# 水分胁迫对半干旱地区玉米生长发育及产量的影响

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**摘要**:为了确定最佳的灌水模式,通过抗旱棚试验,分析水分胁迫对半干旱地区玉米生长发育及产量的影响。结果表明:(1)不同处理间株高、穗位差异达到显著水平,其中苗期重旱和拔节期干旱对玉米株高影响较大,导致植株生长速度下降和矮化。但不同生育期的干旱胁迫均使植株穗位降低30%以上。(2)干旱胁迫对植株茎粗的影响不显著。(3)干旱胁迫对不同处理间穗长达到显著差异,其中苗期重旱和拔节期干旱对穗长影响较大,分别比T0减少7.9%、26.3%、15.8%和15.8%,而苗期轻旱、中旱胁迫处理和开花期干旱胁迫处理则穗长有所增加;干旱胁迫处理百粒重和产量差异达到显著水平;拔节期干旱对产量影响极大,分别比对照降低15.4%、11.5%、27.3%。

**关键词**:水分胁迫;半干旱;玉米;产量
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土壤水分亏缺不仅影响玉米的生长发育,还会降低其抗病性,更甚者会严重降低玉米产量。在干旱胁迫条件下,玉米的生长发育严重受到抑制,因此,研究玉米的耐旱性 ,明确干旱对玉米生长发育及产量的影响,为玉米实现逆境生存和高产提供参考。前人研究认为,干旱会降低玉米株高和光合速率,减少干物质积累和玉米抗病抗灾性,而且最终会影响到抗旱性和作物产量。本文从生育期干旱入手,设置不同的水分梯度,探讨水分胁迫对玉米生长发育及产量的影响,为玉米抗旱栽培提供理论依据。

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## 1　材料与方法

### 1.1　试验地概况

试验于2016年在黑龙江省农业科学院齐齐哈尔分院抗旱棚进行,供试土壤0～20 cm耕作层有机质含量为26.5 g·kg$^{-1}$,碱解氮为100 mg·kg$^{-1}$,

**Abstract**:In order to clarify the environmental benefits and effects of fertilization and transplanting integrated technology on rice, the effects of fertilization and transplanting integrated technology on rice yield, nitrogen concentration, nitrogen loss quantities and loss rate in surface runoff were studied by using slow-release fertilizer with 15%, 30%, 50% reduction of nitrogen, and the base fertilizer-transplanting integration + top application mode. The results showed that the integrated technology could achieve higher rice yield. Rice yield with the application of slow-release fertilizer was increased by 6.27% under the condition of 15% nitrogen reduction, by 4.04% under the condition of 30% reduction of nitrogen. Rice yield was increased by 3.87% when the base fertilizer - transplanting integration + top application mode was used under the condition of 15% nitrogen reduction. The fertilization and transplanting integrated technology could effectively reduce the concentration of N in surface runoff. Total nitrogen concentration of conventional fertilization treatment was up to 13.12 mg·L$^{-1}$, the treatments of integrated technology reached 2.38 mg·L$^{-1}$ only. The application of integrated fertilization and transplanting technologycould significantly reduce the loss amount and rate of nitrogen. The total nitrogen loss of conventional fertilization treatmentduring the whole growth period reached 15.47 kg·hm$^{-2}$, the loss rate was 9.38%; total nitrogen loss of integrated technology treatments was only 3.35 kg·hm$^{-2}$ on average with the loss rate of 2.85%. The application of fertilization and transplanting integrated technology could reduce the amount of nitrogen fertilizer, increase the rice yield and reduce the nitrogen loss. Therefore, the fertilization and transplanting integrated technology is a resource-saving and environment-friendly planting technology on rice.
**Keywords**:integration of fertilization and transplanting; rice; yield; nitrogen loss

有效磷为 16.9 mg·kg$^{-1}$，速效钾为 134 mg·kg$^{-1}$，pH7.82。田间持水率为 27.5%。5 月 5 日播种，9 月 25 日收获。肥料为长效缓释肥，尿素、磷酸二铵、硫酸钾、硫包衣的配比为 14∶22∶14∶50。

### 1.2 材料

供试玉米品种为当地主栽品种先玉 335。

### 1.3 方法

1.3.1 试验设计　试验区面积为 12 m$^2$，分 7 个小区(4 m×3 m)，垄宽 65 cm，株距 23 cm，种植密度为 67 500 株·hm$^{-2}$。小区试验采用 3 因素，即水分胁迫生育阶段、胁迫历时、胁迫程度。共设置 10 个处理，3 次重复(见表 1)。

对照田间持水率维持在 80%～90%，轻旱、中旱、重旱土壤含水率变化范围分别为 70%～80%、60%～70%、50%～60%。

T0 为无水分胁迫处理，苗期轻旱为 T1 处理，苗期中旱为 T2 处理，苗期重旱为 T3 处理，拔节期轻旱为 T4 处理，拔节期中旱为 T5 处理，拔节期重旱为 T6 处理，开花期轻旱为 T7 处理，开花期中旱为 T8 处理，开花期重旱为 T9 处理。

1.3.2 测定项目　玉米成熟后，每小区取样 10 株，测定株高、穗位及茎粗、穗长、穗粗、单穗行数、单行粒数、籽粒干重、果穗干重及千粒重。

1.3.3 统计分析　采用 Microsoft Excel 2010 和 DPS 统计分析软件数据处理系统进行数据分析。

表 1　试验设计

Table 1　Experiment design

| 处理 Treatments | 胁迫历时/d Stress duration | 胁迫程度 Stress degree | 含水量控制范围/% Water content control range |
|---|---|---|---|
| T0 | 0 | 无 | 80～90 |
| T1 | 5 | 轻度 | 70～80 |
| T2 | 10 | 中度 | 60～70 |
| T3 | 15 | 重度 | 50～60 |
| T4 | 5 | 轻度 | 70～80 |
| T5 | 10 | 中度 | 60～70 |
| T6 | 15 | 重度 | 50～60 |
| T7 | 5 | 轻度 | 70～80 |
| T8 | 10 | 中度 | 60～70 |
| T9 | 15 | 重度 | 50～60 |

## 2 结果与分析

### 2.1 水分胁迫对玉米株高和穗位的影响

由图 1 可知，不同处理间差异达到显著水平，其中苗期重度(T3)和拔节期干旱(T4、T5、T6)对玉米株高影响较大，导致植株生长速度下降和植株矮化。但不同生育期的干旱胁迫均使植株穗位降低，而且干旱使穗位降低 30%以上。从图 1 中还可看出，拔节期干旱对穗位矮化最明显，这与干旱对株高的影响一致，说明玉米株高与穗位高之间相关密切。

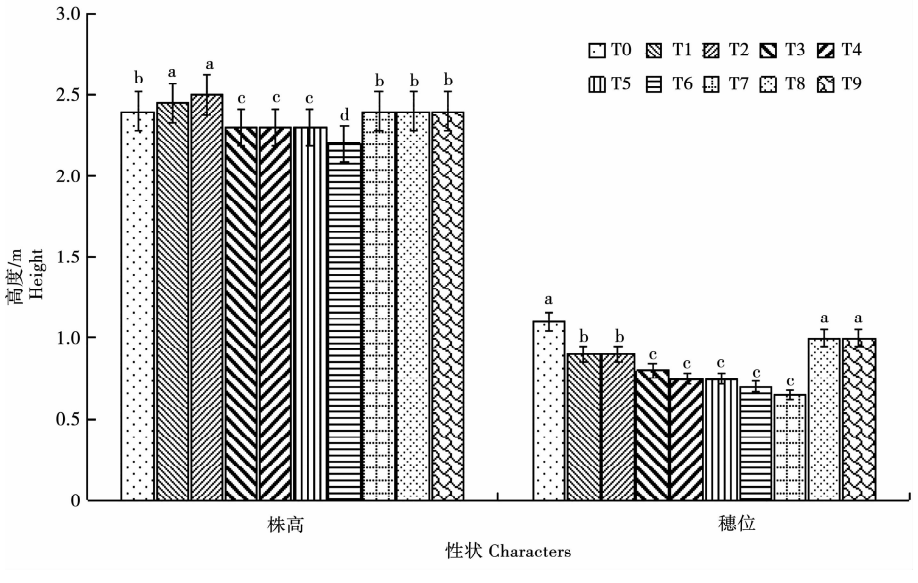


图 1　不同生育期水分胁迫对株高和穗位的影响

Fig. 1　Effects of water stress on plant height and ear height at different growth stages

### 2.2　水分胁迫对玉米茎粗的影响

由图 2 可知,不同干旱胁迫对植株茎粗的影响差异不显著。

### 2.3　水分胁迫对玉米产量的影响

由表 2 可知,干旱胁迫对不同处理间穗粗、穗行数、行粒数差异不显著,不同处理玉米穗长达到显著差异,其中苗期重旱和拔节期干旱对穗长影响较大,分别比 T0 减少 7.9%、26.3%、15.8%和 15.8%,而苗期轻旱、中旱胁迫处理和开花期干旱胁迫处理穗长有所增加;干旱胁迫百粒重和产量差异达到显著水平;拔节期干旱对产量影响极大,分别比对照降低 15.4%、11.5%、27.3%。

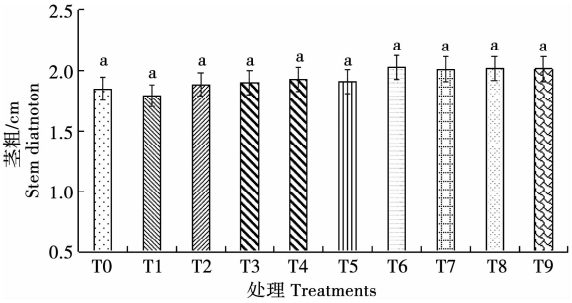


图 2　不同生育期水分胁迫对茎粗的影响

Fig. 2　Effects of water stress on stem diametert at different growth stages

**表 2　玉米生育期胁迫对完熟期产量及产量性状的影响**

**Table 2　Effects of maize growth stage stress on yield and its characters at mature stage**

| 处理 Treatments | 穗长/cm Ear length | 穗粗/cm Ear diameter | 百粒重/g 100-seed Weight | 穗行数 Row number per ear | 行粒数 Row number | 含水量/% Water content | 产量/(kg·hm$^{-2}$) Yield |
|---|---|---|---|---|---|---|---|
| T0 | 19.0 a | 4.6 a | 25.8 a | 14 a | 41 a | 33.1 a | 7090.92 a |
| T1 | 22.0 a | 4.8 a | 27.0 a | 18 a | 41 a | 27.4 b | 7474.33 a |
| T2 | 22.0 a | 4.6 a | 29.7 a | 16 a | 48 a | 28.9 b | 7172.05 a |
| T3 | 17.5 a | 4.7 a | 23.9 b | 16 a | 42 a | 31.7 a | 7025.49 a |
| T4 | 14.0 b | 4.6 a | 22.1 b | 16 a | 42 a | 26.7 b | 5999.06 b |
| T5 | 16.0 b | 4.8 a | 20.5 b | 16 a | 42 a | 28.4 b | 6276.21 b |
| T6 | 16.0 b | 4.7 a | 18.2 b | 16 a | 44 a | 31.0 a | 5153.40 b |
| T7 | 20.5 a | 4.6 a | 26.6 a | 14 a | 44 a | 27.2 b | 7293.02 a |
| T8 | 19.5 a | 4.3 a | 26.6 a | 16 a | 44 a | 29.3 a | 7505.50 a |
| T9 | 22.0 a | 4.7 a | 24.7 a | 14 a | 42 a | 25.2 b | 7998.75 a |

## 3　结论与讨论

### 3.1　水分胁迫对玉米生长发育的影响

玉米作为需水量、耗水量较多的旱作物之一,其生长发育的态势与土壤水分储量紧密相连[1]。本文研究表明拔节期干旱对穗位矮化最明显,这与干旱对株高的影响一致,说明玉米株高与穗位高之间相关密切,这与陈玉水[2]等人的研究结论相符。拔节期干旱对玉米株高影响较大,可能是拔节期为夏玉米株高增速最快时期,因此导致植株生长速度下降和植株矮化。生育前期,不同土壤含水量对株高影响的差异较小,拔节期后差异加大[3]。不同水分处理下春玉米生育期茎粗的变化动态曲线基本一致,且在不同生育期干旱处理对茎粗影响较小。茎秆粗壮,则玉米抗倒伏能力显著提高,而严重的水分亏缺,抗倒伏能力减弱[4]。

### 3.2　水分胁迫对玉米产量的影响

水分胁迫对植株生长发育和干物质的积累产生了严重影响,故在生产上应尽量避免发生重度或中度水分胁迫[5]。本文研究表明拔节期干旱对产量影响极大,分别比对照降低 15.4%、11.5%和 27.3%。但苗期干旱胁迫和开花期干旱胁迫则对玉米产量影响不大,说明适度的水分胁迫在复水后可以加快贮存在营养器官中的物质向籽粒中转移,从而也弥补了产量的下降[6]。为此在玉米适当生育期,合理减少灌溉次数和灌水量并不会明显影响产量。

**参考文献:**

[1]　白莉萍,隋方功,孙朝晖,等.土壤水分胁迫对玉米形态发育及产量的影响[J].生态学报,2004,24(7):1556-1560.

[2] 陈玉水，卢川北. 玉米穗位高与株高的相关研究[J]. 南方农业学报，2004，35(2)：111.
[3] 山仑，陈培元. 旱地农业生理生态基础[M]. 北京：科学出版社，1998.
[4] Brown K W，Jordan W R，Thomas J C. Water stress induced alterations of the stomatal response to decreases in leaf water potential[J]. Physiologia Plantarum，2010，37(1)：1-5.
[5] 吴少辉，高海涛，王书子，等. 干旱对冬小麦粒重形成的影响及灌浆特性分析[J]. 干旱地区农业研究，2002，20(2)：49-51.
[6] 邓良佐，李玉成，李艳杰，等. 寒地旱作玉米高产形态指标诊断技术研究[J]. 玉米科学，2005，13(Z1)：122.

# Effects of Water Stress on Growth and Yield of Maize in Semi Arid Area

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**Abstract**：In order to determine the optimal irrigation mode，the effects of water stress on maize growth and yield in semi－arid area were analyzed through drought resistance test. The results showed that (1) plant height and ear height had the significant difference between each treatments，both severe drought in seedling stage and drought in jointing stage had a greater impact on maize plant height，caused the growth rate to slow down and the maize performed symptoms of dwarfing. However，the drought stress in each growth stages reduced the maize ear height by more than 30%. (2) The stem diameter under different drought stress treatments had no significant difference. (3) The ear length in different drought stress treatments had significant difference，severe drought in seedling stage and drought in jointing stage had a greater impact on maize ear length，the ear length were 7.9%，26.3%，15.8% and 15.8% less than T0. And ear length of maize under the light and moderate drought in seedling stage，drought in flowering stage increased. 100-seed weight and the yield were significant difference in different drought stress treatments；drought at jointing stage had a great influence on yield，which was 15.4%，11.5% and 27.3% lower than that of CK.

**Keywords**：water stress；semi-arid；maize；yield