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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 3 (6): 957-959, 2000

Effect of VAM on Drought Tolerance and Growth of Plant in Comparison with the Effect of Growth Regulators

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Abstract: The present study was carried out to investigate the involvement of VAM and phytohormones under drought stress. An experiment was conducted to evaluate the effect of vesicular arbuscular mycorrhizal inoculation on plant growth and yield under controlled and drought conditions. Plant growth regulators viz. ABA and GA were used in combination with VAM and/or drought, to find out the interactive effect of VAM and phytohormones on plant growth and yield under drought stress. Foliar spary of phytohormones viz. Gibberellic acid (GA) and Abscisic acid (ABA) each at a concentration of 10^{-6} M was made prior to the imposition of first water stress. The treatments including VAM showed better vegetative and reproductive growth than non-VAM plants. The plants which were subjected to foliar application of GA and ABA in combination with VAM (VAM + ABA and VAM+GA) gave better yield than VAM alone. The vegetative and reproductive growth was decreased in drought stressed, non-VAM plants as a result of which, shoot and root dry weights and yield were reduced. However, VAM+Drought+ABA increased the weight of pods/plant and shoot dry weight/plant. The VAM and foliar application of ABA, helped the plants to increase the yield insignificantly in VAM+ABA+Drought and significantly in VAM+ABA. Foliar application of ABA and GA in the absence of VAM has not been found to be stimulatory to yield.

Key words: VAM, Drought, Growth regulators, *Vigna radiata*

Introduction
Drought is one of the major limitation to crop yield, as it affects both morphology and physiology of plants. Brumm and Hurburgh (1990) observed shrivelled and wrinkled hypocotyle growth of soybean by drought stress. Under adverse conditions several internal and external factors e.g., growth regulators, changes in level of inoculation with VAM fungus ameliorate the adverse affects of drought. The use of VAM fungi in cultivated crop can be important factors in increasing productivity even under adverse conditions as well as enhancing a more rational use of fertilizers (Menge, 1983). Under low moisture levels, water absorption capacity of roots might be enhanced by mycorrhiza. The improved water status and enhanced drought tolerance caused by VAM infection was due to absorption and translocation of water by external hypae (Runjin,1989). Zajicek *et al*. (1987) observed that the growth of two forbs with no supplemental phosphorus was improved by all the *Glomus* spp. tested under drought stress conditions. It has been suggested that VAM plants acclimatize more efficiently to water stress (Sweatt and Davies, 1984). The influence of *Accacia nilotica* and *Leucaena leucocephala* seedlings was found to be positive (Michelsen and Rosendahl, 1990). Among ten isolates of VA mycorrhizal fungi evaluated, one of *Glomus fasciculatus* and two other were equally effective for improving the performance of *Vigna radiata* both under stressed and normal watered conditions (Kehri and Chandra, 1990). Plant dry weight was greater in inoculated plants under all irrigation treatments, photosynthetic rate and stomatal conductance were significantly greater in VAM colonized than in non-VAM inoculated plants under dry or moderately dry conditions (Ibrahim *et al*., 1990).

Drought also affects the level of growth hormones in plants. Bano *et al*. (1993) reported that the level of Abscisic acid (ABA), Gibberellic acid (GA) and their conjugated forms increased during the drought stress while the level of cytokinins decreased. The exogenously applied ABA can affect the physiology and growth responses of plants in water stressed conditions. Seed treatment with ABA increased grain yield in water stressed plant of Sorghum cultivar. Drying seeds after soaking in ABA has beneficial effect on yield (Traore and Sullivan, 1990). The present work involves the study of interaction between VAM infection, drought and exogenous application of plant growth regulators: viz. ABA and GA in different combinations.

Materials and Methods
A pot experiment was conducted in which *Vigna radiata* cultivar NCM-212 was grown in sterile soil. The seeds were obtained from National Agriculture Research Council, Islamabad. Ten seeds per pot were sown and the plants were supplied with Hoagland's nutrient solution without KH_2P0_4. The following treatments were made:

VAM
Drought
VAM+Drought
VAM+Drought+ABA
Drought + ABA
VAM+ABA
ABA
Drought+GA
VAM+GA

Pot soil was inoculated with VAM at the spore concentration of 300/100 g soil + 5 g of root pieces, added to 1.2 kg soil and was spread in the form of a layer about 4cm below the upper surface of soil. Aqueous solution of growth regulators were applied as foliar spray (10^{-6} M) prior to the imposition of water stress. Two water stress treatments were made first after 75 days of sowing and second after 13 days of first stress. At harvest, plant parts were dried in an oven connected with a vacuum pump at 70°C for 75h. Shoot dry weight was taken to assess the growth and for yield, number and weight of pods/plant and number and weight of seeds/plant were recorded.

Results and Discussion
Results of the experiment showed that VAM inoculated plant has better growth than that of drought stressed plants (Table 1). Ibrahim *et al*. (1990) found that dry weight of plants was found to be greater in VAM-inoculated plants under all irrigation treatments. The mycorrhizal plants were taller than non-VAM plants. The data given in Table 1 shows that drought caused a significant decrease in shoot dry weight over the control but the VAM inoculated plant had significantly higher shoot dry weight than non-VAM plants.

Table 1: Dry weight of shoot plant^{-1}

Treatment	Mean	SE	Duncan test
VAM (Control)	1.983	0.111405	CDE
Drought	1.207	0.152133	DE
VAM + Drought	2.957	0.611292	BC
VAM + Drought + ABA	2.260	0.583866	CD
Drought + ABA	1.242	0.216333	DE
VAM + ABA	3.607	0.688573	B
ABA	1.143	0.184059	DE
Drought + GA	0.794	0.090185	E
VAM + GA	5.180	0.20664	A

Means which share a common English letter are insignificantly different, otherwise they differ significantly at least at $p < 0.05$.
LSD valu + 1.184.

Table 2: Dry weight of root plant^{-1}

Treatment	Mean	SE	Duncan test
VAM (Control)	0.1100	0.017321	BC
Drought	0.03433	0.00636	D
VAM + Drought	0.08600	0.026274	BCD
VAM + Drought + ABA	0.1000	0.026274	BC
Drought + ABA	0.06833	0.006833	CD
VAM + ABA	0.1367	0.027285	B
ABA	0.07000	0.011547	CD
Drought + GA	0.04967	0.015191	CD
VAM + GA	0.3167	0.012019	A

Means which share a common English letter are insignificantly different, otherwise they differ significantly at least at $p < 0.05$.

Table 3: Number of pods plant^{-1}

Treatment	Mean	SE	Duncan test
VAM (Control)	16.67	0.666667	B
Drought	4.000	0.57735	F
VAM + Drought	14.00	0.57735	C
VAM + Drought + ABA	15.00	0	BC
Drought + ABA	10.33	0.881917	D
VAM + ABA	21.00	1	A
ABA	10.00	1	D
Drought + GA	6.667	0.333333	E
VAM + GA	20.67	0.333333	A

Means which share a common English letter are insignificantly different, otherwise they differ significantly at least at $p < 0.05$.
LSD value = 2.057

Table 4: Weight of pods plant^{-1}

Treatment	Mean	SE	Duncan test
VAM (Control)	3.717	0.381153	B
Drought	0.7467	0.151694	C
VAM + Drought	3.267	0.497773	B
VAM + Drought + ABA	3.770	0.698642	B
Drought + AB	1.650	0.246644	C
VAM + ABA	5.633	0.088192	A
ABA	1.607	0.23497	C
Drought + GA	1.367	0.116667	C
VAM + GA	6.667	0.233333	A

Means which share a common English letter are insignificantly different, otherwise they differ significantly at least at $p < 0.05$.
LSD value = 1.085

This finding is in accordance with previous reports, which showed that drought decreased the shoot growth (Simpson, 1981; Cavalieri and Boyer, 1982). It has been observed that VAM infection helped the plants to overcome the drought conditions by the uptake of water and nutrients especially phosphorus from soil which leads to improve the plant growth.

Drought-stressed VAM inoculated plants had greater shoot weight than non-VAM inoculated and drought stressed plants (Table 1). Busse and Ellis (1985) reported that VAM plants undergoing three water stress periods had twice the biomass as compared to non-inoculated drought plant. Similar results were reported by the Michelsen and Rosendahl (1990).

Table 5: Number of seeds plant^{-1}

Treatment	Mean	SE	Duncan test
VAM (Control)	95.33	14.88101	C
Drought	18.33	2.962731	E
VAM + Drought	53.67	7.838651	D
VAN + Drought + ABA	58.33	3.179797	D
Drought + AB	42.00	8.736895	DE
VAM + ABA	133.0	1.154701	B
ABA	42.33	5.238745	DE
Drought + GA	34.33	6.17342	DE
VAM + GA	157.3	2.962731	A

Means which share a common English letter are insignificantly different, otherwise they differ significantly at least at $p < 0.05$.
LSD value = 22.22

Table 6: Weight of seeds plant^{-1}

Treatment	Mean	SE	Duncan test
VAM (Control)	2.940	0.439242	B
Drought	0.5503	0.102258	C
VAM + Drought	2.500	0.305505	B
VAM + Drought + ABA	2.810	0.461988	B
Drought + AB	1.310	0.180093	C
VAM + ABA	4.200	0.057735	A
ABA	1.220	0.156205	C
Drought + GA	0.6933	0.126667	C
VAM + GA	5.067	0.437163	A

Means which share a common English letter are insignificantly different, otherwise they differ significantly at least at $p < 0.05$.
LSD value = 0.9337

The results of the present study showed that VAM inoculated plants receiving drought stress + ABA showed an insignificant increase in shoot dry weight over the control (Table 1). This result is also in accordance with the previous findings that exogenously applied ABA regulates the physiology and growth responses of plants in water stressed conditions (Traore and Sullivan, 1990). The foliar application of GA on VAM inoculated plants was very effective in increasing the shoot dry weight. This may be attributed to the promoting effect of GA on cell elongation and cell enlargement. Haber and Luippold (1960) observed that growth stimulation achieved by GA may be attributed to stimulate cell enlargement. The VAM-inoculated plants treated with ABA significantly increased the shoot dry weight but the magnitude was less as compared to VAM + GA.

There are many reports, which show that VAM increases the root growth. In this study, root dry weight of VAM + GA treated plant was significantly higher than control(Table 1). This result corroborates previous finding which revealed that VAM inoculated plants had consistently increased root weight and rooting depth in comparison with non-VAM plants (Busse and Ellis, 1985). Drought stress decreased the root growth (Table 2). Taylor and Klepper (1974) reported that root length stopped to increase as water stress developed in cotton plant.

Drought has been found to decrease the yield significantly over control. The yield (Table 3-6) was greater in VAM inoculated plant either in combination with drought, ABA, or GA than non-VAM plants. It has been found previously by Dzhamrishavili *et al*. (1989) that foliar application of GA_3 increased the seed yield by increasing the vegetative and reproductive parameters. Gibberellic acid and Abscisic acid augmented the stimulatory effect of VAM inoculation on plant growth particularly under drought stress. Traore and Sullivan (1990) showed that ABA seed treatment increased grain yield in drought stressed plants of sorghum cultivars. Craufurd and Peacock (1993) showed that drought stress imposed during early flowering in sorghum caused 87% reduction in grain yield. Busse and Ellis (1985) found that drought tolerance in soybean is increased by inoculation with *G. fasciculatum* (Slater, 1967).

The present study indicates that one of the benefits of VAM to plant is attributed to the ability of VAM to increase drought resistance. Foliar application of ABA and GA further augments the promotive effect of VAM on plant growth and yield particularly under stress. ABA being more effective than GA can be implicated in association with VAM inoculation to ameliorate the adverse effects of drought stress.

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