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Response of sulphur aerosols on morphological traits in wheat (*Triticum aestivum* L.)

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Abstract
In this study "Response of Sulphur aerosols on morphological traits in wheat (*Triticum aestivum* L.)" was conducted to find out effect of 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 five wheat genotypes (*viz*., GW-322, GW-366, GW-273, GW-173, JW-336). 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. However, the total concentration of each of the S-aerosols was 900 ppm ≈ 0.9% were carried out under pot (October, 2017-March, 2018) (Expt.1) and field (October, 2018-March, 2019) (Expt.2). Foliar misting of S-aerosols affects the physiological traits both in field and pot experiment which was confirmed by the significant changes at maximum tillering and spike initiation stages of effective tillers (5.7-12%), plant height (6.5-10.6%) at harvest pot experiment effective tillers (0.11-5.8%), plant height (3.2-6.2%) at harvest stage in field. The genotype GW-366 was the most responsive for effective tillers & plant height. Among the S-aerosols, $(NH_4)_2SO_4$ was the most effective for all the traits in the work. The aim of the study is find out effect of sulphur aerosols using PCA principle component analysis.

Keywords: PCA, wheat, S-aerosols, $(NH_4)_2SO_4$, GW-366, effective tillers, plant height

Introduction
Wheat is a major contributor to the country's food bowl, and is the second most important cereal next to rice. In India, wheat occupies an area of 24.23 million hectares with a production of 70.26 million tonnes. The food grain requirement of India by the year 2020 is estimated at 109 million tonnes (Shoran, J. *et al.,* 2004) [9]. Tea, I. *et al.,* (2004) [10] reported that Nitrogen (N) and Sulfur (S) supplies have a strong influence on the quality and quantity of wheat storage proteins, Nitrogen derived from urea, S from micronized elemental sulfur, and a mixture of both (N+S) were applied at anthesis stage on wheat by foliar spray. Fageria, N. *et al.*, (2009) [2] reported that when nutrients are applied to soils, they are absorbed by plant roots and translocated to aerial parts. In case of foliar application, the nutrients penetrate the cuticle of the leaf or the stomata and then enter the cells. Hence, crop response occurs in short time in foliar application compared to soil application. 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, G.L. *et al.,* 2002) [6]. (Ernst, DE.*et.al*.,1993) [1] reported that 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, The responses of wheat crop to Sulfur aerosols, and how the S-aerosols improves physiological traits of wheat crop are explored in the present investigation.

Materials and methods
Experimental site and situation
The present study was carried out at the ICR farm, Assam Agricultural University, Jorhat during the year 2017-18 & 2018-2019. Jorhat is situated at 26°45' N latitude and 94°12'E longitude with an altitude of 87 meters above mean sea level. The climatic conditions of Jorhat as a whole, is subtropical, humid, dry summer and cold winter.

The aerosol treatment condition
The crop was treated with S- aerosols, and cultivated in the meteorological conditions of cold winter (9.4-29.780C) with high humidity (55-99%), low rainfall (0.15-3.78mm) and lower bright sunshine (4.16-6.24) hours (Table 1). & cold winter (10.88-31.11C) with high humidity

(68-99%), low rainfall (0-1.1mm) and lower bright sunshine (3.6-6.54) hours (Table 2).

Experimental materials

Five wheat varieties (*viz.*, GW-322, GW-366, GW-273, GW-173, JW-336) were collected from the eastern wheat-growing zone of India (*viz.*, Uttar Pradesh), and used in the experiment.

Crop husbandry

Seeds were put in a container, and Captan @ 2.5g kg-1 seed was added to it. The fungicide was mixed thoroughly with seeds by agitating them for five minutes. The plots were ploughed thoroughly, mowed and leveled. Recommended doses of N, P, K fertilizers @ 80:46:42 per hectare were applied as basal. The Randomised Block Design (RBD) with two replications was followed in the experiment. The crop was irrigated regularly during the growth period. The plots were kept weed free always manually. Prophylactic measures were taken to prevent the crop from the attack of insects and pests.

Table 1: Meteorological date during crop season (October, 2017 to March,2018)

Months	Temperature (°C)		Average Relative Humidity morning hrs. (%)	Average Relative Humidity evening (hours) (%)	Monthly total Rainfall (mm)	Monthly total Bright sunshine (hours)
	Max.	Min.				
October	31.8	22.7	96	71	12.5	7.14
November	28..8	16.5	97	67	15.6	6.32
December	26.3	11.9	99	62	0.15	6.24
January	25.2	9.4	98	57	2.1	5.77
February	26.8	13.0	95	55	1.38	4.99
March	29.78	15.74	97	58	3.78	4.16
Total					39.5	34.62

Table 2: Meteorological date during crop season (October, 2018to March, 2019)

Months	Temperature (°C)		Average Relative Humidity (%)	Average Relative Humidity evening (hours) (%)	Monthly total Rainfall (mm)	Monthly total Bright sunshine (hours)
	Max.	Min.				
October	31.1	23	96	77	19.25	8.14
November	28.46	15.12	95	68	14.7	7.12
December	25.8	10.88	99	69	0.0	6.54
January	25.2	12.34	98	69	2.7	5.57
February	26.89	15.56	91	71	4.6	4.59
March	28.38	16.35	95	75	1.1	3.6
Total					42.35	35.56

Misting of aerosols on plants

The foliages 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 (1000ml for a single stage) was applied in 3 splits on cloud free and clear sunny days in the afternoon when air temperature was low. The cumulative volume of one aerosol solution was 0.9% (≈ 300 ppm x 3=900ppm) only. While spraying the aerosol solutions, its drifting was checked from one plant to another using hard board as partition between two plots. 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

Effective tillers (Spike bearing tillers)

The number of tillers bearing productive spikes was counted randomly and non-destructively at the reproductive stage of the five observational plants. This average number of effective tillers was recorded.

Plant height

Plant height was recorded from the surface of the soil to the apex of the plant at physiological maturity, and it was expressed in cm.

Statistical analysis

Data for each plant parameter was analysed by Fisher's method of analysis of variance (Panse and Sukhatme, 1978) [7]. Significance or non-significance of variance due to the treatments was determined by the respective 'F' values. The standard error of the means (S.Ed.±) was calculated by using the following expression. The critical difference between a pair of treatment means was judged by comparing the values obtained from the product of S.Ed (±) and Probability at (0.05)

Results

The results obtained in the observation into the Response of Sulphur aerosols on physiological traits in wheat (*Triticum aestivum* L.) under field & pot conditions are presented in tabular form. The main aim of the work was to study the responses of the wheat genotype in terms of more number effective tillers & plant height. Improving physiological traits that results in increases the more number of panicles/plant & test weight of the crop and finally it improves the grain yield and quality of the crop. Using PCA principle component analysis.

In field experiment at spike initiation stage wheat varieties eigenvalue (>1) is greater than 1 then PC1 is significant between PC1 and PC 2. PC1 is contributing 99% to diversity. Plant height having highest values in PC1 are contributing towards total diversity.

In pot experiment at spike initiation stage wheat varieties eigenvalue (>1) is greater than 1 then PC1 is significant between PC1 and PC 2. PC1 is contributing 97% to diversity. Plant height having highest values in PC1 are contributing towards total diversity.

In field experiment at spike initiation stage wheat treatments eigenvalue (>1) is greater than 1 then PC1 is significant between PC1 and PC 2. PC1 is contributing 99% to diversity. Plant height having highest values in PC1 are contributing towards total diversity.

In pot experiment at spike initiation stage wheat treatments eigenvalue (>1) is greater than 1 then PC1 is significant between PC1 and PC 2. PC1 is contributing 99% to diversity. Plant height having highest values in PC1 are contributing towards total diversity.

Table 3: Principal Component Analysis and Mean performance of wheat varieties effect on effective tillers and plant height at spike initiation stages in field expt.

S.no	PC1	PC2
Eigenvalue	11.6047	0.029358
Variance (%)	99.748	0.25234
Traits Eigenvector		
Effective Tillers	0.032699	0.99947
Plant height	0.99947	-0.0327

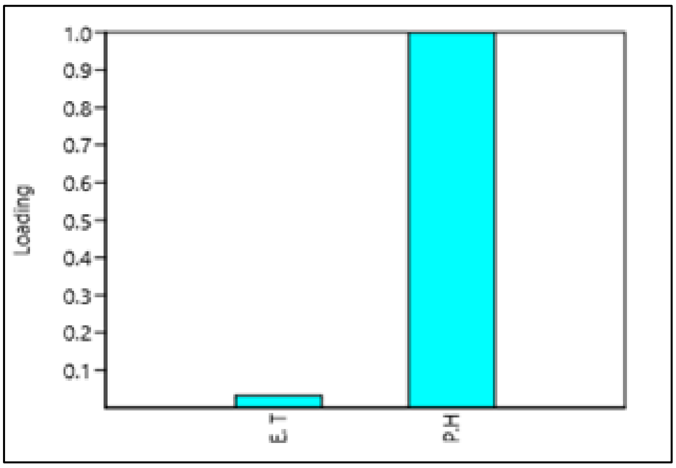

Fig 1: The principal component and loading plot analysis for PC1, PC2 based on the trait means

Table 4: Principal Component Analysis and Mean performance of wheat varieties effect on effective tillers and plant height at spike initiation stages in Pot expt.

S.no	PC1	PC2
Eigenvalue	2.70706	0.056138
Variance (%)	97.968	2.0316
Traits Eigenvector		
Effective Tillers	0.077004	0.99703
Plant height	0.99703	-0.077

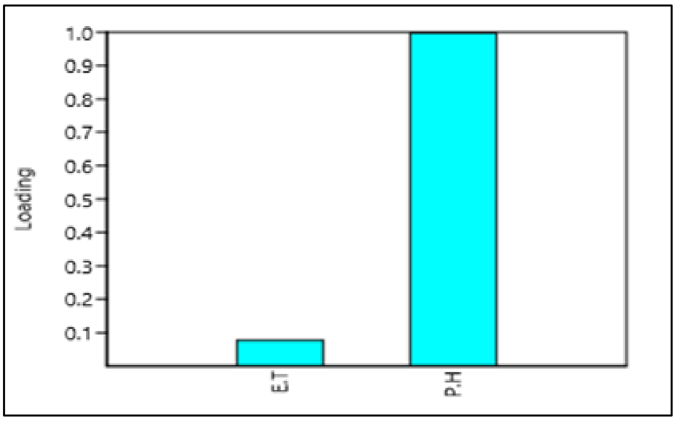

Fig 2: The principal component and loading plot analysis for PC1, PC2 based on the trait means

Table 5: Principal Component Analysis and Mean performance of wheat treatments effect on effective tillers and plant height at spike initiation stages in field expt.

S.no	PC1	PC2
Eigenvalue	6.42213	0.000331
Variance (%)	99.995	0.00516
Traits Eigenvector		
Effective Tillers	0.061292	0.99812
Plant height	0.99812	-0.06129

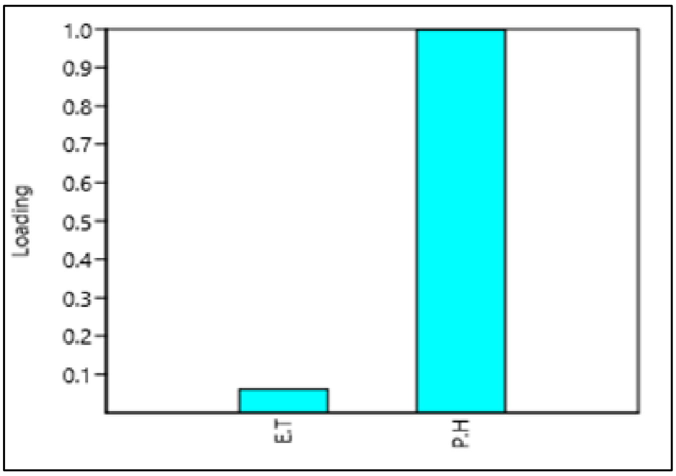

Fig 3: The principal component and loading plot analysis for PC1, PC2 based on the trait means

Table 6: Principal Component Analysis and Mean performance of wheat treatments effect on effective tillers and plant height at spike initiation stages in Pot expt.

S.no	PC1	PC2
Eigenvalue	6.39823	0.013256
Variance (%)	99.793	0.20675
Traits Eigenvector		
Effective Tillers	0.005865	0.99998
Plant height	0.99998	-0.00586

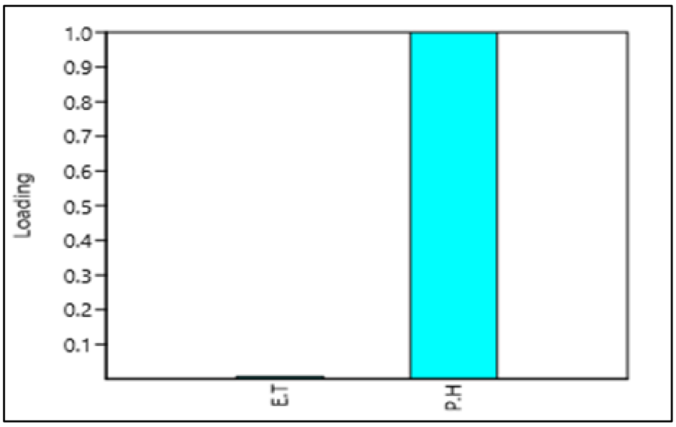

Fig 4: The principal component and loading plot analysis for PC1, PC2 based on the trait means

Discussions

The main objective behind the recent inquisition was to look into the responses of wheat genotypes to misting of S-aerosols at two prominent maximum tillering stage & spike initiations of wheat crop. Improving the morpho-physiological traits *viz*., effective tillers, number of panicles/plant that results in increasing the grain quality and yield.

In the field experiment, at spike initiation stage effective tillers increased significantly due to the Sulphur aerosols.

Among the aerosols treatments, the highest increment was shown by $(NH_4)_2SO_4$ (12%) followed by K_2SO_4 (6.6%), and the lowest was shown by $CaSO_4$ (5.7%) as compared to control. Eigen value of (6.4) accounting for (99%) of the total variance. Among the varieties the highest increment in GW-273(3.076)>GW-173 (2.933) > GW-322 (2.87), and the lowest was found in JW-336 (2.728). Eigen value of (11) accounting for (99%) of the total variance.

In the field experiment, at spike initiation plant height increased significantly due to the Sulphur aerosols. Among the aerosols treatments, the highest increment was shown by $(NH_4)_2SO_4$ (10.6%) followed by $CaSO_4$ (7.0%), and the lowest was shown byK_2SO_4 (6.5%) as compared to control. Eigen value of (6.4) accounting for (99%) of the total variance. Among the varieties the highest increment GW-322(89.175cm)>GW- 366(87.655cm)>GW-173(87.303 cm) >GW-273(86.288 cm), and the lowest was observed in JW-322 (80.353cm). Eigen value of (11) accounting for (99%) of the total variance.

In the pot experiment, at spike initiation stage effective tillers increased significantly due to the Sulphur aerosols. Among the aerosols treatments, the highest increment was shown by K_2SO_4 (5.8%) followed by $(NH_4)_2SO_4$ (2.0%), and the lowest was shown by$CaSO_4$ (0.11%) as compared to control. Eigen value of (6.3) accounting for (99%) of the total variance. Among the varieties the highest increment in GW-366(3.806) had the highest effective tillers followed by GW- 273 (3.688)>GW-173 (3.638)> GW-322 (3.426), and the lowest effective tillers was found in JW-336 (3.125). Eigen value of (2.7) accounting for (97%) of the total variance.

In the pot experiment, at spike initiation plant height increased significantly due to the Sulphur aerosols. Among the aerosols treatments, the highest increment was shown by $(NH_4)_2SO_4$ (6.2%) followed by K_2SO_4 (3.9%), and the lowest was shown by $CaSO_4$ (3.2%) as compared to control. Eigen value of (6.3) accounting for (99%) of the total variance. Among the varieties the highest increment variety GW-366 (97.921 cm) had the highest plant height followed by GW-273 (96.707 cm)>JW-173 (96.132 cm) >GW-173 (95.639 cm), and the lowest plant height was found in GW-322 (93.464cm). Eigen value of (2.7) accounting for (97%) of the total variance.

The foliar application of both S and N had a significant effect on plant height. The probable reason could be more vegetative growth at a high dose of N and S resulting in taller plants. Matsi, T.A *et al.*, (2003) [5]. Ling and Silberbush, (2002) [4] based on no. of productive tillers and plant height there will be increases in economical yield and no. of panicles/ plant. N is one of the important constituents of nucleotides, proteins, chlorophyll and enzymes. Similarly, Sulphur is involved in plant growth, metabolism and enzymatic reactions. Sulphur is one of the constituents of amino acids such as cystine, cysteine, and methionine, S-glycosides (mustard oils), coenzyme-A and vitamins *viz*., biotine and thiamine. Plant roots and translocated to aerial parts. In case of foliar application, the nutrients penetrate the cuticle of the leaf or the stomata and then enter the cells. Hence, crop response occurs in short time in foliar application compared to soil application. The rate, by which an ion passes through the cuticle, and generally the epidermal tissues of the leaves, depends on many factors, including the concentration and the physical and chemical properties of the sprayed ion. Application of Sulphur and Nitrogen aerosols foliarly gave significant effects on productive tiller. Efficient utilization of Sulphur as well as Nitrogen produces more number of productive tillers Ryant & Hrivna, (2004) Jain, S.C. (1991) [8, 13].

Conclusion

In the present work, GW-273 followed by 366 emerged as the most efficient genotype physiologically as these possessed higher effective tillers & plant height. Furthermore, regard to the field & pot 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, $(NH_4)_2SO_4$ @30kgha-1 could be applied as foliar spray to explore the potential productive tiller numbers and plant height of the selected wheat varieties. S and N derived from the aerosol $(NH_4)_2SO_4$ might have played pivotal roles in physiological process of wheat crop including the quality and quantity of wheat storage proteins linked to the bread making process.

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