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Effect of antitranspirants on rice (*Oryza sativa*) grown under submerged and water stressed condition in an inceptisol of Varanasi, Uttar Pradesh

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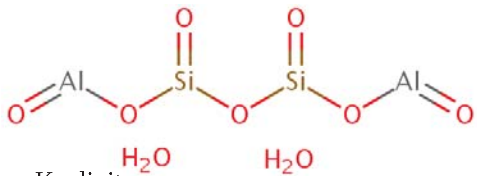
ABSTRACT

A pot experiment was carried out to determine the impact of application of antitranspirants, viz. Kaolin and Green Miracleon growth, yield and nutrient content of rice (HUR-105) under both submerged and water-stressed condition grown in an Inceptisol of Varanasi, Uttar Pradesh. The Kaolin (0%, 4%, 6%, and 8%) and Green Miracle (0.0%, 0.15%, 0.3%, and 0.6%) water suspension / solution respectively, were sprayed twice viz.during vegetative-stage and panicle initiation stage. The plant parameters including plant height, number of leaves, tillers numberwere taken at tillering, panicle initiation and grain filling stages. The nutrient concentration including N, P, K and S in grain and straw were analyzed. Results indicated that antitranspirants treatments have positive effect on the plant growth parameters and dry matter production of rice. Plants treated with long chain fatty alcohol (Green Miracle) and kaolinite (Kaolin) produced higher i.e. 6.7% to 19.3% dry matter than untreated (control) plants.

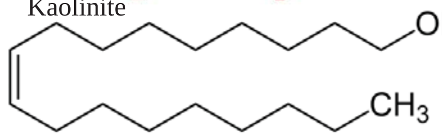
Keywords: Antitranspirants, growth attributes, nutrient content, rice, water stress.

The second most crucial food crops in the world after wheat are rice (*Oryza sativa*). In India, more than 65% of the population depends on the rice crop as staple food. It is cultivated in four agro-ecologicalzones (Subramaniam, 1983). In India, there are four rice agroecology such as irrigated lowland rice, flood-prone rice,rainfed lowland riceand upland rice (Maclean*et al*., 2002).Water is the crucial natural resources which are usually in short supply. The entire northern parts of India *viz*., Uttar Pradesh,Punjab, Haryana, and Bihar and most of the interior peninsula fall under arid and semiarid climatic zones where rainfall is very less and erratic. Due to the uneven distribution of rainfall, shortage of moisture at the critical stage of rice crop growth *viz*., tillering stage, vegetative stage, and panicle initiation stage adversely affect the yield. Transpiration reduction of plants can check the luxurious loss of water *via*. Stomata(Khalil*et al*., 2012).Recently, efforts have been invented to asset substances, which are applied to the plant and reducing the transpiration, *i.e.*,antitranspirant materials. On the basis of mechanisms of action, there are four types of antitranspirants: (i) film-forming materials,stops the transpiration by formation of thin film coat on leaves surface; (ii) stomata closing type, regulate the stomata opening and closing; (iii) reflecting type materials, reflect the solar radiation falling on the leaves surface and (iv) growth retardant type (Galeand Hagan,1966). Antitranspirants are chemical substances involved in increasing drought resistance by stabilizing cell structure (Ouda*et al*., 2007). In the present study, reflecting type antitranspirants*viz*., Kaolin and Green Miracle are sprayed on the rice crop. Kaolin is an alumino-silicate clay mineral, kaolinite [$Al_2Si_2O_3(OH)_4$] (Ibrahim and Selim, 2010)and Green Miracle antitranspirant is a long chain fatty alcohol(El-Hady and Doklega, 2017). A reflective type antitranspirants *viz*., Kaolin and Green Miracle spray are generally reduce the leaf temperature by leaf reflectance mechanisms (Nakanoand Uehara,1996; Rosati, 2006).

Green Miracle is a long chain fatty alcohol reflective type of antitranspirants and derived from non-edible vegetable oil. Thus, for the cultivation of *kharif* rice under the water-stressed condition in the Uttar Pradesh, particularly in the Inceptisolof Varanasi, inorganic (Kaolin) and organic (Green Miracle) reflecting type antitranspirants can be treated to tackle the climate change scenario. The purpose of the present study was to estimate the impact of antitranspirants application and their interaction with water levels including submerged and water-stressed condition on growth, dry matter and nutrient concentration of *kharif* rice.



Kaolinite



Long Chain Fatty Alcohol

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MATERIALS AND METHODS

Pot experiment

The pot experiment was conducted in factorial completely randomized design (CRD). The water levels and antitranspirants were considered two factors in factorial CRD; with 2 water levels and 7 antitranspirants treatments *i.e.*, 14 treatments combination with three replication. The details treatments of water levels and antitranspirants were given in details.

Soil moisture level

Rice seedlings in pot were regularly irrigated with water for 50 days after transplanting (DAT); each pot was maintained to submerged condition one day before application of antitranspirants treatments for uniformity in the moisture content in each pot. The water stress (*i.e.* field capacity) was maintained after 50 days oftransplanting in the treatment of water stressed condition (W_2). Thus, the soil moisture levels in 50 percent pots were maintained continuously submerged(W_1) and rest 50 percent pots was maintained water stressed condition after 50 DAT.

Antitranspirants treatments

Antitranspirants were sprayed (*i.e.* Kaolin suspension and solution of Green Miracle) twice according to the physiological growth period of rice crop;first during vegetative stage and another at panicle initiation.The Kaolin (alumino-silicate clay, kaolinite) used as solid powder suspensionand the Green Miracle (long chain fatty alcohol) used as liquid solution. The inorganic (Kaolin) and organic (Green Miracle)antitranspirants were sprayed in three doses each (A_1=4% Kaolin, A_2=6% Kaolin, A_3=8% Kaolin; A_4= 0.15% Green Miracle, A_5= 0.30% Green Miracle, A_6= 0.60% Green Miracle).

Treatment combinations of antitranspirants and water levels

T_1	$\mathbf{A_0W_1}$	=	Control (Submerged)
T_2	$\mathbf{A_0W_2}$	=	Control (Water Stressed)
T_3	$\mathbf{A_1W_1}$	=	Kaolin (4%) + Submerged
T_4	$\mathbf{A_1W_2}$	=	Kaolin (4%) + Water Stressed
T_5	$\mathbf{A_2W_1}$	=	Kaolin (6%) + Submerged
T_6	$\mathbf{A_2W_2}$	=	Kaolin (6%) + Water Stressed
T_7	$\mathbf{A_3W_1}$	=	Kaolin (8%) + Submerged
T_8	$\mathbf{A_3W_2}$	=	Kaolin (8%) + Water Stressed
T_9	$\mathbf{A_4W_1}$	=	Green Miracle (0.15%) + Submerged
T_{10}	$\mathbf{A_4W_2}$	=	Green Miracle (0.15%) + Water Stressed
T_{11}	$\mathbf{A_5W_1}$	=	Green Miracle (0.30%) + Submerged
T_{12}	$\mathbf{A_5W_2}$	=	Green Miracle (0.30%) + Water Stressed
T_{13}	$\mathbf{A_6W_1}$	=	Green Miracle (0.60%) + Submerged
T_{14}	$\mathbf{A_6W_2}$	=	Green Miracle (0.60%) + Water Stressed

Transplanting and watering

The pot experiments were carried out at the net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University during rainy seasons of 2017 to evaluate the impact of different soil moisture levels and different antitranspirant treatments on growth, dry matter and nutrient content of *kharif*rice. Rice seedling (HUR-105) was collected from the Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Uttar Pradesh and transplanted on the third week *i.e.*, 21^{st} of July in earthen pots. The pot diameter was 30 cm and filled with 10 kg of Inceptisol soil of Varanasi. Rice seedling wastransplanted to four/pot. The soil was loamy in texture, where the clay was 19.60%, the sand 49.83%, and silt 30.41%. The physical and chemical analyses of the soil were determined by standard methodsand results are shown in Table 1.

Table 1: Physical and chemical properties of soil under study

Soil Parameter	Value
pH $_w$ (1:2.5)	7.76
EC (1:2.5) (dSm^{-1})	0.255
Bulk density (Mg m^{-3})	1.35
Particle density (Mg m^{-3})	2.30
Porosity (%)	41.72
Textural class (USDA)	Sandy loam
Sand (%)	49.83
Silt (%)	30.41
Clay (%)	19.60
Soil colour (Munsell)	10YR 6/3Pale brown
Water Holding Capacity (%)	44.37
Organic carbon (g kg^{-1})	4.6
CEC [cmol (p^+) kg^{-1}]	10.91
Calcium carbonate (%)	1.53
Available N (kg ha^{-1})	144.23
Available P (kg ha^{-1})	24.29
Available K kg ha^{-1})	119.90
Available S (kg ha^{-1})	19.33
Available Fe (mg kg^{-1})	6.58
Available Mn (mg kg^{-1})	13.15
Available Zn (mg kg^{-1})	0.52
Available Cu (mg kg^{-1})	1.61

Fertilizer Application

All pots were received anequal recommended dose of N, P and K fertilizers (N: P_2O_5: K_2O: 120: 60 : 60 kg / ha), *viz.*,0.34g of urea (46%N)/pot, 0.60g of diammonium phosphate (DAP) (18%N, 46%P_2O_5) /pot, and 0.50g of muriate of potash (MOP) (60%K_2O)/pot were used for supplying nitrogen, phosphorus and potassium, respectively(Tiwari*et al*., 2014). The half quantity of nitrogen and the entire dose of P and K were applied as basal dose. The fertilizer doses 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 at 30days after transplanting (DAT)and second at 55 DAT.Zinc sulfate was sprayed twice during the plant life cycle to control the khaira disease of rice; the first one at tillering stage (33 DAT) and another at vegetative-stage (25 Days after first application) @ 0.5%with urea @ 2%. Zinc sulfate ($ZnSO_4.7H_2O$) solution with 2% urea was prepared by using lime water (2.5%) to neutralize the acidity.

Plant sample collection

After harvesting the plants were sampled to estimate the fresh weight (FW) and dry weight (DW)of rice grain and straw both. The crop growth parameters were observed in three stages, *viz.* 60 days, 80 days, and 100 days after transplanting, *i.e*., plant height (cm), leavesnumber /plant and tillers number/plants.

Statistical analysis

The generated data were analyzed statisticallythrough analysis of variance (ANOVA) using the normal (F) test at 5% level Least Significant Difference (LSD) test (Snedecor and Cochran, 1980). OP STAT software packages were used for statistical analysis of completely randomized design (CRD).

RESULTS AND DISCUSSION

Effect of antitranspirantsand soil moisture levels on plant growth

The plant height (cm),number of leavesand tillers number increased considerably from 60 to 80 DAT and thereafter plant height, number of tillers increased gradually and reached maximum at harvest stage but the increase in number of leaves was not observed significantly from 80 to 100 DAT in presence of antitranspirants (Table 2). Plant height, tillers number and leaves number were decreased under water-stressed condition (W_2) in comparison to submerged condition (W_1) in all the days of observation. The interaction effects between antitranspirants and water level treatments for plant height was found significant at 80 and 100 days after transplanting, but the interaction effects on tillers number was found significant at all the intervals and leavesnumber was observed non-significant at all growth stages.The performance of treatments combinations of A_2W_1 (104.4cm) & A_1W_2 (97.41cm) at 80 DAT and A_0W_1 (106.9 cm) & A_5W_2 (105.33) at 100 DAT were better than other treatment combinations in respect to plant height and treatment combinations of A_2W_1 (29.0) & A_1W_2 (26.67) at 60 DAT and A_1W_2 (29.33) & A_6W_2 (27.67) at 80 DAT and A_2W_1 (29.67) & A_1W_2 (28.67) at 100 DAT were noticed higher than other treatment combinations for tillers number under submerged and water stressed conditions, respectively (Table 3).

Among the different treatments of antitranspirant, treatment A_2 *i.e*., Kaolin antitranspirants @ 6% and A_1 *i.e*., Kaolin antitranspirant @ 4% were significantly superior to the other treatments as well as control for number of leaves and tillers number, respectively. The highest plant height was associated with organic antitranspirants, *i.e.*, Green Miracle @ 0.15% (A_4), closely followed by inorganic antitranspirants, *i.e.*, Kaolin @ 6% (A_2) at 100 DAT. The percent increase of plant height, tillers number and number of leaves at 60, 80 and 100 DAT under six antitranspirants treatments were comparatively higher in A_1 (1.21%), A_4(7.34%), and A_4(5.07%), respectively for plant height, A_1(5.71%), A_1(4.2%), and A_1(1.17%), respectively for tillers number and A_2 *i.e.*, 24.71%, 12.7%, and 12.5% for number of leaves, respectively in comparison to control (Table 2). The application of Kaolin @ 4% and @ 6% showed better result on plant height under submerged and water stressed condition, respectively at 80 DAT and Green miracle @ 0.30% showed better performance under water stressed condition at 100 DAT and the application of Kaolin @ 4% and @ 6% showed better results on number of tillers under submerged and water stressed condition, respectively at 60 DAT and 100 DAT and Green miracle @ 0.60% showed better results in water stressed condition at 80 DAT (Table 2). The similar research findings were also observed by application of film forming antitranspirants (Mobileaf) in wheat (*Triticum aestivum*) (Abdullah*et al*., 2015), some antitranspirants foliar application including $MgCO_3$, K_2SO_4 and Deuteronon eggplant (*Solanum me longena*)(El-Aal *et al*., 2008) and application of ABA(Abscisic acid) and fulvic acid in wheat(*Triticum aestivum*) with respect to crop growth parameters such as plant height, number of leaves and tillers number (Zhang *et al*., 2016).Karuppaiah*et al*.(2003) foundthe application of Kaolin @7.5% on brinjal (*Solanum melongena*) recorded the maximum biomass production, number of branches and plant height.

Effect of antitranspirants and soil moisture levels on yield of rice

The treatment combinations of $A_2W_1$and A_3W_2 for yield of straw (Fig. 1) and $A_4W_1$and A_4W_2 for grain yield (Fig. 2) were noticed better than other treatment combinations under submerged and water stressed conditions, respectively. The interaction effect between Kaolin @ 6% under submerged conditions on straw yield

Table 2: Impact of antitranspirants and soil moisture levels on growth and development of rice

Treatments	Plant height (cm)			Number of tillers. pot^{-1}			Number of leaves pot^{-1}		
	60 DAT	80 DAT	100 DAT	60 DAT	80 DAT	100 DAT	60 DAT	80 DAT	100 DAT
Water level									
W_1	80.74	99.44	101.40	27.28	28.04	28.71	33.6	36.2	36.45
W_2	79.45	99.73	101.30	25.38	26.76	27.61	30.3	33.2	33.38
SEm (±)	**0.19**	**0.61**	**1.15**	**0.445**	**0.36**	**0.27**	**0.54**	**0.33**	**0.34**
LSD(0.05)	**0.55**	**1.78**	**0.35**	**1.29**	**1.04**	**0.78**	**1.57**	**0.98**	**0.98**
Antitranspirant									
A_0	80.47	96.37	100.20	26.00	27.50	28.83	27.6	32.8	32.3
A_1	81.45	97.91	98.41	27.50	28.67	29.17	31.2	34.7	34.9
A_2	81.22	100.66	102.08	26.50	27.50	28.17	34.4	37.0	37.3
A_3	79.60	100.12	101.79	25.17	26.17	27.17	31.9	34.7	34.5
A_4	79.54	103.45	105.29	26.00	27.00	27.83	32.50	34.5	34.4
A_5	79.33	99.66	101.28	26.83	28.00	28.33	33.3	35.8	36.4
A_6	79.04	98.91	100.40	26.33	27.00	27.67	32.8	33.6	34.3
SEm (±)	**0.35**	**1.11**	**1.15**	**0.833**	**0.6755**	**0.507**	**1.0**	**0.63**	**0.63**
LSD(0.05)	**1.03**	**3.23**	**3.34**	**2.414**	**0.9554**	**1.471**	**2.94**	**1.83**	**1.85**

Note : DAT= Days after transplanting

Table 3: Interaction effects of antitranspirants and soil moisture levels on growth and development of rice

Treatments	Plant height (cm)			Number of tillers pot^{-1}			Number of leaves pot^{-1}		
	60 DAT	80 DAT	100 DAT	60 DAT	80 DAT	100 DAT	60 DAT	80 DAT	100 DAT
$A_0 W_1$	81.03	100.16	106.9	27.67	29.00	29.65	28.3	34.6	33.9
$A_1 W_1$	82.91	104.00	104.83	28.33	29.33	29.65	31.8	35.1	35.4
A_2W_1	82.29	104.40	105.25	29.00	29.33	29.67	37.3	38.6	39.0
$A_3 W_1$	80.24	102.75	104.08	25.33	26.32	27.00	34.2	36.8	36.5
$A_4 W_1$	79.66	102.75	103.59	26.67	27.33	28.33	34.6	35.4	35.0
A_5W_1	79.49	103.66	104.83	28.32	28.67	29.33	34.6	38.0	38.3
$A_6 W_1$	78.54	104.25	105.83	25.66	26.33	27.33	34.3	35.2	37.0
$A_0 W_2$	79.91	93.08	93.25	24.33	26.00	28.00	26.9	31.0	30.7
$A_1 W_2$	79.99	97.41	98.75	26.67	28.00	28.67	30.6	34.3	34.4
$A_2 W_2$	80.16	95.41	96.75	24.00	25.67	26.67	31.5	35.3	35.6
$A_3 W_2$	78.95	92.50	93.50	25.00	26.00	27.33	29.6	32.7	32.6
$A_4 W_2$	79.41	97.33	99.33	25.33	26.67	27.33	30.3	33.6	33.9
$A_5 W_2$	79.16	102.5	105.33	25.33	27.33	27.33	32.0	33.6	34.5
$A_6 W_2$	79.54	95.08	96.75	27.00	27.67	28.00	31.3	32.0	31.7
SEm (±)	**0.50**	**1.57**	**1.63**	**1.18**	**0.95**	**0.72**	**1.43**	**0.89**	**0.89**
LSD(0.05)	**NS**	**4.57**	**4.73**	**3.41**	**2.76**	**2.08**	**NS**	**NS**	**NS**

was found better followed by Green Miracle @ 0.15% under submerged condition in comparison to control and the interaction effect between Kaolin @ 8% under water stressed condition on straw yield was found better followed by Green Miracle @ 0.30% 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 foundbetter 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. The similar research findings wereobserved with application of film antitranspirants in wheat (*Triticumaestivum*)

Table 4: Interaction effects of antitranspirants and soil moisture levels on N, P, K and Scontent (%) of rice straw and grain

Treatment	Straw				Grain			
	N	P	**K**	**S**	**N**	**P**	**K**	**S**
$A_0 W_1$	0.50	0.075	1.267	0.068	1.47	0.251	0.457	0.064
$A_1 W_1$	0.52	0.070	1.263	0.064	1.45	0.253	0.497	0.061
A_2W_1	0.60	0.076	1.270	0.065	1.49	0.229	0.499	0.053
$A_3 W_1$	0.54	0.078	1.257	0.057	1.54	0.245	0.52	0.060
$A_4 W_1$	0.55	0.071	1.247	0.069	1.55	0.223	0.470	0.066
A_5W_1	0.56	0.069	1.240	0.075	1.52	0.233	0.467	0.072
$A_6 W_1$	0.53	0.067	1.250	0.051	1.50	0.235	0.437	0.057
$A_0 W_2$	0.42	0.066	1.223	0.090	1.33	0.217	0.420	0.075
$A_1 W_2$	0.42	0.065	1.227	0.092	1.42	0.208	0.430	0.090
A_2W_2	0.39	0.064	1.227	0.087	1.39	0.219	0.423	0.089
$A_3 W_2$	0.42	0.066	1.223	0.096	1.39	0.215	0.423	0.091
$A_4 W_2$	0.38	0.059	1.220	0.076	1.38	0.216	0.420	0.094
$A_5 W_2$	0.43	0.056	1.207	0.080	1.36	0.206	0.423	0.061
$A_6 W_2$	0.41	0.042	1.210	0.098	1.36	0.209	0.425	0.108
SEm (±)	**0.03**	**0.006**	**0.008**	**0.006**	**0.05**	**0.006**	**0.020**	**0.078**
LSD(0.05)	**0.10**	**0.017**	**0.024**	**0.016**	**0.15**	**0.018**	**0.059**	**NS**

(Kettlewell, *et al*., 2010) and application of Kaolin, PMA and Mobileaf in barley (*Hordeumvulgare*) (Patil and De, 1978) in respect to yield *i.e.* grain and straw yield.Water stress at the sensitive stage (tillering stage and panicle initiation stage)results the reduction in the flowers and the destruction of developing pollen, so that the seed number is reduced and finally reduced the grain yield (pot experiment) (Morgan 1980). Foliar spray of antitranspirants (Kaolin and Green Miracle) improves the yield of rice by the reductionin transpiration loss and improved the water potential in plants during the flower developmentperiod.

Effect of antitranspirantsand soil moisture levels on nutrient content of rice

The nitrogen (N), phosphorus (P), potassium (K), and sulphur (S) content in straw and grain have been presented in Table 4. Potassium concentration in both grain and straw of *kharif*rice was comparatively higher under submerged condition than water stressed condition. The potassium content in straw of rice was noticed more than 2.5 times than in grain under both the conditions of soil moisture, *i.e*. W_1 and W_2. The treatment combinations of A_2W_1 (0.607%) & A_5W_2 (0.43%) in straw and A_4W_1 (1.55%) & A_1W_2 (1.42%) in grain, A_3W_1 (0.078%) & A_3W_2 (0.066%) in straw and A_1W_1 (0.253%) & A_2W_2 (0.219%) in grain and A_2W_1 (1.27%) & A_2W_2 (1.22%) in straw and A_3W_1 (0.499%) &A_1W_2 (0.430%) in grain were noticed better than other treatment combinations in respect of N,P and K under submerged and water stressed conditions, respectively. It was further noticed that the nutrient content including nitrogen and potassium content in both straw and grain of rice was comparatively higher under submerged condition than water stressed condition. While the content of P was depressed by 14.75% and 5.93% in straw and grain, respectively under water stressed condition and the S content in grainand straw were not affected under water levels and application of antitranspirants. The interaction effect between antitranspirantsand different water level treatments regarding N, P and K content in grain and straw was observed significant while S content in grain andstraw was found not significant. Nazar*et al*. (2011)observed that the application of 0.5 mMsalicylic acid antitranspirantson mungbean (*Vignaradiata*) cultivars increased N and S assimilation, GSH concentration and APX and GRactivity. Foliar spray of antitranspirantslike Kaolin and Green Miracle on rice (*Oryza sativa*) improved the nutrient content (N, K) of grain and straw. Antitranspirants(Kaolin and Green Miracle)alleviates the harmful effects of water stress on photosynthesisand higher photosynthetic efficiency of plant shows more ability to allocate nutrient (N,K) to the plant.

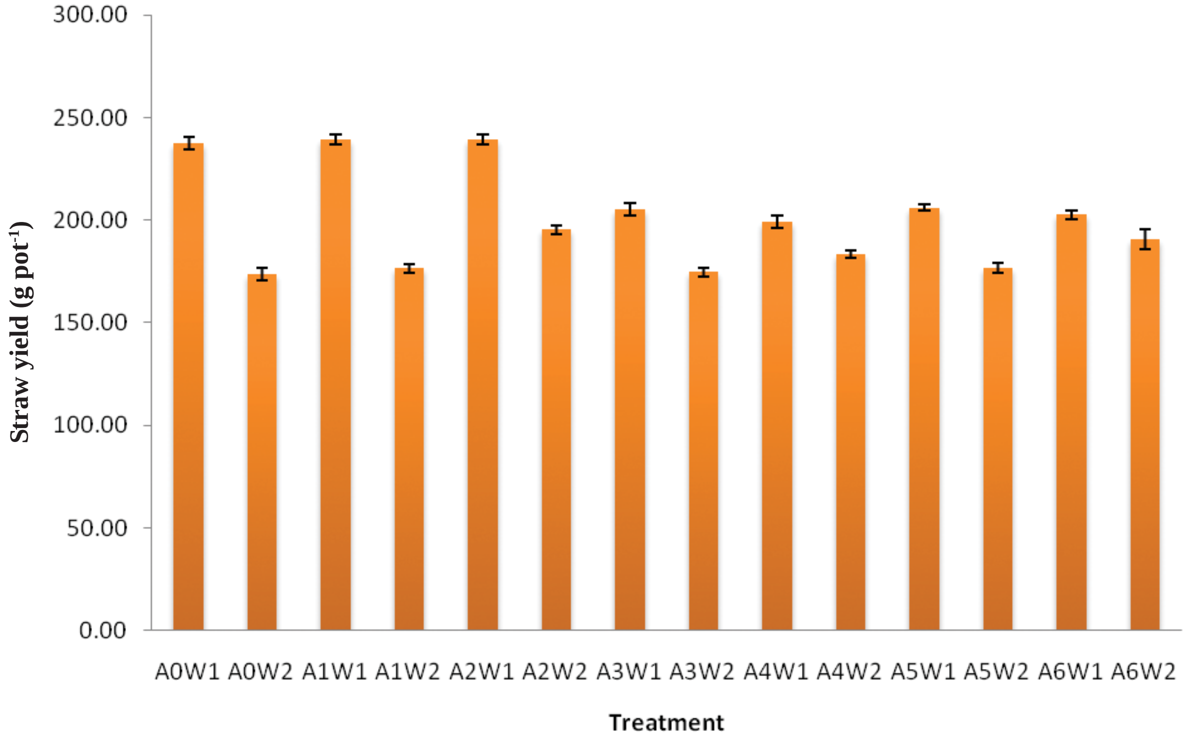

Fig. 1: Interaction effects of antitranspirants and soil moisture levels on straw yield (g pot^{-1}) of rice

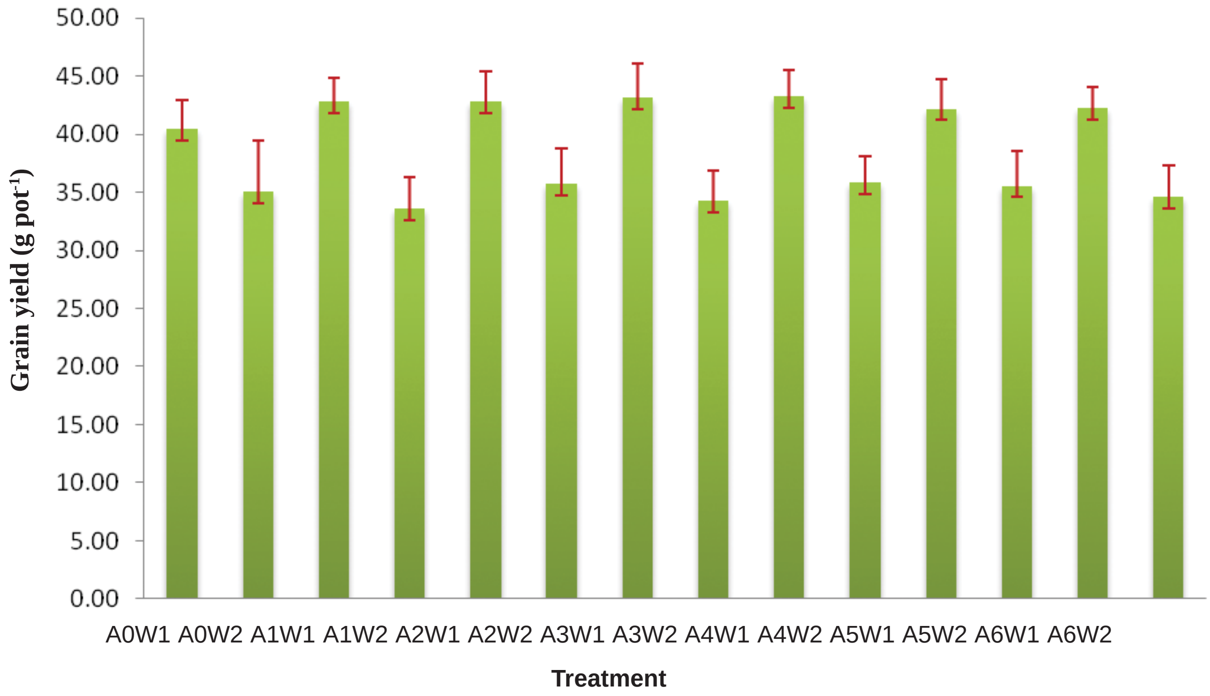

Fig. 2 : Interaction effects of antitranspirants and soil moisture levels on grain yield (g pot^{-1}) of rice

It can be concluded from this study, that the plant growth parameter orgrowth attributes(plant height, tillersnumber, and leaves number) and yield (straw and grain) of *kharif* rice were noticed significantly higher under submerged condition than under water-stressed condition in an Inceptisol of Varanasi, Uttar Pradesh. Spraying of all antitranspirants (both inorganic and organic) in two growth stages of rice crop were significantly improved the plant growth attributes and yield. The order of antitranspirants which improved the overall economic yield in comparison to control was inorganic source (Kaolin) > organic source (Green miracle).The crop growth and consequently the yield (dry matter) of *kharif*rice were noticed maximum through spraying of alumino-silicateclay, kaolinite (inorganic source) under submerged condition and application of long chain fatty alcohol (organic source) under water stressed condition.The nutrients content (N, P, K and S) of rice were not significantly influenced due to the spraying of antitranspirants under water stressed condition, but nutrient content were significantly improved under submerged condition.

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