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EVALUATION OF GRAIN FILLING RATE AND PATH ANALYSIS IN DIFFERENT COMBINATIONS OF NITROGEN AND ZINC IN MAIZE

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Abstract

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This research was conducted to evaluate maize grain yield by path analysis and its grain filling rate in different combinations of nitrogen and zinc at field conditions. Three maize cultivars were grown at factorial split-plot (FFSP) design with 3 replications based on RCBD (Randomized Complete Block Design). Three levels of nitrogen, including 120, 260, 400 kg/ha and three levels of Zinc, 0, 15 and 30 kg/ha were applied. Results showed that, hybrid 540 have the better grain filling rate to compare with 704. Grain filling rate at 120 kg/ha urea and 15 kg/ha zinc Sulphate, resulted to the highest grain filling rate (3.19 g/m^2 per day). Path analysis showed row number have the most direct effects on grain yield in N_3Z_1 fertilizer combination then thousand kernel weights had the most direct effects on grain yield (0.96) in N_1Z_2 fertilizer combination. According to the results, proper combination of nitrogen and zinc can increase grain yield in maize.

Key words: grain filling rate, maize, nitrogen, path analysis, zinc

Introduction

Maize (*Zea Mays* L.) is one of the most important crops in the world. Maize is planted vastly in many countries due to its adaptation and higher productivity. Maize is known as a “king of cereals” because of its high yield potential among them (Lucas, 1996). Depending on different climates, soil type, rotation, and the aim to harvest, it has different nutritional requirements (Arora and Singh, 2004). Grain filling period in corn has three stages; the first stage is from silking to maximum seed growth. The second stage is increasing seed weight that is linear; the third stage is continuing until complete seed maturity. The growth stage one and three is slow; in stage two seed growth is quick. Seed weight is different and depends on its place on the kernel. The lighter seeds are in the top end of kernel; and they are 20% lighter than other seeds; depends on different varieties. The abnormal situation (stresses) during seed filling period can cause higher weight in those seeds in the base end of kernel. Maximum seed dry weights are at physiological maturity; and in this stage, seed has 65% dry weight; a black layer in kernel base is a sign of seed maturity (Maafpourian, 1994). Path coefficient is one of the most useful and practical methods to study genetic and phenotypic correlations and understanding their direct and indirect effects. Path analysis is one of the best methods to study the cause and effect among different variables (Kordestani, Mohammadinejad, Tohidinejad, Rezaie, Zareaie and Kamyabi, 2009). Nitrogen is the most important macronutrient that has an important role in function of proteins, enzymes, co-enzymes, nucleic-acids and cytochromes molecular structure. Also zinc is one of the most important microelements, which is very essential for synthesis of different proteins (Regina, 2008).

However, zinc can cause toxicity, if it is used more than necessity. Zinc is an important in producing halides, sulphates and cyanides (Broudly et al., 2007). Zinc deficiency can be diagnosed by decreasing internodes growth and abnormal appearance. This can be the result of producing none enough amount of IAA in plant. In plants like corn and bean leaf chlorosis and then necrosis can be observed due to zinc

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deficiency; the chlorosis can be appear in plant because of malfunction in chlorophyll biosynthesis (Ozer et al., 2004). Nitrogen might be affect zinc concentration in different crops by increasing plant growth and changing pH around root zone. Increasing nitrogen in soils can be a limiting factor for growth and yield; so growth, development and yield increases depend on positive interactions of nitrogen and zinc application (Ranjan, 2003). Most crops show positive reactions to zinc and nitrogen combination; nitrogen application without zinc can result zinc deficiency, although nitrogen can increase vegetable growth and vegetable growth can cause Cu deficiency, in zinc deficiency conditions. This can be increased in case of interaction between zinc and copper. Nitrogen fertilizers such as SO_4 $(NH_2)_2$ can decrease soil pH; and finally increase zinc effects in crops; but Ca $(NO_3)_2$ has the opposite effects following lower zinc efficiency (Ranjan, 2003). According to Karimian's report, the application of nitrogen increased both the density and absorption of zinc by maize (Karimian, 1995). This research was conducted to evaluate the grain filling rate and path analysis in different combination of nitrogen and zinc fertilizers in maize.

Materials and Methods

This research was done at experimental field of Shiraz University, (Badjgah) in Fars province (29°50′N and 52°46′E; 1810 m) during 2008 growing season. The experimental design was factorial split plot with 3 replications based on RCBD (randomized complete block design). Three levels of applied nitrogen as urea including 120, 260 and 400 kg ha^{-1} and three levels of zinc as zinc sulphate were 0, 15 and 30 kg/ha, and 2 maize hybrids i.e., SC704 and SC540 were used. Both fertilizers were added to the soil. Zinc used before cultivating and nitrogen used in three stages before cultivating and during maize growth. Agronomic management (including irrigation and weed control), was done during the growing season. Irrigation was done two times per week except at final growth stage; weed control was done two times during maize growth. The grain humidity at harvest (around two square meters) was 14%. The grain was hand harvested from the two internal rows of each plot, considering the margin. Collected data were subjected to analysis of variance and the means were compared using Duncan new multiple Range Test. Also to determine the direct and indirect effects of yield components used path analysis and to evaluate the nitrogen and zinc combinations effect used grain filling rate.

Results and Discussion

Results from ANOVA analysis of grain yield showed that the interaction effect between nitrogen and zinc was significant (Table 2). Also results from mean compare of grain yield

Table 1
Physical and chemical characteristics of field grown maize (*Zea mays* L.). soil

Soil texture	Organic matter, %	pH	E.C, $ds.m^{-1}$	Nitrogen, %	Potassium, $mg.\ kg^{-1}$	Phosphorous, $mg.\ kg^{-1}$	Zinc, $mg.\ kg^{-1}$
Clay loam	1.4	7.4	0.43	0.11	264	23.7	4.8

Table 2
Analysis of variance (ANOVA) for grain yield of maize (*Zea mays* L.)

S.O. V	df	SS	MS	F	Prob.
Rep.	2	8.72	4.36	0.35	0.71
Nitrogen	2	39.8	19.9	1.59	0.24
Zinc	2	3.92	1.96	0.16	0.85
Nitrogen×Zinc	4	104.38	26.09*	2.08	0.14
Error	16	105.22	7.01	0.56	0.85
Var.	1	62.98	62.98*	5.03	0.04
Var.×Nitrogen	2	37.62	18.81	1.50	0.26
Var.×Zinc	2	17.57	8.78	0.70	0.51
Var.×Nitrogen×Zinc	4	109.66	27.41	2.19	0.13
CV.			23.87		

**: significant level 1%,*: significant level 5%

revealed that combination of second level of nitrogen and third level of zinc (260 kg/ha Nitrogen, 30 kg/ha Zinc) had maximum amount (Table 3).

Table 3
Mean comparison of grain yield for different treatments of maize (*Zea mays* L.)

Nitrogen, kg ha^{-1}	Zinc, kg ha^{-1}	Grain Yield, ton ha^{-1}
120	0	13.94^{ab}
120	15	15.51^{ab}
120	30	11.57^{b}
260	0	14.48^{ab}
260	15	15.22^{ab}
260	30	18.62^{a}
400	0	15.79^{ab}
400	15	14.04^{ab}
400	30	13.48^{b}

N_1: first level of nitrogen120 kg ha^{-1}, N_2: second level of nitrogen 260 kg ha^{-1}. N_3: third level of nitrogen 400 kg ha^{-1}. Z_1: first level of zinc 0 kg ha^{-1}, Z_2: second level of zinc 15 kg ha^{-1}, Z_3: third level of zinc 30 kg ha^{-1}

According to the path analysis's results (Table 5), in N_1Z_2 (120 kg/ha Nitrogen, 15 kg/ha Zinc), the weight of 1000 grains had the maximum direct effect on yield (0.96). After that the number of rows (0.733) had direct effect, and the lowest direct effect was belonged to the number of grain per row (0.536).

The weight of 1000 grain also had a highest positive indirect effect due to the grain number per row (0.671) and treatment of row number had highest negative indirect effect due to the grain number (0.536). However, it is understandable because of negative correlation between the number of rows and 1000 grain weight (0.189). So increasing the number of rows causes to increase the grains number and absolutely weight of 1000 grain get decrease. In N_1Z_2 (120 kg/ha Nitrogen, plus 15 kg/ha Zinc), coefficient of determination ($1-U^2$) was 0.88, which is equal to total amount of variances and co-variances influenced by independent variances in multiple regression models.

According to the results, in N_3Z_1 (400 kg/ha Nitrogen, plus 0 kg/ha Zinc), row number had highest direct effect (1.003) on yield. After that weight of 1000 grain (0.699) and finally number of grain per row had highest direct effect (-0.321) on yield. The number of row due to the weight of 1000 grain

Table 4
Grain filling rate of maize at different combination of nitrogen and zinc

Fertilizer Treatment	N_1Z_1	N_1Z_2	N_1Z_3	N_2Z_1	N_2Z_2	N_2Z_3	N_3Z_1	N_3Z_2	N_3Z_3
	2.34	3.19	2.03	2.76	2.04	0.5	2.37	1.94	1.12

N_1:first level of nitrogen120 kg ha^{-1}, N_2:second level of nitrogen 260 kg ha^{-1}. N_3:third level of nitrogen 400 kg ha^{-1}. Z_1: first level of zinc 0 kg ha^{-1}, Z_2: second level of zinc 15 kg ha^{-1}, Z_3: third level of zinc 30 kg ha^{-1}

Table 5
Path coefficient analysis of main components on grain yield of maize (*Zea mays* L.)

	N_1Z_2	N_3Z_1	N_2Z_3
Row number direct effect	0.733	1	0.341
Indirect effect due to grain number per row	0.391	0.065	-0.009
Indirect effect due to 1000 kernel weight	-0.182	-0.346	0.172
Total	0.943	0.694	0.505
Grain number per row direct effect	-0.536	-0.321	-0.055
Indirect effect due to row number	-0.536	0.201	0.055
Indirect effect due to weight of 1000 grain	0.671	-0.373	0.651
Total	-0.401	-0.491	0.652
1000 kernel weight direct effect	0.96	-0.699	-0.824
Indirect effect due to row number	-0.139	0.352	-0.072
Indirect effect due to grain number per row	-0.315	-0.171	0.043
Total	0.446	-0.518	-0.852
Residual effect	-0.336	-0.215	0.401

N_1: first level of nitrogen120 kg ha^{-1}, N_2:second level of nitrogen 260 kg ha^{-1}.N_3:third level of nitrogen 400 kg ha^{-1}. Z_1:first level of zinc 0 kg ha^{-1}, Z_2: second level of zinc 15 kg ha^{-1}, Z_3: third level of zinc 30 kg ha^{-1}

had highest positive indirect effect (0.352) on yield. Also the weight of 1000 grain due to number of grain per row had highest negative indirect effect (-0.373) on yield. Because of positive correlation between weight of 1000 grain and number of row, in N_3Z_1 opposite to N_1Z_2 (120 kg/ha Nitrogen, and 15 kg/ha Zinc), increasing number of row cause to increasing weight of 1000 grain. This result is predictable because of positive correlation between weight of 1000 grain with row number and grain number per row. In this treatment coefficient of determination ($1-U^2$) is equal to 0.95.

According to variance analysis, in N_2Z_3 (260 kg/ha Nitrogen, plus 30 kg/ha Zinc) number of row had highest direct effect (0.341) on yield. After that weight of 1000 grain (-0.824) and finally number of grain per row (-0.055) had lowest effect on yield. The weight of 1000 grain due to number of grain per row (0.651) had highest positive indirect effect on yield and number of grain per row due to number of row (-0.009) had lowest indirect effect on yield . Because of negative correlation between weight of 1000 grain and grain number per row, by increasing number of grain, they become smaller and finally weight of 1000 grain get decreased. Also there was a negative correlation between weight of 1000 grain and row number, whatever explain that by increasing number of row, grains weight get decreased. In this treatment coefficient of determination ($1-U^2$) is equal to 0.84.

Therefore the new released maize hybrids have higher dry matter than the old ones, mainly due to higher grain filling rate. According to the path analysis results, in first treatment (N_1Z_2), weight of 1000 grain had highest direct and positive effect on yield (0.96). Also number of row direct effect was positive and significant (0.733), however number of grain per row had negative effect on yield (-0.536). So that as a point of plant breeding, weight of 1000 grain has highest potential for yield increasing. Also this treatment had high effect from nitrogen and zinc fertilizer and similar that in second treatment (N_3Z_1), number of row had high effect on yield (1.003). In third treatment (N_2Z_3) number of row had high effect on yield (0.341). So in second and third treatment, number of row had highest effect on yield that influenced from nitrogen and zinc.

According to the grain filling rate results (Table 4), in different fertilizer combinations, the highest amount of grain filling rate was related to N_1Z_2 (3.19 g/m^2/day). Such this high grain filling rate demonstrated positive and effective interaction between nitrogen and zinc fertilizer which can be lead to high grain yield (15.51 ton/ha) and it was evaluated by a logistic regression model as below:

Y = 122.41+e [-3.19(x-1.53]

that *Y*=dependent variable (grain yield) and X = grain filling rate.

Furthermore grain filling rate in 704, was 1.43 g/m^2.day^{-1} and in 540 was 2.19 g/m^2.day^{-1}, so the latter had high grain filling rate. This result confirms the former similar results in Fars province (Bahrani and Mesgarbashi,1993). Increasing grains weight depends on the rate and time of grain filling (Saeedi, 2008). Also, high yield of those treatments cause by high grain filling rate and it's Durante (Yazdandoost and Rezaie, 2001). Grain filling rate depends on the period before silkilng and also influenced by source size and availability of dry matter. So lengthen the period before silking, to compare with grain filling period increase grain yield. Also other researches confirm the positive correlation between grains number and grain yield. Hybrids with higher grain filling rate produce higher yield (Seyyedi, 1999).

According to that researches, grain filling rate have direct relation with grain yield which confirm results of this experiment. Furthermore higher growth rate show higher yield in plant and have direct relation with grain weight. In another reports also mentioned positive correlation between grain weight and grain yield (Ranjan, 2003). During the grain filling, grain weight is determined (Bahrani and Mesgarbashi, 1993; Wang et al., 2008). Finally by these results this experiment and similar researches, grain filling rate have direct effect on grain weight and grain yield. Grain filling period indirectly effects grain yield. Time of grain filling depends on growth period and depends on genotype, kind of hybrid and environmental conditions take 30 or 60 days. Nitrogen store up in grain during grain filling. Also nitrogen effects on grain number and Durability of this process. Also it can affect the producing process and carbohydrate metabolism (Bahrani and Mesgarbashi, 1993). Zinc is useful to store hydrocarbon in pollen and of course increasing viability of pollen and also lead to increasing grain number and high yield (Masoni, Ercoli and Mariotti, 1996). This experiment showed that the best combinations of zinc and nitrogen fertilizer and usefulness of their application into different maize hybrids. Finally it can be concluded and will be suggested that hybrids 540 showed better potential for this region. Since there is a significant interaction between nitrogen and zinc the used level of each fertilizer should more managed according to the other ones.

Conclusions

According to this experiment N_1Z_2, N_2Z_3 and N_3Z_1 showed high grain yield due to high grain filling rate. Also, yield components direct effects on yield determined by path analysis. It will be suggested use of those combined fertilizer (nitrogen and zinc) in proper amount for similar agro climatic conditions can increase maize yield and quality.

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