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Amelioration of herbicide stress with plant growth regulators and nutrients in transplanted rice

S. Mohapatra*, S.K.Tripathy and B.R Nayak

Regional Research and Technology Transfer Station, Orissa University of Agriculture and Technology, Chiplima, Sambalpur, Odisha 768 025

Email: sanjukta.mohapatra34@gmail.com

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ABSTRACT

Foliar application of two plant growth regulators (PGR)-brassinolide at 0.5 ppm, gibberellic acid at 10 ppm and one complex fertilizer NPK 19:19:19 at 1% concentration were tested alone as well as in combination with control (double dose of fenoxaprop-ethyl) and absolute control (normal dose of fenoxaprop-ethyl) against herbicide stress to rice during *Kharif* 2015 and 2016. The treatments were given 5 days after application of fenoxaprop-ethyl as foliar spray. Among the PGRs and nutrients, tank mix application of brassinolide at 0.5 ppm + NPK 19:19:19 at 1% recorded the lowest incidence of phytotoxicity (1.2) at 30 days after application and gave the highest grain yield (6.12 t/ha), net returns (` 49,431/ha) and benefit : cost ratio (1.32). Grain yield was more (5.92 to 6.12 t/ha) in brassinolide treated plot than that of gibberellic acid (5.81 to 5.83 t/ha) indicating more effectiveness of brassinolide than gibberellic acid in mitigating herbicide stress. Use of plant growth regulator and nutrient prevented 25.9% yield loss due to herbicide stress in rice.

INTRODUCTION

Biotic stress caused by improper use of herbicide is the prime factor in creating devastating tragedies in rice (*Oryza sativa* L.), which sometimes is anticipated to be incidence of unidentified disease or physiological disorder. It is increasing in current years due to wide use of herbicides without its technical knowledge of dosage, poor water management and time of application. Under severe herbicide stress due to over dosage, there might be total failure of crop. The discovery of herbicide antidotes revealed new opportunities for solving the phytotoxic effect caused by improper use of herbicide. The use of various antidotes, antagonists, protectors etc. have enabled induced crop tolerance to the specific herbicides.

Many scientific reports proposed the positive effect of plant growth regulators and nutrients on growth of stressed plant due to herbicide over dose. Brassinolides at 1 ppm can reduce the phytotoxicity of rice seedlings affected by 2,4-D and butachlor (Choi *et al*. 1990). Brassinosteroids affect the mechanical properties of cell wall during cell elongation. It is also observed from brassinosteroids deficient and insensitive mutants that brassinosteroids are essential for cell elongation and also plays role in vascular differentiation, senescence, fertility, leaf morphology and light–dark regulation development (Clouse 2011).

Gibberellins are plant hormones that participate in regulation of many growth and developmental processes in various plants (Emongor 2007) and these are especially important in regulating stem elongation (Schomburg *et al*. 2003). Role of gibberellic acid (GA) for mitigating herbicide toxicity in crop plants has been established. Treatment of *Vicia faba* with either gibberellic acid (GA_3 at 50 ppm) alone or in mixture with cytokinin reversed the phytotoxic effect of glyphosate herbicide. (Shaban *et al*. 1987). Foliar nutrient solutions containing N, P, K, Mn, Zn, B and Mo resulted in partial recovery of the negative herbicide effects on photosynthetic rate in *Zea mays*, *Triticum aestivum* and *Glycine max* under field condition (Haley 2017). The present study was designed to study the effect of brassinolide, gibberellic acid and nutrient in mitigating herbicide stress of rice plant caused due to over dosage of fenoxaprop-ethyl, a widely used new generation herbicide of this region.

MATERIALS AND METHODS

A field experiment was conducted at Regional Research and Technology Transfer Station, Chiplima, Odisha, during *Kharif* 2015 and 2016. The soil of the experimental field was sandy clay loam with pH 6.6, organic carbon 0.43% and available N ($KMnO_4$ method), P (Olsen) and K (NH_4OHC method) content of 268, 13.4 and 132 kg/ha, respectively. The experiment was laid out using randomized block design (RBD). The treatments were replicated three times. The details of treatments are absolute control fenoxaprop-ethyl at 56.2 g/ha at 20 DAT, control fenoxaprop-ethyl at 112.4 g/ha at 20 DAT, gibberellic acid at 10 ppm 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT, gibberellic acid at 10 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ ha at 20 DAT, NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT, brassinolide at 0.5 ppm 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT, brassinolide at 0.5 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT.

Twenty five days old seedlings of variety '*MTU 1001*' were transplanted in plot size of 5 x 5 m with a spacing of 20 x 10 cm at the rate of two seedlings per hill. A common fertilizer dose of 80, 40 and 40 kg of N, P_2O_5 and K_2O/ha, respectively was applied to the crop. Full dose of P_2O_5 and K_2O and half dose of N were applied as basal and remaining N was top-dressed in 2 equal splits, at maximum tillering and panicle-initiation stages of the crop. Plant protection measures and irrigation were provided as and when required. The experiment included 7 treatments including sole and combined application of two growth regulators and one nutrient along with one absolute control, *i.e.* normal dose of fenoxaprop-ethyl and control, *i.e.* double dose of fenoxaprop-ethyl. Foliar spray of fenoxaprop-ethyl was made at 20 days after transplanting (DAT) with a knapsack sprayer fitted with flood jet nozzle. Growth hormone and nutrient were applied at 5 days after application (DAA) of fenoxaprop-ethyl after appearance of visual symptoms of herbicide stress. Crop injury was recorded on 5 and 30 DAA of herbicide by visual assessment based on 1-10 injury scale where 1 was no crop injury and 10 was complete mortality of rice plant. The recovery of crop was recorded 30 DAA of plant growth regulator and nutrient.

As a lab study, emulsion stability test was conducted. Recommended spray concentration of growth regulator and nutrient combinations were taken in a beaker and 30 ml of hard water was added and stirred with a glass rod at the rate of 4 revolutions per second. Then transferred to a 100 ml graduated cylinder and volume was made up to the mark using standard hard water. The cylinder was kept in a thermostat at 30 +/- 1 ^{0}C for 30 min. After the expiry of specified time the volume of sediment at the bottom and creamy material at the top were noted. Creamy material should not exceed ISI limit of 2 ml (Deepa and Jayakumar 2008).

RESULTS AND DISCUSSION

Laboratory study

No sediment at bottom and creamy material was found in any of the combinations. Hence it confirms that the growth hormone like brassinolide or gibberellic acid can be safely used in combination with nutrient like NPK (19:19:19).

Crop injury

Visual initial injury following double dose application of fenoxaprop-ethyl was 4 with all the treatments resulting in greater injury than fenoxaprop-ethyl applied at normal dose (**Table 1**). Foliar application of nutrient did not reverse the fenoxaprop-ethyl induced phytotoxicity in rice. Crop injury was primarily in the form of death of primary shoot and reduced overall growth of plants. Among the plant growth regulator and nutrient treatments, the maximum plant height of 66.5 cm was recorded at 30 DAA by brassinolide + NPK 19:19:19 application followed by sole- brassinolide (64.9 cm) and gibberellic acid and its combination with nutrient (56.9 to 58.1 cm). There was no significant difference in plant height of treatment receiving normal dose of herbicide absolute control fenoxaprop-ethyl at 56.2 g/ha at 20 DAT without any plant growth regulator and double dose of herbicide with plant growth regulator indicating corrective effect of PGR in neutralizing herbicide stress.

Effect on crop

The significant increase in plant height was observed in all the treatment combinations due to exogenous application of growth regulator and nutrient. Treatment brassinolide at 0.5 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT (112 cm) was the tallest followed by T6 (110.4 cm), which was at par with absolute control fenoxaprop-ethyl at 56.2 g/ha at 20 DAT, (113.5 cm), *i.e.* normal dose of application of fenoxaprop-ethyl herbicide. The increase in plant height is due to application of plant hormones which promoted vegetative growth by active cell division, cell enlargement and cell elongation and thus helped in

Table 1. Rice response to plant growth regulator (PGR) and nutrient (Nu) against herbicide stress (pooled data of 2015 and 2016)

Treatment	Crop injury		Plant height (cm)	
	Initial (5 DAA of herbicide)	30 DAA of PGR and Nu	Initial (5 DAA of herbicide)	30 DAA of PGR and Nu
Absolute control fenoxaprop-ethyl at 56.2 g/ha at 20 DAT	1	1	31.6	68.2
Control (fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	4	4	27.1	50.8
Gibberellic acid at 10 ppm 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	4	1.3	27.1	56.9
Gibberellic acid at 10 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	4	1.2	27.0	58.1
NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	4	2.3	27.1	55.9
Brassinolide at 0.5 ppm 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	4	1.3	27.0	64.9
Brassinolide at 0.5 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	4	1.2	27.1	66.5
LSD (p=0.05)				2.54

DAA – Days after application, Crop injury is measured on a Scale 1-10, 1= No crop injury and 10 = complete mortality of rice plant.

Table 2. Effect of treatments on yield attributes, yield and economics of rice (pooled data of 2015 and 2016)

Treatment	Plant height (cm)	Tillers/ m^2	Panicle Length (cm)	Spikelet/ panicle	Fertile spikelet /panicle	Test Wt. (g)	Grain yield (t/ha)	Straw yield (t/ha)	Gross returns ($x10^3$ `/ha)	Cost of cultivation ($x10^3$ `/ha)	Net return ($x10^3$ `/ha)	Benefit: cost ratio
Absolute control fenoxaprop-ethyl at 56.2 g/ha at 20 DAT	113.5	445	23.8	149	130	23.7	6.45	7.92	91.58	35.50	56.08	1.58
Control (fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	96.3	349	20.8	103	75	23.2	4.78	5.2	67.81	36.70	31.11	0.85
Gibberellic acid at 10 ppm 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	102.4	418	23.77	139	109	23.6	5.81	6.7	82.46	36.38	46.07	1.27
Gibberellic acid at 10 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	103.6	438	22.5	141	114	23.4	5.83	7.1	82.77	36.82	45.95	1.25
NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	101.4	390	23.3	122	91	23.5	4.94	6.5	70.17	36.13	34.04	0.94
Brassinolide at 0.5 ppm 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	110.4	440	23.8	146	125	23.6	5.92	7.3	84.06	37.05	47.01	1.27
Brassinolide at 0.5 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT	112	442	23.8	147	127	23.7	6.12	7.8	86.92	37.48	49.43	1.32
LSD (p=0.05)	3.39	106.6	NS	28.18	18.61	NS	0.66	1.85				

Input price (`/kg) rice seed, 14.1; straw, 8: urea, 5.52; di ammonium phosphate, 24.45; muriate of potash, 17.44; fenoxaprop-ethyl-ethyl 9 EC, ` 400/250 ml; brassinolide 0.1% SL, ` 135/25 ml; gibberlic acid ` 62/g; NPK 19:19:19 ` 44/kg.

improving growth characteristics and also facilitated reproductive growth (Pareek *et al.* 2000).

The effective tillers per plant are closely associated with high grain yield. A perusal of data (**Table 2**) revealed that there was significant increase in effective tillers/m^2 ranging between 390 to 442 and the highest being recorded with brassinolide at 0.5 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT (442) followed by T6 (440), gibberellic acid at 10 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT (438) and gibberellic acid at 10 ppm 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT (418).

Regulating total spikelets is necessary to gain high rice yields. The number of spikelet/panicle ranged from 103 to 149. All the treatment combination showed significant increase in spikelet number except only nutrient treated plot. The number of spikelets/panicle was the highest with application of brassinolide + NPK (147). More number of fertile spikelets is closely associated with higher yield/plant resulting in higher productivity. The range of fertile spikelets/panicle varied from 75 to 130. Among them, brassinolide at 0.5 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT (127) had highest estimate followed by brassinolide at 0.5 ppm 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT (125). Similar findings in rice were also reported by Takematsu and Takeuchi (1989).

The treatment brassinolide + NPK (brassinolide at 0.5 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT) gave significantly higher grain yield (6.12 t/ha) causing

28% increase of control followed by brassinolide (5.92 t/ha), gibberellic acid + NPK (5.83 t/ha and gibberellic acid (5.81 t/ha). The increase in yield with various plant growth regulators might be due to increased yield attributes, which in turn resulted from effective translocation of photosynthates. The higher yield might be due to increase in mobilization of reserve food material to the developing sink by plant growth regulator through increased hydrolyzing and oxidizing enzyme activities. (Hitoshi *et al.* 2015)

Rice yield was the highest (6.45 t/ha) in the plot of absolute control (absolute control fenoxaprop-ethyl at 56.2 g/ha at 20 DAT) without any crop injury and similar yield of 6.12 t/ha (brassinolide at 0.5 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT) was recorded when applied with brassinolide and nutrient (**Table 2**). No significant difference in yield between these two treatments indicates reversal of stress caused by over dose of fenoxaprop--ethyl.

Economics

Treatment without herbicide toxicity (absolute control fenoxaprop-ethyl at 56.2 g/ha at 20 DAT) registered the highest grain yield (6.45 t/ha) and monetary returns (` 56,079/ha) than sole and tank mix application of plant growth regulator and nutrient mixtures. The sole nutrient applied plot (NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT) recorded less net returns (` 34,039/ha) and benefit: cost ratio (0.94), than sole PGA applied plots but was higher than the control plot (0.85) which shows application of PGR is more effective in reducing the loss than nutrient mixture. The plant growth regulator Brassinolide in mixed application with nutrient recorded higher monetary returns than its sole application as well as all other treatments for the stressed plants (**Table 2**). Among the herbicide stressed plot (gibberellic acid at 10 ppm 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT to brassinolide at 0.5 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT), plant growth regulator, brassinolide + NPK 19:19:19 (brassinolide at 0.5 ppm + NPK 19:19:19 (1%) 5 DAA of fenoxaprop-ethyl at 112.4 g/ha at 20 DAT) gave the maximum net returns (` 49,431/ha) and benefit : cost ratio (1.32) followed by brassinolide alone owing to quick recovery from stress and higher grain yield as compared to other treatments.

It can be concluded that brassinolide and gibberellic acid can be safely tank mixed with NPK 19:19:19. Foliar spray of brassinolide 0.5 ppm along with 1% NPK aqueous solution can reduce the phyto toxicity caused by over-dose of fenoxaprop-ethyl in rice.

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