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Effect of foliar application of bio-regulators on yield components and economics of wheat (*Triticum aestivum* L.) crop

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Abstract
A field experiment was conducted to study the effect of bio-regulators on different yield and yield attributing characters on medium black calcareous clayey soil of Instructional Farm, Department of Agronomy, Junagadh during *rabi* season of 2017-18. The experiment comprising of twelve treatment combinations was laid out in randomized block design having factorial concept and replicated thrice. The treatment comprising 4 levels of thiourea (water spray, 250, 500 and 1000 ppm) and 3 levels of thioglycollic acid (water spray, 100 and 200 ppm) sprayed at tillering and flowering stages. Significantly higher number of spikes/plant, number of spikelets/spike, number of grains per spike, length of spike, test weight, grain, straw and biological yields of wheat were recorded with the increasing concentration of thiourea up to 500 ppm over water sprayed control and 250 ppm thiourea. Similarly foliar application of 100 ppm thioglycollic acid, being at par with 200 ppm TGA significantly increased all yield attributes and yields over water spray. Significantly maximum gross and net returns were obtained due to foliar application of thiourea @1000 and thioglycollic acid @ 200 ppm while higher B:C ratio was observed in foliar spray of thiourea @ 500 ppm and thioglycollic acid @100 ppm.

Keywords: Wheat, thiourea, thioglycollic acid, bio-regulator

Introduction
Wheat is one of the most important grain crops which is belongs to *Poaceae* family and staple food crop of the world and emerged as the backbone of India's food security. Wheat is the second most significant cereal in India following rice, contributing substantially to the national food security by providing more than 50% of the calories to the people who mainly depend on it. It is grown all over the world for its wider adaptability and high nutritive value. The major wheat producing states in India are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Gujarat and Maharashtra. It is grown in India under sub-tropical environment during *rabi* season and occupies an area of 39.72 million hectares with the production of 98.61 million tonnes and productivity of 3310 kg/hectare (Anonymous, 2018) [1]. In Gujarat, wheat occupies an area of 1.06 million hectares with a production of 3.052 million tonnes and productivity of 2890 kg/ha (Anonymous, 2018) [1].

Production of wheat crop depends on several factors like soil, nutrition, irrigation, plant protection measures, environment conditions etc. There are several reasons of low productivity of wheat and one of them is improper sink-source relationship and internal hormonal imbalance which are of primary importance. Since different growth substances are used for the increase in water and crop productivity. Sulphydryl (-SH-) compounds improve phloem translocation of photosynthates and crop productivity. Thus, they act as bio-regulator and play an important role in improving water use efficiency through enhanced phloem translocation and yield formation. In recent years, use of bio-regulators has offered new avenues for enhancing productivity of several crops.

Exogenous application of plant bio-regulators offer unique opportunities of scaling plants to any size and alter physiological processes in the plant to increase seed yield. Application of thiourea and thioglycollic acid has been reported to induce higher physiological efficiencies of plants which resulted in better growth and yield of agronomic crops without substantial increase in cost of production. Thiourea, a sulphydryl compound, contains one –SH group besides containing nitrogen in the form of NH_2. It plays several bio-regulatory roles in crop plants, as the –SH group has diverse biological activities (Jocelyn, 1972) [6]. Thioglycollic acid is also called mercaptoacetic acid (MAA). Thioglycollic acid is also a sulphydryl compound. It contains both a thiol (mercaptan) and a carboxylic acid.

The foliar spray of thiourea (TU) and thioglycollic acid (TGA) increases the plant photosynthetic efficiency and canopy photosynthesis due to presence of -SH group as an integral constituent of these thiols. Foliar application of thiourea and thioglycollic acid either alone or in combination significantly increased the number of tillers, spikes/m², dry matter accumulation, grain and straw yield, flag leaf area and chlorophyll content over control in barley crop (Dhikwal *et al.*, 2012) [4]. Therefore, use of these bio-regulators may provide greater options for achieving maximum economic yield in wheat. Keeping these facts in mind, the present investigation was carried out to explore the effect of foliar application of bio-regulators on yield attributes, yield and economics of wheat.

Materials and Methods

The field experiment was conducted during 2017-18 at Instructional Farm, Department of Agronomy, JAU, Junagadh situated at 21.5° N latitude and 70.5° E longitude with an altitude of 60 m above the mean sea level on the western side at the foothill of mountain 'Girnar' under South Saurashtra Agro-climatic region of Gujarat. The soil of experimental site was clayey in texture with pH 7.67 and EC 0.52 dS/m. The soil was low in available nitrogen (245.20 kg/ha), medium in available phosphorus (35.10 kg/ha) and potassium (270.70 kg/ha), respectively. The experiment was laid out in factorial randomized block design with three replications. The treatment consisted of 4 levels of thiourea (water spray, 250, 500 and 1000 ppm) and 3 levels of thioglycollic acid (water spray, 100 and 200 ppm) sprayed at tillering and flowering stages of wheat. The wheat variety GW-366 was sown on 17th November, 2017 at a depth of 4-5 cm keeping inter row spacing of 22.5 cm using recommended seed rate 120 kg/ha. Recommended dose of nitrogen, phosphorus and potassium (120-60-60 N, P_2O_5, K_2O kg/ha) in the form of urea, DAP (Di-ammonium phosphate) and MOP (Muriate of potash) was applied in each plot. The first irrigation was given immediately after sowing. The subsequent irrigations were applied at critical stages and as per need for successful wheat production. Other agronomic practices and disease pest management were followed as per the recommendations. Statistical analysis of data was carried out for each character as described by Panse and Sukhatme (1985) [9]. Critical difference (CD) values at P=0.05 were used for determine the significance of differences between mean values of treatments.

Results and Discussion

Yield attributes

Numbers of spikes per plant

Experimental data revealed that foliar spray of 500 ppm thiourea twice at tillering and flowering stages significantly enhanced the number of spikes per plant (4.99) over water spray (control) and 250 ppm thiourea. Further increase in thiourea up to 1000 ppm significantly influenced the number of spikes per plant but remained at par with 500 ppm thiourea. The application of thiourea @ 500 and 1000 ppm increased number of spikes per plant to the tune of 10.64 and 12.42 per cent, respectively over control. The foliar application of 200 ppm thioglycollic acid significantly increased number of spikes per plant (4.96) as compared to control but found at par with thioglycollic acid @ 100 ppm. The extent of improvement in number of spikes per plant due to application of thioglycollic acid @ 100 and 200 ppm was 8.39 and 9.87 per cent, respectively over water spray. The results are in conformity with the work of Rana (2015) [10] and Sharma (2016) [12].

Table 1: Effect of bio-regulators on yield attributes and yields of wheat

Treatments	Number of spikes/plant	Number of spikelets/ spike	Number of grains/ spike	Length of spike (cm)	Test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
Thiourea (ppm)								
S_0 : 0 (Water spray)	4.51	14.56	31.11	7.26	43.63	4086	5626	9712
S_1 : 250	4.60	14.72	31.63	7.37	44.96	4254	5813	10068
S_2 : 500	4.99	16.03	34.56	7.91	48.66	4729	6569	11298
S_3 : 1000	5.07	16.33	35.22	8.01	48.90	4772	6598	11370
SEm±	0.12	0.44	0.99	0.18	1.26	136	252	249
CD (P = 0.05)	0.36	1.29	2.90	0.53	3.69	399	740	730
Thioglycollic acid (ppm)								
T_0 : 0 (Water spray)	4.52	14.58	31.17	7.26	43.66	4105	5649	9755
T_1 : 100	4.90	15.76	33.95	7.80	47.87	4619	6378	10997
T_2 : 200	4.96	15.90	34.28	7.85	48.08	4657	6427	11084
SEm±	0.11	0.38	0.86	0.16	1.09	118	219	215
CD (P = 0.05)	0.31	1.12	2.51	0.46	3.19	346	641	632

Number of spikelets per spike

It is explicit from data presented in Table 1 that the increasing concentration of thiourea up to 500 ppm significantly increased the number of spikelets per spike at harvest over control and 250 ppm thiourea, respectively. The highest number of spikelets per spike at harvest (16.33) was recorded with the application of 1000 ppm thiourea which remained at par with 500 ppm thiourea. The foliar application of 500 ppm thiourea increased the number of spikelets per plant to the tune of 10.10 per cent, over control. Foliar spray of 200 ppm thioglycollic acid at tillering and flowering stages significantly increased number of spikelets per spike (15.90) over water spray control and remained at par with 100 ppm thioglycollic acid spray (15.76). The increase in number of spikelets per spike with the foliar application of thioglycollic acid @ 100 and 200 ppm was 8.09 and 9.05 per cent, respectively over water spray.

Number of grains per spike

Experimental data revealed that foliar application of 500 ppm thiourea, being at par with application of 1000 ppm thiourea and significantly produced higher number of grains per spike at harvest over rest of the treatments. The maximum number of grains per spike (35.22) was recorded with 1000 ppm thiourea spray closely followed by 500 ppm thiourea spray (34.56) which was significantly higher by 13.21 and 11.09 per cent over water spray control, respectively. Different concentrations of thioglycollic acid exerted their significant influence on number of grains per spike. The maximum number of grains per spike at harvest (34.28) was recorded under 200 ppm thioglycollic acid sprayed plots being at par with thioglycollic acid (100 ppm) sprayed plots and was higher by 9.98 and 8.92 per cent, respectively over control. The present finding is within close vicinity of those reported by Dhikwal *et al.* (2012) [4], Nilesh *et al*. (2012) [8], Rana (2015) [10] and Sharma (2016) [12].

Length of spike

A perusal of data presented in Table 1 construe that the increasing concentration of thiourea significantly increased the length of spike up to 1000 ppm thiourea spray. Maximum length of spike (8.01 cm) was recorded with the foliar application of thiourea @ 1000 ppm, which was significantly higher over control and 250 ppm thiourea spray but remained at par with 500 ppm spray. The application of thiourea @ 500 and 1000 ppm increased the length of spike by 8.95 and 10.33 per cent, respectively over control. A critical analysis of data explicit that foliar application of thioglycollic acid @ 200 ppm significantly increased length of spike (7.85 cm) over control but remained statistically at par with foliar application of thioglycollic acid @ 100 ppm with the value of 7.80. The application of thioglycollic acid @ 100 and 200 ppm increased length of spike to the tune of 7.44 and 8.13 per cent, respectively over control. These results are in accordance with the findings of Dhikwal *et al.* (2012) [4] and Wakchaure *et al*. (2015) [13].

Test weight

An evident of data presented in Table 1 observed that different levels of foliar spray of thiourea exerted their significant influence on test weight of wheat grain. Foliar spray of thiourea @ 500 ppm, being at par with application 1000 ppm thiourea and produced significantly higher test weight over rest of the treatments. Maximum test weight (48.90 g) was recorded with the application of 1000 ppm thiourea. The extent of improvement in test weight due to application of thiourea @ 500 and 1000 ppm was 11.51 and 12.08 per cent, respectively over water spray. Foliar application of 200 ppm thioglycollic acid significantly increased test weight over control. However, application of thioglycollic acid @ 100 and 200 ppm remained at par in respect of test weight. The per cent increase in test weight due to application of thioglycollic acid @ 100 and 200 ppm was 9.64 and 10.12 per cent, respectively over water spray. The beneficial effect of TU and TGA on the test weight has also been reported by several research workers Dhikwal *et al.* (2012) [4], Nilesh *et al*. (2012) [8], Wakchaure *et al*. (2015) [13] and Sharma (2016) [12].

Grain yield

A perusal of data presented in Table 1 indicated that grain yield increased significantly with the increasing concentration of thiourea up to 500 ppm (4729 kg/ha). Further increase in the dose of thiourea up to 1000 ppm though significantly increased the grain yield (4772 kg/ha) over control and 250 ppm thiourea but remained statistically at par with 500 ppm thiourea spray. The application of thiourea @ 500 and 1000 ppm increased grain yield to the tune of 15.74 and 16.79 per cent, respectively over control (4086 kg/ha). Giaquinta (1976) [5] also reported that the bio regulatory effect of thiourea was chiefly through mobilization of dry matter and translocation of photosynthates to sink which ultimately significant improved the seed yield.

Foliar spray of thioglycollic acid @ 200 ppm recorded significantly higher grain yield (4657 kg/ha) over control which was remained statistically at par with the application of 100 ppm thioglycollic acid (4619 kg/ha). The observed increase in grain yield due to application of thioglycollic acid @ 100 and 200 ppm was 12.52 and 13.45 per cent, respectively over water spray. Plant under the influence of bio-regulator (TGA) might have maintained greater photosynthetic efficiency and better source to sink relationship which provided adequate metabolites to reproductive sinks for greater growth and development which ultimately resulted in yield. Significant improvement in the grain yield due to foliar spray of thiourea and thioglycollic acid was also reported by Dhikwal *et al.* (2012) [4], Nilesh *et al.* (2012) [8], Sharma *et al.* (2012) [11], Kumawat *et al.* (2013) [7], Bhunia *et al.* (2015) [2], Dadhich *et al.* (2015) [3], Rana (2015) [10], Wakchaure *et al*. (2015) [13], Sharma (2016) [12] and Yadav *et al.* (2018) [14].

Straw yield

An assessment of data revealed that foliar spray of thiourea @ 1000 ppm recorded significantly higher straw yield of wheat (6598 kg/ha) over water spray and 250 ppm thiourea but remained at par with 500 ppm thiourea (6569 kg/ha). The application of thiourea @ 500 and 1000 ppm increased straw yield to the tune of 16.76 and 17.28 per cent, respectively over control. The foliar application of 200 ppm thioglycollic acid registered significantly higher straw yield (6427 kg/ha) over water spray (5649 kg/ha) but remained at par with 100 ppm thioglycollic acid spray. The per cent increase in straw yield due to application of 100 and 200 ppm thioglycollic acid (TGA) was 12.90 and 13.77, respectively over water spray. Positive increment in crop growth in terms of plant height and dry matter accumulation increased the straw yield and further increases in biological yield as well as grain yield was the cumulative effect of improved growth parameters due to foliar spray of thiourea and thioglycollic acid treatments as compared to water spray. The results are in conformity with those reported by Dhikwal *et al.* (2012) [4], Sharma *et al.* (2012) [11] and Rana (2015) [10].

Biological yield

A glance of data (Table 1 and 2) revealed that the different concentrations of thiourea noticed significant influence on biological yield of wheat. Maximum biological yield (11370 kg/ha) was recorded with the foliar spray of 1000 ppm thiourea at tillering and flowering stages which was significantly higher over water spray and 250 ppm thiourea but found at par with 500 ppm thiourea spray. The increase in biological yield under foliar application of 500 and 1000 ppm thiourea was 16.33 and 17.07 per cent, respectively over control. Foliar application of thioglycollic acid @ 200 ppm significantly increased biological yield (11084 kg/ha) over control, which was statistically at par with the treatment comprising foliar application of 100 ppm thioglycollic acid (10997 kg/ha). The increase in biological yield was 12.73 and 13.62 per cent, respectively with foliar application of thioglycollic acid @ 100 and 200 ppm. The biological yield is a function of grain and straw yields. Thus, significant increase in biological yield with the application of thiourea and thioglycollic acid could be ascribed to the improvement in yields might have resulted from favourable influence of TU and TGA on growth and efficient partitioning of metabolites to reproductive structure. The results are in conformity with the work of Dhikwal *et al.* (2012) [4], Wakchaure *et al*. (2015) [13].

Economics

Gross returns

The experimental findings presented in Table 2 revealed that gross returns increased significantly due to successive increase in thiourea concentrations. Application of 500 and 1000 ppm thiourea recorded the gross returns of ₹ 77055 and ₹ 77740/ha which were at par with each other. The per cent increase in gross returns with 500 and 1000 ppm thiourea was 15.77 and 16.80 per cent, respectively over control. Significantly higher gross return of ₹ 75864 and 75238/ha was obtained with foliar application of thioglycollic acid @ 200 and 100 ppm, respectively which were remained at par with each other.

Net returns

From examination of data (Table 2), it is clear that application of thiourea had significant effect on net returns obtained from wheat. The net returns increased significantly up to 500 ppm thiourea (38978 ₹ /ha) but remained at par with 1000 ppm TU (38967 ₹ /ha). The net returns of ₹ 37157/ha obtained with the foliar spray of thioglycollic acid @100 ppm, closely followed by 200 ppm thioglycollic acid (₹ 37219/ha). These results are in accordance with the findings of Sharma *et al.* (2012) [11], Rana (2015) [10] and Sharma (2016) [12].

Table 2: Effect of bio-regulators on gross returns, net returns and B:C ratio of wheat

Treatments	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
Thiourea (ppm)				
S_0 : 0 (Water spray)	36834	66556	29722	1.81
S_1 : 250	37792	69276	31484	1.83
S_2 : 500	38077	77055	38978	2.02
S_3 : 1000	38647	77740	39094	2.01
SEm±	-	2088	2088	0.05
CD (P = 0.05)	-	6125	6125	0.16
Thioglycollic acid (ppm)				
T_0 : 0 (Water spray)	36785	66869	30084	1.82
T_1 : 100	38081	75238	37157	1.97
T_2 : 200	38645	75864	37219	1.96
SEm±	-	1809	1809	0.05
CD (P = 0.05)	-	5304	5304	NS

B:C ratio

The data furnished in Table 2 illustrated that highest B: C ratio (2.02) was recorded with the foliar application of thiourea @ 500 ppm, closely followed by 1000 ppm thiourea spray (2.01). The per cent increase due to application of 500 and 1000 ppm thiourea was 11.60 and 11.05 over control, respectively. The maximum B:C ratio of 1.97 was achieved with foliar application of 100 ppm thioglycollic acid, followed by application of 200 ppm thioglycollic acid having B:C ratio of 1.96. The results are in conformity with the work of Sharma *et al.* (2012) [11], Rana (2015) [10] and Sharma (2016) [12].

Conclusion

The results presented here indicated that foliar application of 500 ppm thiourea or 100 ppm thioglycollic acid (TGA) at tillering and flowering stages were found effective in improving yield attributes, yields and profitability of irrigated wheat on medium black calcareous soil of South Saurashtra Agro-climatic Zone.

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