RESEARCH ARTICLE

Effect of Paclobutrazol and Mepiquat chloride on Growth, Culm strength and Lignin content in stem of rice (*Oryza sativa* L.)

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ABSTRACT

A field experiment with the application of growth retardants such as paclobutrazol and mepiquat chloride on lodging resistance, plant height, culm strength and lignin content in rice (Oryza sativa L.) was conducted at a college farm, Agricultural college, Bapatla during Kharif season. The experiment was laid in Randomized Block Design which was replicated thrice to find out the effect of different concentrations of paclobutrazol and mepiquat chloride on lodging, plant height, culm strength and lignin content. The nine treatments in each replication consisting of two different concentrations of paclobutrazol and mepiquat chloride at two different stages of crop growth (100 and 200 ppm paclobutrazol and mepiquat chloride at 35 DAT and panicle initiation stage) and a control. Results indicated a significant difference in lodging percentage, plant height, culm strength and lignin content under different concentrations of paclobutrazol and mepiquat chloride. Data on different parameters were collected at 30 days intervals. Significantly higher lignin content, culm strength, and lower lodging percentage were recorded with foliar application of 100 ppm mepiquat chloride spray at panicle initiation stage (T7) when compared to other treatments.

Keywords: *Vetiver oil microcapsules, wool fabric, standardization, pad-dry-cure method, aroma treatment*

INTRODUCTION

Rice (*Oryza sativa* L.) is the 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 [1]. Nearly half the world population depends on rice, and an increase in rice production by 0.6-0.9% annually until 2050 is required to meet the demand [2]. At the end of the fiscal year 2019, India had approximately 44 million hectares of land area for the cultivation of rice. This area had been relatively consistent during the past three years. In the fiscal year 2020, rice was the most produced food grain across the south Asian nation [3]. In Andhra Pradesh, rice is grown in an area of 15.87 lakh Ha, with a productivity of 5.44 tonnes/ha and production is about 86.39 lakh million tonnes. The use of plant growth regulators in reducing lodging losses, thereby increased yield in rice. Proper application of plant growth regulators at the optimum time could help to reduce plant height, which would possibly have a direct impact on grain yield [4]. In crops like cotton, sugarcane, wheat and soybeans, plant growth regulators are being commonly used to reduce plant height and to provide greater plant uniformity [5-7]. Some of these regulators are inhibitors of gibberellins biosynthesis, a plant hormone associated with stem elongation [8-9]. In rice, plant growth retardants are used to reduce plant height thereby lodging.

Paclobutrazol is a synthetic plant growth regulator, is a triazole type inhibitor of gibberellin (GA) biosynthesis which affects plant growth and development. It reduces internodal growth to give stouter stems, increased root growth; early fruit set, and increased seed set in plants [10]. Trials conducted by [11-15] gave

an idea that foliar application of paclobutrazol at the tillering stage can be taken as a chemical approach for reducing the risk of lodging in cereal crops. Mepiquat chloride (PIX), another GA biosynthesis inhibitor application has been shown to produce the highest total dry matter in rice [16-17]. It was found to reduce leaf area and to increase Ribulose-1,5- carboxylase/ oxygenase (Rubisco) activity in cotton plants [18] and lodging resistance of maize by enhancing stem physical strength and lignin biosynthesis in maize [19].

MATERIALS AND METHODS

Experimental design and treatments

A field experiment was carried out at an agricultural college farm, Bapatla, Andhra Pradesh in a randomized block design (RBD) with 3 replications and 9 treatments to find out the best treatment for the lodging resistance during *Kharif* season 2020. In the present study, MTU -7029 is used as a variety. Nine treatments such as 100 and 200 ppm paclobutrazol and Mepiquat chloride sprays at 35 DAT and panicle initiation stage and an untreated check. Two sprayings were done at 35 days after transplanting and panicle initiation stage. The details of treatment in the experiment are given below:

Treat-ments	Application rate
T_1	Control (No application)
T_2	100 ppm paclobutrazol spray at 35 DAT
T_3	100 ppm paclobutrazol spray at the panicle initiation stage
T_4	200 ppm paclobutrazol spray at 35 DAT
T_5	200 ppm paclobutrazol spray at the panicle initiation stage
T_6	100 ppm mepiquat chloride spray at 35 DAT
T_7	100 ppm mepiquat chloride spray at the panicle initiation stage
T_8	200 ppm mepiquat chloride spray at 35 DAT
T_9	200 ppm mepiquat chloride spray at the panicle initiation stage

Observations and data analysis

Plant height: Plant height was measured from the ground level to the tip of the youngest leaf up to the stage of panicle emergence. At maturity, plant height was measured from the ground level to the tip of the earliest panicle excluding its awns.

Culm strength test by Prostrate tester: The pushing resistances of the whole plant (hill) was taken as the indicator of physical strength of the culms, which was measured with a prostrate tester (DIK-7401, Daiki Rika Kogyo Co., Tokyo, Japan) as per the method reported by [20]. The pushing hand of the prostrate tester was set perpendicular to the plants at the midpoint of a rice hill and the hill was pushed until the plants had inclined to an angle of 45^0 from the vertical, using the white spring (strength 9.8 N/40 mm). pushing resistance was expressed in the compressive movement of spring by mm.

The lignin content of the stem: The lignin content of the stem was estimated by following the method given by [21].

For estimation of Acid detergent lignin,

a. 1g of powdered sample was taken in a round bottom flask and 100mL of acid detergent solution. Heated to boil for 5 to 10 min and refluxed for 1h after the onset of boiling.
b. Later filtered the contents through a pre weighed sintered glass crucible (G-2) by suction and washed with hot water twice.
c. Then it was washed with acetone and broke up the lumps and repeated acetone washing was done until the filtrate was colorless.
d. After that, it was dried at 100^0C overnight and weigh after cooling in a desiccator, which was the acid detergent fibre.
e. The acid detergent fibre was transferred to a 100mL beaker with 25-50 mL of 72% sulphuric acid, 1g asbestos was added and allowed to stand for 3h with intermittent stirring with a glass rod.
f. Then it was diluted with distilled water and filtered with pre weighed Whatman No. 1 filter paper. Washed the glass rod and the residue several times to get rid of the acid.
g. Dried the filter paper at 100^0C and weighed it after cooling in a desiccator.
h. The filter paper was transferred to a pre-weighed silica crucible and ashed the filter paper with the content in a muffle furnace at 550^0C for about 3h.
i. Then the crucible was cooled in a desiccator and weighed and calculated the ash content.
j. For blank, without sample, the same steps were followed with 1g asbestos and 72% H_2SO_4.

Calculations:

$$\% \text{ Acid Detergent Lignin} = \frac{\text{Weight of 72\% } H_2SO_4 \text{ washed fibre} - \text{Ash}}{\text{Weight of sample}} \times 100$$

Lodging Percentage: The percentage of lodging index was calculated by the formula given by (Bridgemohan and Bridgemohan, 2014).

$$\text{Lodging Index} = \frac{\% \text{ of area lodged} \times \text{degree of lodging}}{100} \times 100$$

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Here per cent of the area lodged was found by measuring the land area where lodging takes place out of the total land area under cultivation. The degree of lodging was quantifiedusing the angle of displacement of the stem from the vertical position where 0˚ is no displacement (zero) and 90˚ is completely horizontal (100).

Table: 1 Effect of paclobutrazol and mepiquat chloride on Plant height (cm) in rice

Treatments	Plant height (cm)		
	30 DAT	60 DAT	90 DAT
T_1 : Control	52.07	99.36	118.10
T_2 : 100 ppm paclobutrazol spray at 35 DAT	48.50	81.20	100.00
T_3 : 100 ppm paclobutrazol spray atpanicle initiation stage	52.31	92.00	100.80
T_4 : 200 ppm paclobutrazol spray at35 DAT	51.30	84.44	104.00
T_5 : 200 ppm paclobutrazol spray at panicle initiation stage	51.64	93.03	102.00
T_6 : 100 ppm mepiquat chloride spray at 35 DAT	49.80	85.92	104.40
T_7 : 100 ppm mepiquat chloride spray at panicle initiation stage	51.70	96.20	104.46
T_8 : 200 ppm mepiquat chloride spray at 35 DAT	51.10	87.96	105.00
T_9 : 200 ppm mepiquat chloride spray at panicle initiation stage	50.53	92.33	107.00
SE (m)±	2.12	2.74	3.12
CD (0.05)	NS	8.23	9.36
CV (%)	6.35	5.48	5.15

*DAT (Days after transplanting)
*NS (non-significant)

Table: 2 Effect of Paclobutrazol and Mepiquat Chloride on Culm strength (mm) in rice

Treatments	Culm strength (mm)		
	30 DAT	60 DAT	90 DAT
T_1 : Control	20.98	20.70	19.56
T_2 : 100 ppm paclobutrazol spray at 35 DAT	21.26	22.58	21.30
T_3 : 100 ppm paclobutrazol spray atpanicle initiation stage	21.38	21.75	21.00
T_4 : 200 ppm paclobutrazol spray at35 DAT	21.59	21.02	20.00
T_5 : 200 ppm paclobutrazol spray at panicle initiation stage	20.88	20.90	21.17
T_6 : 100 ppm mepiquat chloride spray at 35 DAT	20.88	23.10	22.02
T_7 : 100 ppm mepiquat chloride spray at panicle initiation stage	21.67	22.90	22.04
T_8 : 200 ppm mepiquat chloride spray at 35 DAT	21.40	22.96	21.99
T_9 : 200 ppm mepiquat chloride spray at panicle initiation stage	20.80	21.00	21.98
SE (m)±	0.85	0.75	0.66
CD (0.05)	NS	1.84	1.99
CV (%)	2.84	5.47	5.39

*DAT (Days after transplanting)
*NS (non-significant)

RESULTS AND DISCUSSION

Plant height (cm)

The data about variation in plant height as influenced by foliar application of different concentrations of paclobutrazol and mepiquat chloride at different stages in rice are presented in Table 1. In the present study gradual increase in plant, height was recorded up to 90 DAT. At 30 DAT, i.e., before the imposition of treatments the plant height varied from 48.50 cm to 52.31 cm and there was no significant difference was observed among the treatments regarding plantheight. But significant variation was noticed among the treatments at 60 and 90 DAT.

At 60 DAT, the plant height ranged from 81.20 cm to 99.36 cm. Among the treatments, a significant reduction in plant height was noticed by the foliar application of 100 ppm PBZ spray (T_2-81.20 cm) followed by 200 ppm PBZ (T_4-84.44 cm), 100 ppm MC (T_6-85.92 cm) and 200 ppm MC sprays at 35 DAT (T_8-87.96 cm). Higher plant height was noticed in control (T_1-99.36 cm), which was at par with the foliar application of 100 ppm MC spray (T_7-96.20 cm), 200 ppm PBZ (T_5-93.03 cm), 200 ppm MC spray (T_9-92.33 cm) and 100 ppm PBZ sprays at panicle initiation stage (T_3-92.00 cm).

At 90 DAT, the plant height ranged from 100 cm to 118.1 cm. Lower plant height was recorded with the foliar application of 100 ppm PBZ spray at 35 DAT (T_2-100 cm). Control plants recorded higher plant height (T_1-118.10 cm), followed by foliar application of 200 ppm MC spray at panicle initiation stage (T_9-107.00 cm), 200 ppm MC spray at 35 DAT (T_8-105.00 cm), 100 ppm MC spray at panicle initiation stage (T_7-104.46 cm), 100 ppm MC spray at 35 DAT (T_6-104.40 cm), 200 ppm PBZ spray at 35 DAT (T_4-104.00 cm), 200 ppm PBZ spray at panicle initiation stage (T_5-102.00 cm) and 100 ppm PBZ spray at panicle initiation stage (T_3-100.80 cm).

Based on the above results, it is clear that the foliar application of paclobutrazol and mepiquat chloride showed a significant influence in reducing the plant height in rice. In the present study, at 90 DAT, T_2 (100 ppm paclobutrazol (PBZ) spray at 35 DAT) reduced the plant height by 15.3 per cent over control. The reason for the reduction in plant height with foliar

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application of paclobutrazol was due to decreased internodal length. These results are following the results of [22-23] and also with [24-25] who reported that the application of mepiquat chloride significantly decreased the endogenous GA_3 and GA_4 levels in the elongating internodes that inhibited the cell elongation and reduced the plant height without affecting the rice yield. The studies conducted by [20] support the results of the present investigation which indicates that synthetic compounds like paclobutrazol or mepiquat chloride generally inhibit many physiological functions mediated by gibberellins and are responsible for controlling cell elongation and shoot or stem growth.

Table: 3 Effect of Paclobutrazol and Mepiquat Chloride on Lignin content (%) of the stem in rice

Treatments	Lignin content (%) of the stem
T_1 : Control	13.75
T_2 : 100 ppm paclobutrazol spray at 35 DAT	15.30
T_3 : 100 ppm paclobutrazol spray atpanicle initiation stage	14.80
T_4 : 200 ppm paclobutrazol spray at35 DAT	14.60
T_5 : 200 ppm paclobutrazol spray at panicle initiation stage	15.10
T_6 : 100 ppm mepiquat chloride spray at 35 DAT	16.50
T_7 : 100 ppm mepiquat chloride spray at panicle initiation stage	16.80
T_8 : 200 ppm mepiquat chloride spray at 35 DAT	16.40
T_9 : 200 ppm mepiquat chloride spray at panicle initiation stage	16.20
SE (m)±	0.51
CD (0.05)	1.52
CV (%)	5.66

*DAT (Days after transplanting)

Culm strength (mm)

Foliar application of paclobutrazol and mepiquat chloride significantly influenced the culm strength in rice and the results were presented in Table 2. At 30 DAT, culm strength ranged from 20.80 to 21.67 mm. Before the treatment's imposition, there were no significant differences observed with regards to culm strength. At 60 and 90 DAT, significant differences were noted among the treatments. At 60 DAT, culm strength ranged from 20.70 to 23.10 mm. The maximum culm strength was recorded with the foliar application of 100 ppm MC spray at 35 DAT (T_6-23.10 mm) followed by 200 ppm MC spray at 35 DAT (T_8-22.96 mm), 100 ppm MC spray at panicle initiation stage (T_7-22.90 mm), 100 ppm PBZ spray at 35 DAT (T_2-22.58 mm) and 100 ppm PBZ spray at panicle initiation stage (T_3-21.75 mm), and these were found on a par with one another in influencing the culm strength. The minimum culm strength was recorded by control (T_1-20.70 mm) which was at par with the foliar application of 200 ppm PBZ spray at panicle initiation stage (T_5-20.90 mm), 200 ppm MC spray at panicle initiation stage (T_9-21.00 mm) and 200 ppm PBZ spray at 35 DAT (T_4-21.02 mm).

Table: 4 Effect of Paclobutrazol and Mepiquat Chloride on Lodging percentage (%) of rice

Treatments	Lodging percentage (%)
T_1 : Control	44.86
T_2 : 100 ppm paclobutrazol spray at 35 DAT	34.62
T_3 : 100 ppm paclobutrazol spray atpanicle initiation stage	37.40
T_4 : 200 ppm paclobutrazol spray at35 DAT	38.68
T_5 : 200 ppm paclobutrazol spray at panicle initiation stage	34.64
T_6 : 100 ppm mepiquat chloride spray at 35 DAT	33.72
T_7 : 100 ppm mepiquat chloride spray at panicle initiation stage	33.60
T_8 : 200 ppm mepiquat chloride spray at 35 DAT	34.02
T_9 : 200 ppm mepiquat chloride spray at panicle initiation stage	34.16
SE (m)±	1.45
CD (0.05)	4.35
CV (%)	6.95

*DAT (Days after transplanting)

At 90 DAT, culm strength ranged between 19.56 mm to 22.04 mm. Higher culm strength was recorded with the foliar application of 100 ppm MC spray at panicle initiation stage (T_7-22.04 mm) followed by 100 ppm MC spray at 35 DAT (T_6-22.02 mm), 200 ppm MC spray at 35 DAT (T_8-21.99mm), 200 ppm MC spray at panicle initiation stage (T_9-21.98 mm), 100 ppm PBZ spray at 35 DAT (T_2-21.30 mm), 200 ppm PBZ spray at panicle initiation stage (T_5-21.17 mm) and 100 ppm PBZ spray at panicle initiation stage (T_3-21.00 mm) and these were found on a par with one another in influencing the culm strength. Lesser culm strength was recorded by control (T_1-19.56 mm) which was at par with the foliar application of 200 ppm PBZ spray at 35 DAT (T_4-20.00 mm). In the current study, at 90 DAT, foliar application of 100 ppm MC spray at panicle initiation stage (T_7) recorded a 12.70 per cent increase in culm strength over control (T_1).

In the present investigation, foliar spray of different concentrations of paclobutrazol and mepiquat chloride increased the culm strength might be due to the changes in cell wall constituents like lignin, cellulose and compaction of parenchymatous cells. The results in the present study were partially in line with the

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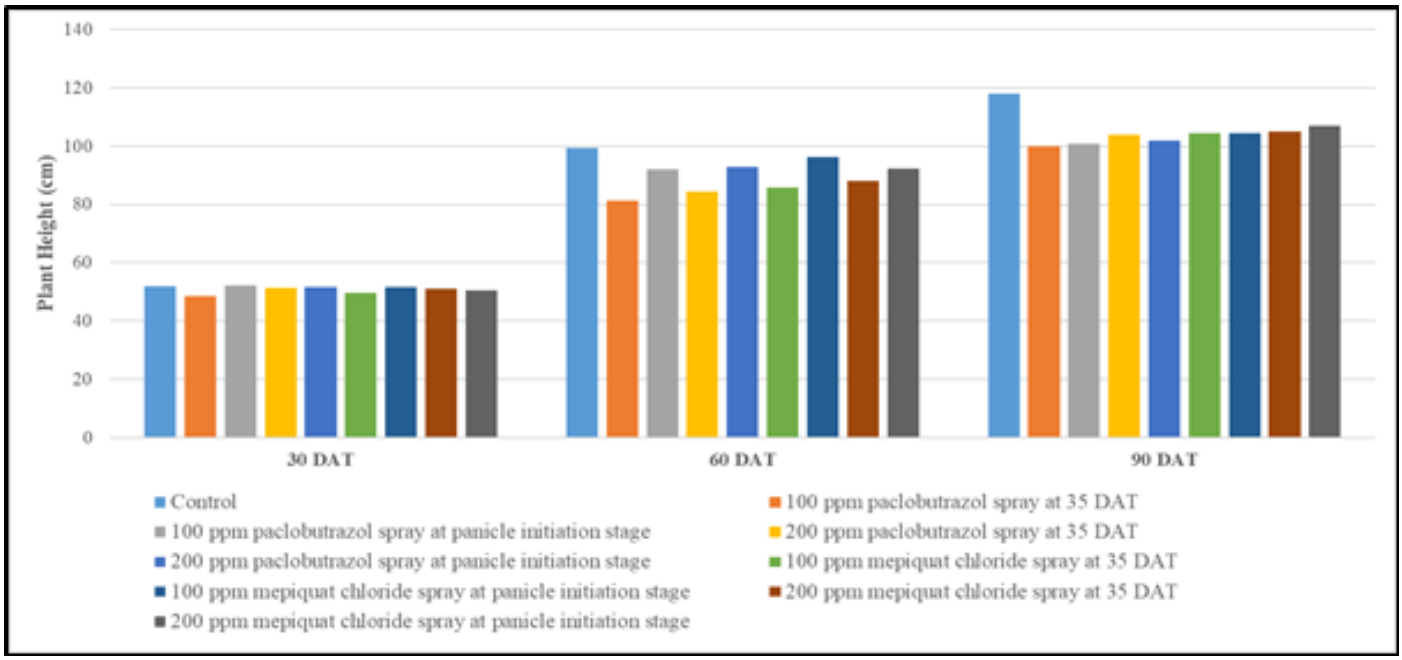

Figure 1: Effect of paclobutrazol and mepiquat chloride on Plant height (cm)

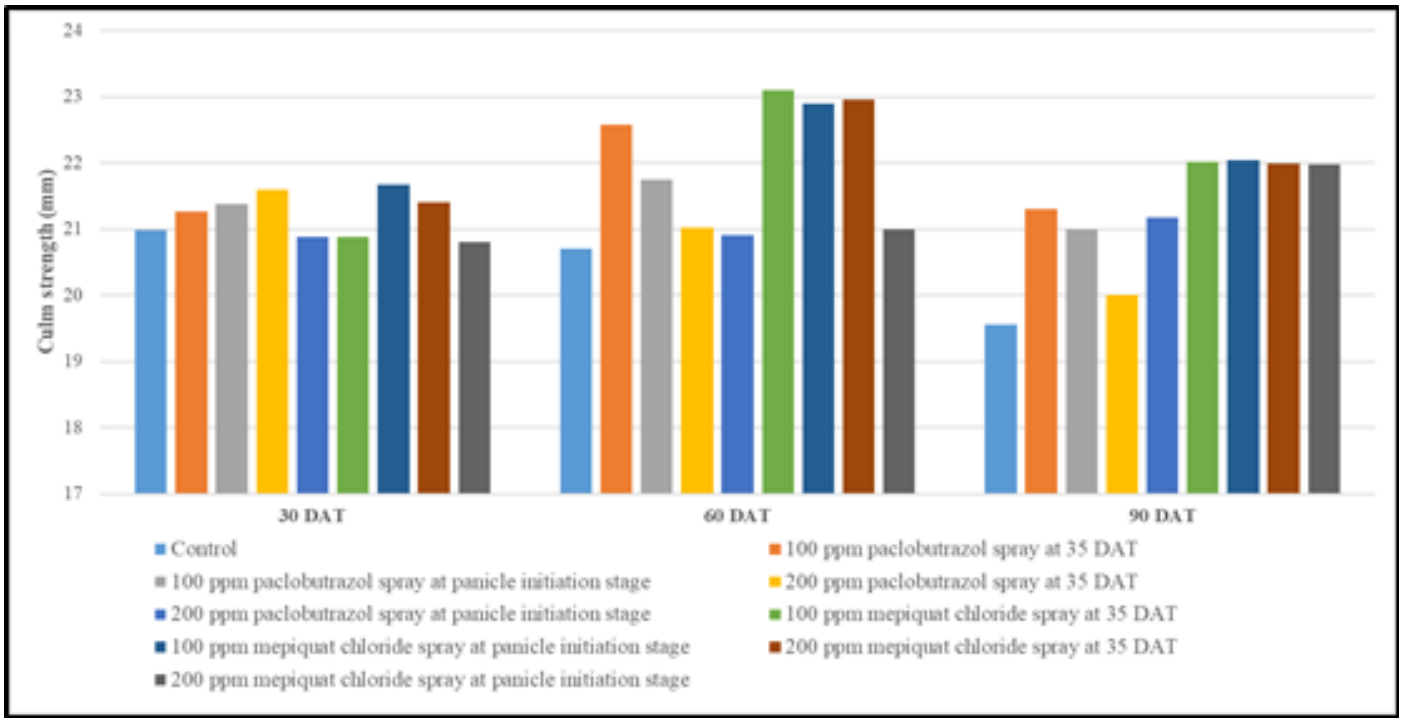

Figure 2: Effect of paclobutrazol and mepiquat chloride on Culm strength (mm)

findings of [19] and similar results were also reported in maize by [13].

The lignin content of the stem

The influence of the foliar application of different concentrations of paclobutrazol and mepiquat chloride on the lignin content of the rice culm was found significant and presented in Table 4.3. The lignin content in the rice culm varied from 13.75 to 16.80 per cent and there was a significant difference observed among the treatments.

The highest lignin content of the stem was recorded with the foliar application of 100 ppm MC spray at panicle initiation stage (T_7-16.80%) followed by 100 ppm MC spray at 35 DAT (T_6-16.50%), 200 ppm MC spray at 35 DAT (T_8-16.40%), 200 ppm MC spray at panicle initiation stage (T_9-16.20%) and 100 ppm PBZ spray at 35 DAT (T_2-15.30%), and these were found on a par with one another. The lowest lignin content was found in control (T_1-13.75%), which was on a par with foliar application of 200 ppm PBZ spray at 35 DAT (T_4-14.60%), 100 ppm PBZ spray at panicle initiation stage (T_3-14.80%), and 200 ppm PBZ spray at panicle initiation stage (T_5-15.10%).

Different concentrations of paclobutrazol and mepiquat chloride increased the lignin content of the stem when compared to control in the present study,

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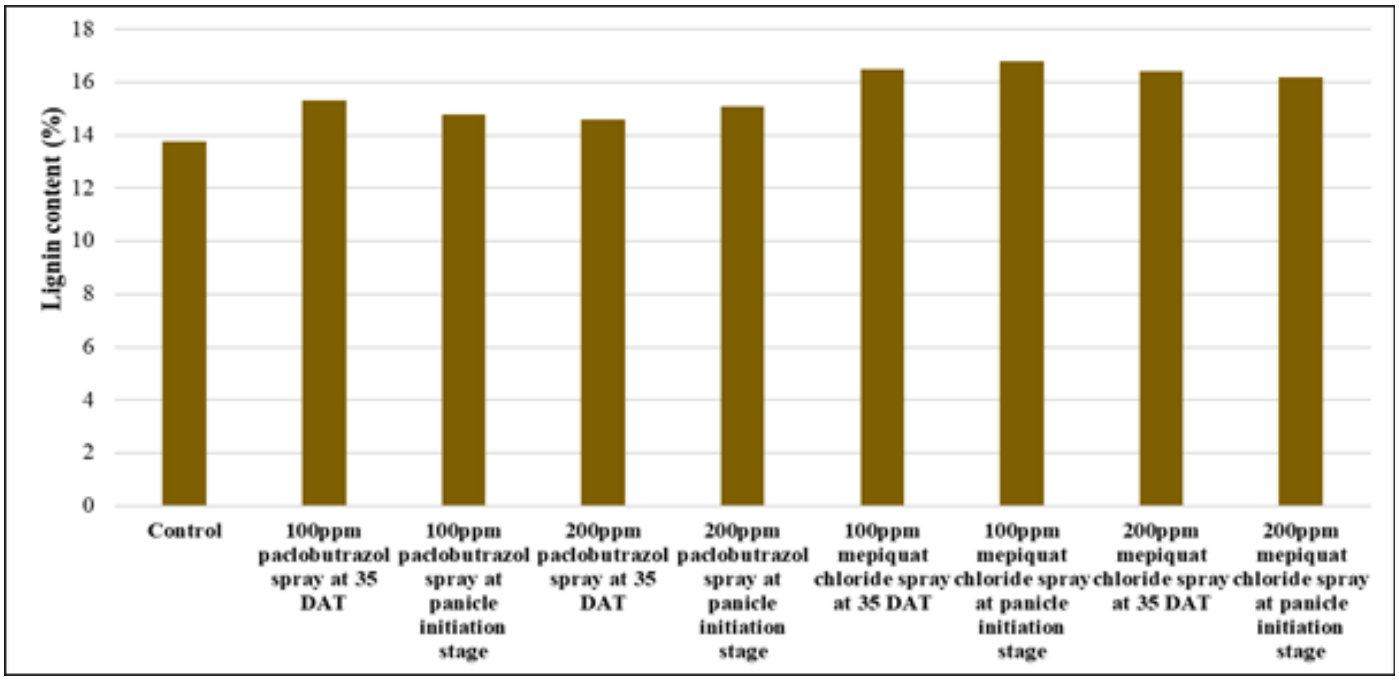

Figure 3: Effect of paclobutrazol and mepiquat chloride on Lignin content of the stem (%)

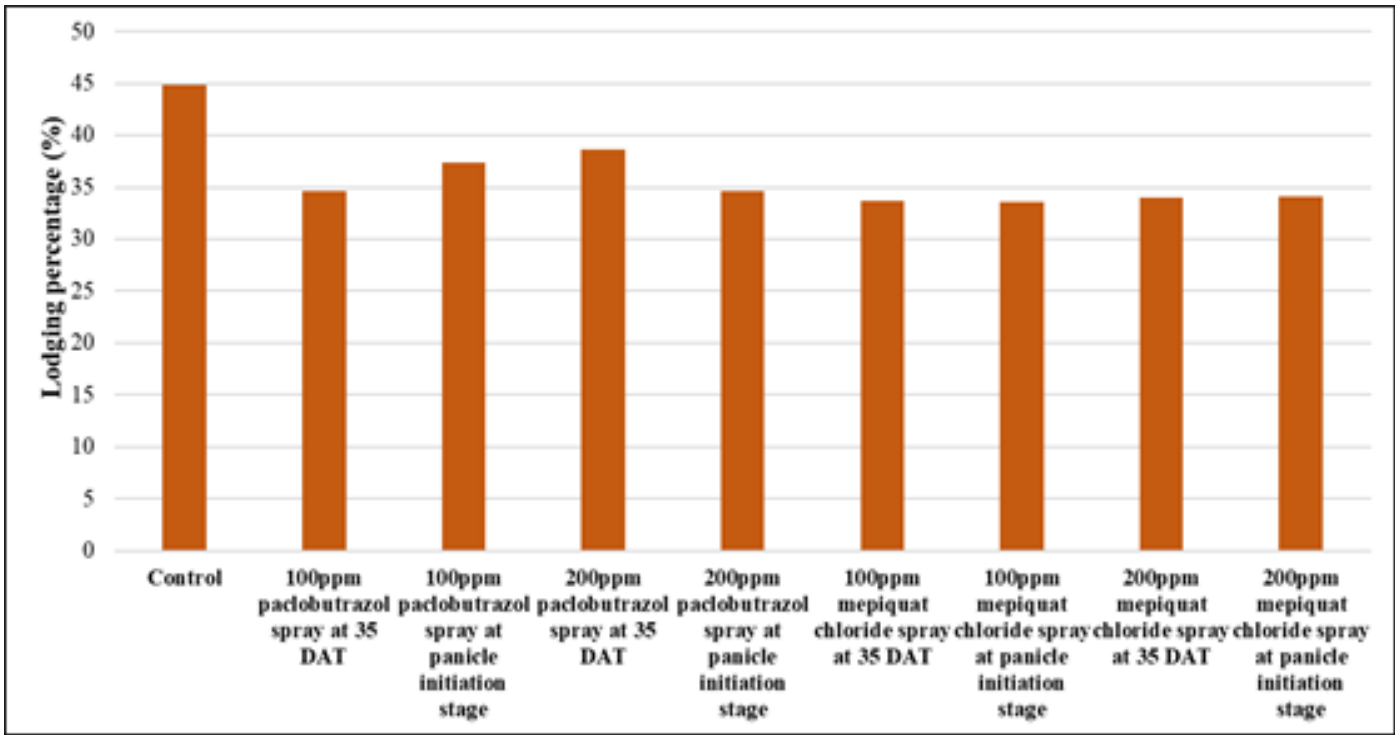

Figure 4: Effect of paclobutrazol and mepiquat chloride on Lodging percentage (%)

which provides resistance against lodging, and these results are following the finding of [7] who reported that exogenous application of paclobutrazol in wheat increased the lignin deposition and the activities of lignin biosynthesis enzymes, thus improved the lodging tolerance. Similar results were also reported with mepiquat chloride application in maize by [16].

Lodging percentage

Lodging percentage is significantly influenced by the foliar application of different concentrations of paclobutrazol and mepiquat chloride at different stages of crop growth and the results were presented in Table 4. The lodging percentage ranged between 33.60 to 44.86 per cent. Significant reduction in lodging percentage was noticed with the foliar application of 100 ppm MC spray at panicle initiation stage (T_7-33.60%) followed by 100 ppm MC spray at 35 DAT (T_6-33.72%), 200 ppm MC spray at 35 DAT (T_8-34.02%), 200 ppm MC spray at panicle initiation stage (T_9-34.16%), 100 ppm PBZ spray at 35 DAT (T_2-34.62%), 200 ppm PBZ spray at panicle initiation stage (T_5-34.64%) and 100 ppm PBZ spray at panicle initiation stage (T_3-37.40%) and these were found on par with one another in influencing the lodging percentage. The highest percentage of lodging was observed in the control (T_1-44.86%).

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In the present study, foliar application of paclobutrazol and mepiquat chloride decreased the lodging percentage when compared to control, might be due to higher mechanical strength in the culm which is the combination effect of higher amount of lignin, cellulose and the compaction of cells in culm which in turn gives lodging resistance. Similar results were also reported by [24-25] in maize who stated that the stalk bending strength, stem diameter, and lignin accumulation resulting in strong lodging resistance in maize with mepiquat chloride application.

CONCLUSION

In the present study plant growth regulators such as paclobutrazol and mepiquat chloride were used to estimate the lodging resistance, plant height, culm strength and lignin content in rice (*Oryza sativa* L.)." The foliar application of 100 ppm mepiquat chloride spray at panicle initiation stage followed by 100 ppm mepiquat chloride spray at 35 DAT, 200 ppm mepiquat chloride spray at 35 DAT and 200 ppm mepiquat chloride spray at panicle initiation stage showed beneficial effect on reducing the lodging percentage and plant height. The foliar application of 100 ppm mepiquat chloride spray at panicle initiation stage followed by 100 ppm mepiquat chloride spray at 35 DAT, 200 ppm mepiquat chloride spray at 35 DAT and 200 ppm mepiquat chloride spray at panicle initiation stage showed significantly higher lignin content and culm strength.

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