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ORIGINAL ARTICLE

The Effects of Water stress and Foliar Putrescine Hormone on the Yield and Yield Components of Maize (*Zea mays.* L)

Reza Zarghami[1], Navid Ataie[2], Parinaz Pouresmaeil[2], Faranak Moshabaki Isfahani[3], Mohsen Tarighaleslami[4]*
[1] Agricultural and Biotechnology Research Institute of Karaj, Iran
[2]Department of Agronomy, Varamin Branch, Islamic Azad University, Varamin, Iran
[3]Department of Agriculture, Fars Science and Research Branch, Islamic Azad University, Shiraz, Iran
[4] Young Researchers Club, Varamin-Pishva Branch, Islamic Azad University, Varamin-Pishva, Iran
*Corresponding Author e-mail: m_tarighi1360@yahoo.com

ABSTRACT
Agricultural plants usually are subject to environmental stress. The amount of water available to the plant is one of the factors that dictates the yield of the plant. A split plot experiment in completely random block design with three replications was conducted in 2011 farming year to examine the effect of water stress and putrescine hormone solution on the yield of the zea mays and the elements of the yield. The stress was induced at three levels of D1 (control group no stress) D2 (no water in 4 days during vegetative growth – knee stage), and D3 water stress (no water in 4 days during flowering state). Concerning the secondary factor, 5 treatments were designed including H1 (no hormone), H2 (1mM putrescine hormone at mid vegetative growth (7 leaves)), H3 (2mM putrescine hormone at mid vegetative growth (7 leaves)), H4 (1mM putrescine hormone at mid pollination stage) and H5 (2mM putrescine hormone at mid pollination stage). Weight of 1000graínds, row number, length of ear, total grains on an ear were measured. The results showed that water stress had a significant effect (1% level) on all the traits except for the row number. In addition, Putrescine hormone did not have significant effect on the traits under study. Regarding the mutual effects on the treatments under study, water stress and putrescine were significantly effective on grain yield at 5% level. The best performance of the seeds was obtained in the plants under no stress which received putrescine hormone at late growth stage.
Key words: *Corn, Water stress, Yield, Yield components, Putrescine*

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INTRODUCTION

Economic role of maize, which has been farmed for thousands of years, is crystal clear as each and every parts of the plant including the grains, the leaves, and the stem are used for different purposes including human food, animal feeds, industrial and pharmacological usages [1]. Water stress on the crops is effective on physiological and morphological traits of the plant, and consequently on the yield. In addition, there is direct relationship between the effectiveness of the stress and the growth period in which the stress has been exerted [2]. The dire consequence of water stress on growth and yield of maize is also subject to the stage of growth when the stress is induced, severity of the stress, and genotype of the plant [3]. The process used by the stress to exert its effect can be studied by measuring the yield and elements of the yield [4]. The amines are among the organic bases. Ammoniac derivatives are found in amines. One nitrogen atom bounded to one/tow/three alkyl groups yield amine type 1/2/3 respectively. Base properties of amines type 2 are stronger than the others candidate materials and due to its effect on human nervous system it has found several applications. Some of neurotransmitters like Adrenaline are amine, while some of painkillers such morphine is in amines group. Of other amine combinations are codeine and ephedrine. Amino acids are other group amines [5]. In many cases, variety of stresses result in accumulation of polyamine; this hints that polyamine biosynthesis is one of the main biochemical responses of plants [6].

MATERIALS AND METHODOLOGY

The experiment was conducted in research farm of Islamic Azad University, Varamin-Pishva unit, Ghale Sin Varamin (51°31' east longitude, 35°20' north latitude, height of 1050m from sea level, and area of 1250ms) in farming year 2011. The design of the experiment was split plots of fully randomly blocks with 3 replications. The cultivar used was two-purpose single-cross 260 (Sc260) (feed and grain), which is a fast growing cultivar. The main factor was irrigation regimes and the secondary factor was putrescine hormone solution. Regarding the main factor, three treatments were designed including D1 (control group no stress) D2 (no water in 4 days during vegetative growth – knee stage), and D3 water stress (no water in 4 days during flowering state). Regarding the secondary factor, 5 treatments were used including H1 (no hormone), H2 (1mM putrescine hormone at mid vegetative growth (7 leaves)), H3 (2mM putrescine hormone at mid vegetative growth (7 leaves)), H4 (1mM putrescine hormone at mid pollination stage) and H5 (2mM putrescine hormone at mid pollination stage). The soil was fertilized based on the soil test results to determine level of nutritious materials of the soil (N, P, K). Each experiment units (plot) included five stacks with7m length and 75cm intervals. The distance on the line was 20cm and the seeds were planted in 25th March 2011 in pile (3 seeds at 3-5cm depth). Irrigation was conducted in 7days period and until exertion of water stress, rain irrigation method was employed. The solution was sprayed in the farm at designated periods using back pack sprayer. Ten samples from each plot were used for further tests.

RESULTS AND DISCUSSION

Grain yield

The results confirmed that water and the hormone stresses each had separate effects on grain yield at 1% level. In addition, the reciprocal effect of water stress and putrescine stress on the grain yield was significant at 5% (Table 1). Maximum reduction in grain yield was among the treatments which experienced the stress at flowering stage following by those which were affected by the stress during vegetative growth stage. The control treatment had the best grain yield. The stage of exerting the stress have different effects on structure of the plant, which among them smaller size plant and decrease of dry mass is most noticeable. The plant sustains the worst damage, when the water stress starts in vegetative stage until mid point of the stage, so that great reduction in dry mass happens. Water stress at this stage does not have direct and measurable effect on number of grain and the main factor that influences the plant is reduction in photosynthesis materials. Comparing the effects of water stress on grain yields and total number of grain in the ear, it appears that the main cause of less grain yield in by water stress is less number of grain. This result is consistent with results by [7,8].

When the water stress happens at late growth stage (pollination and flowering), a reduction in pollination and fewer grain number, consequently, happen [9]. In addition, there are proven evidences that a considerable reduction in organic compound and photosynthesis material happens during the stress period and retransfer, which plays an important role in filling the grains [10].

As indicated in Table 2 regarding the isolated effect of putrescine hormone, the best stage for supplying the hormone is at late growth stage before flowering. Clearly, both 1mM and 2mM have achieved a considerable better result regarding gain yield comparing with the other treatments. The other 3 treatments are also in the same statistical group. This result is consistent with [11,5]. They reported that polyamines have a role in embryogenesis, root development, pollen development, flower induction, early fruit development, and reaction to stresses. In addition, [12] showed that in addition to positive effects during environmental stresses, polyamines also induce cellular division and growth. Furthermore he argued that putrescine, as one of the main polyamines poly-structures in plants, play a role in different processes of cell reproduction, growth, morphogenesis, and differentiation of the cells.

Surveys of the reciprocal effects of water stress and putrescine hormone showed a significant difference between irrigation regimes. As illustrated in diagram 1, maximum grain yield is achieved by the treatment without water stress and 1mM putrescine hormone at late growth stage and before flowering. On the other hand, treatments which underwent water stress at late growth stage had the lowest yield. More specifically, the treatment that received to putrescine hormone had the minimum grain yield. In addition, diagram 1 pictures that regardless of the fact that under which stage the stress has been exerted, treatment that received the hormone produced better results. Thus, putrescine hormone has limited effects, which disappear over time. In fact, the shorter the time interval between spraying the hormone and the measurement, the higher the effects of the hormone.

1000 grains weight

As listed in Table 1, the isolated effects of water stress and putrescine hormone of 1000grains weight are significant at 1% level. On the other hand, the reciprocal effects of the stress and hormone on 1000 grains

weight showed that best yield was obtained by the control treatment followed by water stress before germination; furthermore, water stress at mid growth stage produced minimum yield. (Table 2)
The main effect of water stress on 1000 grains weight is induced through interruption of photosynthesis and also interruption of retransfer. These findings are consistent with [13]. As pointed out regarding grain yield, when water stress occurs at late growth stage and before pollination stage, a great reduction in number of grain happens as many flowers remain undeveloped and lose their reproduction power; however, reduction in total number of grains is coincident with increase 1000 grains weight as a limited number of smlit is distributed among fewer grains. The results are consistent with [9].
The isolated effects of putrescine hormone on 1000 grains weight pictured in the diagram shows that the highest weight was obtained in the treatment with 2mM hormone at late growth stage. The treatment with 1mM putrescine hormone at the same stage is ranked in the 2nd place and the other three treatments are at the same level. (Table 2)

Row number / ear

As listed in Table 1, water stress treatment and putrescine treatment were effective on number of grain in row at 1% level, while the reciprocal effect of the two treatments was significant at 5%.
The isolated effect of water stress on row number (Table 2) showed that the control group yielded highest number of seeds and water stress at late growth stage and flowering stage yielded minimum row number. The row number is a function of number of tassel and pollination and number of tassel in turn is a function of access to enough water. Thus, water stress near to tassel formation stage results in considerable decrease in number of tassel and pollination, which eventuate in fewer grains on ear and less grain yield.
These results are consistent with [14]. They reported that water stress, damages to pollen and interrupts tassel development, which is responsible for smaller row number. In addition, they argued that under water stress, damage to pollen and lack of pollen when the tassel emerges are one of the reasons of fewer seeds. In addition, gain yield is affected with lighter and fewer number of grain in row. Water stress before development of results in fewer grain at the top section of the ear, which is due to increase in sterilized pollens caused by lack of required materials [15].
Table 2 lists the results regarding the isolated effects of Putrescine hormone on row number, and by far the best yield, as indicated, is obtained by the treatment of 2mM at late growth stage followed by the treatment of 1mM at the same stage. The both are located in the same statistical group and the least performance is obtained by the control treatment.
Diagram2 pictures the reciprocal effects of water stress and putrescine hormone. Evidently, the best yield is obtained for the treatment without water stress and those which have received 1 and 2mM hormone. The minimum yield is obtained by the treatment of water stress at late growth stage, and among them, those without hormone spray produced the minimum performance.
As listed in Table 1, the effects of water stress and the hormone on the length of the ear is significant at 1% level, while the reciprocal effect of the two factors on the length of the ear is not significant. Water stress delays development of ear and supply of the materials needed for development of the ear.
Table 2 also indicates that maximum length of the ear was obtained by the control treatment, while the minimum length was obtained by the water stress treatment at the early flowering stage. The rate of development of the ear – a reliable destination for the photosynthesis materials during flowering was reduced due to water stress induced in vegetative growth stage. The Table indicates that the maximum and minimum length of the ears were obtained by 2mM treatment at the late growth stage and control treatments. This proves effectiveness of the hormone on length of the ear.
As indicated in Table 1, the isolated effects of water stress and Putrescine hormone on row number was significant at 1% level, while the reciprocal effect is not significant on row number. Table 2 also indicates that control treatment yields the maximum row number. In addition, the strongest negative effect on row number occurs when the water stress is exerted at flowering stage. Failure to develop grain after water stress can be explained by inadequate photosynthesis materials during pollination, development of grains and before that [16]. According to Setter et al. (2001), water stress during pollination stage influences development of embryo cells [17]. They also argued that grain development stage in maize is a function of leaves photosynthesis, supply of glucose, starch, Abscisic acid and cytokine. Thus, lack of water at pollination stage reduces the number of grains at the tail of the ear and the whole length of the ear, consequently, by influencing pollination process.
Detailed examination of the isolated effect of putrescine hormone on grain yield reveals that spraying the hormone at the late growth stage is more effective than supplying the hormone at early stage of growth. This hints the short term effect of the hormone and probably more effect of the hormone on grain development. To put it another way, by starting germination phase and considerable decrease is growth

controlling hormone, artificial supply of growth hormone is considerably effective on number of grain on ear. (Table 2).

Table1. Analysis Variance of agronomical characteristic

S.O.V	Df	Yield	1000 grain weight	Row number/ear	Length of ear	Total number
Replication	2	64504.62 ns	4.222222 ns	1.35555556 ns	0.00955556 ns	118.4889 ns
Factor A	2	11650957.36 **	805.066667 **	291.75555556 **	9.81422222 **	81162.7556 **
Error	4	139010.19	2.66667	1.8555556	0.03688889	591.1222
Factor B	4	454376.42 **	37.422222 **	4.9222222 **	0.31188889 **	3168.3 **
AB	8	66685.52 *	4.28889 ns	2.75555556 **	0.10422222 ns	529.5333 ns
Error	24	21816.14	4.216667	0.577778	0.062778	266.3556
CV%	-	13.37	10.96	3.10	11.81	4.43

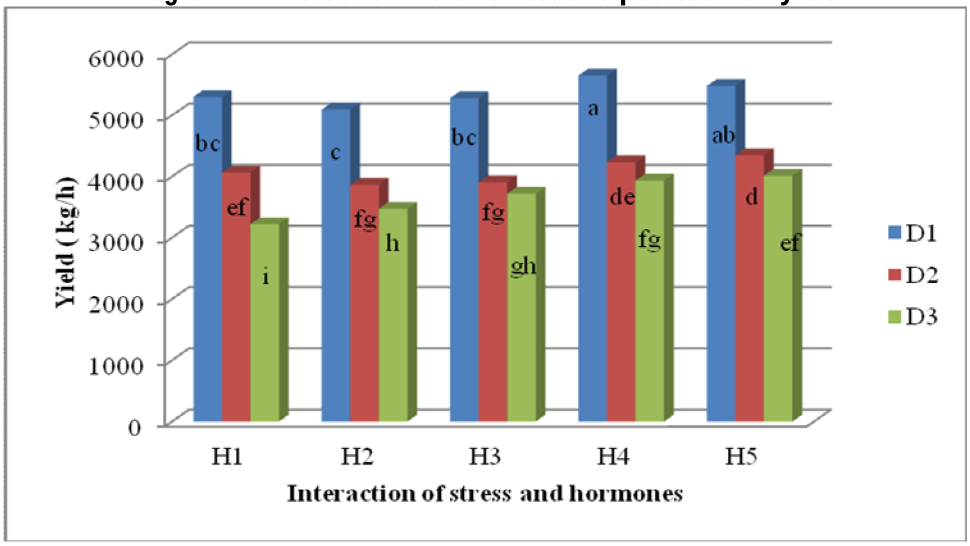
ns,*,**: Non- significant and significant at in 0.05 and 0.01 level of probability respectively.

Table2. Means comparison of agronomical characteristic

Treatment	Yield (Kg/h)	1000 grain weight (g)	Row number/ear	Length of ear	Total number
D1	5363.33 a	218.33 a	29.4 a	14.45 a	450.7 a
D2	4086.07 b	204.86 c	23.2 b	14.13 b	343.4 b
D3	3672.73 c	216.60 b	20.8 c	12.92 c	309.9 c
H1	4196.33 bc	211.77 c	23.7 c	13.63 c	352. 6 b
H2	4146.11 c	212.66 bc	23.8 c	13.68 c	348.3 b
H3	4303.44 b	211.33 c	24.3 b	13.82 b	363.8 b
H4	4608.89 a	214.22 b	24.8 b	13.94 b	387.3 a
H5	4615.44 a	216.33 a	25.5 a	14.08 a	387.8 a

D1 (control group no stress) D2 (no water in 4 days during vegetative growth – knee stage), and D3 water stress (no water in 4 days during flowering state).
H1 (no hormone), H2 (1mM putrescine hormone at mid vegetative growth (7 leaves)), H3 (2mM putrescine hormone at mid vegetative growth (7 leaves)), H4 (1mM putrescine hormone at mid pollination stage) and H5 (2mM putrescine hormone at mid pollination stage)

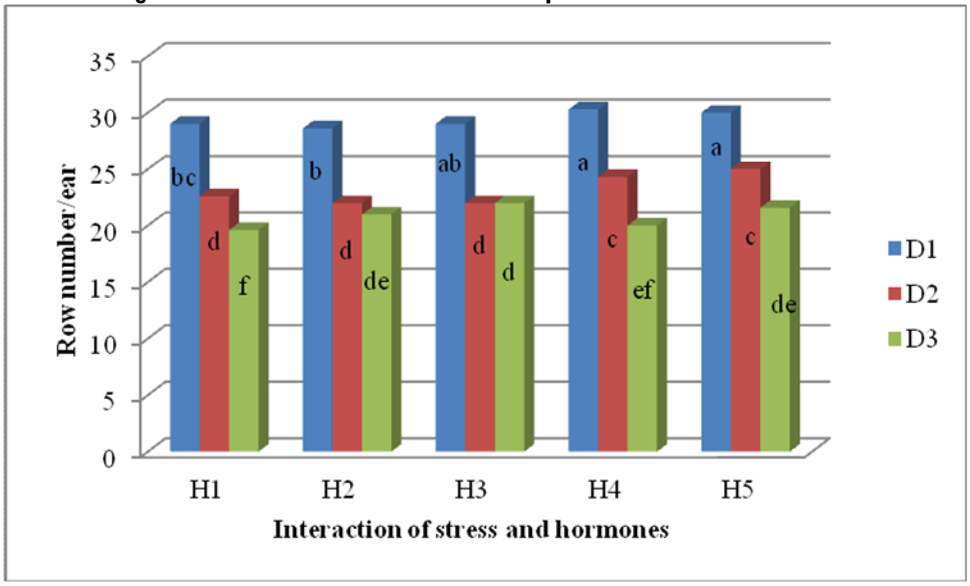
Diagram 1. Interaction Water Stress and putrescin on yield.



D1 (control group no stress) D2 (no water in 4 days during vegetative growth – knee stage), and D3 water stress (no water in 4 days during flowering state).

H1 (no hormone), H2 (1mM putrescine hormone at mid vegetative growth (7 leaves)), H3 (2mM putrescine hormone at mid vegetative growth (7 leaves)), H4 (1mM putrescine hormone at mid pollination stage) and H5 (2mM putrescine hormone at mid pollination stage).

Diagram 1. Interaction Water Stress and putrescin on Row number / er.



D1 (control group no stress) D2 (no water in 4 days during vegetative growth – knee stage), and D3 water stress (no water in 4 days during flowering state).

H1 (no hormone), H2 (1mM putrescine hormone at mid vegetative growth (7 leaves)), H3 (2mM putrescine hormone at mid vegetative growth (7 leaves)), H4 (1mM putrescine hormone at mid pollination stage) and H5 (2mM putrescine hormone at mid pollination stage).

CONCLUSION

As the results showed, to have maximum efficiency on grain yield, hormone spray must be carried out at the late growth stage and germination stage. At this stage, the plant has completed vegetative growth and starts to dedicate its energy to supply required materials for development of grains. Thus, hormone spray at this stage has a direct role in development of grain. Less decrease in grain yield was observed when the hormone spray is carried out immediately after water stress. This highlights necessity to supply the hormone at proper time as a measure to fight water stress's effects. Given that majority of the traits were significantly different between 1 and 2mM treatments, and taking into account cost of hormone spray operation, 1mM hormone spray is recommended. This operation, which needs mechanized farming equipment and method, is economically justifiable for industrial farming.

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