.95	59.75
T_{11}	0.779	0.818	1.347	0.654	0.659	0.631	0.615	1.02	41.77	1.02	41.73	41.77	4.01	9.60	86.96	41.60	61.57	41.43	54.37
T_{12}	1.884	1.657	3.069	1.324	1.142	1.078	1.028	1.02	41.88	1.02	41.84	41.94	4.56	10.87	65.00	41.71	65.66	41.48	26.96

Table 5: Loadings of sea weed formulations and measures as per significant principal components for Thousands grains weight

Measures	Principal Component 1	Principal Component 2	Principal Component 1	Principal Component 2
	Thousands grains weight		Grains per ear head	
IPC1	-0.094	-0.087	0.055	-0.008
IPC2	-0.020	0.086	-0.113	-0.189
IPC3	0.029	-0.106	-0.053	0.112
IPC4	0.012	0.000	-0.054	-0.035
IPC5	-0.179	0.009	0.042	0.030
IPC6	0.010	0.031	-0.031	0.239
IPC7	0.011	-0.137	0.074	-0.042
ASV1	0.002	-0.257	-0.143	0.186
ASV	-0.003	-0.260	-0.152	0.189
MASV1	-0.066	-0.198	-0.109	0.145
MASV	-0.077	-0.187	-0.111	0.152

PRVG	0.220	0.007	0.156	0.188
PRVG*G	0.224	0.010	0.162	0.189
HMPRVG	0.220	0.007	0.164	0.175
HMPRVG*G	0.223	0.015	0.167	0.188
Mean	0.225	-0.002	0.145	0.198
Stdev	0.144	-0.165	-0.111	0.065
CV	0.128	-0.175	-0.158	-0.008
SIMe	0.203	0.119	0.189	0.071
GAI	0.224	0.013	0.165	0.187
SIG	0.198	0.131	0.202	0.054
HM	0.221	0.026	0.177	0.177
SIHm	0.027	0.260	0.164	-0.226
W1	0.009	-0.248	-0.109	0.164
W2	0.006	-0.258	-0.163	0.201
W3	0.085	-0.183	-0.172	0.194
W4	-0.003	-0.262	-0.164	0.220
W5	-0.024	-0.261	-0.157	0.238
W6	-0.027	-0.263	-0.159	0.234
WAASB	-0.022	-0.261	-0.161	0.231
PRVGu	0.223	-0.028	0.174	0.122
PRVG*Gu	0.226	-0.023	-0.158	0.033
HMPRVGu	0.223	-0.028	-0.180	0.002
HMPRVG*Gu	0.226	-0.021	0.203	-0.014
Meanu	0.225	-0.033	0.190	0.110
Stdevu	0.124	-0.182	0.187	0.117
CVu	0.099	-0.192	0.194	0.106
SIMu	0.210	0.099	0.165	-0.225
GAIu	0.225	-0.023	0.188	0.143
SIGu	0.225	-0.025	0.190	0.116
HMu	0.225	-0.011	0.182	0.062
SIHmu	0.029	0.260	0.189	0.107
T_1	-0.410	0.182	-0.174	0.024
T_2	-0.257	0.114	0.062	0.119
T_3	-0.473	-0.216	0.052	0.431
T_4	-0.060	-0.162	0.073	0.417
T_5	0.066	0.488	0.399	-0.167
T_6	0.291	0.005	0.165	-0.582
T_7	-0.213	0.138	-0.644	-0.039
T_8	-0.015	-0.284	0.520	0.005
T_9	-0.006	-0.343	-0.032	0.204
T_{10}	0.248	0.368	-0.011	0.011
T_{11}	0.428	0.208	-0.203	-0.463
T_{12}	0.399	-0.497	-0.209	0.039
% share of factors in PC1 and PC2	46.01%	33.18% (79.19%)	50.83	19.05(69.88%)

Table 6: Performance behaviour of sea weed formulations by AMMI analysis based measures for Grains per ear head

	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	-5.713	-1.644	-1.266	-1.239	-0.764	-0.040	-1.765	9.25	7.40	10.54	8.51	0.99	32.25	0.99	32.21	32.29	8.23	25.5	19.55	31.28	19.31	30.26	31.53
T_2	-4.636	-0.186	-2.842	-4.644	0.032	0.293	-0.469	7.39	5.85	13.32	10.78	1.00	32.44	1.00	32.41	32.40	7.97	24.6	30.69	31.47	35.30	30.55	34.33
T_3	-3.403	-3.368	1.355	3.988	-2.524	3.388	1.261	6.38	5.46	15.58	12.42	1.01	32.93	1.01	32.87	32.96	8.49	25.8	68.49	31.92	60.80	30.90	28.04
T_4	2.487	-5.796	0.644	2.495	3.593	-0.544	-2.224	7.02	6.59	15.45	12.72	1.01	32.90	1.01	32.84	32.90	8.45	25.7	65.16	31.89	59.88	30.91	29.20
T_5	1.098	-2.348	-2.477	-1.400	0.577	-0.263	1.322	2.93	2.73	7.49	6.34	1.01	32.73	1.01	32.71	32.69	8.05	24.6	71.63	31.75	72.92	30.81	52.31
T_6	-0.847	0.152	-2.433	2.807	-0.761	-4.598	2.497	1.36	1.08	13.43	10.58	0.99	32.36	0.99	32.33	32.37	8.21	25.4	49.00	31.39	50.14	30.42	54.77
T_7	-4.131	4.747	4.922	1.012	1.797	0.018	0.701	8.11	7.05	14.94	12.60	0.99	32.16	0.99	32.08	32.27	8.63	26.7	6.47	31.17	0.00	30.07	19.55
T_8	1.077	0.793	2.588	-2.320	3.639	0.059	1.189	1.89	1.57	9.71	8.34	1.02	33.13	1.02	33.03	33.02	8.10	24.5	98.05	32.10	98.05	31.20	53.33
T_9	3.942	-1.277	4.354	-3.092	-3.942	-0.996	-0.135	6.41	5.14	14.15	11.98	1.01	32.71	1.00	32.69	32.72	8.34	25.5	50.05	31.73	48.19	30.78	28.70
T_{10}	5.742	-0.237	-0.738	-0.768	-0.633	1.354	0.711	9.15	7.25	10.01	7.93	1.00	32.45	1.00	32.44	32.45	8.15	25.1	39.09	31.49	40.95	30.54	38.66
T_{11}	1.316	4.308	-0.264	2.139	-1.579	-1.421	-3.289	4.79	4.62	11.64	9.58	0.99	32.17	0.99	32.12	32.23	8.40	26.1	27.57	31.20	25.84	30.16	43.72
T_{12}	3.066	4.855	-3.843	1.023	0.566	2.752	0.203	6.89	6.21	14.63	11.97	0.99	32.25	0.99	32.20	32.19	7.96	24.7	7.38	31.27	14.54	30.38	27.13

Table 7: Ranking of sea weed formulations by superiority and BLUP indexes for Grains per ear head

	W1	W2	W3	W4	W5	W6	WAASB	Meanu	Stdevu	CVu	SIMu	GAIu	SIGu	HMu	SIHmu	PRVGu	PRVG*Gu	HMPRVGu	HMPRVG*Gu
T_1	5.71	4.06	3.51	3.19	3.00	2.84	2.81	32.59	8.55	26.22	57.91	31.52	46.02	30.44	31.65	1.00	32.53	1.00	32.42
T_2	4.64	2.83	2.83	3.09	2.85	2.71	2.65	32.91	8.32	25.29	76.66	31.91	62.13	30.92	34.58	1.01	32.92	1.01	32.84
T_3	3.40	3.39	2.99	3.13	3.08	3.10	3.04	32.78	8.50	25.93	63.68	31.73	54.29	30.69	27.91	1.01	32.76	1.00	32.64
T_4	2.49	3.83	3.20	3.10	3.14	3.00	2.97	32.75	8.35	25.51	63.58	31.78	55.83	30.83	29.15	1.01	32.82	1.00	32.68
T_5	1.10	1.61	1.78	1.72	1.64	1.56	1.55	32.88	7.97	24.25	92.96	31.95	62.43	31.01	52.43	1.01	32.95	1.01	32.89
T_6	0.85	0.56	0.93	1.20	1.16	1.35	1.39	32.42	8.00	24.67	72.59	31.47	42.46	30.51	54.83	1.00	32.48	1.00	32.38
T_7	4.13	4.38	4.49	4.00	3.83	3.62	3.53	31.69	9.05	28.57	0.00	30.46	1.45	29.25	19.01	0.97	31.47	0.96	31.31
T_8	1.08	0.96	1.28	1.43	1.60	1.52	1.51	32.96	8.19	24.85	98.05	32.02	65.38	31.08	53.26	1.02	33.09	1.01	32.90
T_9	3.94	2.86	3.15	3.15	3.21	3.09	3.00	32.27	7.81	24.20	38.72	31.41	40.80	30.56	28.56	1.00	32.42	0.99	32.31
T_{10}	5.74	3.50	2.96	2.65	2.49	2.43	2.38	32.48	8.23	25.33	59.33	31.50	45.24	30.52	38.65	1.00	32.48	1.00	32.43
T_{11}	1.32	2.53	2.08	2.09	2.05	2.02	2.05	32.12	8.57	26.69	46.02	31.03	23.96	29.93	43.57	0.98	32.02	0.98	31.92
T_{12}	3.07	3.79	3.80	3.41	3.19	3.17	3.08	32.64	9.04	27.70	55.82	31.51	44.99	30.45	27.18	1.00	32.54	1.00	32.41

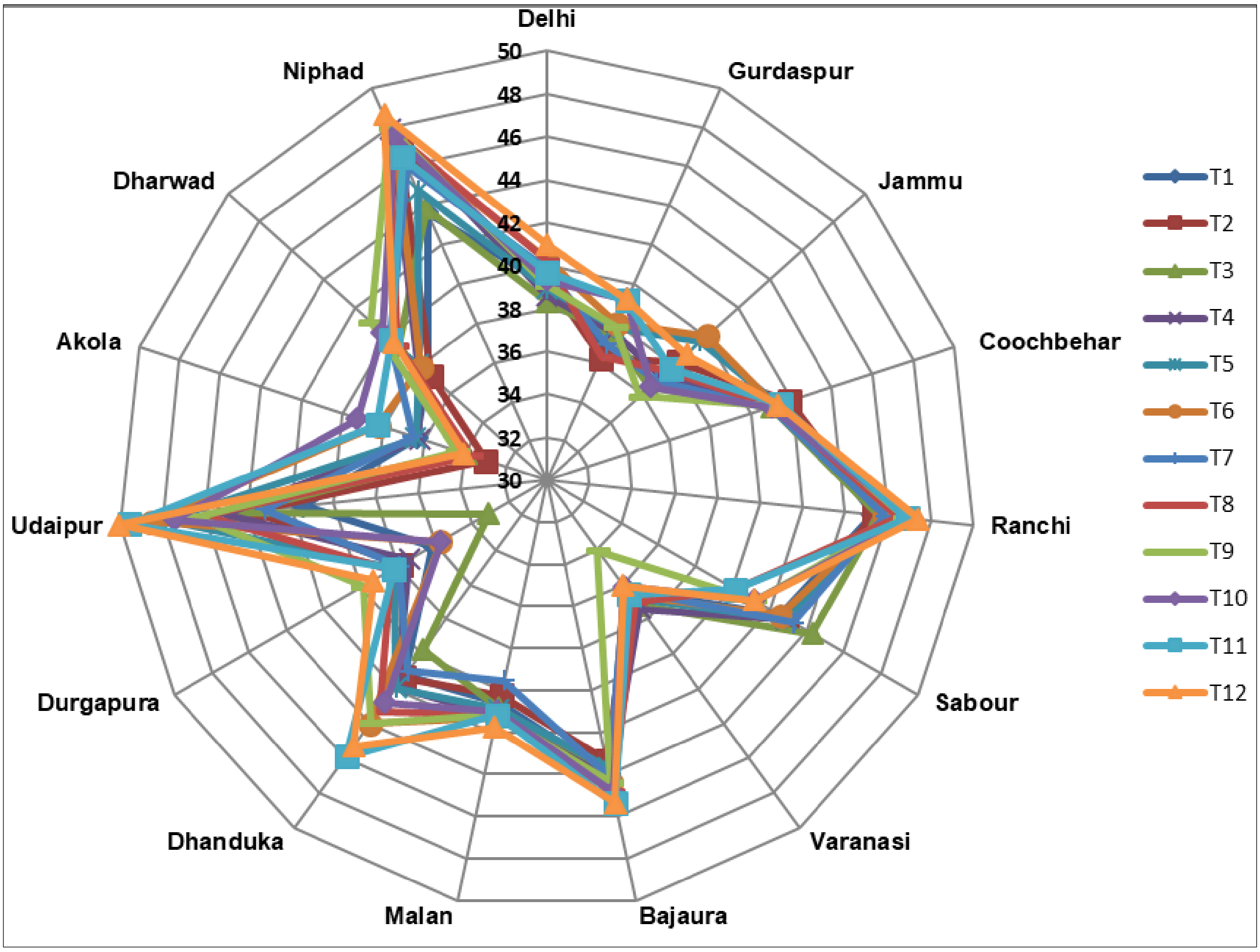

Fig 1: Variations in sea weed formulations for Thousands grains weight

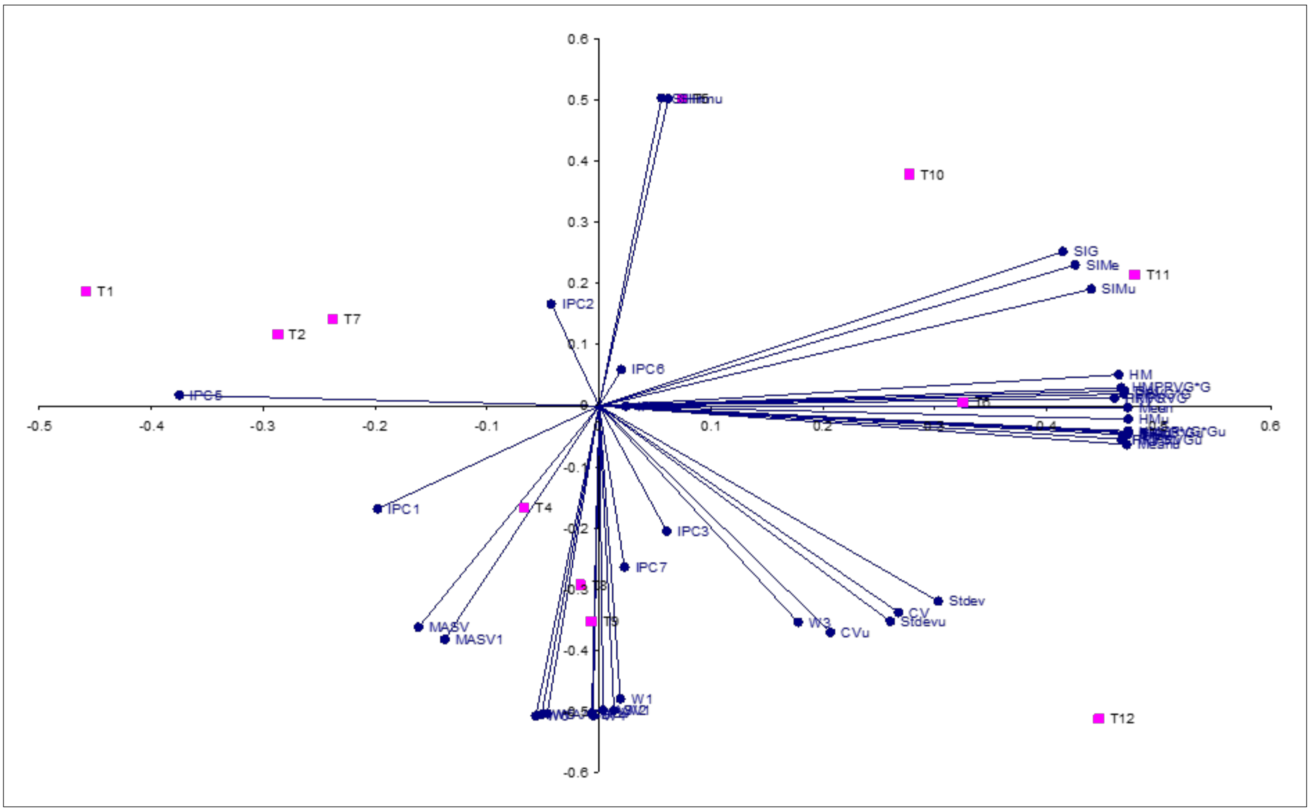

Fig 2: Biplot analysis of sea weed formulations and studied measures for Thousands grains weight

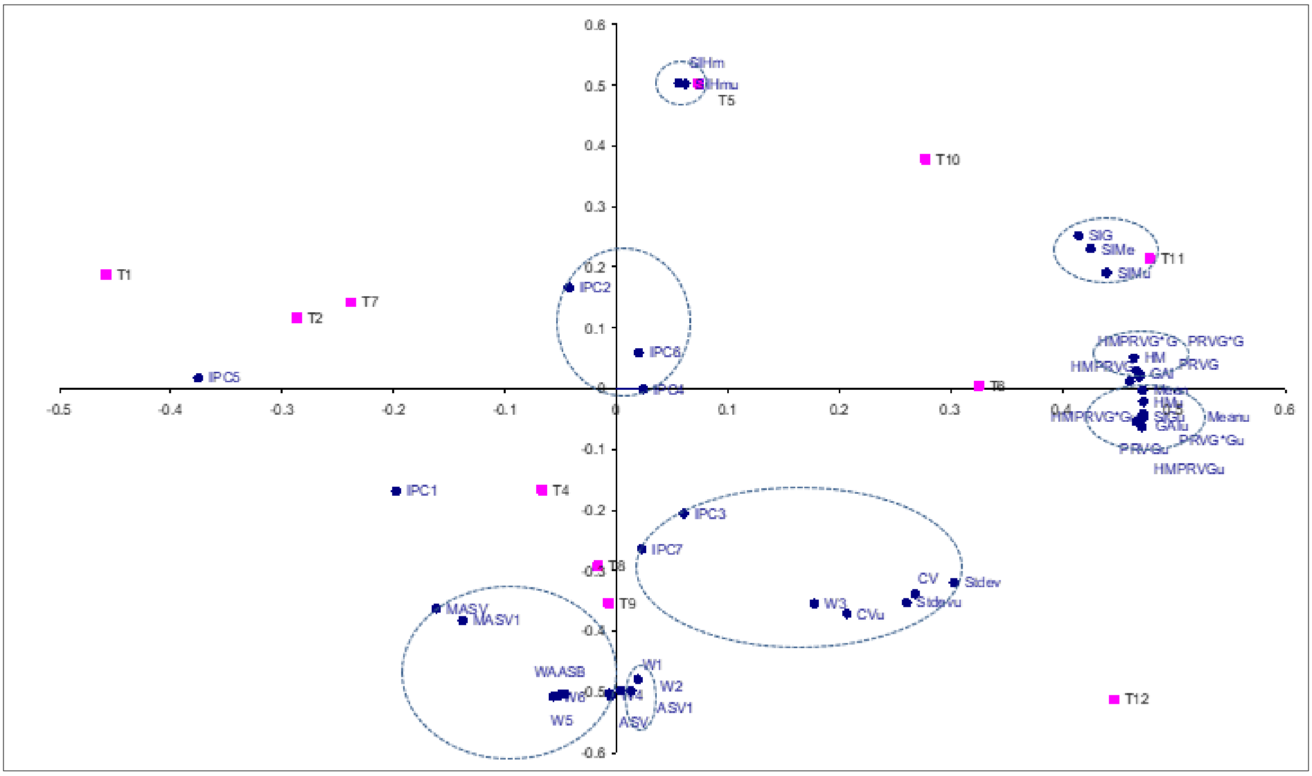

Fig 3: Cluster patternofsea weed formulations and studied measures for Thousands grains weight

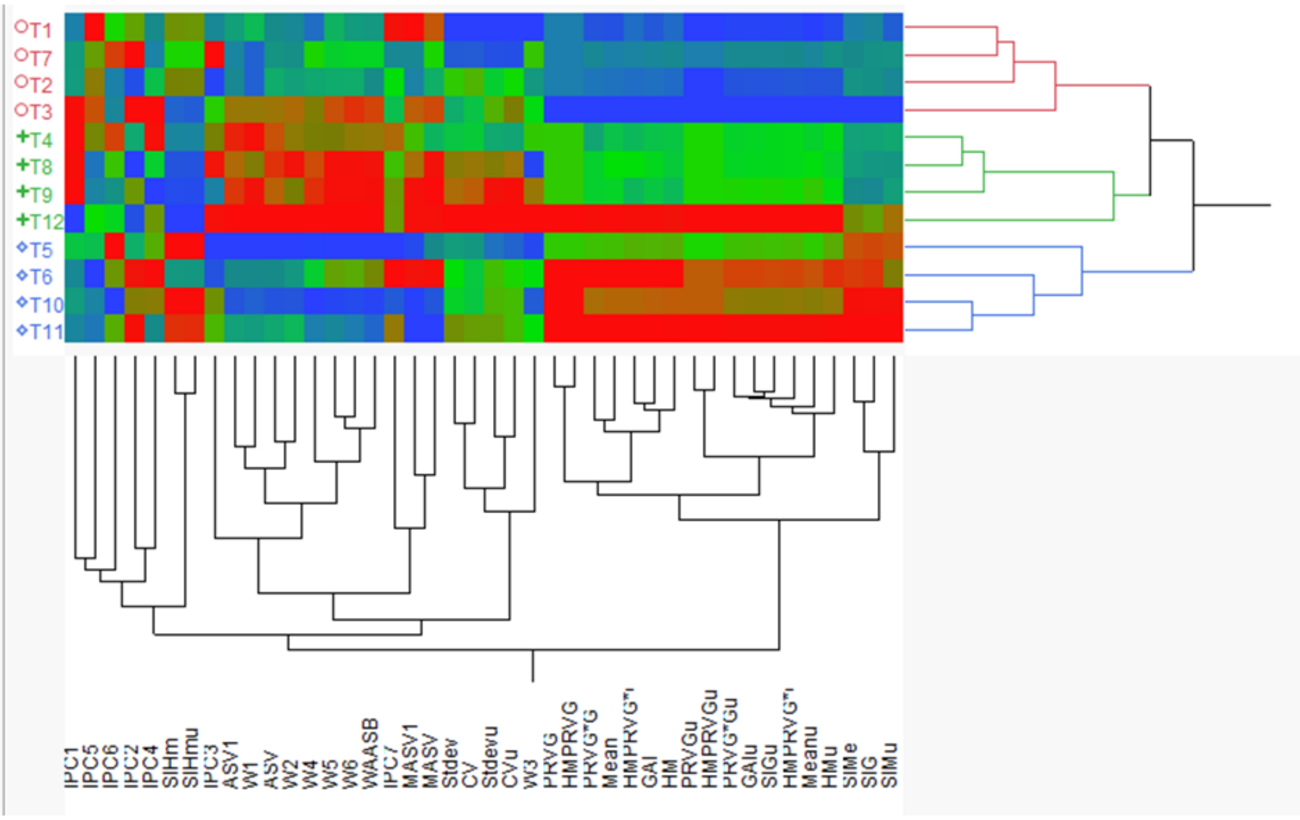

Fig 4: Multivariate hierarchical Clustering for sea weed formulations and measures for Thousands grains weight

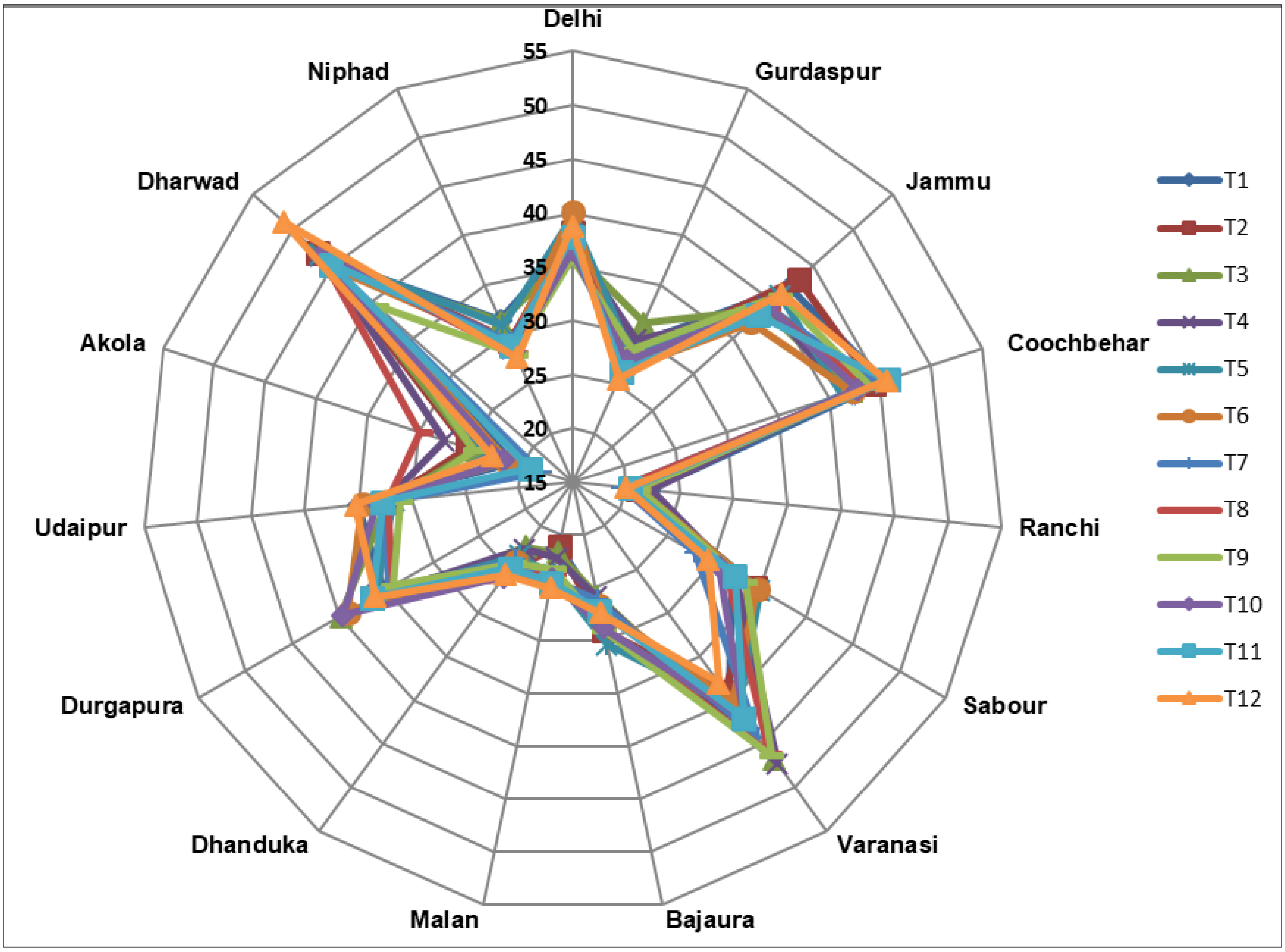

Fig 5: Variations in sea weed formulations for Grains per ear head

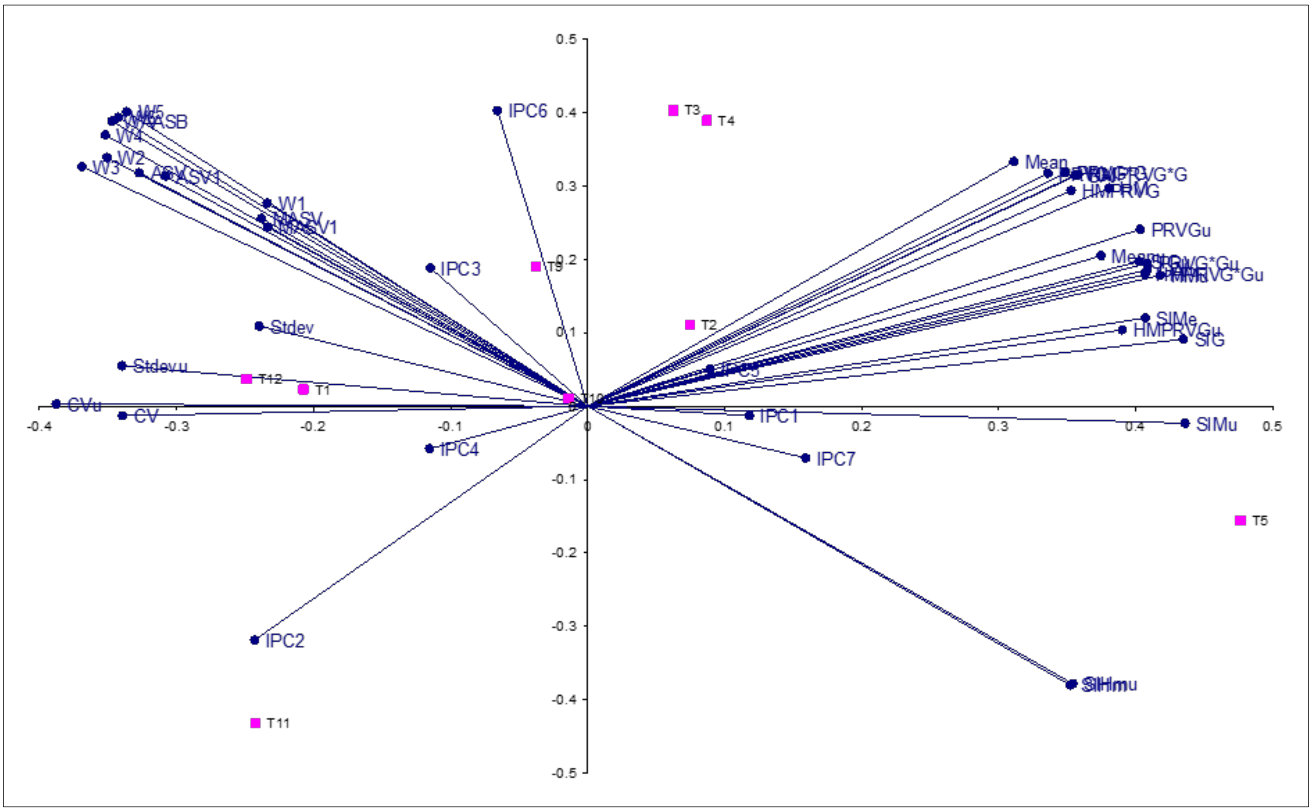

Fig 6: Biplot analysis ofsea weed formulations and studied measures for Grains per ear head

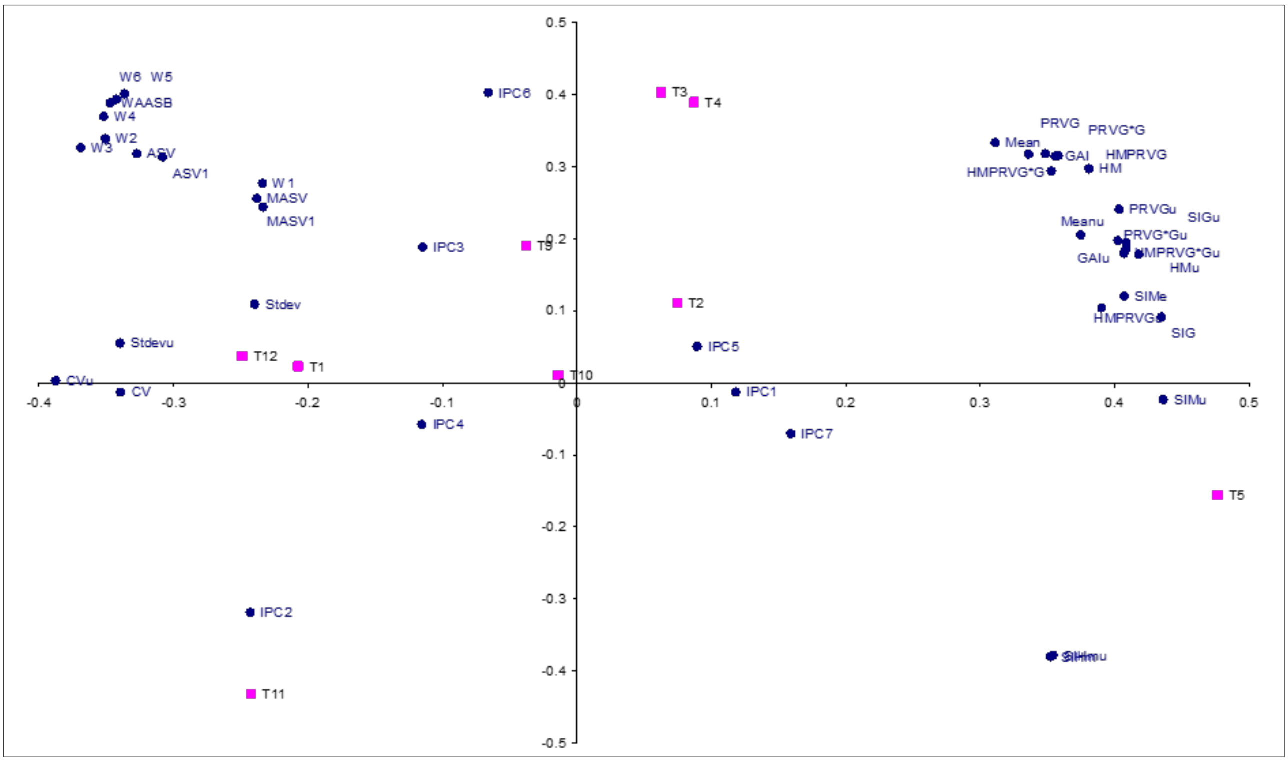

Fig 7: Cluster patternofsea weed formulations and studied measures for Grains per ear head

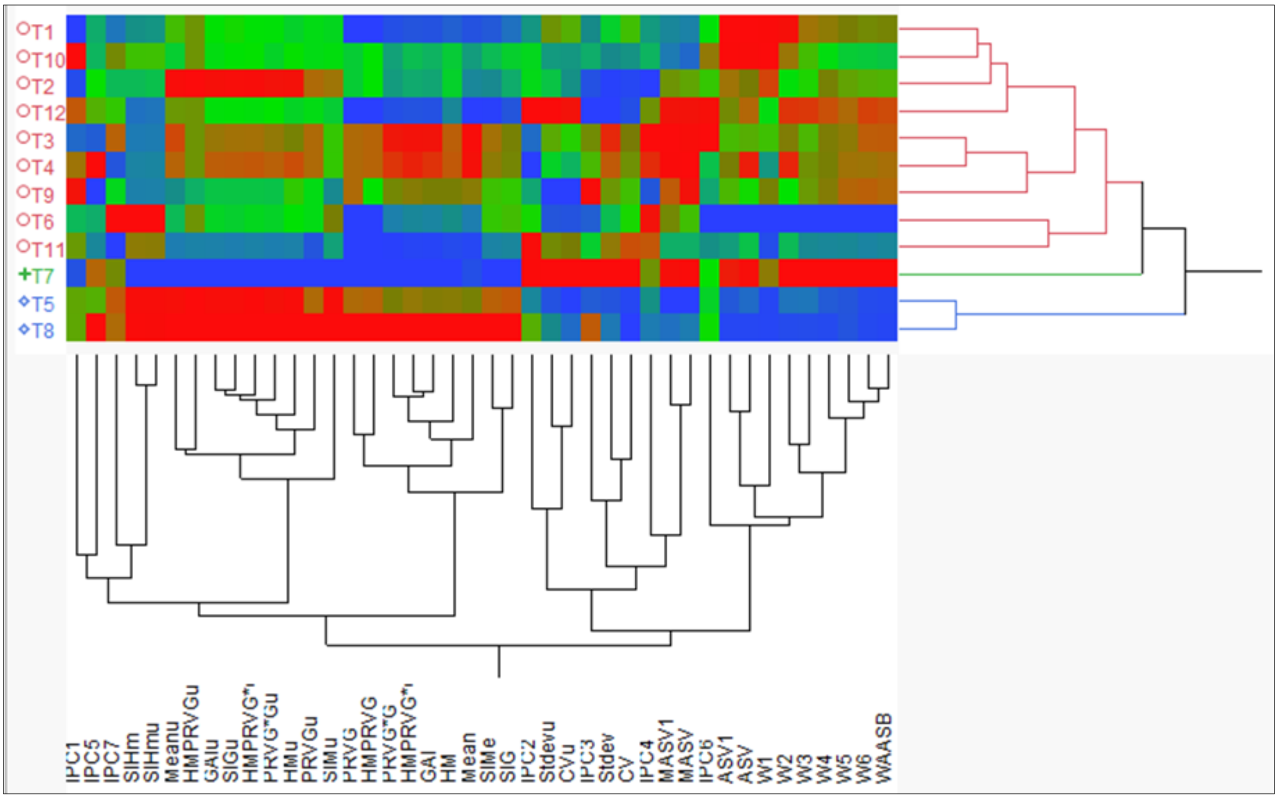

Fig 8: Multivariate hierarchical Clustering for sea weed formulations and measures for Grains per ear head

Conclusions

Analysis of variance for twelve sea weed formulations treatments evaluated at fifteen major locations of coordinated wheat and barley locations across the country during 2021-22 cropping seasons observed highly significant variations due to locations, Treatments x Locations interactions effects and treatments for thousands grains weight of wheat crop. First two interaction principal components in ASV1 and ASV measures for thousands grains weight recommended (T_5, T_{10}, T_7) and (T_5, T_{10}, T_6) as of stable performance. The analytic adaptability measures MASV and MASV1considered all significant components had identified T_{11}, T_{10}, T_5 treatments. Measures PRVG and PRVG*Mean for grains per ear heads settled for T_8, T_3, T_4 whereas HMPRVG along with HMPRVG*Mean measures also identified the same treatments and large average values expressed by T_8, T_3, T_4

treatments only. Average values for thousands grains weight based on BLUP effects of sea weed formulations achieved by T_{12}, T_{11}, T_6 and measures GAIu and HMu observed the more values for the same treatments T_{12}, T_{11}, T_6 treatments. Biplot analysis for thousands grains weight found tight direct association of MASV, MASV1 measures observed with IPC1 and W5, W6 and WAASB values. Direct strong relations had observed among adaptability measures PRVG, PRVG*G, PRVG*Gu, mean, HMu, GAIu, meanu, HMPRVGu, HMPRVG values. The multivariate hierarchical clustering analysis based on Ward's method for grains per ear heads observed Superiority index measure while considering average values separated W1, W2, W3, W4, W5, W6, WAASB, ASV1, ASV IPC6, IPC4, MASV, MASV1 Stdev, Stdevu CV, IPC2, IPC3, SiG measures from IPC1, IPC5, IPC7, SiHm, SiHmu, Meanu, Adaptability measures, GAI, HM at the first node of classification.

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