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Yield and Yield Components of Corn (*Zea mays* L.) In Response to Foliar Application with Indole Butyric Acid and Gibberellic Acid

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Abstract: The aim of present investigation was to study the effect of indole butyric acid (IBA) and gibberellic acid (GA_3) spraying on yield and yield components corn (*Zea mays* L.) single cross 704. Two field experiments were carried out during the 2009 and 2010 growing seasons near the city of Shiraz. Split plot design was used, where foliar application of two growth regulators (GA_3, IBA) during two physiological sensitive growth phases, i.e. 4 to 6 leaf and flowering stages constituted the main plots and concentration of 0, 50 and 100 mg L^{-1} of both IBA and GA_3 formed the subplots. Evaluated physiological traits include ear length, kernel number per area, kernel weight, grains per row and grain yield. In comparison with control, application of IBA and GA_3 during flowering stage increased ear length and grain yield to 26.3 cm and 17.2 ton ha^{-1}, respectively. On the other hand, the interaction between IBA and GA_3 mostly affected the kernel number per area and number of grains per row. Additionally, the most effective treatment to increase kernel weight was the application of IBA_{100} in both growth stages. Generally, the results show that in both growth stages, application of IBA and GA_3 increased yield and yield components of corn plants.

Key words: Spray · IBA · GA_3 · Corn and yield

INTRODUCTION

Certainly, sustainable production can be achieved by selecting effective approaches, which make maximum use of the means of production to stimulate high yield, preserve water and soil and produce better long-term profit. However, to obtain a favorable yield there first needs to be an understanding of the morphological and physiological parameters of the plant, the roles of the various yield components and identification of the most important factors instrumental in increasing those components. Therefore, identification of these relevant factors can potentially increase yield [1]. There is an important relationship between source and sink in plant physiology. The fact that source or sink can limit the yield is a challenging subject to plant physiologists. One of the effective factors that can control the size of sink and source are plant growth regulators [2]. IBA increases the ability of cell division in meristematic zones of plant and hence the ability of plant to absorb nutritive material which finally lead to the increase of grain yield [3]. While, GA also increases the sink strength via increasing the length and growth rate of cells [3]. Additionally, both growth regulators increase the strength of physiological source by increasing chlorophyll [4] and effective age of leaves [5] which finally lead to the increase of grain yield per area. Some researchers have shown that spraying GA_3 or IAA on leaves considerably increases the growth rate of corn [6]. In another experiment, application of 2-4-D (in low concentration act like IAA) has increased length, number of leaves and grain yield [7]. Also, Cao and coworkers [8] showed that application of GA_3 increased growth, protein secretion and starch accumulation in maize endosperm suspension cells. Spraying different concentration of gibberellic acid over the plans at 3-4 leaf growth stage increased seed yield and yield components in soybean [1]. Increasing maize grain yield per unit area is an important issue in Iran's farmlands due to the limited areas with appropriate weather conditions for growing this strategic plant. Considering the successful

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applications of natural growth regulators mentioned above, is the present study was conducted to investigate the best time and concentration to implement two growth regulators IBA and GA_3 for increasing the grain yield and yield components of corn plants.

MATERIALS AND METHODS

A field experiments were performed near the city of Shiraz in Iran (53°13'N, 27°17'E) during 2009 and 2010 growing seasons. The soil texture was Clay Loam. The results of soil analysis are shown in Table 1. The experiment was laid out in split plot design with three replications. The foliar application of two growth regulators (GA_3, IBA) in two physiological sensitive growth phases, i.e. 4 to 6 leaf and flowering stages constituted the main plots and concentration of 0, 50 and 100 mgL^{-1} of both IBA and GA_3 formed the subplots. Each experimental plot had an area of 16 m^2 including five planting rows of 3m length and 0.6m distance from one another. Each two plants were 20cm apart. The test crop was corn (*Zea mays* L.) single cross 704 and harvested at maturity to study yield and yield components. Required nitrogen and phosphorous were applied to each plot as urea (0.46 N) and ammonium phosphate (0.17 N, 0.26 P) at the rate of 400 and 250 kg ha^{-1} based on soil analysis, respectively. Half of the nitrogen fertilizer (urea) was top dressed at the 6-leaf stage. The plots were regularly hand weeded and irrigated by furrow irrigation at weekly intervals. The growth regulators were weighed out and dissolved in small volume of ethanol and then brought up to the required volumes by tap water. The growth regulators were used as foliar application by a back-pack sprayer system consisting of a hand-held boom with nozzles 0.76 m apart. Plots were sampled at final harvest. At each sampling 10 plants form each plot were taken for yield and yield components measurements. Data were analyzed using ANOVA, by SAS software. The means were compared using Duncan multiple range test ($p < 0.05$).

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 (%)	36
Sand (%)	20
Soil texture	Clay Loam
Chemical characteristics	
Soil pH	7.5
Potassium (mg kg^{-1})	561
Phosphorus (mg kg^{-1})	12
Organic carbon (%)	0.84
Organic matter (%)	0.91
Total nitrogen (%)	0.112
Fe (mg kg^{-1})	3.9
Mn (mg kg^{-1})	0.8
Zn (mg kg^{-1})	0.62
Cu (mg kg^{-1})	2.3

Electronic conductivity (dSm^{-1}) 0.55

RESULTS

Ear length: In our experiment, application of GRs led to an increase of ear length compared to the control. In 4-6 leaf stage, the best result was obtained for application of $IBA_{100}GA_{3-100}$ (with ear length of 26.1 cm.). At flowering stage, however, the best treatments were $IBA_{50}GA_{3-100}$ and $IBA_{100}GA_{3-100}$ with ear lengths of 26.3 cm and 26.1 cm, respectively. In addition, the present data showed that increasing of concentration in separate application of GRs was important in 4-6 leaves stage, while it did not significantly change the results during flowering stage (Table 2). In this study the correlation between ear length and yield was positive (r =0.87**) as shown in Table 3. The (regression) equation (y=0.7004x-1.1775) showed that an increase in ear length as a result of increase in grain yield (Fig. 1).

Number of Grains per Row: The results of the present study indicated that application of IBA in both growth stages of increased number of grains pre row regardless of the concentration and/or time of application. In contrast, the increment in number of grains per row in GA_3 treated samples depended on the concentration of growth regulator so that the best result, in both growth stages was obtained by application of 100 mg L^{-1} GA_3.Also, the interaction effect of GRs showed that the

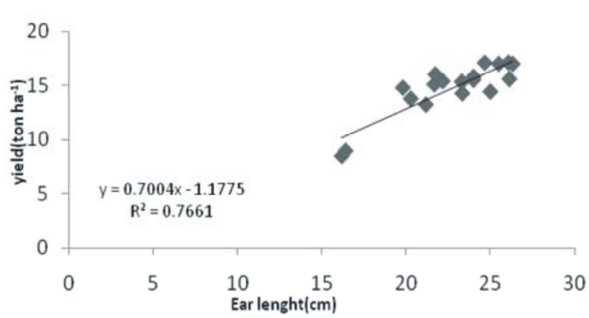

Fig. 1: Relationship between ear length and grain yield of corn in two difference phases

Table 2: Effect of different application time (4-6 leaf stage or flowering stage), IBA level and GA_3 level on yield and yield components

	Ear length				Number of grains per row			
	2009		2010		2009		2010	
	Flowering	4-6 leaf	Flowering	4-6 leaf	Flowering	4-6 leaf	Flowering	4-6 leaf
Control	16.9^{G}	15.5^{G}	16.17^{G}	16.4^{G}	40.33^{H}	39.3^{H}	39^{H}	40.33^{H}
IBA50	24.5^{ABC}	22^{DE}	24^{AD}	21.73^{DEF}	51.2^{AF}	53.21^{AB}	51^{AF}	52.33^{ABC}
IBA100	25^{B}	25.5^{AB}	24.67^{ABC}	25.5^{AB}	53.33^{AB}	51.8^{ABC}	53.67^{A}	52.33^{ABC}
GA350	20.7^{EF}	20^{F}	21.17^{EF}	20.27^{F}	46.7^{FG}	45.2^{G}	47.33^{E}	44.67^{G}
GA3100	21.67^{DEF}	22.8^{DE}	21.67^{DEF}	22.17^{DE}	51^{AF}	50.5^{AF}	50^{BF}	51.67^{AD}
IBA50GA350	23.7^{BE}	18.3^{F}	23.3^{BE}	19.8^{F}	47.67^{EFG}	48.67^{CF}	48.33^{DG}	47.67^{EFG}
IBA50GA3100	26.13^{A}	25.6^{AB}	26.3^{A}	25^{AB}	55^{A}	50.3^{AF}	54^{A}	51.5^{AE}
IBA100GA350	24.4^{ABC}	22.67^{DE}	24^{AD}	23.33^{BE}	50.33^{AF}	47.3^{EFG}	50.67^{AE}	48.67^{CF}
IBA100GA3100	26.6^{A}	26.17^{A}	26.13^{A}	26.1^{A}	53.2^{AB}	53.67^{A}	53^{AB}	53^{AB}

Means with the same letter(s) are not significantly different using Duncan (0.05).

Table 3: Correlation coefficients between yield and yield components

	Yield
1000 kernels weight	0.92**
Number of grains per row	0.94**
Kernels number per area	0.95**
Ear length	0.87**

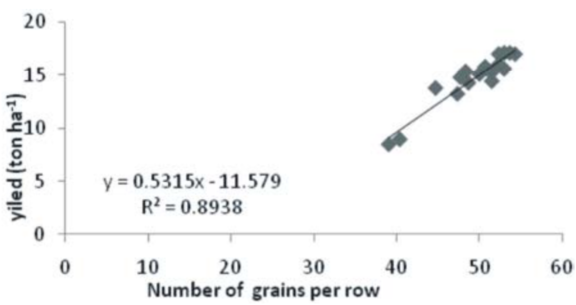

Fig. 2: Relationship between number of grains per row and grain yield of corn in two difference phases

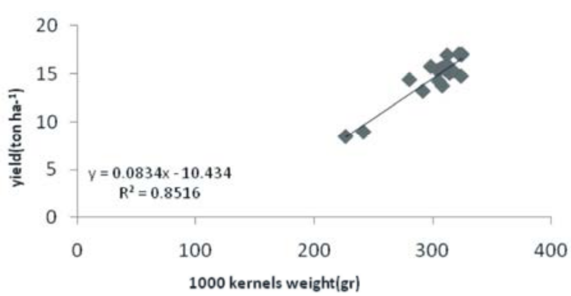

Fig. 3: Relationship between 1000 kernels weight and grain yield of corn in two difference phases

increase in GA_3 concentration would generally lead to the increase of grains per row. The highest increase of grains per row was obtained with IBA_{100} GA_{3-100} treatment at 4-6 leaf stage and $IBA_{50}GA_{3-100}$ treatment during flowering stage (Table 2). In this study, the correlation between grains per row and yield was positive (r =0.94**) as shown in Table 3. Also, the regression equation (y=5315x-11.579) showed that an increase in number of grains per row and grain yield (Fig. 2).

1000 Kernels Weight: The results indicated that application of IBA and GA_3 at higher concentration led to better results during flowering stage. Additionally, the interaction effect indicated that at the level of IBA_{50}, GA_{3-50} in both growth stages significantly affected the kernel weight. On the other hand, at the level of IBA_{100}, treatments with GA_{3-100} in 4-6 leaf stage and GA_{3-50} during flowering stage were the best treatments. Overall, the best results were obtained by IBA_{100} and $IBA_{100}GA_{3-50}$ treatments in 4-6 leaf stage and IBA_{100} in flowering stage as shown in Table 4. In this study there was a significant correlation between 1000 kernels weight and yield (r=0.92**) as indicated in Table 3. Furthermore, the regression between 1000 kernels weight and yield (y=0.834x-10.434) showed that an increase in 1000 kernels weight and yield increment (Fig. 3).

Kernel Numbers per Area: Treatments with higher concentrations of IBA and GA_3 had better effect on the kernel numbers per area. The interaction effect of IBA and GA_3 indicated that at the level of IBA_{50} resulted in the best result with application of GA_{3-100} regardless of growth stage which the GRs were implemented. However, it was observed that at the level of IBA_{100}, the obtained results depended on the time of application. For example, for GA_{3-50} and GA_{3-100} the best time of application of GRs were

Table 4: Effect of different application time (4-6 leaf stage or flowering stage), IBA level and GA_3 level on yield and yield components.

	1000 kernels weight				Kernel numbers per area			
	2009		2010		2009		2010	
	Flowering	4-6 leaf	Flowering	4-6 leaf	Flowering	4-6 leaf	Flowering	4-6 leaf
Control	220^{F}	243^{F}	226.7^{F}	241.7^{F}	601^{E}	594^{E}	599.3^{E}	592^{E}
IBA50	312^{ABC}	315.2^{ABC}	310^{ABC}	311.7^{ABC}	794^{AD}	818^{AD}	799.3^{AD}	820.3^{AD}
IBA100	325^{A}	323^{A}	324.3^{A}	324^{A}	838^{ABC}	840^{AB}	842^{AB}	837.3^{ABC}
GA350	295DE	311^{ABC}	291.7^{DE}	308^{AD}	719^{D}	716^{D}	725.3^{D}	714.7^{D}
GA3100	316^{AB}	306^{BCD}	314^{ABC}	304^{BCD}	772^{AD}	811^{AD}	768.7^{AD}	808.8^{AD}
IBA50GA350	318^{AB}	322^{AB}	317^{AB}	323.7^{A}	768^{AD}	726^{CD}	773.3^{AD}	730^{CD}
IBA50GA3100	294DE	283^{E}	298.3^{CD}	280.3^{E}	865^{A}	824^{AD}	869.3^{A}	821.3^{AD}
IBA100GA350	315^{ABC}	307^{AD}	312^{ABC}	305^{BCD}	849^{AB}	740^{CD}	844^{AB}	737.3^{CD}
IBA100GA3100	305^{BCD}	321^{AB}	307^{AD}	322^{AB}	820^{AD}	850^{AB}	813.3^{AD}	848^{AB}

Means with the same letter(s) are not significantly different using Duncan (0.05).

Table 5: Effect of different application time (4-6 leaf stage or flowering stage), IBA level and GA_3 level on yield and yield components

	Yield			
	2009		2010	
Flowering	4-6 leaf	Flowering	4-6 leaf	
IBA50	15.6^{ABC}	15.4^{ABC}	15.49^{ABC}	15.98^{AB}
IBA100	17.1^{A}	16.7^{A}	17.2^{A}	16.96^{A}
GA350	12.9^{D}	13.5^{CD}	13.21^{D}	13.76^{CD}
GA3100	15.4^{ABC}	15.5^{ABC}	15.1^{ABCD}	15.36^{ABC}
IBA50GA350	15.1^{ABC}	14.33^{BCD}	15.3^{ABC}	14.76^{BCD}
IBA50GA3100	15.4^{ABC}	14.1^{BCD}	15.76^{ABC}	14.4^{BCD}
IBA100GA350	16.4^{A}	14.5^{BCD}	16.96^{A}	14.24^{BCD}
IBA100GA3100	15.4^{ABC}	16.9^{A}	15.6^{ABC}	17.1 ^{A}

Means with the same letter(s) are not significantly different using Duncan (0.05).

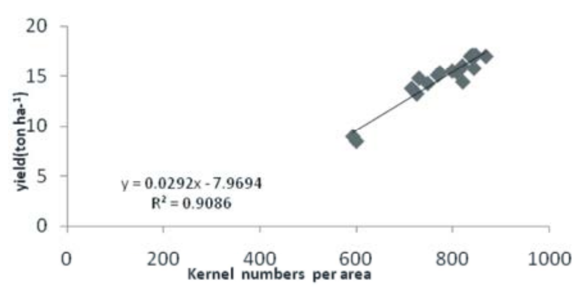

Fig. 4: Relationship between kernel numbers per area and grain yield of corn in two difference phases

respectively the flowering stage and 4-6 leaf stage. Our results also indicated that in 4-6 leaf stage had the best with application of $IBA_{100}GA_{3-100}$, whereas during flowering stage a significant effect would be provided by using of $IBA_{50}GA_{3-100}$ (Table 4). In this study, the correlation between kernel number per area and grain yield was positive (r=0.95**) as shown in Table 3. The regression equation (y=0.0292x-7.9694) showed that an increase in kernel numbers per ear area which lead to the increase of grain yield (Fig. 4).

Grain Yield: Application of IBA and GA_3 during both growth stages increased grain yield. The results showed that growth regulators are more beneficial to grain yield at higher concentrations. The interaction effects at IBA_{50} level showed that the increment of GA_3 concentration had not significant effect on grain yield. However, plants treated during flowering stage showed better results than those treated in 4-6 leaf stage. On the other hand, application of IBA_{100} increased grain yield with increasing the concentration of GA_3 at 4-6 leaf stage. The results showed that the same treatment, i.e. $IBA_{100}GA_{3-50}$, during flowering stage had the inverse effect and decreased grain yield. In general, the results indicated that at 4-6 leaf stage, IBA_{100} and $IBA_{100}GA_{3-100}$ treatments had the most significant effects on grain yield (16.96 ton ha^{-1} and

17.1 ton ha^{-1}, respectively). At flowering stage, the best result was obtained for IBA_{100} and $IBA_{100}GA_{3\text{-}50}$ treatments (17.2 ton ha^{-1} and 16.96 ton ha^{-1}, respectively) (Table 5).

DISSCUSSION

Much research has been done to study effect of indole butyric acid and gibbrellic acid as plant growth regulators (PGRs) on plant agronomy for yield improvement [9- 10-11]. In this study we used PGRs in two physiological sensitive growth phases 4 to 6 leaf stage and flowering stages. Application of PGRs at 4 to 6 leaf has mostly affected the strength of physiological source. Under these situations growth parameters such as leaf area index, net assimilation rate, crop growth rate and leaf area duration improves [7-12-13] and thus lead to yield increase. These findings were in good agreement with the results of Azizi *et al*, [1] and Shirzad *et al*. [10]. At flowering stage, corn has the highest growth, so PGRs affected sink and the relation between source and sink. Growth regulators are proved to improve effective partitioning and translocation of accumulates from source to sink in the field crops [14-15]. The plant growth regulators also increase mobilization of reserve food materials to the developing sink through increases in hydrolyzing and oxidizing enzyme activities and lead to yield increases [16]. Sink include yield components and have direct relation with yield, two important factors are number of grain per cluster and length cluster [17]. In our study plant growth regulators increased ear length and number of grains per row in corn. Similar results were reported by Ahmad *et al.* [18], who reported that auxin and gibberellic acid increased ear length and number of grain per row in corn. Also, Kariali and Mohapatra [19] showed that auxin and gibberellic acid increased numbers of grains per cluster and length cluster in rice. 1000 kernels weight has been recognized as the most stable component of grain yield [20]. Our results showed that highest 1000 kernels weight at both growth stages is obtained by using IBA_{100}. With suitable environmental conditions and plant growth rates, the amount of materials given to grain increases. Auxin plays an important role in the formation of grains and increases transport of metabolic compounds to the grains [21]. In study of different wheat cultivars, the cultivar of wheat with highest yield and yield components has high level of auxin [22]. Also auxin and gibberellic acid have effect on yield of corn [18]. In this study, IBA and GA_3 increased yield components which led to increase in grain yield per unit area. It can be concluded that implementing growth regulators at 4-6 leaf stage has mostly affected the strength of physiological source while their implementing at flowering stage has affected the physiological sink strength. Both of these effects would finally lead to the increase of yield.

REFERENCES

1. Azizi, Kh., J. Moradii, S. Heidari, A. Khalili and M. Feizian, 2012. Effect of different concentrations of gibberellic acid on seed yield and yield components of soybean genotypes in summer intercropping. Int. J. Agirc. Sci., 2(4): 291-301.
2. Taiz, L. and E. Zeiger, 2002. Plant Physiology.3rd Edition. Sinauer Associates Publisher, pp: 690.
3. Arteca, R.N., 1996. Plant Growth Substances, Principles and Applications, Chapman & Hall, NY.
4. Wareing, P.F., M.M. Khalifa and K.J. Treharne, 1968. Rate-limiting processes in photosynthesis at saturating light intensities. Nat., 222: 453-457.
5. Nooden, L.D. and A.C. Leopold, 1978. Phytohormones and the endogenous regulation of senescence and abscission. In phytohomones and related compounds, a comprehensive Treatise. Vol. 2: Phytohormones and the Development of Higher Plants, Elsevier, Amsterdam, pp: 329-370.
6. Koter, M., J. Czapla, G. Nowak and J. Nowak, 1983. Study on use of growth regulators in agricultural production. 1. Effect of GA_3, IAA and kinetin on growth and development of bean, maize and flax. Plant Physiology and Biochemistry, 36: 17-27.
7. Thavaprakaash, N., K. Velayudham and L. Gurusamy, 2007. Influence of herbicides growth regulators on growth and yield of Baby Corn (*Zea mays* L.). Int. J. Agric. Res., 2(8): 731-735.
8. Cao, H. and C. Shannon, 1997. Effect of gibberellin on growth, protein secretion and starch accumulation in maize endosperm suspension cells. J. Plant. Growth Regul., 16(3): 173-140.
9. Sarkar, P.K., M.S. Haque and M.A. Karim, 2002. Effects of GA_3 and IAA and their Frequency of application on morphology, yield contributing characters and yield of soybean. Pak. J. Agro., 1(4): 119-122.
10. Shirzad, S., H. Aroole and M. Azizi, 2012. Influence of plant growth regulators (PGRs) and planting method on growth and yield in oil Pumpkin (*Cucurbita pepo* var. *styriaca*). Not. Sci. Biol., 4(2): 101-107.
11. Tiwari, D.K., P. Pandey, S.P. Giri and J.L. Dwivedi, 2011. Effect of GA3 and other plant growth regulators on hybrid rice seed production. Asia. J. Plant. Sci., 10(2): 133-139.

12. Rahman, M.S., N.I.M.A. Tahar and M.A. Karim, 2004. Influence of GA_3 and MH and their time of spray on dry matter accumulation and growth attributes of Soybean. Pak. J. Bio. Sci., 7(11): 1851-1857.
13. Sarkar, P.K., M.S. Haque and M.A. Karim, 2002. Growth analysis of soybean as influenced by GA3 and IAA and their frequency of application. Pak. J. Agro., 1(4): 123-126.
14. Solaimalai, A., C. Sivakumar, S. Anbumani, T. Suresh and K. Arumugam, 2001. Role of plant growth regulators in rice production. A review. Agric. Rev., 22: 33-40.
15. Senthil, A., M. Djanaguiraman and R. Chandrababu, 2003. Effect of roof dipping of seedling with plant growth regulators and chemicals on yield and yield components of rice (*Oryza sativa* L.) transplanted by broadcast method. Madras Agric. J., 90: 383-384.
16. Jayachandran, M., N.O. Gopal and R. Marimuthu, 2000. Performance of nitrogen in combination with growth regulators. Madras Agric. J., 89: 462-465.
17. Balasubramanian, P. and S. Planiappan, 1993. Effect of population density, fertilizer level and time of application on rice (*Oryza sativa* L.) and groundnut (*Arachis hypogea*). Filed. Crop. Abs., 48: 3.
18. Ahmad, R.M., Z.A. Arshad, M.A. Zahire, M. Naveed, M. Khalid and H.N. Asghar, 2008. Integrating-enriched compost with biologically active substances for improving growth and yield of cereals. Pak. J. Bot., 40(1): 283-293.
19. Kariali, E. and P.K. Mohapatra, 2007. Hormonal regulation of tiller dynamics in differentially-tillering rice cultivars. Plant. Growth Regul., 53: 215-223.
20. Matsushima, 1957. Analysis of developmental factors determining yield and yield production in low land rice. Bull. Natl. Inst. Agric. Sci. Japan. Ser., 45: 233.
21. Prochazka, S., 1978. Effect of indol-3-acetic acid on the translocation of assimilates in winter wheat (*Triticum aestivum* L.) in the period of kernel formation. Act. Univ. Agric. Brno., 26: 99-104.
22. Eradatmand, D. and A. Houshmandfar, 2011. Dry matter accumulation and auxin levels within developing grains of different durum wheat genotypes. Adv. Environ. Biol., 5(4): 678-682.