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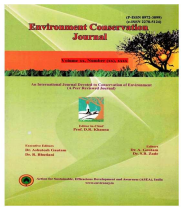

Influence of sulphur aerosols on physiological, yield and yield attributing of wheat (*Triticum aestivum* L.) using principal component analysis

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ABSTRACT

Among several constrains curtailing the yield potential of a crop, lack of proper mineral nutrition in particular sulphur management, a nutrient that is needed in trace amount but essential for plant growth is more alarming. Sulphur is the main source of protein particularly for cereal crop. An experiment was conducted to find out influence of sulphur aerosols on morpho-physiological, yield, and yield traits of wheat. S-aerosols viz., $(NH_4)_2SO_4$, $CaSO_4$, and K_2SO_4: @ 300 ppm each (≈30 kg N ha-1) along with a control were misted on the plants, on sunny days in the afternoon (after 2–3 P.M.) at three different growth stages i.e. seedling, maximum tillering and spike initiation stages. Therefore, a total concentration of each S-aerosols was 900 ppm ≈ 0.9%.Genotypes (viz., GW-322, GW-366, GW-273, GW-173, JW-336) were raised both under Pot culture (Expt.1) and field (Expt.2) observations recorded are : LA, LAI, SLW, Tiller numbers, No. of seed per spike, length of spike, spike weight, TW, BY, EY, HI. The investigation was carried out aiming to test the hypothesis that foliar fed Sulphur aerosols influence economic yield of wheat crop positively. The genotype GW-366 was the most responsive in physiological traits and GW-273 for yield traits under the influence of foliar fertilization with S-aerosols. Among the S-aerosols, $(NH_4)_2SO_4$ was the most effective in the work. The results in this experiment are contribution of Sulphur aerosols using PCA towards total diversity.

Introduction

In past decades, growth of India's agricultural sector, has been remarkable with almost five-fold increase in food grains production by last 50 years thereby, transforming India to a net food exporter (FAO-2017). India is one of the most popular country in the world comprising 18% of the global population with a food grain requirement of 109 MT, by the end of the year 2020, (Shoran *et al.,* 2004) and is expected to reach to 1.7 B by 2050 (UN 2017) (Lobell *et al.,* 2011; 2013; Burney and Ramanathan, 2014). Wheat is the main crop of India, rice-wheat cropping system with a current production of 98.4 MT, India is the second largest wheat producing country in the world (FAO 2018) with an area of about 30.2 M. ha (DES 2017). Atmospheric aerosols effect may further be serious due to uncertain implications (Myhre *et al.,* 2013; Chen *et al.,* 2018). Aerosols, influence boundary layer height there-by, weakening the atmospheric turbulence (Petaja *et al.,* 2016). Several evidences of negative impacts of aerosols on wheat production (Chameides *et al.,* 1999). Aerosols have diverse impacts on crop (Hu *et al.,* 2017). Sulphur plays varied structural and functional roles in plants, that exhibit diverse responses to sulphur deficiency, it leads to yellowing of young leaves of plants, decreases biomass (Lunde *et al.,* 2008). Toxicity of Sulphur (caused by SO_2) produces

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chlorosis and interveinal necrosis in plants (Farooq and Hans 1999), which ultimately reducing growth and yield (Wali *et al.,* 2004). Sulphur is assimilated in the form of cysteine which behaves as a precursor or reduced Sulphur donor of most other organic Sulphur compounds in plants. Cysteine also plays a critical role in protection against biotic/abiotic stress (Noctor *et al.,* 2002).

Nitrogen (N) and Sulfur (S) supplies have a more influence on the wheat storage proteins by quality and quantity. Nitrogen derived from urea, S from micronized elemental sulfur, and a mixture of both application of (N+S) at anthesis stage on wheat by foliar spray. (Fageria *et al.,* 2009) reported that when nutrients are applied to soils, they are absorbed by plant roots and translocated to aerial parts. In such, case of foliar application, the nutrients penetrate the cuticle of the leaf, the stomata and then enter the cells. Hence, crop response occurs faster, compared to soil application. Sulfur plays important role in wheat productivity as it is the constituent of several amino acids viz., methionine, cysteine, sulfolipds and co-enzymes such as biotin, coenzyme-A, thiamine pyrophosphate and lipoic acid. But, little information is available on the influence sulphur on wheat applied in the form of aerosols.

Material and Methods

Experimental Site

Field & pot experiments were conducted at the ICR farm, AAU, Jorhat during the year 2017-18 (Expt.1) & 2018-19 (Expt. 2).

Experiment Design and Crop Management

Pot & Field experiments were conducted to study the yield related characters. Randomized Block Design (RBD) with two replications was followed in the experiment with spacing (22 cm) & seed rate 30 Kg ha^{-1}.

Misting of aerosols on plants

The foliage of plants were misted with S-aerosols @ 300 ppm (≈30 kg S ha-1) at three growth stages of the crop viz., at seedling stage, maximum tillering stage and spike initiation stages. Each of the S-aerosol was applied in 3 splits on cloud free and clear sunny days in the afternoon when air temperature was low.

pH of Aerosol

A digital pH meter with standard pH (4&7) was used to measure the pH of the S-aerosols which were found as distilled water: 7.00; $(NH_4)_2SO_4$: (5.34); $CaSO_4$: (5.49), K_2SO_4 (5.66)

Quantifying the following morphological and yield parameters

Leaf area, Leaf Area Index, Specific leaf weight (SLW), Tiller number were recorded at maximum tillering and spike initiation stage. Number of seeds per spike, Length of spike, Spike weight, Test weight, Economical yield and Biological yield, Harvest Index were recorded at spike initiation stage. Leaf area was measured at maximum tillering and spike initiation stages. Fully expanded green leaves were selected at random from five plants per replication. The length and breadth of each leaf were measured and used for calculation of Leaf area at the respective stages**.** Leaf area index was measured by proportioning the leaf area to the ground area covered by the individual plant canopy. Specific leaf weights were calculated by taking total Leaf dry weight/ Area of leaf (mg cm^{-2}) (Singh 1988). Number of tillers in five observational plants from each experimental plot was counted at maximum tillering and spike initiation stages of the crop. Random selection of five spikes, length of five spikes, and weight of five spikes, number of grains per spike was counted from field. Thousand seeds, Grain yield were randomly selected from each seed lot of individually harvested and thrashed out separately. Similarly, in case of pot experiment, too, economical yield, Biological yield was recorded from thrashed plants per pot. Harvest index (HI) suggested by Nichiporovich (1967)

Statistical analysis

Data for each plant parameter was analysed by Fisher's method variance (Panse and Sukhatme 1978).

Principal Component Analysis (PCA)

PCA makes it possible to transform a given set variables, which are mutually correlated, into a new system of characteristics, known as principal components, which are not correlated. The obtained variables may also be used for further analysis. Moreover, the analysis is characterized by the fact that it includes the total variance of variables, explains maximum of variance within a data set, and is a function of primary variables (Krzyśko *et al.,* 2008; Gregorczyk *et al.,* 2008).

Results and Discussion

Different morpho-physiological and grain characteristics are studied using Principal component analysis (PCA) to know the major characteristics contributing to yield at different stages viz., seedling, maximum tillering and spike initiation stages.

The results of PCA at maximum tillering stage in field experiment of wheat varieties depicted that PC1 itself accounted 97.74 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (1.94) and it is significant among all 4 PCs (Table 1). PC1 is mainly correlated with leaf area and it is important component in PC1 with highest loading factor (0.92). So, leaf area is in direct relation with increase in the crop canopy with more number of tillers and also related with yield traits by increasing the no. of grains per spike. Among the four traits leaf area having high values in PC1 are contributing towards total diversity. The results of PCA at spike initiation stage in field experiment of wheat varieties depicted that PC1 itself accounted 96.10 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (1.62) and it is significant among all 4 PCs (Table 2). PC1 is mainly correlated with leaf area and it is important component in PC1 with highest loading factor (0.96). So, leaf area is in direct relation with increase in the crop canopy with more number of tillers and also related with yield traits by increasing the no. of grains per spike. Among the four traits leaf area having high values in PC1 are contributing towards total diversity. The results of PCA at maximum tillering stage in pot experiment of wheat varieties depicted that PC1 itself accounted 89.18 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (1.23) and it is significant among all 4 PCs (Table 3). PC1 is mainly correlated with leaf area, leaf area index (LAI) and it is important component in PC1 with highest loading factor (0.70, 0.68). So, leaf area and leaf area index is in direct relation with increase in the crop canopy with more number of tillers and also related with yield traits by increasing the no. of grains per spike. Among the four traits leaf area, LAI having high values in PC1 are contributing towards total diversity. The results of PCA at spike initiation stage in pot experiment of wheat varieties depicted that PC1 itself accounted 84.37 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (1.21) and it is significant among all 4 PCs (Table 4). PC1 is mainly correlated with leaf area and it is important component in PC1 with highest loading factor (0.86). So, leaf area is in direct relation with increase in the crop canopy with more number of tillers and also related with yield traits by increasing the no. of grains per spike. Among the four traits leaf area, LAI having high values in PC1 are contributing towards total diversity. The results of PCA at maximum tillering stage in field experiment of wheat treatments depicted that PC1 itself accounted 98.28 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (2.3) and it is significant among all 4 PCs (Table 5). PC1 is mainly correlated with leaf area and LAI it is important component in PC1 with highest loading factor (0.92). So, leaf area is in direct relation with increase in the crop canopy with more number of tillers and also related with yield traits by increasing the no. of grains per spike. Among the four traits leaf area having high values in PC1 are contributing towards total diversity.

The results of PCA at spike initiation stage in field experiment of wheat treatments depicted that PC1 itself accounted 99.21 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (2.05) and it is significant among all 4 PCs (Table 6). PC1 is mainly correlated with leaf area and it is important component in PC1 with highest loading factor (0.93). So, leaf area is in direct relation with increase in the crop canopy with more number of tillers and also related with yield traits by increasing the no. of grains per spike. Among the four traits leaf area having high values in PC1 are contributing towards total diversity. The results of PCA at maximum tillering stage in field experiment of wheat treatments depicted that PC1 itself accounted 95.47 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (1.94) and it is significant among all 4 PCs (Table 7). PC1 is mainly correlated with leaf area and LAI it is important component in PC1 with highest loading factor (0.90, 0.4). So, leaf area, LAI is in direct relation with increase in the crop canopy with more number of tillers and also

Table 1: Principal component analysis and Mean performance of wheat varieties effect on Morphological Parameters at maximum tillering in field expt.

SN	PC1	PC2	PC3	PC4
Eigenvalue	1.941142	0.014904	0.005258	0.001519
Variance (%)	97.748	1.5479	0.54608	0.15781
Traits Eigenvector				
Leaf area	0.91946	0.22685	-0.29636	-0.1237
Leaf area index	0.17897	0.26493	0.89174	-0.3203
Specific leaf weight	0.080867	0.40146	0.18535	0.89327
Tiller Number	0.34062	-0.84686	0.28744	0.29013

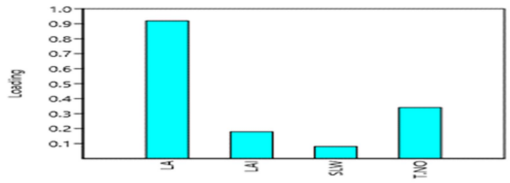

Figure 1: The principal component and loading plot analysis for PC1, PC2, PC3, and PC4 based on the trait means.

Table 2: Principal Component Analysis and Mean performance of wheat varieties effect on Morphological Parameters at spike initiation stages in field expt.

SN	PC1	PC2	PC3	PC4
Eigenvalue	1.6217	0.019195	0.005787	0.000187
Variance (%)	96.109	2.9673	0.89456	0.028893
Traits Eigenvector				
Leaf area	0.96266	-0.20667	0.04451	-0.16911
Leaf area index	0.21983	0.65945	-0.66621	0.27012
Specific leaf weight	0.098486	0.71102	0.68433	-0.12819
Tiller Number	0.12356	-0.12983	0.29304	0.93915

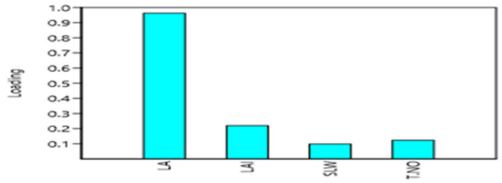

Figure 2: The principal component and loading plot analysis for PC1, PC2, PC3, and PC4 based on the trait means.

Table 3: Principal component analysis and Mean performance of wheat varieties effect on Morphological Parameters at maximum tillering in Pot expt.

SN	PC1	PC2	PC3	PC4
Eigenvalue	1.23809	0.145781	0.003703	0.000615
Variance (%)	89.187	10.502	0.26674	0.044285
Traits Eigenvector				
Leaf area	0.70404	0.64412	-0.29008	-0.07275
Leaf area index	0.68522	-0.72479	0.062562	-0.03534
Specific leaf weight	0.16247	0.16248	0.55454	0.7998
Tiller Number	0.091659	0.18276	0.77745	-0.59479

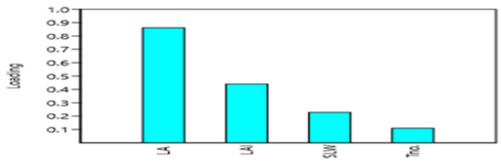

Figure 3: The principal component and loading plot analysis for PC1, PC2, PC3, and PC4 based on the trait means.

Table 4: Principal component analysis and Mean performance of wheat varieties effect on Morphological Parameters at spike initiation stage in Pot expt.

SN	PC1	PC2	PC3	PC4
Eigenvalue	1.21955	0.206511	0.018304	0.000992
Variance (%)	84.377	14.288	1.2664	0.068665
Traits Eigenvector				
Leaf area	0.86139	-0.29841	-0.4082	-0.0483
Leaf area index	0.44045	0.8373	0.32178	-0.03729
Specific leaf weight	0.22822	-0.45093	0.83635	-0.21235
Tiller Number	0.10919	-0.08095	0.17419	0.97529

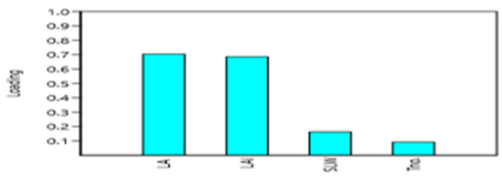

Figure 4: The principal component and loading plot analysis for PC1, PC2, PC3, and PC4 based on the trait means.

related with yield traits by increasing the no. of grains per spike. Among the four traits leaf area having high values in PC1 are contributing towards total diversity. The results of PCA at spike initiation stage in pot experiment of wheat treatments depicted that PC1 itself accounted 95.25 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (1.75) and it is significant among all 4 PCs (Table 8). PC1 is mainly correlated with leaf area and it is important component in PC1 with highest loading factor (0.89). So, leaf area is in direct relation with increase in the crop canopy with more number of tillers and also related with yield traits by increasing the no. of grains per spike. Among the four traits having high values in PC1 are contributing towards total diversity. The results of PCA at spike initiation stage in field experiment of wheat varieties depicted that PC1 itself accounted 87.85 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (4.64) and it is significant among all 4 PCs (Table 9). PC1 is mainly correlated with Number of seeds per spike, and Test weight it is important component in PC1 with highest loading factor (0.74, 0.66). So, Number of seeds per spike, and Test weight is in direct relation with increase in the related with yield traits spike. Among the four traits having high values in PC1 are contributing towards total diversity.

The results of PCA at spike initiation stage in pot experiment of wheat varieties depicted that PC1 itself accounted 88.79 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (3.6) and it is significant among all 4 PCs (Table 10). PC1 is mainly correlated with Number of seeds per spike it is important component in PC1 with highest loading factor (0.87). So, Number of seeds per spike, is in direct relation with increase in the with yield traits by increasing the no. of grains per spike. Among the four traits having high values in PC1 are contributing towards total diversity. The results of PCA at spike initiation stage in field experiment of wheat treatments depicted that PC1 itself accounted 93.11 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (1.9) and it is significant among all 4 PCs (Table 11). PC1 is mainly correlated with Number of seeds per spike, harvest index, test weight, biological index it is important component in PC1 with highest loading factor (0.79, 0.6, 0.03, 0.01). So, Number of seeds per spike, harvest index, test weight, biological index is in direct relation with increase in the with yield traits. Among the four traits having high values in PC1 are contributing towards total diversity.

The results of PCA at spike initiation stage in pot experiment of wheat treatments depicted that PC1 itself accounted 64.42 per cent of variation among all the principal components (PCs). Also, it had >1.00 eigen value (1.31) and it is significant among all 4 PCs (Table 11). PC1 is mainly correlated with Length of the spike, Spike weight, test weight it is important component in PC1 with highest loading factor (0.08, 0.08, 0.7). So, Length of the spike, Spike weight, test weight is in direct relation with increase in the with yield traits. Among the four traits having high values in PC1 are contributing towards total diversity. In the field experiment, seed number per spike increased significantly due to the Sulphur aerosols. Among the aerosols treatments, the highest increment in seed number per spike was shown by $(NH_4)_2SO_4$ (15.3%) followed by $CaSO_4$ (9.7%), and the lowest was shown by K_2SO_4 (7.7%) as compared to control. Eigen value of (1.91) accounting for (93.117 %) of the total variance. Among the varieties the highest increment in seed number per spike was shown by GW-366 (40.215)>GW- 273 (39.58) > GW-322 (39.095) >GW-173 (38.021), and the lowest number of seed was observed in JW-336 (36.084). Eigen value of (4.64) accounting for (87.851 %) of the total variance. Tea *et al.,* (1990) stated a synergistic effect, of the foliar-applied N, and S fertilizers that appears to increase their number of grains per ear, number of spikes per plant, and assimilates in grain. The probable reason may be due to the maximum availability and absorption of sulphur in case of foliar spray that resulted in more grains spike (Garcia del Moral *et al.,* 1991; Ramos *et al.,* 1995). Yield gains obtained from sulphur fertilization ranged between 280 &310 kg ha^{-1} (+7%).

In the field experiment, Spike weight increased significantly due to the Sulphur aerosols. Among the aerosols, the highest increment in Spike weight was shown by $(NH_4)_2SO_4$ (23%) followed by K_2SO_4 (19.2%), and the lowest was shown by

Table 5: Principal component analysis and Mean performance of wheat Treatments effect on Morphological Parameters at maximum tillering in Field expt.

SN	PC1	PC2	PC3
Eigenvalue	2.39725	0.034087	0.00764
Variance (%)	98.289	1.3976	0.31324
Traits	**Eigenvector**		
Leaf area	0.92944	-0.19045	-0.28601
Leaf area index	0.091625	-0.06505	-0.12226
Specific leaf weight	0.20355	-0.39485	0.89349
Tiller Number	0.29377	0.89643	0.32392

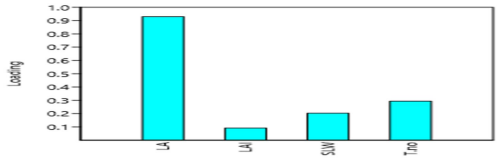

Figure 5: The principal component and loading plot analysis for PC1, PC2, PC3, and PC4 based on the trait means.

Table 6: Principal component analysis and Mean performance of wheat Treatments effect on Morphological Parameters at spike initiation stage in field expt.

SN	PC1	PC2	PC3
Eigenvalue	2.05026	0.015947	0.000372
Variance (%)	99.21	0.77168	0.017988
Traits Eigenvector			
Leaf area	0.93288	-0.24323	-0.22984
Leaf area index	0.11743	-0.29975	0.2673
Specific leaf weight	0.23292	0.89739	-0.19118
Tiller Number	0.2484	0.21372	0.91607

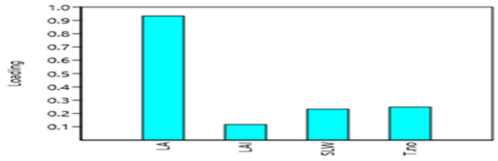

Figure 6: The principal component and loading plot analysis for PC1, PC2, PC3, and PC4 based on the trait means.

$CaSO_4$ (5.7%) as compared to control. Eigen value of (1.91) accounting for (93.117 %) of the total variance. Among the varieties the highest increment in seed number per spike was shown by variety GW-273 (2.288 g) > GW-366 (2.25 g) > GW- 173 (2.225 g)>JW-336 (2.025g), while the lowest was observed in GW-322 (1.963 g). Eigen value of (4.64) accounting for (87.851 %). effect of foliar sulphur aerosols spike weight is correlated with no. of spikelet's (Zebrath *et al.,* 1992)

In the field experiment, Test weight (g) increased significantly due to the Sulphur aerosols. Among the aerosols, the highest increment in Test weight was shown by $(NH_4)_2SO_4$ (11.8%) followed byK_2SO_4 (4.9%), and the lowest was shown by$CaSO_4$ (3.6%) as compared to control. Eigen value of (1.91) accounting for (93.117 %) of the total variance. Among the varieties the highest increment in seed number per spike was shown by variety GW-366 (40.07g) >GW-273 (39.319g) >GW- 322 (38.293g) >GW-173 (37.164 g), and the lowest was seen in JW-336(36.534g). Eigen value of (4.64) accounting for (87.851 %) of the total variance. Soylu *et al.,* (2005) Application of N, and S resulted a significant increase in 1000 grain weight. The heavier grain weight may be due to the efficient metabolic activities which increased the gluten content in grain and improves nutritional status. Whereas foliar sulphur application slightly increased test weight from 79.9 to 81 kg h^{-1}. In the field experiment, HI increased significantly due to the Sulphur aerosols Among the aerosols, the highest increment in HI was shown by $(NH_4)_2SO_4$ (28.7%) followed by $CaSO_4$ (23%), and the lowest was shown by K_2SO_4 (17.3%) as compared to control. Eigen value of (1.91) accounting for (93.117 %) of the total variance. Among the varieties the highest increment in seed number per spike was shown by variety GW- 366 (0.846 %) followed by GW-322 (0.839 %) GW-273 (0.811%) GW-173 (0.77%), and the lowest was seen in JW-336 (0.733 %). Eigen value of (4.64) accounting for (87.851 %) of the total variance. S application significantly enhanced wheat yield and yield components. This is because Ca, and S contents enhance the availability of macro, and micronutrients due to synergic effect on plant growth. However, Ca, and S help to maintain K concentration in plants, and thereby healthy crop stand due to increased nutrient use efficiency (Prasad, 2003; Ali *et al.,* 2008).

In the field experiment, biological yield increased significantly due to the Sulphur aerosols Among the aerosols, the highest increment in biological yield was shown by $(NH_4)_2SO_4$ (9.38%) followed by K_2SO_4 (3.8%), and the lowest was shown by $CaSO_4$ (3.55%) as compared to control. Eigen value of (1.91) accounting for (93.117%) of the total

Table 7: Principal Component Analysis and Mean performance of wheat Treatments effect on Morphological Parameters at maximum tillering in Pot expt.

SN	PC1	PC2	PC3
Eigenvalue	1.94336	0.077813	0.014407
Variance (%)	95.47	3.8227	0.70777
Traits Eigenvector			
Leaf area	0.90204	-0.40596	-0.1318
Leaf area index	0.40177	0.91373	-0.04443
Specific leaf weight	0.088387	0.010307	0.088093
Tiller Number	0.13074	-0.01401	0.98635

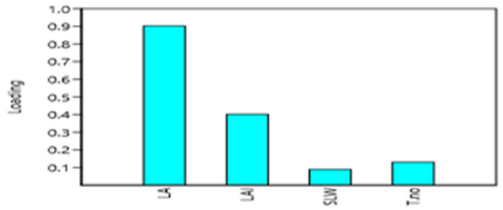

Figure 7: The principal component and loading plot analysis for PC1, PC2, and PC3 based on the trait means.

Table 8: Principal Component Analysis and Mean performance of wheat Treatments effect on Morphological Parameters at spike initiation stage in Pot expt.

SN	PC1	PC2	PC3
Eigenvalue	1.75564	0.072967	0.014411
Variance (%)	95.259	3.9591	0.78194
Traits Eigenvector			
Leaf area	0.89377	-0.44125	-0.06147
Leaf area index	0.42653	0.87663	-0.18951
Specific leaf weight	0.075755	0.18336	0.49749
Tiller Number	0.11618	0.056601	0.84428

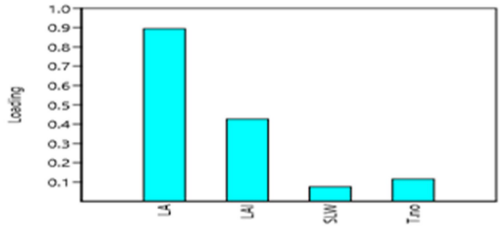

Figure 8: The principal component and loading plot analysis for PC1, PC2, PC3, and PC4 based on the trait means.

Table 9: Principal Component Analysis and Mean performance of wheat varieties effect on yield and yield attributes at spike initiation stages in field expt.

SN	PC1	PC2	PC3	PC4
Eigenvalue	4.6458	0.539206	0.100112	0.003127
Variance (%)	87.851	10.196	1.8931	0.059126
Traits Eigenvector				
Number of seeds per spike	0.7427	-0.17512	0.63661	-0.09677
Length of the spike (cm)	-0.01248	0.95216	0.24859	-0.17643
Spike weight (g)	0.035313	0.1371	0.16006	0.9501
Test weight	0.66761	0.20704	-0.71129	0.065041
HI (%)	0.020467	-0.02128	-0.00162	-0.17532
BY (t ha -1)	0.024787	-0.01477	-0.03139	-0.06355
EY (t ha-1)	0.016026	-0.01982	0.019688	-0.1335

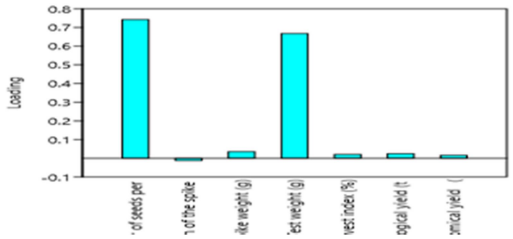

Figure 9: The principal component and loading plot analysis for PC1, PC2, PC3, and PC4 based on the trait means.

Table 10: Principal Component Analysis and Mean performance of wheat varieties effect on yield and yield attributes at spike initiation stages in pot expt.

SN	PC1	PC2	PC3	PC4
Eigenvalue	3.66409	0.302245	0.154774	0.005372
Variance (%)	88.795	7.3245	3.7507	0.13019
Traits Eigenvector				
Number of seeds per spike	0.87614	-0.30772	0.20117	-0.13203
Length of the spike (cm)	0.12326	0.28442	-0.79761	-0.03148
Spike weight (g)	0.019037	0.20325	0.33189	0.52001
Test weight	0.4643	0.51359	-0.17085	0.17357
HI (%)	-0.01465	0.12011	0.071466	-0.37708
BY (t ha -1)	-0.01097	0.70822	0.42224	-0.31013
EY (t ha-1)	0.030274	0.057753	0.024665	0.66534

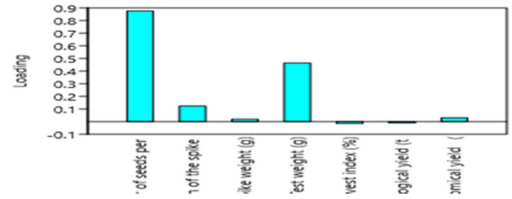

Figure 10: The principal component and loading plot analysis for PC1, PC2, PC3, and PC4 based on the trait means

Table 11: Principal component analysis and Mean performance of wheat treatments effect on yield and yield attributes at spike initiation stages in field expt.

SN	PC1	PC2	PC3
Eigenvalue	1.9129	0.734673	0.071932
Variance (%)	93.117	6.2688	0.61378
Traits Eigenvector			
Number of seeds per spike	0.79041	-0.39747	0.40963
Length of the spike (cm)	0.016533	0.76927	0.5649
Spike weight (g)	0.067402	0.047644	-0.51625
Test weight	0.60683	0.495	-0.49473
HI (%)	0.032322	-0.03726	0.030005
BY (t ha -1)	0.016733	0.01072	0.001802
EY (t ha-1)	0.029589	-0.03805	0.030409

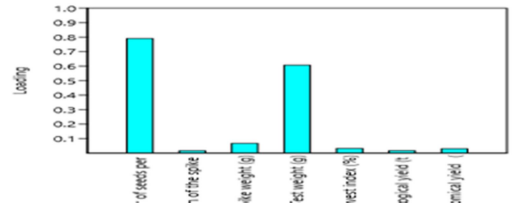

Figure 11: The principal component and loading plot analysis for PC1, PC2, and PC3 based on the trait means.

Table 12: Principal Component analysis and Mean performance of wheat treatments effect on yield and yield attributes at spike initiation stages in pot expt.

SN	PC1	PC2	PC3
Eigenvalue	1.31843	0.59709	0.13082
Variance (%)	64.429	29.178	6.3929
Traits Eigenvector			
Number of seeds per spike	0.47101	0.75491	-0.39661
Length of the spike (cm)	0.087969	-0.15912	-0.06519
Spike weight (g)	0.084243	0.083642	-0.10132
Test weight	0.72747	-0.56628	-0.29413
HI (%)	0.025	-0.10172	0.011226
BY (t ha -1)	0.45401	0.052963	0.78307
EY (t ha-1)	0.16537	0.25293	0.35826

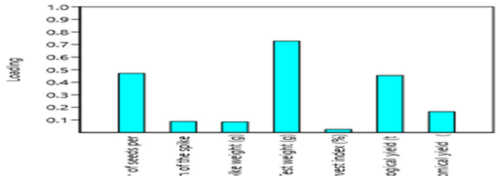

Figure 12: The principal component and loading plot analysis for Number of seeds per spike, Length of the spike (cm), Spike weight (g), Test weight (g), Harvest index (%),Biological yield (t ha -1), Economical yield (t ha-1) based on the trait means

variance. Among the varieties the highest increment in seed number per spike was shown by variety The maximum biological yield was observed in the variety GW-366 (1.334 t ha^{-1}) followed by GW-273 (1.308 t ha^{-1}), GW- 322 (1.308t ha^{-1}) GW-173 (1.228 t ha^{-1}), and the lowest was recorded in JW-336 (1.208 t ha^{-1}). Eigen value of (4.64) accounting for (87.851 %) of the total variance. Foliar application of sulphur improves dough mixing properties it increases grain yield and straw yield (Tea *et al.,* 2004). In the field experiment economic yield increased significantly due to the Sulphur aerosols. Among the aerosols, the highest increment in biological yield was shown by $(NH_4)_2SO_4$ (27.3%) followed by $CaSO_4$ (22.4%), and the lowest was shown by K_2SO_4 (16.6%) as compared to control. Eigen value of (1.91) accounting for (93.117 %) of the total variance. Among the aerosols, the highest increment is shown by variety GW-322(0.814 t ha^{-1}) followed by GW-366(0.812 t ha^{-1}) >GW-273(0.787 t ha^{-1}) >GW- 173 (0.767t ha^{-1}), and the lowest was recorded in JW-336 (0.72t ha^{-1}). Eigen value of (4.64) accounting for (87.851 %) of the total variance. foliar spraying of spring wheat with nitrogen, and sulphur fertilizers -ammonium sulphate, especially when there is low content of plant available sulphur in the soil. Positive interaction of foliar S with N have reportedly augmented yield to over control levels in different cereals (Scott *et al.,* 1984)

Conclusion

In the present work, In the Field & Pot experiments, number of seed per spike, spike weight, TW, EY, and BY varied significantly among the varieties and treatments. The variety GW-366 followed by 273

emerged as the most efficient genotype Further, as regard to the field application of sulfur aerosols, $(NH_4)_2SO_4$ was more effective than $CaSO_4$ and $>K_2SO_4$ and controlled distilled water. Thus, among the aerosols, $(NH_4)_2SO_4$ applied as foliar spray to explore the potential economic yield. Foliar applied nutrients are better rather than soil application shows fast recovery for farmer.

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