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Improving Yield and Yield Components of Rice (*Oryza sativa* L.) By Indolebutyric Acid (IBA), Gibberellic Acid (GA_3) and Salicylic Acid (SA) Pre-Sowing Seed Treatments

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Abstract: Since plant growth and development are controlled by plant growth regulators and per-sowing seed treatments have proven advantageous to germination, seedling growth and yield of several field crops, in the present study the growth and developmental responses of rice (*Oryza sativa* L.) cultivar Sadri to soaking seeds for three days in 0.0, 50 and 100 mg l^{-1} indole butyric acid (IBA), gibberellic acid (GA_3) and salicylic acid (SA) were investigated. Percent germination and germination rate rose significantly in all the hormonal treatments. Root and shoot lengths were increased significantly by nearly all the treatments. The fresh and dry weights at seedlings were affected the most by IBA. Significant increase in chlorophyll, carotenoids and antocyanins contents of leaves occurred by soaking seeds in hormonal solutions. Except for IBA, treatments did not change tillers number significantly. Panicle grain numbers increased significantly by all the treatments, whereas, 1000 kernels weight was affected only by IBA and SA at 50 mg l^{-1}. IBA at 50 mg l^{-1} had the highest impact on grain yield with 9.4 compared to 7.5 ton per hectare in control which is more than 25% increase in grain yield. Among the treatments, IBA at 50 mg l^{-1} significantly affected all the yield tested components. These finding strongly suggest the practicability of seed pre-sowing hormonal treatments in producing better crop stand and higher grain yield in rice. Since cross-talk during signal transduction occurs between phytohormones, studies on the influence of seed per-sowing treatments on the grain yield production by combinations of plant growth regulators are suggested.

Key words: Rice · Seed soaking · Growth regulators · Yield

INTRODCTION

It has been estimated that half of the world's population subsists wholly or partly on rice [1]. Therefore, improved grain yield production has attracted the attention of many researchers. Seed invigoration treatments such as hydropriming, osmopriming, osmohardening and soaking before sowing have been reported to enhance rapid and uniform seed emergence, vigorous seedlings production and increased yield in many field crops [2, 3]. Tavaili *et al*. [4] reported that seed hydropriming with distilled water and osmopriming with polyethylene glycol (PEG) 6000 significantly improved germination percentage of *Bromus* seeds. Higher vigor index was observed in hydropriming for 12 hr. In wheat, compounds that have shown good potential to enhance germination, emergence, growth and grain yield included KH_2PO_4, PEG and KCl [5]. When chickpea plants were raised form seeds primed with water or 4% mannitol, higher number of seeds and seed yield were obtained compared to control plant. Higher activities of the enzymes involved in sucrose metabolism were correlated with increasing grain yield of chickpea crops raised from primed seeds [3]. Improved rice seed invigoration techniques are reported to give better stand and increased tillers number, 1000 kernels weight and kernel yield in fine, medium and coarse grain rice [7-9]. Ruan *et al*. [10] conducted an experiment to find out the influence of osmopriming of rice seeds with $CaCl_2$ and $CaCl_2$+NaCl on germination and seedling emergence and performance in

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flooded soil. Osmopriming improved seedling vigor index and seedling establishment. Among various treatments, improved seed performance has also been achieved by priming or soaking seeds in plant growth regulators [11-14]. By treating seeds with 10 ppm GA_3 for 24 hrs, improved seed germination and seedling growth in *vigna mungo* and *macrotyloma uniflorum* was reported by Chauhan *et al*, [11]. Bhatt *et al*. [14] found substantial increase in germination of *myrica esculenta* by treating seeds with 100 ppm GA_3. Seed treatment with GA_3 caused taller mungbeen plants and increased seed number per pod and 1000 seed weight [13]. Soaking rice seeds in salicylic acid solution resulted in enhanced germination and seedling growth [1]. Miyoshi and Sato [15] treated dehusked seeds of indica and japonica rice with kinetin and gibberellins under aerobic and anaerobic conditions. They found stimulatory effects on seed germination under most of the treatments. Priming coarse and fine rice seeds with salicylic acid resulted in vigor enhancement compared with control. Germination rate, radical and plumule length and seedling fresh and dry weights all were improved by hormonal seed priming [16]. Improved rice seed germination under salt stress by soaking seeds in gibberellins and auxin was reported by Kim *et al*. [17]. The exogenous application of GA3 significantly increased seed yield of hybrid rice $NDHR_2$ [18]. Although, seed per-sowing treatments with various substances have been extensively investigated, information on the effects of hormonal treatments of rice seeds on grain yield and yield components is relatively scarce. The present experiment is designed to further explore the influence of soaking rice seeds in IBA, GA3 and salicylic acid on seed germination seedling vigour, yield and yield components of rice cultivar Sadri.

MATERIALS AND METHODS

This experiment was conducted in a field located at Saadatshahr (30°5' N and 5°4' E; elevation 1790 m above mean sea level) in Fars province, Iran, during 2010 - 2011 growing season. The soil physical and chemical characteristics of the experimental field are given in Table 1. The experiment was laid out in randomized complete block design with three replications. The plant growth regulators indolebutyric acid (IBA), gibberellic acid (GA_3) and salicylic acid (SA), each at 0.0, 50 and 100 mg l^{-1} were the factors of the experiment. These hormones were weighed out and dissolved in small volume of ethanol and then brought up to the required volumes by tap water. The nursery soil was plowed in late March in addition to a deep plow in autumn. The nursery was reinforced by applying 250 kg ha^{-1} ammonium phosphate and 150 kg ha^{-1} ammonium nitrate together with compost fertilizer. Rice (*Oryza sativa* L.) cultivar Sadri seeds were soaked in 0, 50 and 100 mg l^{-1} of the plant growth regulators for three days. The sprouted seeds were nursery sown to provide healthy seedlings at 4- to 5 leaf stage for transplantation to the plots in the main field. The field was plowed and irrigated in April after making long land borders and proper segmentation. Ammonium phosphate at 100 kg ha^{-1} and 46% urea at 50 kg ha^{-1} were applied before transplantation. In order to control narrow leaf weeds, Saturan herbicide (50%) was applied 5 days after transplanting at the rate of 6 lit ha^{-1}. Half of the urea was top dressed at the heading as well as the clustering stage at the rate of 50 kg ha^{-1}. The plots were regularly hand weeded in different stages of growth. Each plot was 1.75m wide and 7.0m long. Seedlings were planted in hills with 25*25 cm arrangements and four seedlings were planted together. Germination percentage (GP) and germination rate (GR) were calculated according to the international seed testing association (ISTA) methods using the following equations [19]:

$$GP=\frac{\text{Number of normally germinated seeds}}{\text{Total number of seeds}}$$

$$GR=\sum_{i=1}^{j} n_i / D_i$$

Table 1: Soil physicochemical characteristics of the experimental field.

Physicochemical Characteristics	
Physical characteristics	
Classification	Clacixerollic, Xeropchrepts
Field capacity (%)	32
Wiling point (%)	14
Silt (%)	45
Clay (%)	34
Sand (%)	23
Soil texture clay	
Chemical characteristics	
Soil pH	7.98
Potassium (mg kg^{-1})	591
Phosphorus (mg kg^{-1})	13
Organic carbon (%)	1.2
Organic matter (%)	1.4
Total nitrogen (%)	0.112
Fe (mg kg^{-1})	8.18
Mn (mg kg^{-1})	0.8
Zn (mg kg^{-1})	0.62
Cu (mg kg^{-1})	2.3
Electronic conductivity (dSm^{-1})	0.55

where^{n} is the number of seeds emerged on i^{th} day and D_i is the number of days counted from the beginning of the experiment; j is set to 10 days in this experiment; root and shoot lengths, ratio of root to shoot, total fresh and dry weights, pigments content and tissue water content (TWC) of the seedlings were measured at 4- to 5 leaf stages. Pigments content were determined as describe by Lichtenthale [20].The tissue water content (TWC) was calculated by the following formula Black and Pritchard [21]:

$$TWC = \frac{\text{Fresh weigth-Dry weigth}}{\text{Fresh weigth}} \times 100$$

Number of tillers, number of grains per panicle, 1000 kernels weight and plant height, length of cluster, harvest index, biological yield and grain yield were measured on mature plants. Experimental data were analyzed using SAS statistical technique, version, 2010. Treatment means were compared by Duncan's multiple comparison tests at 5% probability level.

RESULTS

Per-sowing treatment of seeds with the plant growth regulator significantly increased germination percentage and germination rate (Table 2). The most effect was observed with 50 and 100 mgl^{-1} IBA and 100 mg l^{-1} SA. Shoot and root lengths of the seedlings also were significantly affected by all soaking treatments. Longer roots were obtained by IBA treatments, whereas shoot lengths were higher when seeds were soaked in GA_3. IBA proved to be most effective in elevating total fresh and dry weights of the seedlings. Total water content of the seedlings was unaffected by hormonal treatments. As shown in Fig. 1 chlorophylls, carotenoids and anthocyanins contents of the seedlings were significantly higher at all per-sowing treatments, except carotenoids at 50 mg l^{-1} SA. Table 2 shows results obtained when yield and yield components were measured on mature plants. Number of tillers was significantly increased by IBA treatments. Higher cluster lengths were observed by nearly all the treatments with IBA having the most effect on this yield component. Number of grains per panicle increased significantly with all the tested plant growth regulators. More seeds were obtained at 50 compared to 100 mg l^{-1} treatments. At 50 mg l^{-1} IBA, SA and GA_3, 13, 9 and 5 percent rise in the number of grains were

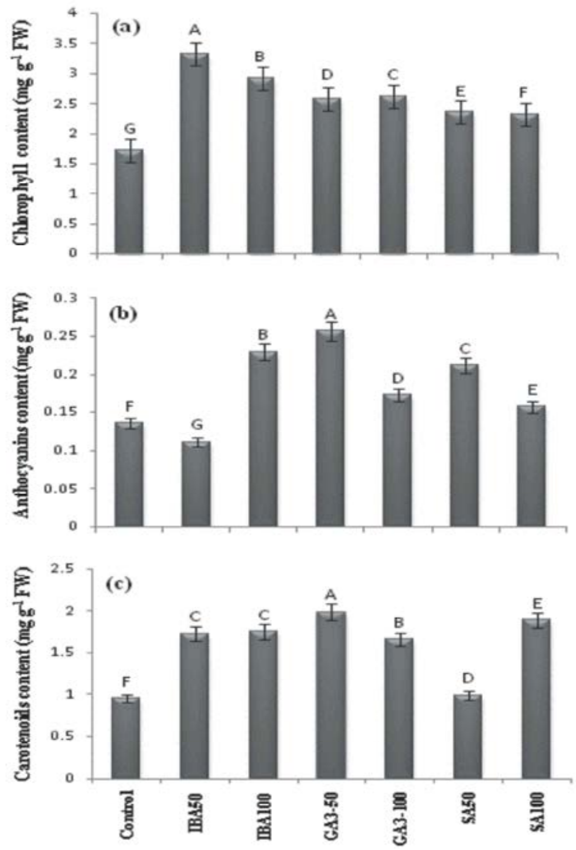

Fig. 1: Effects of soaking rice seeds in different levels of IBA, GA_3 and SA on chlorophylls, carotenoids and anthocyanins contents of rice seedling

observed, respectively. With respect to 1000 kernels weight, IBA at both concentration and SA at 50 mg l^{-1} significantly elevated 1000 kernels weight. At 50 mg l^{-1} IBA, increase in 1000 kernel weight contributed about 10 percent rise in grain yield relative to control. Grain yield, expressed as tons ha^{-1}, increased significantly in all the treatments. Soaking seeds in 50 mg l^{-1}hormone influenced grain yield more than 100 mg l^{-1}. Compared to control plants, 50 mg l^{-1} IBA, GA_3 and SA elevated grain yield by 25, 4 and 12 percent, respectively. Harvest index and biological yield were also affected significantly by most of the per-sowing hormonal treatments.

DISCUSSION

Seed pre-sowing treatments result in enhanced germination, uniform emergence and improved yield in many field crops [1]. Incorporating plant growth regulators during pre-sowing seed treatments have

Table 2: Effects of soaking rice seeds in 0.0, 50 and 100mg l^{-1} of IBA, GA_3 and SA on seed germination and seedling growth.

TWC	Total dry weight (mg)	Total fresh weight (mg)	Root shoot ratio	Shoot length (cm)	Root length (cm)	GR (%)	GP (%)	
80.9^{A}	0.07^{D}	0.34^{D}	0.27^{B}	34^{E}	9^{D}	41.7^{C}	81.7^{C}	Control
81.4^{A}	0.11^{A}	0.57^{ABC}	0.39^{A}	39^{BDE}	15^{A}	56.4^{A}	100^{A}	IBA_{50}
82.3^{A}	0.13^{A}	0.72^{A}	0.38^{A}	40.7^{BC}	15.2^{A}	57.3^{A}	100^{A}	IBA_{100}
82.8^{A}	0.1^{BC}	0.61^{AB}	0.33^{AB}	41.5^{B}	13.5^{AB}	49.4^{B}	91.7^{B}	$GA3_{50}$
84.3^{A}	0.08^{CD}	0.49^{BCD}	0.27^{B}	44.3^{A}	12^{BC}	48.5^{B}	90^{B}	$GA3_{100}$
80.4^{A}	0.08^{CD}	0.42^{CD}	0.29^{B}	38^{CD}	11^{C}	47.3^{B}	90^{B}	SA_{50}
81.8^{A}	0.1^{BC}	0.53^{D}	0.31^{B}	37.8^{D}	11.7^{BC}	54.5^{A}	98.3^{A}	SA_{100}

Means with different letter(s) are significantly different using range to Duncan (0.05).

Table 3: Effect of soaking rice seeds in different levels of IBA, GA_3 and SA on yield and yield components

Plant height (cm)	Seed yield (tonha^{-1})	Biological yield (ton ha^{-1})	Harvest Index	Length of cluster (cm)	Number of tillers	Kernels 1000 weight (g)	Number of grains per panicle	
135.6^{D}	7.5^{E}	16.5^{c}	45.39^{D}	25.33^{D}	4.47^{B}	23.57^{c}	151.33^{G}	Control
144.1^{c}	9.4^{A}	18.0^{A}	51.77^{A}	27.77^{A}	5.65^{A}	25.87^{A}	171.33^{A}	IBA50
144.7^{c}	9.1^{B}	18.0^{A}	50.87^{A}	27.87^{A}	5.73^{A}	25.53^{A}	169.67^{B}	IBA100
150.7^{A}	7.8^{D}	16.6^{c}	47.23^{c}	26.87^{B}	4.41^{B}	23.33^{c}	159.77^{D}	GA350
148.4^{B}	7.7^{D}	17.0^{B}	45.67^{D}	26.7^{B}	4.63^{B}	23.65^{c}	156.0F	GA3100
136.1^{D}	8.4^{c}	17.0^{B}	49.4^{B}	26.0^{c}	4.93^{B}	24.13^{B}	165.0^{c}	SA50
136.5^{D}	7.8^{D}	16.8^{cB}	46.77^{c}	25.87^{cD}	4.62^{B}	23.60^{c}	158.0^{E}	SA100

Means with different letter(s) are significantly different using range to Duncan (0.05).

resulted in improved seed performance [15]. This study revealed that employing growth plant regulators during seed soaking treatment enhance germination as indicated by higher GP and GR. Increased germination rate and uniformity have been attributed to elevated metabolic activates in the treated seeds [3]. It is well established that gibberellins and auxin regulate various developmental processes throughout the life cycle of plants [22]. GA_3 increases transcription of á– amylase gene, stimulate the elongation of seedling internodes and promote seed development. Auxin is required to promote cell division, differentiation and oriented cell expansion [18]. Seed hormonal treatments also enhanced seedling vigor as seen by higher shoot and root lengths and higher total fresh and dry weights. Accelerated cell division and cell enlargement party explain the production of vigorous seedlings by per-sowing seed treatment with plant growth regulators [23]. In addition to germination and seedling vigour, the three main components of grain yield, i.e. tillers number in unit area, grain numbers and 1000 kernels weight were also increased by seed hormonal treatments (Table 3). Treating seeds with 50 mg l^{-1} IBA had the highest impact on seed yield which caused 25% increase in grain yield relative to control. Therefore, establishment of vigorous seedling by soaking seeds in plant growth regulators leads to improved yield components which in turn influence the grain yield production. It is well established that cross-talk between various hormones occurs during plant growth and development. As a result, the output of plant hormone action depends on specific hormonal combinations. Therefore, research on per-sowing seed treatments using combinations of plant growth regulators with proper concentrations will be valuable to raise production in crop cultivation.

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