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Impact of antitranspirant application on nutrient uptake and yield of rice (*Oryza sativa*) grown under water stress condition in inceptisol of Varanasi, Uttar Pradesh

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Abstract
Antitranspirants are applied to plant foliage to curtail water loss. Antitranspirants, in general, reduce the transpiration loss of water occurring mainly through closing stomatal pores present on the leaf surface. Keeping these points in view, a pot experiment was conducted to find out the effect of application of leaf reflectance type antitranspirants, *viz*., kaolinite (kaolin) and long-chain fatty alcohol (Green Miracle) on yield and nutrient uptake of rice under both submerged and water stress condition grown in inceptisol in Varanasi, Uttar Pradesh. The present investigation was carried out in a greenhouse and rice (HUR-105) was grown under both submerged and water stress conditions. The kaolin (0%, 4%, 6% and 8%) and Green Miracle (0.00%, 0.15%, 0.30% and 0.60%) water suspension / solution respectively, were sprayed twice *viz.* in during vegetative-stage (50 days after transplanting) and panicle initiation stage (70 days after transplanting). The N, P and K content in straw and grain were analyzed for nutrient uptake pattern by rice crop. Results indicated that antitranspirants treatments affected dry matter production significantly. Plants treated with Green Miracle and kaolin produced more dry matter than untreated check (control). The nutrient uptakes by rice crops were also significantly improved by the application of both Green Miracle and Kaolin.

Keywords: Kaolin, long-chain fatty acids, nutrient uptake, rice, water stress, yield

Introduction
Rice (*Oryza sativa*), one of the second most important food crops in the world after wheat, forms the staple diet of 2.7 billion people. Nearly 90% of global production *i.e*., 640 million tons of rice is grown in Asia. More than half of the area (55%) is rainfed & distribution wise 80% of rainfed rice area is in eastern India. In Uttar Pradesh of India, almost once in every third year in the western part and once in five years in the eastern part, drought is experienced in the past few years. To cope-up with the coming vulnerability in agriculture production, certain strategies that include improvement in water use efficiency through irrigation, rainwater harvesting and agronomic practices like mulching [1]. Besides traditional efficient irrigation systems like drip irrigation, sprinkler irrigation recent research exploring possibilities towards the use of a certain environmentally friendly chemical which may increase water holding capacity of the soil or may reduce the rate of transpiration (antitranspirants), which will make varieties withstand underwater deficient condition and application can be managed on requirement bases. Antitranspirants are the chemical compound which favors a reduction in the rate of transpiration from plant leaves by reducing the size and number of stomata and gradually hardening them to stress [2]. Nearly 95-98% of the water absorbed by the plant is lost in transpiration [3]. It is a chemical substance involved in increasing drought stress resistance. Kaolin is a reflective antitranspirants material; it is an engineered clay (an aluminum phyllosilicate, $Al_2Si_2O_5$ $(OH)_4$. When it is sprayed it covers leaves and fruit with thin films of kaolinite clay [4]. Subjecting kaolin to the heating process converts the silicate to white color and increasing their reflectance properties to light. Kaolin particle film reflects photosynthetically active, ultraviolet radiations and infrared thus reduce temperatures of treated leaves and fruits [5]. Long-chain fatty alcohol is a new-generation, also a reflective type of antitranspirant cum anti-stress compound. It is based on long-chain fatty alcohol acquire from non-edible vegetable oil. Thus, for the cultivation of *kharif* rice under water stress conditions in the Gangetic plains, particularly in the inceptisol of Varanasi,

reflecting type antitranspirants (both inorganic and organic) can be treated to combat the climate change scenario. The two main objectives of this research were [1] Evaluation of the effect of antitranspirants application on yield of *kharif* rice grown under both submerged and water-stressed conditions in an inceptisol of Varanasi [2] Determination of the nutrient uptake at the various physiological growth stage of *kharif* rice crop.

Materials and Methods

The present investigation involved one year of research of pot experiment, 2017. The experiment was carried out at greenhouse of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, and the soil and plant samples were analyzed in the laboratory of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Rice Seedling (HUR-105) was transplanted in the third week *i.e.* 21st of July (4seedlings/pot) in earthen pots of 30 cm diameter filled with 10 kg of inceptisol soil of Varanasi and under submerged condition. The characteristics of the soil were loamy in texture, where the clay was 19.60%, the sand 49.83%, and silt 30.41%. All pots received a recommended dose of N, P and K fertilizers, which were added immediately after puddling as a basal dose & just before transplanting. Urea 0.34g (46%N)/pot, diammonium phosphate (DAP) 0.60g (18%N, 46%P_2O_5) /pot, and muriate of potash (MOP) 0.50g (60%K_2O) /pot were used as a source of fertilizer for supplying nitrogen, phosphorus and potassium, respectively. Treatment wise the half quantity of nitrogen and the entire dose of phosphorus and potassium were applied as basal. The remaining half dose of nitrogen was top dressed in the time of the tillering stage (28 DAT) and vegetative-stage (56 DAT). The doses of fertilizer applied in each pot were uniform including control. A Split dose of N fertilizer (0.29g of urea/pot) was applied for two times (the first 28 & second 55 days after transplanting (DAT). Zinc sulfate sprayed twice during the plant life cycle the first one at the tillering stage (33 DAT) and another at vegetative-stage (25 Days after first application) at the rate of 0.5% with urea at the rate 2%. Zinc sulfate ($ZnSO_4.7H_2O$) solution was made by using lime water (2.5%) to neutralize the acidity. Rice seedlings were regularly irrigated with water for 50days; each pot was maintained to submerged condition one day before applying the treatments so that the moisture amount in each pot was uniform. The water stress (*i.e.* field capacity) was maintained after 50 days after transplanting in the treatments of water-stressed conditions (W_2). Antitranspirants were sprayed twice during the plant life cycle once during the vegetative stage and another at panicle initiation. All the antitranspirants were in liquid (suspension/emulsion) formulation and were applied through a sprayer, mixing/diluting with water. The crop was harvested at 120 days after transplanting when foliage started yellowing and grain husk becoming brownish. The crop growth parameters were collected in three stages, *viz.* 60 days, 80 days and 100 days after transplanting all the treatment combinations in the pot experiment. Soil samples collected from the rice crop field were air-dried at room temperature under shade. Air-dried samples were manually grind by the wooden grinder and passed through a 2 mm sieve. The plant samples were collected after the harvesting of rice crops for the assessment of nutrient concentration (N, P & K) of the plant. The samples were oven-dried at 65ºC in a hot air oven. The crop growth and developmental data and laboratory analytical data from all the observations were statistically analyzed applying Factorial Completely Randomized Design. Statistical analysis and interpretation were done by calculating the value of S.Em (±) and CD at a 5% level of significance.

Table 1: Antitranspirants included in the study

Antitranspirants formulation	Origin	Source
Kaolin (Solid powder)	Aluminosilicate clay, kaolinite (inorganic)	Loba Chemie Lab. Reagents & Fine Chemicals Loba Chemie Pvt. Ltd. Jehangir Villa, 107, Wode House Road, Colba, Mumbai-400005, INDIA
Green Miracle (Liquid suspension)	Long chain fatty alcohol (organic)	T. Stanes and Company Ltd. 8/23-24, Race Course Road, Coimbatore-641 018, Tamil Nadu, INDIA

Table 2: Treatments

Irrigation treatment	
Irrigation	**Notation**
Submerged	W_1
Water stressed	W_2
Antitranspirants treatments	
Antitranspirants	**Notation**
Control	A_0
Kaolin-4%	A_1
Kaolin-6%	A_2
Kaolin-8%	A_3
Green Miracle-0.15%	A_4
Green Miracle-0.30%	A_5
Green Miracle-0.60%	A_6

Treatment combinations

A_0W_1 = Control (Submerged)
A_1W_1 = Kaolin (4%) + Submerged
A_2W_1 = Kaolin (6%) + Submerged
A_3W_1 = Kaolin (8%) + Submerged
A_4W_1 = Green Miracle (0.15%) + Submerged
A_5W_1 = Green Miracle (0.30%) + Submerged
A_6W_1 = Green Miracle (0.60%) + Submerged

A_0W_2 = Control (Water Stressed)
A_1W_2 = Kaolin (4%) + Water Stressed
A_2W_2 = Kaolin (6%) + Water Stressed
A_3W_2 = Kaolin (8%) + Water Stressed
A_4W_2 = Green Miracle (0.15%) + Water Stressed
A_5W_2 = Green Miracle (0.30%) + Water Stressed
A_6W_2 = Green Miracle (0.60%) + Water Stressed

Results and Discussion

Effect of water level, antitranspirants and their interaction on yield and harvest index

Table 3 shows the effect of water levels and antitranspirants on the yield of rice plants. It is apparent from the data that maximum straw yield was registered under A_2 (186.40 g/pot), which was significantly superior to the straw yield obtained under control (156.16 g/pot). So for antitranspirants treatment are concerned, having an application of kaolin @ 6% produced highest straw yield closely followed by application of Green Miracle @ 0.15%. The percent increase of straw yield was comparatively higher in A_2 (19.3%) followed by A_4 (3.3%) showing a better result than other antitranspirants treatments. In considering the soil moisture levels, straw yield was drastically reduced (40.1%) under water-stressed condition in comparison to the submerged condition. Green Miracle antitranspirants @ 0.30% (A_5) resulted in significant increase in grain yield (39.53 g/pot) closely followed by Kaolin @ 6% (A_2) which *i.e.* 39.40 g/pot. The percent increase of grain yield under antitranspirants treatments was comparatively higher in A_6 (6.7%) followed by A_4 (6.42%) showing a better result than other antitranspirants treatments. The yield of the grain of rice was significantly reduced (21.5%) under water-stressed condition. The biological yield and harvest index was showing highest in A_2 (225.80 g/pot) and A_5 (20.97%), respectively. The treatment combination of A_2W_1, and A_2W_2 for straw yield, and A_4W_1 & A_4W_2 for grain yield was better than other treatment combinations under submerged and water-stressed conditions, respectively. The interaction effect between kaolin @ 6% under submerged conditions on straw yield was found better followed by kaolin @ 4% under submerged condition in comparison to control and the interaction effect between Kaolin @ 6% under water-stressed condition on straw yield was found better followed by Green Miracle @ 0.60% under water-stressed condition interaction in comparison to control. The interaction effect between Green Miracle @ 0.15% under submerged condition(A_4W_1) on grain yield was found better followed by kaolin @ 8 % under submerged condition, (A_3W_1) *i.e.,* 43.23 g/pot and 43.13 g/pot, respectively in comparison to control and the interaction effect between antitranspirants and water stressed condition on grain yield was found better in Green Miracle @ 0.15% (A_4W_2) followed by Kaolin @ 6% and water stressed condition (A_2W_2) *i.e.,* 35.80 g/pot and 35.73 g/pot, respectively in comparison to control(Table 4). However, the interaction effect for the harvest index was not significant. The treatment combination of A_4W_1 (17.8 %) recorded the highest harvest index. The similar research finding was observed with application of cycocel in wheat (*Triticum aestivum*) [6] (Balwan *et al.,* 2016) and application of kaolin, PMA and Mobileaf [7] (Patil *et al* .1978) in barley (*Hordeum vulgare* L.) concerning yield *i.e.* grain and straw yield.

Table 3: Impact of antitranspirants and soil moisture condition on straw yield (g/pot), grain yield (g/pot) and harvest index (%) of rice crop

Treatments	Straw yield	Grain yield	Biological yield	Harvest Index
Water levels				
W_1	216.80	42.44	259.24	16.37
W_2	154.74	34.93	189.67	18.41
SEm (±)	5.085	0.27	5.35	0.21
CD (P 0.05)	14.805	0.79	15.59	NS
Antitranspirants				
A_0	156.16	37.02	193.18	19.16
A_1	151.40	38.52	189.92	20.28
A_2	186.40	39.40	225.80	17.44
A_3	161.36	38.63	199.99	19.31
A_4	161.38	39.30	200.68	19.58
A_5	148.93	39.53	188.46	20.97
A_6	153.03	38.42	191.45	20.06
SEm (±)	9.512	0.51	10.02	0.45
CD (P 0.05)	27.698	1.48	29.17	0.970

Table 4: Interaction effect of antitranspirants and soil moisture condition on straw yield (g/pot), grain yield (g/pot), biological yield (g/pot) and harvest index (%) of rice crop

Treatments	Straw yield	Seed yield	biological yield	Harvest Index
A_0W_1	237.73	40.40	278.13	14.5
A_1W_1	239.40	42.86	282.26	15.1
A_2W_1	239.53	42.90	282.43	15.1
A_3W_1	205.33	43.13	248.46	17.3
A_4W_1	199.06	43.23	242.29	17.8
A_5W_1	206.13	42.20	248.33	16.9
A_6W_1	202.60	42.23	244.83	17.2
A_0W_2	173.73	35.03	208.76	16.7
A_1W_2	176.60	33.63	210.23	15.9
A_2W_2	195.26	35.73	230.99	15.4
A_3W_2	174.60	34.27	208.87	16.4
A_4W_2	183.40	35.80	219.2	16.3
A_5W_2	176.66	35.56	212.22	16.7
A_6W_2	190.73	34.63	225.36	15.3
SEm (±)	13.45	0.71	14.16	0.45
CD (P 0.05)	39.17	2.1	41.27	NS

Effect of antitranspirants, water level and their interaction on nutrient uptake of rice plants

Data on the uptake of nitrogen, phosphorus, potassium, and sulfur by rice crop has been presented in Table 5. Data revealed that nutrient uptake by rice crop was not significantly influenced by antitranspirants treatments. In case of water level treatments, the maximum nitrogen, phosphorus, potassium uptake by rice crop was recorded in submergence (W_1) *i.e*. 628.89 mg/pot, 20.12 mg /pot, 696.74 mg /pot, respectively. which was significantly higher (7.47%) than water stressed condition; antitranspirants treatments, A_6 (654.96 mg/pot), A_1 (14.45 mg/pot), A_6 (688.88 mg/pot) showed better results than other antitranspirants treatments in respect to nitrogen, phosphorus, potassium uptake by rice crop. The maximum sulfur uptake in rice crop was recorded under water-stressed condition *i.e*. W_2 (37.54 mg /pot**)** which was significantly higher than submerged condition, whereas S uptake was observed higher by the application of green miracle @ 0.30%. The interaction effect between antitranspirants and water levels (submergence and water stress) regarding nutrient uptake *i.e.* N, K, S was showed significant results. The treatment combination of A_3W_1 (747.96 mg/pot) and A_2W_2 (596.83 mg/pot) for nitrogen uptake, A_3W_1 (771.13 mg/pot) & A_5W_2 (613.23 mg/pot) for potassium uptake and A_4W_1 (35.46 mg/pot) and A_6W_2 (48.13 mg/pot) for sulfur uptake were better than other treatment combinations under submerged and water-stressed conditions, respectively (Table 6).

The uptake of N by rice crop under water-stressed was noticed higher in the application 8% kaolin. The interaction effect between antitranspirants & water level (submergence and water stress) treatments combination concerning phosphorus uptake was recorded non-significant. A similar research finding was observed with foliar application of fulvic acid in wheat [8] (*Triticum aestivum*) for nutrient uptake.

Table 5: Impact of antitranspirants and soil moisture condition on total N, P, K and S uptake by rice crop

Treatments	Total N uptake (mg/pot)	Total P uptake (mg/pot)	Total K uptake (mg/pot)	Total S uptake (mg/pot)
Water levels				
W_1	628.89	20.12	696.74	34.54
W_2	585.13	13.98	677.38	37.54
SEm (±)	13.70	2.49	2.85	1.23
CD (P 0.05)	39.89	4.45	8.32	NS
Antitranspirants				
A_0	608.70	14.42	688.53	38.4
A_1	589.00	14.45	685.83	36.7
A_2	609.78	14.17	686.66	32.8
A_3	563.61	14.47	688.26	31.8
A_4	606.28	13.90	684.95	36.8
A_5	617.25	12.71	686.31	39.5
A_6	654.46	12.79	688.88	36.4
SEm (±)	25.63	0.3035	5.34	0.2308
CD (P 0.05)	NS	NS	NS	NS

Table 6: Interaction effect of antitranspirants and soil moisture condition on N, P, K and S uptake (mg/pot) by rice crop

Treatments	Total N uptake (mg/pot)	Total P uptake (mg/pot)	Total K uptake (mg/pot)	Total S uptake (mg/pot)
A_0 W_1	643.73	19.64	765.46	33.36
A_1 W_1	666.03	19.01	763.36	29.366
A_2 W_1	663.50	17.00	756.66	25.133
A_3 W_1	747.96	19.34	771.13	25.83
A_4 W_1	651.06	17.02	766.73	35.46
A_5 W_1	553.53	15.30	771.00	32.33
A_6 W_1	637.66	15.76	762.53	24.56
A_0 W_2	573.66	15.48	604.93	43.5
A_1 W_2	557.26	15.66	605.53	44.1
A_2 W_2	596.83	16.03	610.1	40.53
A_3 W_2	569.96	15.48	611.6	37.7
A_4 W_2	549.06	13.99	609.96	38.06
A_5 W_2	526.93	14.97	613.23	46.56
A_6 W_2	560.96	13.99	606.63	48.13
SEm (±)	36.24	0.42	7.56	3.26
CD (P 0.05)	85.54	NS	22.027	9.50

Conclusion

It can be concluded from this study that the percentage enhancement of yield, both straw, and grain under submerged conditions were 40% and 21.5%, respectively in comparison to the water-stressed condition in inceptisol of Varanasi, Uttar Pradesh. The percent increase of straw yield and grain yield was comparatively higher in spraying of kaolin @ 6% and green miracle @ 0.30% under submerged condition, respectively. The yield of rice under submerged and water-stressed was positively influenced by the application of antitranspirants. But uptake of plant nutrients (N, P, K, and S) was not significantly influenced by antitranspirants, whereas uptake of plant nutrients was positively influenced under soil submergence.

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