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Effect of Plant Growth Regulators and Boron on Yield Parameters and Yield of Rice (*Oryza sativa* L.) under Water Stress

Rice (*Oryza sativa* L.) is world's second most extensively grown important crop in Asian and African continents in feeding the burgeoning demand of ever increasing population and maintaining global food security (Reynolds *et al.,* 2012). Nearly half the world population depends on rice, and an increase in rice production by 0.6-0.9% anually until 2050 is required to meet the demand (Carriger and vallee, 2007). At the end of fiscal year 2019, India had approximately 44 million hectares of land area for cultivation of rice. This area had been relatively consistent over during the past three years. In fiscal year 2020, rice was the most produced food grain across the south Asian nation (http://www.statista.com). In Andhra Pradesh, rice is grown ian area of 15.87 lakh ha, with the productivity of 5.44 tonnes/ha and production is about 86.39 lakh million tonnes (http://www.apstatista.com).

Water stress severely effects the rice morphology and also reduces the leaf area and photosynthesis resulting in more number of unfertile grains. Water stress signifies the number of unfilled grains per panicle of rice (Hussain *et al.,* 2020). At panicle initiation stage of rice crop, under severe water stress and under low soil moisture levels; unfilled grains are resulted, which might be due to inactive or aborted pollen grains due to dry ness and incomplete development of pollen tube which causes reduction in yield (Ismail *et al*., 1999).

Boron (B) is an essential micronutrient for plant and its availability to plants determines the agricultural production. The primary function of the element is to provide structural integrity to the cell wall in plants. Boron is directly or indirectly involved in several physiological and biochemical processes during plant growth and may be helpful in mitigating some of the harmful effects of the high temperature and drought

Gibberellic acid is a very potent hormone whose natural occurrence in plants controls their development. Gibberellic acids (Gibberellins) are naturally occurring plant hormones used as plant growth regulators to stimulate both cell division and elongation that affects leaves and stems. Since GA regulates growth, applications of very low concentrations can have a profound effect while too much will have the opposite effect. It is usually used in concentrations between 0.01 and 10 mg/L.Gibberellins have a number of effects on plant development. They can stimulate rapid stem and root growth, induce mitotic division in the leaves of some plants, and increase seed germination rates.

Brassinosteroids (BRs) are a group of polyhydroxylated plant steroid hormones that are crucial for many aspects of a plant's life.The plant steroid hormone brassinosteroids (BRs) play important roles in plant growth and development, regulating diverse processes such as cell elongation, cell division, photomorphogenesis, xylem differentiation, and reproduction as well as both abiotic and biotic stress responses.

I have choosen this work to know the effect pollen characters and yield of plant growth regulators and boron uner water stress as very less work was done on this reearch topic.

MATERIALS AND METHODS

The experiment was conducted during late kharif, 2020-21 at Agricultural college farm, Bapatla with the variety BPT-5204. The soil of the experiment field was clay in texture, acidic in reaction (7.42) with organic carbon (0.2 %), available nitrogen (210.6 kg ha^{-1}), phosphorus (49.7 kg ha^{-1}) available potassium (310.4 kg ha^{-1}). The experiment was laid out in a split plot design, replicated thrice with plot size 5m × 4m and row spacing of 15 cm and intra row spacing of 15 cm. Recommended dose of fertilizers were applied and manual weeding was done to raise healthy crop. Two main treatments i.e., no water stress (M_0) and water stress (M_1) and subjected the crop to water stress during anthesis and eight sub treatments *viz.*, control (S_0) 25 ppm Gibberellic acid (S_1), 0.01 mg Brassinosteroids (S_2), 2.5 Boron (S_3), 25ppm of GA + 0.01mg of Brassinosteroids spray (S_4), 25ppm of GA+2.5 ppm of Boron spray (S_5), 0.01mg of Brassinosteroids + 2.5 ppm of Boron spray (S_6) and 25ppm of GA + 0.01mg of Brassinosteroids +2.5 ppm of Boron spray (S_7) applied at 100 DAS.

Yield and yield parameters was recorded during harvesting stage.The number of panicles per m^{-2} was counted in treatmental plots with the help of quadrant. The quadrant was placed in three different locations in each plot randomly. Panicles were pooled and the average of three was taken. Five panicles from tagged plants were collected randomly from each treatment in three replications. Length of the panicle was measured from the base of the panicle to the tip of the topmost spikelet and average was reported as panicle length in cm. Length of the panicle was measured from the base of the panicle to the tip of the topmost spikelet and average was reported as panicle length in cm. Panicles from five tagged plants at harvesting stage were selected randomly from each treatment, threshed and number unfilled spikelets was counted. Spikelet sterility was worked out using the following formula and expressed in percent. (Number of unfilled spikelets /Total number of spikelets) × 100. A lot of seeds were drawn at random from each treatment in three replications. They were put in a seed counter and thousand seeds were seprated. The weight of thousand grains was recorded and expressed in g. At maturity, panicles from one meter square demarcated area in each plot were harvested, sun dried, threshed, cleaned and weight of the grains was recorded and expressed in q/ha.

RESULTS AND DISCUSSION

Number of panicles per square meter

The data pertaining to the number of panicles per m^2 in rice influenced by the foliar application of plant growth regulators and boron under water stress were presented in Table 1. There was significant differences observed among the main treatments, sub treatments and their interactions in number of panicles in rice.

Significantly higher number of panicles per m^2 were recorded under non stress conditions (M_0-616 m^{-2}) when compared to water stress (M_1-512.m^{-2}). The number of panicles decreased by 17 per cent under water stress compared to irrigated conditions. Among the sub treatments, higher number of panicles per m^2 were obtained with foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (S_7-590 m^{-2}) and it was on par with 0.01 mg of Brassinosteroids + 2.5 ppm of Boron spray (S_6-575 m^{-2}), 25 ppm of GA + 2.5 ppm Boron spray (S_5-584 m^{-2}), 25 ppm of GA + 0.01 mg of Brassinosteroids spray (S_4-575 m^{-2}) and 2.5 ppm of Boron spray (S_3-564 m^{-2}).

Regarding the interactions under non stress conditions, significantly higher number of panicles per m^2 was recorded with foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (M_0S_7 treatment-650 m^{-2}) and it was on par with all other treatments except control (M_0S_0-586 m^{-2}). It indicates that under stress conditions, the foliar spray of growth regulators and boron have a great role in increasing the number of panicles per m^2 and these results are in agreement with the findings of Saleem *et al*. (2010) who reported that the application of borax @ 3 kg ha^{-1} has increased the number of panicles m^{-2}, number of spikelets per panicle and number of grains per panicle in rice

Length of the panicle (cm)

The data pertaining to the length of the panicle in rice influenced by the foliar application of plant growth regulators and boron under water stress were presented in Table 1.

The main treatments did not showed any significant impact on length of the panicles. Significant differences were noticed among the sub treatments their the interaction in panicle length of rice.

Among the sub treatments, the mean length of the panicle in rice was significantly higher with foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (S_7-19.3 cm) and it was on par with 0.01 mg of Brassinosteroids + 2.5 ppm of Boron spray (S_6-18.2 cm), 25 ppm of GA + 2.5 ppm Boron spray (S_5-18.3 cm), 25 ppm of GA + 0.01 mg of Brassinosteroids spray (S_4-18.5 cm), 2.5 ppm of Boron spray (S_3-17.9 cm) and 25 ppm of GA spray (S_1- 18.5 cm).Among the interactions, under non-stress conditions higher length of the panicle was recorded in foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (M_0S_7-20.06 cm) which is on par with all other treatments except control (M_0S_0-16.65 cm). Under water stress conditions, significantly higher panicle length was recorded with growth regulators and combination of growth regulators and boron treatments compared to control (15.8 cm) and the panicle length recorded with growth regulators and combination of growth regulators and boron is on par with the control under non-stress conditions. The present investigation, indicates that the growth regulators and micronutrients sprays having impact on panicle number per m^2 and panicle length also which influence the rice yield and the results are in agreement with Rehman et al. (2012) who reported that there was significant increase in spike length, number of spikelets, 1000-grain weight, grain yield and harvest index when sprayed with Boll guard (5% boron W/V) @ 1250 mL ha^{-1} was sprayed in wheat. Emongor, 2007 also reported that exogenous application of GA_3 at 7 days after emergence at 30, 60 and 90 mg/L significantly increased pod length, pod number/ plant, seed number per pod, 100 seed weight, harvest index and seed yield per ha^1 in cowpea.

Numberj of filled spikelets per panicle

The data pertaining to number of filled spikelets per panicle in rice was influenced by foliar application of plant growth regulators and boron under water stress were presented in Table 2. Significant differenced were observed among main treatments, sub treatments and their interactions in number filled spikelets per panicle in rice

Higher number of filled spikelets per panicle in rice were recorded under irrigated conditions (M_0-153.04) when compared to water stress (M_1-119.58). The number of filled spikelets per panicle decreased by 21.8 percent compared to irrigated conditions. Among the sub treatments, significantly higher mean number of filled spikelets per panicle were recorded with foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (S_7-145) and it was on par with 0.01 mg of Brassinosteroids + 2.5 ppm of Boron spray (S_6-142), 25 ppm of GA + 2.5 ppm Boron spray (S_5-140), 25 ppm of GA + 0.01 mg of Brassinosteroids spray (S_4-139).

Regarding the interactions, the main treatments and sub treatments, under non stress conditions, significantly higher number of filled spikelets per panicle were recorded with foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (M_0S_7-160) and it was on par with 0.01 mg of Brassinosteroids + 2.5 ppm of Boron spray (M_0S_6-157), 25 ppm of GA + 2.5 ppm Boron spray (M_0S_5-157), 25 ppm of GA + 0.01 mg of Brassinosteroids spray (M_0S_4-157) and under water stress conditions, significantly higher number of filled spikelets per panicle were recorded with foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (M_1S_7-130) and it was on par with 0.01 mg of Brassinosteroids + 2.5 ppm of Boron spray (M_1S_6-127), 25 ppm of GA + 2.5 ppm Boron spray (M_1S_5-124), 25 ppm of GA + 0.01 mg of Brassinosteroids spray (M_1S_4-120) and 2.5 ppm of Boron (M_1S_3-120). The results of the present investigation indicate that the detrimental effects of water stress on number of filled spikelets per panicle in rice can be ameliorated with the foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (M_1S_7) and 0.01 mg of Brassinosteroids + 2.5 ppm of Boron spray (M_1S_6). Similar results were reported by Ram kumar *et al*. (2013) that the exogenous application of IAA and GA_3 each @ 20 ppm along with 100% sewage water significantly increased the number of ears per plant, grains per ear head, 1000-grain weight, grain yield, straw yield and harvest index in wheat compared to the 100% sewage water with 10 ppm of IAA and 10ppm GA_3, 100% sewage water alone and control (tap water) and also Jagadeeswari et al. (1998) who found significant increase in plant height, panicle exertion, number of filled grains per panicle and grain yield per plant in the field trials of cytoplasmic male sterile (CMS) and restorer line of hybrid rice on seed yield and quality by using foliar application of GA_3 @ 10-100g/ha in different pacing of hybrid rice.

Sterility percentage (%)

The data pertaining to number of filled sterility percentage in rice influenced by the application of plant growth regulators and boron under water stress were presented in Table 2. Significant differences were observed among main treatments, sub treatments and their interactions for sterility percentage in rice.

Higher mean percent sterility in rice was recorded under water stress conditions (M_1-18.67%) when compared to non-stress (M_0-11.88%). The sterility percentage reduced by 57.15 per cent compared to irrigated conditions. The mean lower sterility percentage was recorded due to foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (S_7-9.89%) and higher sterility percentage was observed in control (S_0-21.54%). All the growth regulators and boron treatments are significantly superior in reducing the sterility percentage in rice.

Regarding the interaction of main and sub treatments, both under water stress and non-stress conditions, foliar application of growth regulators and the combination of growth regulators and micronutrient treatments are significantly superior compared to the control. Under water stress conditions, foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (M_1S_7-12.94%) and it was on par with 0.01 mg of Brassinosteroids + 2.5 ppm of Boron spray (M_1S_6-13.91%), 25 ppm of GA + 2.5 ppm Boron spray (M_1S_5-16.14), 25 ppm of GA + 0.01 mg of Brassinosteroids spray (M_1S_4-17.99%), 2.5 ppm of Boron (M_1S_3-18.57%) and these are on par with non-stressed control (M_0S_0-16.76%).

The results indicate that, the lethal effects of water stress can be ameliorated with the foliar application of growth regulators and combination of growth regulators and micronutrients and these results are in agreement with the findings of Bhatta *et al.* (2005) who reported that the application of Boron @ 2 kg ha^{-1} to the soil has shown significant effect on spikelet number, sterility percentage reduction and grain yield in rice

Test weight (g)

The data pertaining to test weight in rice was influenced by the foliar application of plant growth regulators and boron under water stress were presented in Table 3. Significant differences were observed among the main treatments, sub treatments and their interactions in test weight of rice.

Higher mean test weight was recorded under irrigated conditions (M_0-14.39 g) when compared to water stress (M_1-12.08 g). The test weight decreased by 16 per cent under water stress conditions compared to irrigated conditions. Among the sub treatments, significantly higher mean test weight in rice was recorded with foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (S_7-14.45 g) and it was on par with 0.01 mg of Brassinosteroids + 2.5 ppm of Boron spray (S_6-14.01 g) when compared to control (S_0-12.10 g).

Regarding the interactions of main and sub treatments, under non stress conditions, no significant deviation was noticed due to foliar application ofgrowth regulators and growth regulators in combination of micronutrient treatments, whereas under water stress conditions significantly higher test weight in rice was recorded with 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (M_1S_7-12.86 g) and it was on par with 0.01 mg of Brassinosteroids + 2.5 ppm of Boron spray (M_1S_6-13.91%), 25 ppm of GA + 2.5 ppm Boron spray (M_1S_5-12.43 g), of 25 ppm of GA + 0.01 mg of Brassinosteroids spray (M_1S_4-12.13 g), 2.5 ppm of Boron (M_1S_3-12.10 g). foliar application 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (M_1S_7) is on par with the control under non-stress conditions indicating the impact of the foliar application of growth regulators and boron spray on the test weight of rice grain under water stress conditions. The results are in agreement with the findings of Ahmed Shah *et al*. (2011) who reported significant increase in panicle number, test weight and yield due to boron application @ 1 kg ha^{-1} on rice. Similar results were stated by Ram kumar *et al*. (2013) who reported that the exogenous application of IAA and GA_3 each @20ppm along with 100% sewage water significantly increased the number of ears per plant, grains/ear head, 1000-grain weight, grain yield, straw yield and harvest index in wheat compared to the 100% sewage water with 10ppm IAA and 10ppm GA_3, 100% sewage water alone and control (tap water).

Yield (q ha^{-1})

The data pertaining to grain yield as influenced by foliar application of plant growth regulators and boron under water stress were presented in Table 3. Significant differences were observed among main treatments, sub treatments and their interactions for seed yield of rice.

Higher grain yield of rice was recorded under irrigated conditions (M_0-56.78 q/ha) when compared to water stress (M_1-49 qha^{-1}). The grai yield of rice decreased by 13.71 per cent compared to irrigated conditions. Among the sub treatments, higher mean yield was recorded with foliar application 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (S_7-56.66 q ha^{-1}) and it was on par with with 0.01 mg of Brassinosteroids + 2.5 ppm of Boron spray (S_6-54.66 q ha^{-1}), 25 ppm of GA + 2.5 ppm

Table 1. Influence of Plant growth regulators and Boron on Number of panicles per m² and Length of the panicle (cm) in rice under water stress

Treatments	Number of panicles per m^2			Length of the panicle (cm)		
	M_0	M_1	Mean	M_0	M_1	Mean
S_0: No spray (control)	586.33	497.00	541.66	17.50	15.80	16.65
S_1: 25 ppm of GA spray	594.33	502.33	548.33	19.16	17.93	18.55
S_2:0.01mg of Brassinosteriods spray	596.00	504.33	550.16	18.50	16.60	17.55
S_3:2.5 ppm of Boron spray	612.00	507.33	559.66	18.90	16.93	17.91
S_4: 25 ppm of GA +0.01mg of Brassionsteriods spray	623.00	517.00	570.00	19.73	17.36	18.55
S_5: 25 ppm of GA +2.5 ppm of boron spray	635.00	524.00	579.50	19.00	17.60	18.30
S_6: 0.01 mg of Brassinosteriods+2.5 ppm of Boron spray	637.00	514.66	575.83	18.70	17.80	18.25
S_7:25 ppm of GA +0.01 mg of Brassinosteroids +2.5 ppm of boron spray	649.66	530.66	590.16	20.06	18.53	19.30
Means	616.66	512.16		18.94	17.32	

	Number of panicles per m^2			Length of the panicle (cm)		
	Main plots	Sub plots	Interactions	Main plots	Sub plots	Interactions
SEm±	6.52	11.96	16.91	0.31	0.59	0.83
CD (P = 0.05)	39.71	34.64	49	NS	1.71	2.42
CV (%)	5.67	5.19		8.49	7.98	

Table 2. Influence of Plant growth regulators and Boron on Number of filled spikelets per panicle and Sterility percentage (%) in rice under water stress

Treatments	Number of filled spikelets per panicle			Sterility percentage (%)		
	M_0	M_1	Mean	M_0	M_1	Mean
S_0: No spray (control)	143.66	107.66	125.66	16.76	26.32	21.54
S_1: 25 ppm of GA spray	146.33	112.00	129.16	12.91	22.13	17.52
S_2:0.01mg of Brassinosteriods spray	150.66	115.00	132.83	13.20	21.37	17.29
S_3:2.5 ppm of Boron spray	152.00	120.00	136.00	13.11	18.57	15.84
S_4: 25 ppm of GA +0.01mg of Brassionsteriods spray	157.00	120.33	138.66	11.46	17.99	14.72
S_5: 25 ppm of GA +2.5 ppm of boron spray	157.33	124.33	140.83	11.11	16.14	13.63
S_6: 0.01 mg of Brassinosteriods+2.5 ppm of Boron spray	157.33	127.00	142.16	9.68	13.91	11.80
S_7:25 ppm of GA +0.01 mg of Brassinosteroids +2.5 ppm of boron spray	160.00	130.33	145.16	6.85	12.94	9.89
Means	153.04	119.58		11.88	18.67	

	Number of filled spikelets per panicle			Sterility percentage (%)		
	Main plots	Sub plots	Interactions	Main plots	Sub plots	Interactions
SEm±	1.66	2.81	3.97	0.38	0.48	0.68
CD (P = 0.05)	10.12	8.14	11.52	2.34	1.39	1.97
CV (%)	5.97	5.05		12.35	7.73	

Table 3. Influence of Plant growth regulators and Boron on Test weight (g) and Yield (q/ha) in rice under water stress.

Treatments	Test weight (g)			Yield (q/ha)		
	M_0	M_1	Mean	M_0	M_1	Mean
S_0: No spray (control)	13.36	10.83	12.10	55.33	42.00	48.66
S_1: 25 ppm of GA spray	13.86	11.13	12.50	55.00	46.00	50.50
S_2:0.01mg of Brassinosteriods spray	13.76	11.80	12.78	55.33	48.00	51.66
S_3:2.5 ppm of Boron spray	14.20	12.10	13.15	56.33	49.33	52.83
S_4: 25 ppm of GA +0.01mg of Brassionsteriods spray	14.36	12.13	13.25	57.33	50.33	53.83
S_5: 25 ppm of GA +2.5 ppm of boron spray	14.86	12.43	13.65	57.00	51.66	54.33
S_6: 0.01 mg of Brassinosteriods+2.5 ppm of Boron spray	15.16	12.86	14.01	58.00	51.33	54.66
S_7:25 ppm of GA +0.01 mg of Brassinosteroids +2.5 ppm of boron spray	15.53	13.36	14.45	60.00	53.33	56.66
Means	14.39	12.08		56.79	49	

	Test weight (g)			Yield (q/ha)		
	Main plots	Sub plots	Interactions	Main plots	Sub plots	Interactions
SEm±	0.19	0.56	0.80	0.60	1.22	1.73
CD (P = 0.05)	1.16	1.64	2.33	3.70	3.55	5.03
CV (%)	7.08	10.52		5.63	5.68	

M_0 - No Water Stress M_1 - Water Stress

Boron spray (S_5-54.33 q ha^{-1}) and ppm of GA + 0.01 mg of Brassinosteroids spray (S_4-53.83 q ha^{-1}). Regarding the interactions of main treatments and sub treatments, under non stress conditions, no significant variation was noticed among sub treatments, whereas under water stress conditions, higher grain yield of rice was recorded with foliar application of 25 ppm of GA + 0.01 mg Brassinosteroids + 2.5 ppm of Boron spray (M_1S_7-53.33 q ha^{-1}) and it was on par with 0.01 mg of Brassinosteroids + 2.5 ppm of Boron spray (M_1S_6-151.33 q ha^{-1}), 25 ppm of GA + 2.5 ppm Boron spray (M_1S_5-51.66 q ha^{-1}) and 25 ppm of GA + 0.01 mg of Brassinosteroids spray (M_1S_4-50.33 q ha^{-1}). The grain yield of rice with the above treatments under water stress conditions was on par with the control under non stress conditions (55.33 q ha^{-1}). The results indicate that the detrimental effects of water stress and high temperature can be ameliorated with the foliar application of Gibberellins, Brassinosteroids and Boron combination sprays and the results of the present investigation is in agreement with Rao et al. (2013) who reported that the foliar application of boron @ 0.4 ppm significantly increased grain yield (9.6%) and yield attributes along with biomass by increasing grain filling and reducing spikelet fertility in rice Yang Liu *et al.* (2012) who stated that GA_3 @ 10 mg L^{-1} and NAA @ 1000 mg L^{-1} significantly inhibited the growth of unproductive tillers, promoted the growth of productive tillers at the middle and late growth stages, promoted the development of heavy panicles, and finally increased the grain yield in rice.

The results are also in accordance with the Fahad *et al*. (2016) stated that the high temperature and water stress severely effects rice morphology and metabolic activities like photosynthesis and water use efficiency which results in the reduction of biomass production, grain yield and its related attributes except the number of panicles. The same results are information with Mounika et al., (2020) an are reported the grain yield of BPT-5204 range from 5-6 qha^{-1} under well fertilizer conditions. The marginal increase of grain yield in rice with increment of fertilizer and irrigation was reported by Himasravanthi *et.al*., 2020 The exogenous application of plant growth regulators with combination of gibberellic acid, methyl jasmonates and brassinosteroids along with vitamin C and E enhanced the morphological parameters and physiological parameters like photosynthesis, spikelet fertility and grain filling, which compensated the adversities of high temperature and water stress.

CONCLUSION

Foliar application of 25ppm of GA + 0.01mg of Brassinosteroids +2.5 ppm of Boron spray increased the number of panicles m^{-2}, length of the panicle, number of filled spikelets per panicle, sterility percentage, test weight, yield by 6.34, 14.73, 17.39, 50.83, 18.93 and 21.24 per cent in rice Foliar application of 25ppm of GA + 0.01mg of Brassinosteroids +2.5 ppm of Boron spray increased the number of panicles per m^2, length of the panicle, number of filled spikelets per panicle, sterility percentage, test weight, yield both under water stress and irrigated conditions.

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