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Growth Regulator and Nitrogen Fertilization Effects on Performance and Nitrogen-Use Efficiency of Tall and Dwarf Varieties of Rice (*Oryza sativa* L.)

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Abstract: Little information is available on control of lodging, particularly when early-maturing, high-yielding, tall rice (*Oryza sativa* L.) varieties are heavily fertilized with nitrogen (N). Two plant growth regulators, PGRs-chlormequat (applied at 30 mg pot^{-1}) and ancymidol (applied at 1.5 mg pot^{-1}) were tested on two rice cultivars (early maturing, tall 0S-6 and late maturing, dwarf IR-5) after treatment to three N rates (0, 22.5 and 45 mg N kg^{-1}) in an effort to evaluate PGRs and N effects on rice crop performance and N-use efficiency (NUE). Significant ($p<0.5$) responses to N-treatment were obtained with respect to plant height and tiller count. Number of fertile tillers increased, resulting in higher grain yields. At crop half (1/2) -life, N effect was generally insignificant on plant height but IR5 tillers increased while PGRs reduced height of both rice varieties but failed to dwarf them at maturity (full life). At full life, N application increased numbers of tillers, parnicles, spikelets and grains as well as weights of panicles, straw and grains; OS6 plants were taller than the control while IR5 plant heights were not affected just as panicle lengths remained the same. The NUE by OS6 plants increased with increase in N application rate but reduced in IR5 plants. Only OS6 had its grain yield increased by the PGRs. Increased plant heights caused more lodging in the early maturing variety (OS-6) despite the application of the PGRs, implying the inadequacy of PGRs rates sprayed on the plants while PGRs/N interactions were insignificant.

Key words: Ancymidol, chlormequat, nitrogen fertilization, *Oryza sativa*, dwarf and tall varieties, N-use efficiency

INTRODUCTION

Agricultural production can be associated with the extent to which farmers are able to effectively and suitably combine the production factors. One of the most critical aspects of optimizing crop growth is plant nutrition (USDA, 2002; Aiyelaagbe *et al*., 2005) and nitrogen (N) is the nutrient element that most frequently limit crop yields (Bockman *et al*., 1990). Nitrogen increases the concentration and uptake of other nutrients (e.g., Zn, Fe, Mn and Cu) by rice (Lakshmanan *et al*., 2005). Adequate supply of the element is crucial for successful cropping but its over abundance in soil can cause excessive and undesirable vegetative shoot growth with increase in plant height. It can be difficult to fertilize to the extent that growth of only a crop plant part is controlled without adversely affecting growth of another part or the yield.

Fertilization can disproportionately increase growth of specific plant parts so that their ratios are affected (Robinson *et al*., 1992). According to Salisbury and Ross (1992), Raven *et al.* (1999) and White (2003), diseased (fungus-infected) rice plants from which gibberellins (GA) were first isolated, grew excessively tall and were spindly, pale and prone to lodging. GA is capable of stimulating cell division and elongation of stem, leaf, flower stalk and fruit growth; they can also inhibit the development of lateral buds (Salisbury and Ross, 1992; Kappers *et al*., 1997). Most plant growth regulators (PGRs) inhibit some steps in GA synthesis (White, 2003; Harden *et al*., 2004). The retardants specifically exert their influence by inhibiting cell division in the sub-apical zones of the shoot apex and subsequent cell enlargement, resulting in reduced stem elongation. These growth retardants (often called anti-gibberellins) control shoot growth by inhibiting the production of GA, which are responsible for cell elongation of shoots and leaves (Franke and Hassanein, 1996; Barrett, 2001; Barrett *et al*., 2004).

Seedling vigor could be critical when competition for light, nutrients, air and water becomes strong. Seedlings with vigorous growth pattern can compete successfully under stress, influencing stand establishment and ultimately grain yield (Biswas *et al*., 2000). According to Miller and Tworkoski (2003), the desire to regulate excessive vegetative (particularly the shoot) growth is not new as ancient gardeners and modern growers have used scoring and girdling, dwarfing rootstocks, pruning and/or limb positioning techniques to reduce or regulate growth. The need to regulate growth is based on several factors; of significance is the relationship between growths and yields since excessive vegetative growth reduces flowering and ultimately yield (White, 2003; Cavins *et al*., 2003). While a certain amount of vegetative/height growth is necessary to maintain vigor and a healthy canopy with an adequate leaf surface, the ultimate goal of the grower is to produce grains, not leaves or the other vegetative parts. The need to manage excess vigor in crops is thus associated with improved production efficiency and produce quality while excess vigor has a price and ultimately it is necessary to reduce the negative economic impact that excess vegetative growth has on crop yield (Forshey and Elfving, 1989; Tayama and Carver, 1990). This drives our pursuit to regulate growth.

Lodging in cereals (rice in particular) that are heavily fertilized with N under intensive crop production has been one of the most serious threats to the sustainability of their production (USDA, 2002). Although, rice is an important cereal crop, the use of plant growth retardants in its production is not as common as for barley, oats and wheat. Besides the dwarfing effect, reduction of lodging and yield increases of heavily N-fertilized rice plants, there may be other effects. Growth regulators are effective (at low concentrations) in inhibiting growth independently of their calorie value or essential element. Starman *et al*. (2000) observed that Uniconazole at 20 mg L^{-1} was optimal for *Argyranthemum* (variety 'Sugar Baby') while results of Miller and Tworkoski (2003) indicate that 40 mg L^{-1} was optimal for production of *Argyranthemum* (variety 'Comet Pink'), suggesting that the response to Uniconazole in *Argyranthemum* may vary with cultivars.

Evidently, the hypothesis that growth retardants could assist in minimizing height growth and possibly check lodging in N-fertilized rice plants needs to be dissected. Ancymidol, α-cyclopropyl-α-(4-methoxyphenyl)-5-pyrimidinemethanol ($C_{15}H_{16}N_2O_2$) permits control over plant height. Jarret (1997) reported that heavier applications of 'A-rest' (a trade name for ancymidol) produced more compact plants, while lighter applications produced plants nearer to normal growth habits. Chlormequat (2-chloro-N, N, N-trimethylethanaminium chloride) ($C_5H_{13}ClN$) (with trade name 'Cycocel' is another of the earlier GA biosynthesis inhibitors to exhibit growth retarding effects in plants (Davis and Curry, 1991). The objective set up for the present work was to investigate the influence of the growth retardants (Ancymidol and Chlormequat) and N-fertilization on rice. In achieving this, both the performance and N-use efficiency by tall (OS-6) and dwarf (IR-5) rice plants treated to various N levels and sprayed (using a small hand spraying gun) with Ancymidol, Clormequat and their mixture would be evaluated. This is part of the ultimate effort aimed at reducing lodging and hence increasing yields on farmers' plots so as to assist in the feeding of the ever-increasing human population. It is also hoped that such considerations would benefit research workers in rice research stations all over the world.

MATERIALS AND METHODS

The investigation involved a pot experiment conducted at the Agronomy Department, University of Ibadan (Latitude 7° 26'N, Longitude 3° 54'E, 200 m above sea level) in Nigeria. A N-deficient, highly drained loamy sand grouped as Oshun series (Smyth and Montgomery, 1962) under Typic Paleudalf (Soil Survey Staff, 2003) was collected for the experiment from Ibadan Polytechnic (South campus), Nigeria. It was air-dried, sieved (<2 mm) and 10 kg weighed into each of 72 plastic buckets arranged on benches. The pre-cropping soil samples (taken 0-15 cm depth) were analyzed for the parameters given in Table 1 by the standard procedures described by Juo (1981).

Planting of OS-6 and IR-5 rice cultivars (36 buckets for each of the cultivars) was done with 4 pre-germinated seeds per bucket. Fertilizer application (19.5 mg N, 30 mg P, 38 mg K basal dressings in addition to 0, 22.5 and 45 mg kg^{-1} N-treatments) was done using NH_4NO_3 and KH_2PO_4. Manganese chloride, Boric chloride, Ferrous sulphate, Cupric sulphate and Zinc acetate were also applied as sources of Mn, B, Fe, Cu and Zn, respectively (each at 2.5 mg kg^{-1}). 'A-Rest' (Ancymidol) at 1.5 mg pot^{-1} and Cycocel (Chlormequat, CCC) at 30 mg pot^{-1} were sprayed using a small hand spraying gun after thinning to one plant per pot after 2 weeks of growth. Apart from control plants that were not sprayed with the growth regulators, treatment plants were sprayed with Ancymidol or Clormequat or Ancymidol+Clormequat. There was no rainfall for up to 3 days after spraying.

A completely randomized design involving 2 factors (3 N-levels and 4 growth regulator treatment combinations) was adopted. As such, there were 12 treatment combinations (each replicated three times) for each of the 2 cultivars. A fishing net was used to cover the entire experimental area as from the booting stage so as to guide against damages by birds. Weekly measurements of plant heights and tiller counts were done. The tall, early maturing OS-6 plants were harvested after 110 days of growth. The dwarf, late maturing IR-5 plants attained full maturity and was harvested after 160 days of growth. In both cases, the panicles, straws and roots were separated using a sharp knife, weighed immediately and contained in separate envelopes. Dry weights were taken after drying in an oven at 70°C for 2 days.

The effectiveness of the growth regulators (EGR) was estimated as increase or decrease of specific growth or yield parameter per unit growth regulator applied while nitrogen use efficiency (NUE) was estimated as yield produced (Y_{mg}) per unit of Nutrient supplied N_f) and expressed as Y_{mg}/N_{mf} (Moll *et al*., 1982).

All statistical analyses were performed using the Statistical Analysis System (SAS, 1985).

RESULTS AND DISCUSSION

The physico-chemical properties of the soil used are given in Table 1. The pH value of 5.8 and total acidity (Al + H) of 0.21 cmol kg^{-1} indicate that the soil was slightly less acidic than the minimum level (Sanchez, 1996) at which soil acidity problems can be expected in rice production. The high organic carbon content reflects the fact that the location lies within the rainforest belt. The soil was highly drained and as a result of continuous leaching, N, P and K were present in amounts that would not normally support good crop growth.

Visual observation after 10 weeks of growth

- Leaf color could not be used as an indicator for the effectiveness of the various N-levels. Apart from 45 mg N kg^{-1} treated plants, most leaves were yellow, indicating general insufficiency of N. In order to guide against retardation of growth, further N-basal dressing (19.5 mg N kg^{-1}) was done.
- Ancymidol treated plants were the shortest while chlormequat (CCC) treated ones were even taller than control plants, indicating the latter's stimulatory rather than inhibitory effect at the rate (30 mg pot^{-1}) applied. This is further confirmed by the fact that the combined application of the two regulators led to plants taller than ancymidol treated ones.
- Ancymidol treatment produced plants with the largest number of tillers (and hence greatest quantity of biomass) though not statistically different from that of ancymidol/CCC treated plants.
- With 22.5 mg N kg^{-1} inputs, plants not sprayed with the growth regulators were taller and bigger than ancymidol treated ones while chlormequat (CCC) and Ancymidol/CCC treated plants were even taller.

Table 1: Physical and chemical properties of the soil used

Soil Variables	Values
O.C (g kg^{-1})	15.00
Total N (g kg^{-})	0.60
Bray-1-P (mg kg^{-1})	3.35
Exchangeable cations (cmol kg^{-1} soil)	
K	0.09
Ca	1.73
Mg	0.26
Na	0.15
Mn	0.08
Al + H (cmol kg^{-1})	0.21
pH (1:1 Soil:H_2O)	5.8
Sand (g kg^{-1})	660
Silt (g kg^{-1})	130
Clay (g kg^{-1})	210
Textural class	Loamy Sand

- Under high N-fertilization (45 mg N kg^{-1}), plants not treated with growth regulator as well as CCC treated ones were taller than ancymidol treated ones. The CCC-treated plants were, however, shorter than the untreated (control) plants.
- The combined effects of CCC and ancymidol were similar to that of ancymidol when applied alone in terms of plant height. The number of tillers was, however, more in the case of ancymidol and ancymidol/CCC treatments than for both untreated and CCC-applied plants.

Confirmation of visual observation with experimental data

Effects of nitrogen levels on rice cultivars: The influences of N-levels on the rice varieties in respect of 9 growth parameters (plant heights, tillering, panicle number, spikelet and grain numbers, straw, panicle and grain weights as well as panicle lengths) are shown in Table 2 and Fig. 1. Except for panicle lengths, the general trend was a sharp response to 22.5 mg kg^{-1} followed either by further sharp increases or decreases in response to 45 mg N kg^{-1}. It was abundantly clear that the 22.5 mg N kg^{-1} treatment was better than the control. The height and panicle weights of OS-6 rice cultivar increased with increase in N application levels while for IR-5 there were decreases after the 22.5 mg N kg^{-1}. The response of the 2 cultivars to N-levels were essentially the same in respect of numbers of tillers, panicle and straw yields and characterized by further positive increases after the 22.5 mg N kg^{-1}-treatment level. Thus, the respective average numbers of tillers for N-0, N-22.5 and N-45 were 10.00, 12.33 and 15.67 in the case of OS-6 rice cultivar. The corresponding values for IR-5 are 22.67, 27.33 and 40.00. The increased numbers of tillers as N-level increased led to corresponding increases in panicle numbers at full-life.

The non-similarity of response to N by the cultivars in respect of grain and spikelet numbers as well as grain and panicle weights is attributable to bird attack of OS-6

Table 2: Significance of F values derived from analysis of variance (ANOVA) for growth, yield and yield component parameters measured on two rice genotypes (OS6 and IR5) at three N levels and four growth regulator treatment combinations

	Sources of variation											
	Nitrogen-fertilization, NF		Growth regulator, GR Ancymidol, A		Chlormequat, C		NF/A		NF/GR interaction NF/C		NF/AC	
Growth and yield parameters	OS-6	IR-5	OS-6	IR-5	OS-6	IR-5	OS-6	IR-5	OS-6	IR-5	OS-6	IR-5
At half life												
Plant height	ns	ns	**	**	**	**	ns	ns	ns	ns	ns	ns
Number of tillers	ns	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
At full life												
Plant height	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Number of tillers	**	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Number of panicles	**	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Panicle weight	**	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Number of grains	**	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Grain weight	**	**	**	ns	**	ns	ns	ns	ns	ns	ns	ns
Number of spikelets	**	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Pincle	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Straw weight	**	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns Not significant, ** Significant at 0.05

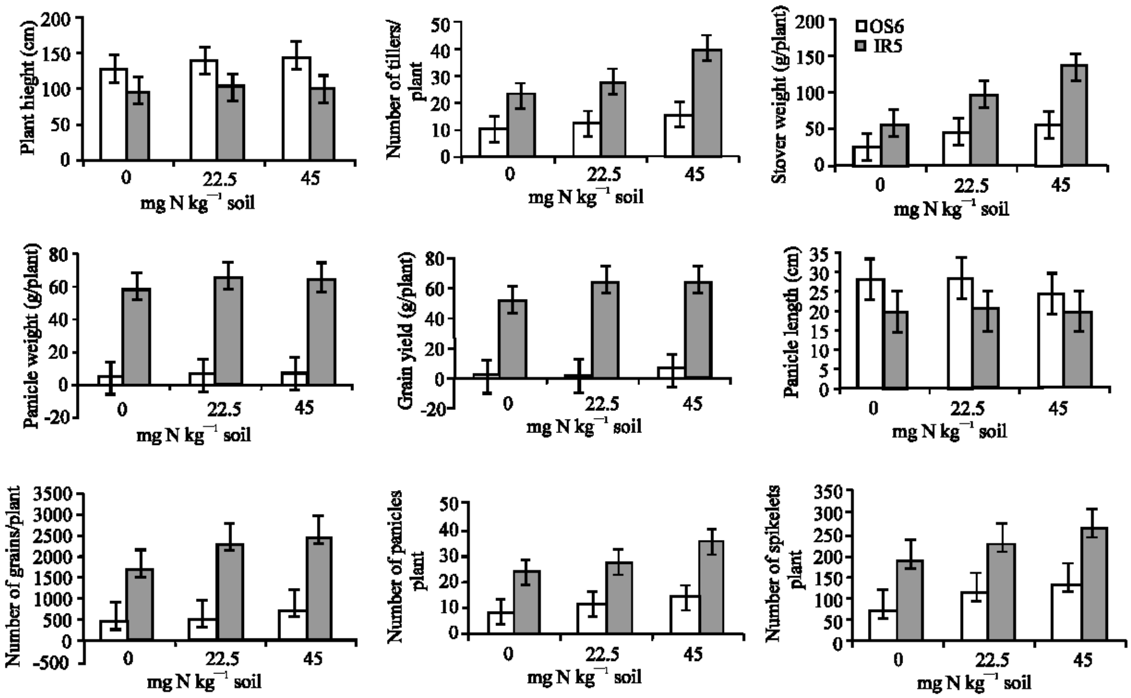

Fig. 1: Effect of nitrogen (N) levels on performance of OS6 and IR5 rice cultivars

cultivar at the milking stage. The lower numbers of grains and spikelets as well as lower grain, panicle and straw weights of OS-6 rice plants are as a result of their correspondingly lower tillering ability compared with IR-5 plants. The tall variety (OS-6) had higher average panicle lengths, which had no effect on grain yield. It is evident, therefore, that the response of rice plant to N fertilization depended on the parameter, rate of N applied, time after N application and cultivars.

The responses are to a large extent in accordance with the findings of Sharma and Prasad (1990). Unlike the findings of Aiyelaagbe *et al.* (2005) and Lakshmanan *et al.* (2005), however, the rice cultivars used in this study are not likely to respond to higher rates of N-fertilizers than 45 mg N kg^{-1}.

Influence of chlormequat and ancymidol on rice cultivars: Table 2 and Fig. 2 shows the response of the rice cultivars to the growth regulators. With regard to OS-6 plant heights, the growth retardants stimulated rather than inhibit growth. Ancymidol treated plants gave the highest stimulatory effects. Statistical analysis, however,

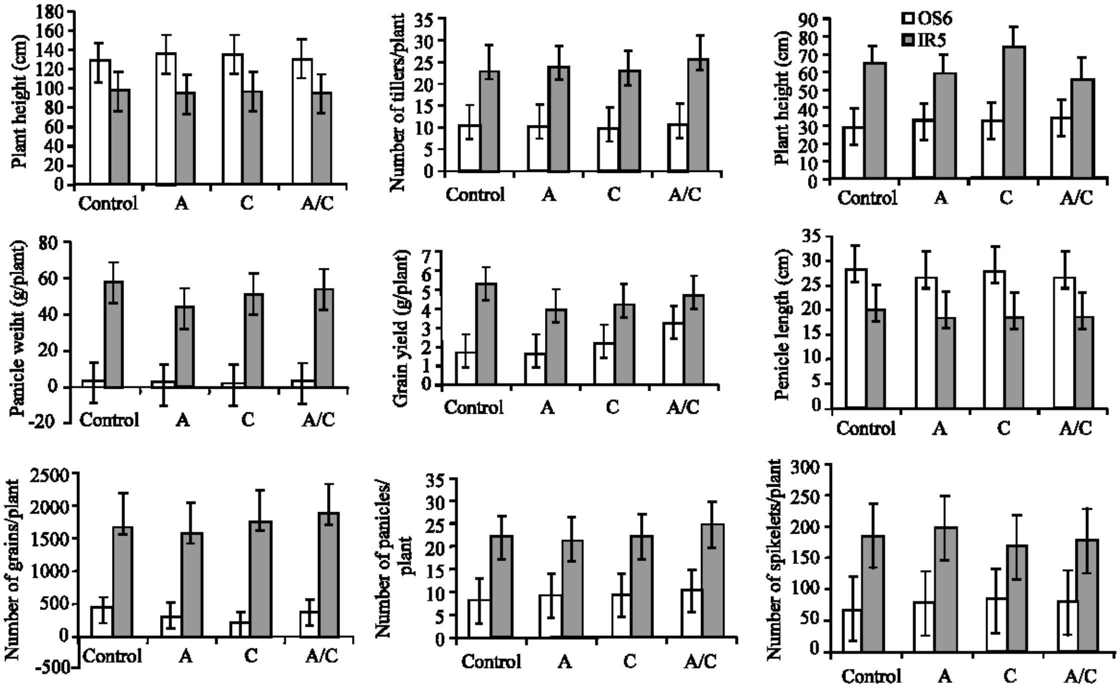

Fig. 2: Effects of ancymidol (A) and chlormequat (C) on the performance of OS6 and IR5 rice cultivars

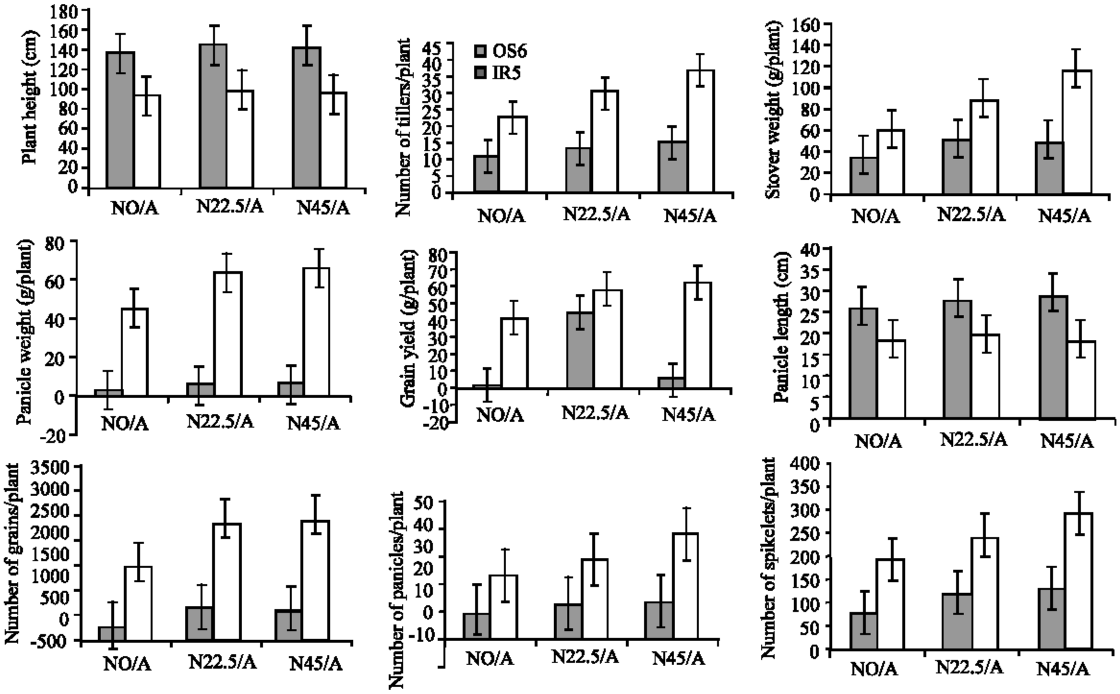

Fig. 3: Effect of nitrogen (N) levels (0, 22.5 and 45 mg kg^{-1}) on the performance of ancymidol (A) treated OS6 and IR5 rice cultivars

indicated that the growth substances significantly influenced only plant heights at half-life of the 2 cultivars and grain yields of OS-6. This is most probably due to low application rates.

Jarret (1997) noted that low rates of ancymidol failed to dwarf plants. Nevertheless, ancymidol decreased IR-5 plant heights while Chlormequat negated the retardation effect of ancymidol and combined application

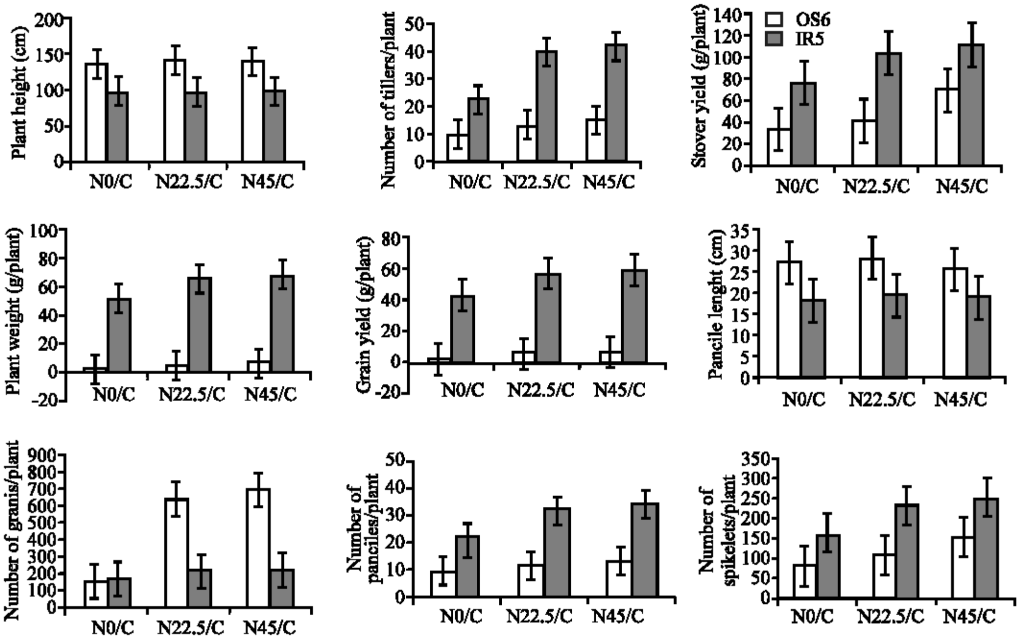

Fig. 4: Effect of nitrogen levels on the performance of chlormequat treated OS6 and IR5 rice cultivars

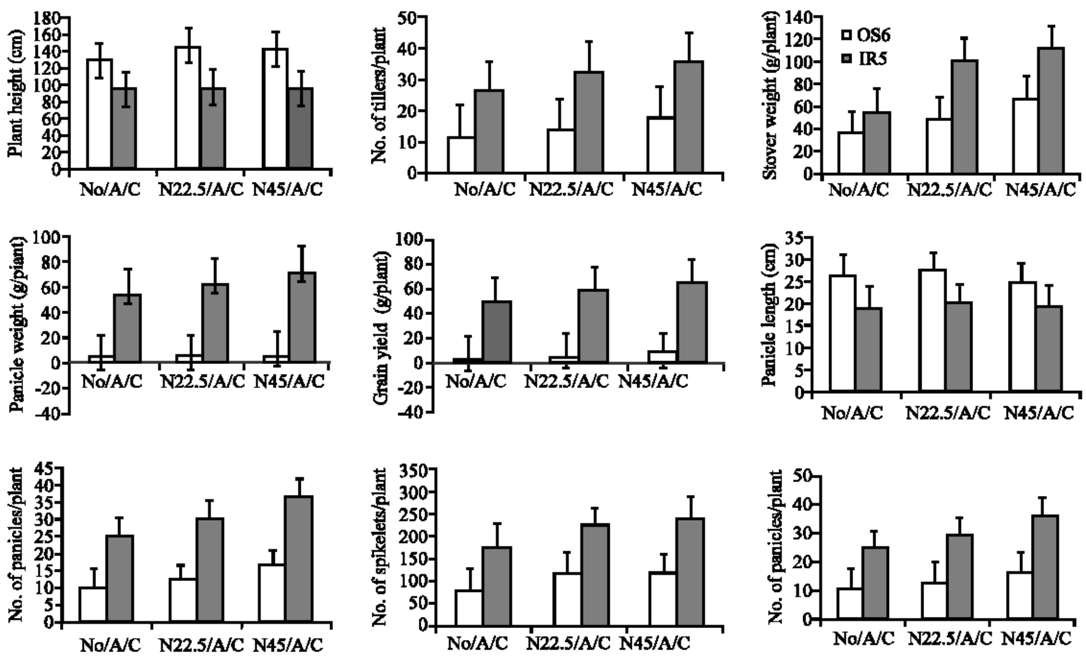

Fig. 5: Effect of nitrogen (N) levels on the performance of ancymidol (A) and chlormequat (C) treated OS6 and IR5 rice cultivars

of the two growth regulators while Chlormequat when applied alone had no effect. Straw yields were decreased by ancymidol and ancymidol/CCC treatments and increased by Chlormequat. The numbers of grains and panicles were decreased by ancymidol but increased by both CCC and CCC/ancymidol treatments while number of spikelets was highest in ancymidol treated plants and lowest in Chlormequat (CCC) treated plants.

Influence of nitrogen levels on ancymidol and/or chlormequat treated rice plants: The influence of N-levels when combined with ancymidol and/or chlormequat treatments on the rice cultivars are illustrated in Table 2 and Fig. 3-5. In all cases, the general trend is the enhancement of growth as N-levels increased regardless of the growth retardants. Thus, the numbers of tillers, grains, panicles and spikelets as well as straw, panicle and

Table 3: Percent change (increase or decrease) in growth attributes, yield parameters and nitrogen use efficiency of rice (Oryza sativa) under the influence of sole treatments of nitrogen and growth regulators (ancymidol, A and chlormequat, C)

Treatment	Plant height	Number of tillers	Stover weight	Panicle weight	Grain yield	Panicle length	Number of grains	Number of panicles	Number of spikelets	NUE (mg mg^{-1}) or EGR
N-levels (mg kg^{-1})										
	OS6				(%)					
0										0.35
22.5	8.8	22.0	76.1	40.6	38.1	0.7	10.0	37.5	60.0	0.47
45	13.9	54.0	123.9	81.3	228.6	-13.7	75.0	75.0	89.6	1.07
	IR5									
0										8.50
22.5	4.7	19.6	72.7	13.0	23.5	1.5	40.1	14.9	18.9	10.10
45	3.4	73.9	145.5	10.6	23.1	-1.0	49.2	48.9	40.5	9.70
Growth regulators										
	OS6									
Control										
A	6.9	0.0	17.9	-9.1	0.0	-5.4	-25.0	12.5	14.9	5.80
C	6.2	-5.1	15.7	-33.3	31.3	-1.9	-55.0	12.5	21.5	0.26
A/C	2.1	6.1	21.4	6.1	100.0	-4.8	-12.5	25.0	16.3	0.08
	IR5									
Control										
A	-2.1	4.9	-7.7	-22.1	-23.1	-7.6	-6.1	-4.1	7.1	-1.33
C	1.1	0.0	15.4	-8.8	-19.2	-8.1	6.1	-0.9	-8.2	0.03
A/C	-2.1	13.3	-13.1	-3.5	-9.6	-6.6	12.4	12.6	-3.3	-0.06

EGR-Effectiveness of growth regulator estimated as increase or decrease of specific growth or yield parameter per unit growth regulator applied; NUE-Nitrogen-use efficiency; N0, N22.5, N45-Nitrogen fertilizer levels in mg kg^{-1}; A, C, AC-sole and combined application of ancymidol (A) and/or chlormequat (C)

grain weights were all increased by increasing levels of N whether the plants were sprayed with the growth retardants or not. This lack of interaction between the two factors (N and growth regulators) was further reflected in the statistically insignificant effect of the growth regulators on the growth parameters.

There are, however, two major deviations to the trend described above. The first is in respect of plant heights. Thus, the OS-6 plant heights were less at 45 mg kg^{-1} than at 22.5 mg kg^{-1} regardless of the growth inhibitors while 22.5 mg kg^{-1} produced the shortest IR-5 plants. The second deviation was observed on the average panicle length. As in the case of plant heights, 22.5 mg kg^{-1} in combination with the growth regulators produced the longest panicles in both cultivars while 45 mg N kg^{-1} produced the smallest ones.

Miller and Tworkoski (2003) observed that maintenance of high fertilization level reduced the severity of leaf senescence and partially overcome the effects of Ancymidol on growth. White (2003) and Cavins *et al.* (2003) also observed interaction effect of added N and growth regulator on crop response parameters.

Effects of the treatment combinations on percent change in the growth attributes, yield and nitrogen use efficiency of rice and the effectiveness of the growth regulators: The influence of the treatments (N application levels and/or growth regulator type) on the performance of the rice cultivars were also defined in terms of % increases or decreases in the relevant parameters as well as the N use efficiency (NUE) by the plants and the effectiveness of the growth regulators (EGR) in dwarfing them. Except for panicle length all the parameters were positively affected by the N levels irrespective of the cultivar whereas the growth regulators had negative influence on majority of the parameters (Table 3).

This result conforms to the original expectation that the growth regulators would moderate the positive influence of the N fertilizer on height growth of the plants, thereby reducing lodging. Besides this, the need to regulate growth is based on the relationship between growth and yield. Excessive vegetative growth reduces flowering and ultimately yield (White, 2003; Cavins *et al.*, 2003).

The NUE increased as OS6 rice plants were increasingly supplied with N whereas there was a decline in the efficiency of IR5 plants to use N above the 22.5 mg kg^{-1} application level of the macronutrient. It is also evident from the data summarized in Table 3 that the effectiveness of the growth regulators was more pronounced on the tall (OS6) rice variety (0.08-5.8) than on the IR5 (-1.33 to 0.03). Miller and Tworkoski, (2003) indicated that the response to Uniconazole in *Argyranthemum* may vary by cultivar. Ancymidol was also portrayed as being more effective than CCC, which reduced the effectiveness of the two when sprayed simultaneously.

The NUE of the cultivars were generally improved by combined application of the growth regulators (Table 4) such that as N level increased, the NUE also increased irrespective of the growth regulator sprayed. On the other hand, the effectiveness of the growth regulators reduced

Table 4: Percent change (increase or decrease) in growth attributes, yield parameters, effectiveness of growth regulators and nitrogen use efficiency of rice (*Oryza sativa*) under the influence of combined treatments of nitrogen and the growth regulators (ancymidol, A and chlormequat, C)

Treatment	Plant height	Number of tillers	Stover weight	Panicle weight	Grain yield	Panicle length	Number of grains /plant	Number of panicles /plant	Number of Spikelets /plant	EGR	NUE mg mg^{-1}
					(%)						
	OS6										
N0/A											0.28
N22.5/A	5.9	28	48.5	63.3	2505.9	6.9	144.3	41.1	52.6	5.3	7.12
N45/A	4.8	49	51.5	96.7	194.1	11.5	138.6	44.4	68.4	0.2	0.78
	IR5										
N0/A											6.83
N22.5/A	4.8	33.3	43.3	40.9	42.7	8.7	56.7	23.9	26.3	3	9.4
N45/A	1.3	64.4	90	47.7	51.2	-0.5	62.7	63.7	52.6	0.04	9.61
	OS6										
N0/C											0.37
N22.5/C	4.3	36.1	28.1	140.9	177.3	2.9	295.1	23.9	33.8	3.9	0.98
N45/C	2.3	51.5	115.6	190.9	190.9	-5.5	332.1	42.4	88.8	0.1	0.99
	IR5										
N0/C											7
N22.5/C	-1.6	77.3	36.7	26.9	33.3	7.1	23.9	45.5	43.8	-1	8.99
N45/C	0.5	86.7	48.3	30.8	38.1	4.4	27.3	53.6	56.3	0.01	8.99
	OS6										
N0/A/C											0.52
N22.5/A/C	12.8	22.7	35.7	43.2	51.6	3.8	65.3	20	48.7	11	0.76
N45/A/C	11.3	59.1	88.6	62.2	167.7	-6.8	105.9	60	51.9	0.5	1.29
	IR5										
N0/A/C											8.18
N22.5/A/C	2.7	23.5	85.2	14.8	20.2	5.9	38.2	20.1	28.6	1.7	9.48
N45/A/C	1.1	34.6	103.7	33.3	32.4	3.2	29.4	44.6	37.1	0.03	10.08

EGR-Effectiveness of growth regulator estimated as increase or decrease of specific growth or yield parameter per unit growth regulator applied; N0, N22.5, N45-Nitrogen fertilizer levels in mg kg^{-1}; A, C, AC-sole and combined application of ancymidol (A) and/or chlormequat (C); NUE-Nitrogen-use efficiency

as N level increased. Kandalkar *et al*. (2005) obtained increased grain yield with the application of recommended fertilizer N and plant growth regulators. The interaction can lead to increasing efficiency to the tune of 95.91%.

CONCLUSIONS

The response of rice plant to N fertilization depends on the parameter, rate of N, time after N application and cultivars. Interaction of the nutrient element with chemical growth substances also plays quite significant role. However, the optimum application rates of CCC and Ancymidol that are required to dwarf the plants, minimize their lodging and significantly increase their tillering ability needs to be ascertained as the ones tried in the present study were not sufficiently effective. Given the present circumstance, the use of cultivars that can naturally resist lodging should be preferred. When the tall, early maturing rice cultivars (prone to lodging) are grown, N supply (native soil + fertilizer applied) should be very moderate.

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