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NOTE

# EFFECT OF SOIL MOISTURE STRESS ON ROOT AND SHOOT DEVELOPMENT OF SEVEN WHEAT (*TRITICUM AESTIVUM* L.) CULTIVARS

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ABSTRACT

To study the effects of two soil moisture levels on root and shoot development of wheat seedlings, and to compare root growth in dry-land and irrigated cultivars of wheat in seedling stage, a pot experiment was conducted at the Agronomy Department, Technical University of Berlin in the 1978 summer season. The two soil moisture levels consisted of 20% and 80% water holding capacity of the soil. From the seven wheat cultivars, Bezostaya, Jubilar, Karaj-1, Omid and 4820 are grown in irrigated land, Boulani comes from dry land area of Zabul and Roshan is grown both in dry lands and with irrigation. A split-plot design with three replications was used in which soil moisture levels were main plots and cultivars as sub-plots. Traits studied were root and shoot length, root and shoot dry weight, 10, 20 and 30 days after germination. The wheat cultivars were also studied for their root number and length in a petri dish experiment, conducted in an incubator. After 72 hr, root length and number of roots in each seedling were determined. Results of the experiments

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showed that: a) There were significant differences between the two moisture levels, 20% and 80%, for all traits at all three harvest dates, with the means of 80% moisture being higher in all cases. b) In pots with low moisture, roots reached their maximum length at the first harvest (in 10 days). No further increase in root length occurred at the second and third harvests, indicating that moisture stress inhibited further root growth. c) Cultivars showed significant differences for all traits at all three harvests, except for shoot length at the second harvest and for root length at the third harvest. d) There were significant differences between cultivars for root length and root number in seedlings grown for 72 hr in an incubator. e) It was concluded that there are four distinctive characteristics for a dryland cultivar: 1) rapid root growth at early stage of development; 2) higher number of seminal roots; 3) more root growth, and 4) longer roots.

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**اثرتنش رطوبت خاک بررشدریشه ،ساقه‌وبرگ هفت رقم‌گندم**

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به‌ترتیب استادودانشیاردانشکده‌کشاورزی دانشگاه‌تهران واستادگروه آگرونومی دانشگاه‌فنی برلین .

## چکیده

بمنظورمطالعه‌اثرات دوسطح رطوبت خاک بررشدریشه ،ساقه‌وبرگ گیاهان جوان درگندم ،یک آزمایش گلدانی درگروه‌آگرونومی دانشگاه‌فنی برلین درتابستان سال ۱۹۷۸ انجام‌شد .دوسطح رطوبت عبارت بودند از ۲۰% و ۸۰% ظرفیت نگهداری آب درخاک . ازهفت رقم‌گندم‌به‌نامهای یزوستایا ،بولانی،جوبیلاز،کرج - ۱،امید ،روشن و ۴۸۲۰ استفاده‌شد .طرح کرت‌های خردشده‌باسه‌تکرارموردا ستفاده‌واقع‌شدکه‌سطوح رطوبت در کرتهای اصلی وارقام‌درکرتهای فرعی قرارگرفتند .صفات موردمطالعه عبارت بودندازطول ریشه ،طول ساقه ،وزن خشک ریشه‌وساقه‌وبرگ ، ۱۰، ۲۰و ۳۰ روزپس ازجوانه‌زدن بذر،ارقام‌موردا ستفاده‌همچنین ازنظر تعدادوطول ریشه‌دریک آزمایش درظروف پتری موردمطالعه‌قرارگرفتند

وپس از ۷۲ ساعت طول وتعداد ریشه درگیاهان جوان تعیین گردید .نتایج آزمایش نشان دادکه :

۱ــ اختلاف معنی داری بین دوسطح رطوبت ۲۰% و ۸۰% برای تمام صفات وسه تاریخ برداشت وجوددارد .میانگین رطوبت ۸۰% درتمام حالات بالاترین میانگین بود .

۲ــ درگلدانهای با رطوبت کم ریشه ها دراولین برداشت به حداکثر رشد طولی خود رسیدند ،دربرداشت دوم وسوم هیچگونه افزایشی دررشد طولی ریشه ها دیده نشد .

۳ــ ارقام ازنظر تمام صفات باستثناء طول ساقه دربرداشت دوم وطول ریشه دربرداشت سوم درسه تاریخ برداشت با یکدیگر اختلاف معنی داردا شتند .

۴ــ درآزمایش باظروف پتری ،بین ارقام ازنظر طول ریشه وتعداد ریشه اختلاف معنی داری دیده شد .

۵ــ نتیجه گرفته شدکه ارقام دیم دارای چندخصوصیت متمایزهستند .

الف ــ سرعت زیاد رشد ریشه درمرحله اولیه رشد .

ب ــ تعداد زیاد ریشه های اولیه .

ج ــ مقدار بیشتر ریشه

د ــ طول بیشتر ریشه

## INTRODUCTION

Studies on the effect of soil moisture stress on root development of any crop species may have a value in determining its drought resistance and yield potential in stress conditions. Numerous field and greenhouse studies have been done on this subject.

Most studies have found that the higher the soil moisture, the longer the wheat roots (8, 10). However, Karmacharya (7) reported that low moisture content in the soil increased root growth in wheat.

Root weight, straw yield, shoot length and grain yield have also shown positive response to higher soil moisture in wheat (1, 2, 3, 4, 5, 11, 12).

Pinthus and Eshel (9) studied root distribution on 25 wheat cultivars under the same conditions. They found significant varietal differences in total length of seminal roots, in number of adventitious roots, and in root distribution.

Hurd (6) studied the roots of three wheat cultivars in growth boxes. He observed that the three cultivars, regardless of moisture levels, had three distinct patterns of root growth, which helped him to explain cultivar differences in resistance to drought. Cultivar differences on root growth have also been noticed by Karmacharya (7).

The aims of this study were: a) to find the effects of soil moisture stress on root and shoot development in wheat seedlings, and b) to compare root growth in dry-land and irrigated wheat cultivars in seedling stage in different soil moisture levels.

## MATERIALS AND METHODS

A pot experiment was conducted at the Agronomy Department, Technical University of Berlin, in the 1978 summer season, to study the effects of two soil moisture levels on seven wheat cultivars. The two soil moisture levels consisted of 20% and 80% water holding capacity of the soil. The wheat cultivars used were Bezostaya, Boulani, Jubilar, Karaj-1, Omid, Roshan and 4820. Bezostaya is a Russian cultivar, being grown for several years in Karaj, Iran. Jubilar, a German winter wheat cultivar obtained from the Agronomy Department, Technical University of Berlin. The rest of the cultivars were Iranian being grown in Karaj, Iran, except Boulani which comes from Zabul, Iran. All cultivars used were of winter habit except for 4820 and Roshan which were spring/winter types. Cultivars used are grown in irrigated land except for Boulani which comes from dry-land area of Zabul and Roshan which is grown both under dry and irrigated conditions.

The soil used was a 2:1 mixture (by volume) of medium-sized sand and soil. Water holding capacity of the soil was 18.2%. Mitscherlich pots with 7 kg soil in each were used. To the soil of each pot was added: 2.4 g N, 0.5 g P, 2.2 g K, 0.3 g Mg, 0.6 g Ca, 5 mg Fe, 8 mg Mn, 1 mg Cu, 1 mg Zn, 1 mg B and

1 mg Mo. To maintain each pot at 20% or 80% water holding capacity, two pots of each moisture level were weighed and the water needed was added daily.

A split-plot design with three replications was used in which soil moisture levels were in main plots and cultivars in sub-plots. Each experimental unit consisted of a pot with 18 plants. Before planting, a germination test was carried out for all cultivars and according to the results obtained, 35 seeds were sown in each pot for Bezostaya, 30 for Omid, and 25 seeds each for other cultivars.

Three sets of the same experiment were started at the same time to study first set, 10 days after germination, second and third sets, 20 and 30 days after germination, respectively. Planting date was 21 July, 1978 for all three sets and harvesting dates were 3 August, 14 August and 24 August for the first, second and third sets, respectively. Pots were kept in greenhouse during nights and rainy days and for the rest of the time they were kept outdoors.

Traits studied were: a) root length of all plants in each pot as a whole, after washing the roots with water; b) shoot length of all plants in each pot as a whole; c) root dry weight and shoot dry weight. Roots and shoots were oven dried over night at 105°C. Dry roots were also burned over night at 400°C to correct root dry weight for sand attached to the roots.

An analysis of variance was performed on the data of each trait and means were compared by non-orthogonal t-tests.

All pots were sprayed with a 0.1% solution of 600 g $1^{-1}$ Tamaton against flies and aphids on August 1, 1978. Another spraying against flies was done on second and third sets with a 0.9 ml 1.5 $1^{-1}$ solution of 500 g $1^{-1}$ parathion on August 7. A third spraying was done on August 11, on the second

and third sets against mildew with a 50 g 100 $l^{-1}$ solution of 50% Benomyl.

On the day of harvest of each set, two plants were chosen at random from each pot for apex studies. The apex of each plant was excised and studied under microscope and the stage of spike development was recorded.

The wheat cultivars were also studied for their root number and length in a petri dish experiment. For each cultivar two petri dishes, each having 10 seeds, were placed in an incubator at 30°C and with adequate moisture. After 72 hr, root length and number of roots in each seedling were determined. Data for each trait were analyzed as a completely randomized design and means were compared using LSD test.

## RESULTS AND DISCUSSION

Table 1 presents mean growth responses over moisture levels and cultivars for all three harvests. It is evident from this table that there were significant differences between the two moisture levels, 20% and 80%, for all traits in all the harvests, with the means of 80% moisture being higher in all cases. Higher level of soil moisture caused roots to grow longer, which is in agreement with the results obtained by other investigators (8, 10). In pots with low moisture, roots reached their maximum length at the first harvest (in 10 days). No further increases in root length occurred at the second and third harvests. For the 80% moisture level, maximum root length appeared at the second harvest and root length did not increase after 20 days. This was possibly due to a) the length of the pots which did not allow roots to grow further. and b) the naturally short roots of the plant.

Shoot length, root weight and shoot weight in pots with 80% moisture were higher, compared with

Table 1. Mean values of various traits moisture levels and cultivars for all three harvests.

| Factor | Root length (cm) | Shoot length (cm) | Root weight (dg)† | Shoot weight (dg) |
|---|---|---|---|---|
| | | First harvest | | |
| Moisture levels: | | | | |
| 20% | 17.5 | 14.8 | 33.5 | 85.2 |
| 80% | 21.8 | 22.6 | 53.7 | 129.0 |
| LSD | 3.9* | 3.2* | 15.3* | 47.4** |
| Cultivars: | | | | |
| Bezostaya | 19.0 | 20.8 | 42.0 | 103.8 |
| Boulani | 20.0 | 17.7 | 47.9 | 93.6 |
| Jubilar | 18.3 | 18.3 | 37.7 | 90.7 |
| Karaj-1 | 20.0 | 19.7 | 46.8 | 103.1 |
| Omid | 19.0 | 18.0 | 41.7 | 91.8 |
| Roshan | 20.8 | 19.7 | 50.8 | 110.2 |
| 4820 | 20.2 | 18.7 | 38.1 | 86.5 |
| LSD | 1.7** | 2.1** | 6.1** | 13.4** |
| | | Second harvest | | |
| Moisture levels: | | | | |
| 20% | 15.8 | 17.4 | 39.3 | 100.6 |
| 80% | 28.5 | 30.9 | 81.5 | 306.5 |
| LSD | 4.5** | 4.8* | 15.9** | 74.6** |
| Cultivars: | | | | |
| Bezostaya | 21.8 | 25.7 | 62.5 | 224.3 |
| Boulani | 22.7 | 23.2 | 66.2 | 182.2 |
| Jubilar | 20.0 | 23.7 | 53.9 | 207.3 |
| Karaj-1 | 20.8 | 24.8 | 66.7 | 229.5 |
| Omid | 20.7 | 23.8 | 55.9 | 199.1 |
| Roshan | 22.2 | 25.3 | 71.1 | 234.9 |
| 4820 | 20.0 | 22.5 | 46.5 | 147.5 |
| LSD | 1.7* | NS | 12.3** | 57.9** |

Table 1. Continued.

| | Third harvest | | | |
|---|---|---|---|---|
| Moisture levels: | | | | |
| 20% | 15.8 | 19.0 | 50.8 | 206.3 |
| 80% | 28.2 | 40.8 | 188.7 | 1137.8 |
| LSD | 2.8** | 4.3** | 25.4** | 333.0** |
| Cultivars: | | | | |
| Bezostaya | 21.3 | 32.3 | 123.7 | 757.1 |
| Boulani | 20.3 | 28.5 | 116.2 | 538.6 |
| Jubilar | 20.0 | 30.3 | 105.7 | 728.6 |
| Karaj-1 | 21.3 | 29.8 | 111.6 | 674.0 |
| Omid | 20.7 | 28.8 | 108.3 | 662.7 |
| Roshan | 21.7 | 31.5 | 157.8 | 718.7 |
| 4820 | 21.7 | 28.5 | 107.3 | 823.4 |
| LSD | NS | 2.1** | 25.4** | 146.0** |

†(dg) decigram.
*Significant at 5% level.
**Significant at 1% level.
NS = Not significant.

pots with 20% moisture. The results are in accordance with previous findings (3, 4, 11, 12). All three traits show a steady increase with time in both moisture levels, however, the differences between the three harvests for each trait are much more pronounced in pots with higher moisture level, when compared with those with low moisture level.

Cultivars showed significant differences for all traits in all three harvests, except for shoot length in the second harvest and for root length in the third harvest. The differences between cultivars for root length were significant at the 1% probability level at the first harvest, and at 5% at the second harvest. However, such differences

disappeared by the third harvest. Furthermore, root length did not increase much after the first harvest. These findings suggest that cultivar differences for root length at early stages of plant growth may play an important role in their response to stress conditions. Other traits increase steadily as plant growth proceeds. Cultivar differences for different traits in wheat have also been noticed by other investigators (6, 7, 9). For root length, Roshan showed the highest mean value at the first and third harvests; however, Bezostaya was leading at the third harvest.

Mean values for moisture levels x cultivar interactions for traits showing significant differences are given in Table 2. At the first harvest root weight was the highest for Boulani in low moisture level, and Roshan was leading at 80% moisture levels. For shoot weight, Bezostaya produced the highest weight at 20% moisture level (without being significantly different from Boulani), whereas Roshan showed the best result at 80% moisture levels. At the third harvest, shoot length gave the highest value for Bezostaya and Roshan at 20% and 80% moisture levels, respectively. However, for root weight, Roshan was the best at 20% and 80% moisture levels, and for shoot weight, Bezostaya was leading at both moisture levels.

Results on shoot apex development showed no clear difference between moisture levels. These studies proved that the cultivars used were winter types except for two of them, Roshan and 4820, which were winter/spring types.

Mean values for root length and root number for seven cultivars 72 hr after seed germination on filter paper are presented in Table 3. This table shows that Boulani had the longest roots and the highest number of roots, compared with other cultivars.

Table 2. Mean values of traits showing significant differences for moisture levels x cultivar interactions.

| | First harvest | | | |
|---|---|---|---|---|
| | Root weight (dg)† | | Shoot weight (dg) | |
| | Moisture levels | | | |
| Cultivars | 20% | 80% | 20% | 80% |
| Bezostaya | 32.9 | 51.1 | 89.4 | 137.8 |
| Boulani | 39.9 | 55.9 | 88.3 | 118.9 |
| Jubilar | 28.5 | 47.0 | 81.4 | 120.1 |
| Karaj-1 | 33.8 | 59.8 | 86.4 | 139.8 |
| Omid | 33.7 | 49.7 | 87.1 | 116.6 |
| Roshan | 36.0 | 65.7 | 87.2 | 153.2 |
| 4820 | 29.4 | 46.9 | 58.6 | 116.3 |
| LSD | 6.3* | | 19.0* | |

| | Third harvest | | | | | |
|---|---|---|---|---|---|---|
| | Shoot length (cm) | | Root weight (dg) | | Shoot weight (dg) | |
| | Moisture levels | | | | | |
| Cultivars | 20% | 80% | 20% | 80% | 20% | 80% |
| Bezostaya | 23.0 | 41.7 | 52.5 | 194.9 | 254.9 | 1259.3 |
| Boulani | 18.3 | 38.7 | 52.6 | 179.9 | 184.2 | 893.0 |
| Jubilar | 18.3 | 42.3 | 39.5 | 171.9 | 203.5 | 1253.7 |
| Karaj-1 | 18.3 | 40.3 | 51.8 | 171.4 | 188.3 | 1148.7 |
| Omid | 17.0 | 40.7 | 47.7 | 168.9 | 184.3 | 1141.0 |
| Roshan | 19.0 | 44.0 | 61.8 | 253.8 | 213.8 | 1225.7 |
| 4820 | 18.3 | 38.7 | 48.6 | 166.0 | 204.8 | 1042.0 |
| LSD | 3.0** | | 35.8** | | 152.3* | |

†(dg) decigram.
*Significant at 5% level.
**Significant at 1% level.

Table 3. Mean values of root length and root number for seven cultivars 72 hr after seed germination in incubator.

| Cultivars | Root length (cm) | Root number |
|---|---|---|
| Bezostaya | 2.4 | 3.0 |
| Boulani | 5.8 | 5.0 |
| Jubilar | 4.8 | 3.2 |
| Karaj-1 | 3.1 | 4.5 |
| Omid | 3.5 | 4.6 |
| Roshan | 3.3 | 4.4 |
| 4820 | 4.7 | 3.5 |
| LSD | 0.54** | 0.47** |

**Significant at 1% level.

In general, it is concluded that the distinctive characteristics of dry-land cultivars such as Boulani are: a) rapid root growth at early stages, as evident from Table 3; b) higher number of seminal roots (Table 3); and c) more root growth (Tables 2 and 3) longer roots (Tables 1 and 3).

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